Vattenfall Wind Power Ltd

Thanet Extension Offshore Wind Farm

Environmental Statement Volume 2

Chapter 2: Marine Geology, Oceanography and Physical Processes

June 2018, Revision A

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Vattenfall Wind Power Ltd

Thanet Extension Offshore Wind Farm

Volume 2

Chapter 2: Marine Geology, Oceanography and Physical Processes

June 2018

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2 MARINE GEOLOGY, OCEANOGRAPHY AND PHYSICAL PROCESSES

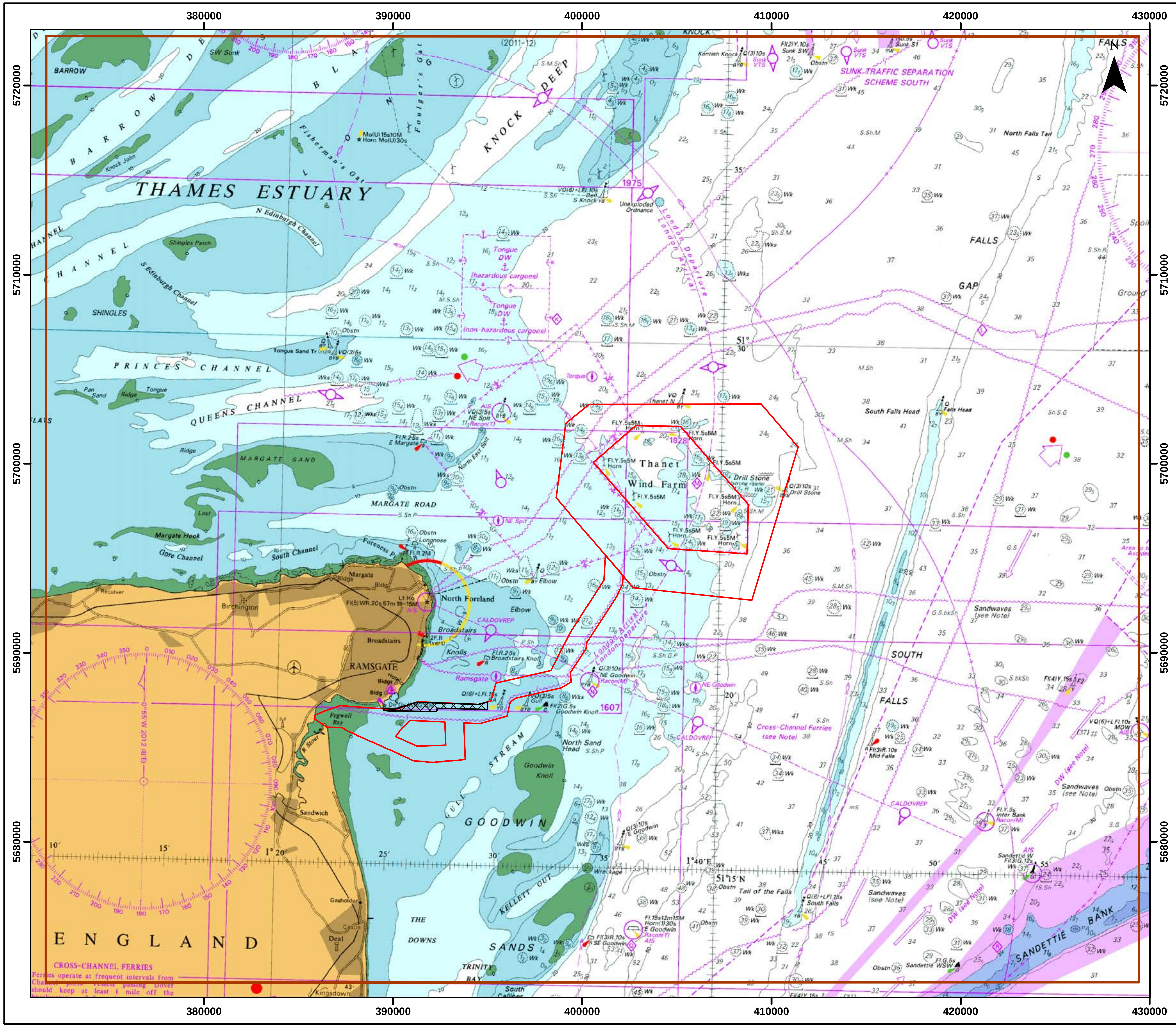
2.1 Introduction

2.1.1 This chapter of the Environmental Statement (ES) presents the results of the Environmental Impact Assessment (EIA) for the potential impacts of the Thanet Extension Offshore Wind Farm (Thanet Extension) on Marine Geology, Oceanography and Physical Processes (hereafter referred to as physical processes). Specifically, this chapter considers the potential impact of Thanet Extension seaward of Mean High Water Springs (MHWS) during its construction, Operations and Maintenance (O&M), and decommissioning phases.

2.1.2 Marine physical processes is a collective term for the following:

- Water levels;
- Currents;
- Waves (and winds);
- Sediments and geology: (including seabed sediment distribution and sediment transport);
- Seabed geomorphology; and
- Coastal geomorphology.

2.1.3 The proposed offshore development area includes the Thanet Extension array area as well as the Offshore Export Cable Corridor (OECC) beyond the array boundary, up to and including the intertidal zone in Pegwell Bay (Figure 2.1).



ABPmer VATTENFALL

THANET EXTENSION OFFSHORE WIND FARM

Figure 2.1

Thanet Extension Offshore Wind Farm Marine Physical Processes Study Area

Legend

- Offshore Red Line Boundary
- Cable Exclusion
- Far Field Study

Datum: ETRS 1989
Projection: UTM31N

1:200,000 | 0 2 4 km | 0 1 2 nm

Drg No	003_ES_Fig2.1_Study_Area			Figure 2.1
Rev	1	Date	24/05/2018	
By	AMC	Layout	N/A	

2.1.4 In order to assess the potential changes relative to the baseline (existing) coastal and marine environment, a combination of complementary approaches has been adopted. These include:

- Consideration of the existing evidence base (especially post-construction monitoring from the operational Thanet Offshore Wind Farm (TOWF));
- Qualitative and quantitative assessments of data from the proposed development; and
- Empirical evaluation.

2.1.5 Consideration of the likely changes to physical processes has been made, adopting a number of conservative assumptions based around the 'worst-case' characteristics of the development. Subsequent effects upon a series of identified physical processes receptors have been determined. These receptors include the coast and adjacent sand banks (see paragraph 2.5.2).

2.1.6 For the most part, physical processes are not in themselves receptors but are instead ‘pathways’. However, changes to physical processes have the potential to indirectly impact other environmental receptors (Lambkin *et al*., 2009), notably those described within:

- Volume 2, Chapter 3: Marine Water and Sediment Quality (Document Ref: 6.2.3)
- Volume 2, Chapter 4: Offshore Ornithology (Document Ref: 6.2.4);
- Volume 2, Chapter 5: Benthic Ecology (Document Ref: 6.2.5);
- Volume 2, Chapter 6: Fish and Shellfish (Document Ref: 6.2.6); and
- Volume 2, Chapter 7: Marine Mammals (Document Ref: 6.2.7).

2.1.7 The more detailed technical information which underpins the impact assessments presented in this chapter is contained within Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1).

2.2 Statutory and policy context

2.2.1 The assessment of potential impacts upon physical processes has been made with specific reference to the relevant National Policy Statements (NPS) and Marine Plans. Those relevant to the project for which development consent is required are:

- Overarching NPS for Energy (EN-1) (July 2011); and
- NPS for Renewable Energy Infrastructure (EN-3) (July 2011).

2.2.2 The relevance of the above with regards to physical processes and how these have been addressed within this assessment are presented in Table 2.1.

Table 2.1: Legislation and policy context

Policy/ legislation	Key provisions	Section where provision addressed
NPS EN-1	Paragraph 5.5.6: Where relevant, applicants should undertake coastal geomorphological and sediment transfer modelling to predict and understand impacts and help identify relevant mitigating or compensatory measures.	Predictions of change to physical processes that could arise from construction, O&M and decommissioning of Thanet Extension are presented in paragraph 2.10.3 to 2.12.12.
NPS EN-1	Paragraph 5.5.7: The Environmental Statement should include an assessment of the effects on the coast. In particular, applicants should assess: • The impact of the proposed project on coastal processes and geomorphology, including by taking account of potential impacts from climate change. If the development will have an impact on coastal processes the applicant must demonstrate how the impacts will be managed to minimise adverse impacts on other parts of the coast; • The implications of the proposed project on strategies for managing the coast as set out in Shoreline Management Plans (SMPs), any relevant Marine Plans…and capital programmes for maintaining flood and coastal defences; • The effects of the proposed project on marine ecology, biodiversity and protected sites;	The impact of the proposed project on coastal processes and geomorphology is considered in paragraph 2.10.3 onwards (for the construction phase), paragraph 2.11.3 onwards (for the O&M phase) and paragraph 2.12.3 onwards (for the decommissioning phase). The implications of the proposed project on strategies for managing the coast are considered within the landfall assessment, presented in Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1). The effects of the proposed project on marine ecology, biodiversity and protected sites is set out elsewhere in the ES, in particular in Volume 2, Chapter 5: Benthic Ecology (Document Ref: 6.2.5); The effects of the proposed project on maintaining coastal recreation sites and features are set out in Volume 2, Chapter 11: Other Marine Users (Document Ref: 6.2.11). The vulnerability of the proposed development to coastal change is considered in the context of landfall infrastructure, in Volume 4, Annex 2-

Policy/ legislation	Key provisions	Section where provision addressed
	• The effects of the proposed project on maintaining coastal recreation sites and features; and • The vulnerability of the proposed development to coastal change, taking account of climate change, during the project's operational life and any decommissioning period.	1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1).
NPS EN-1	Paragraph 5.5.9: The applicant should be particularly careful to identify any effects of physical changes on the integrity and special features of Marine Conservation Zones (MCZs), candidate marine Special Areas of Conservation (cSACs), coastal SACs and candidate coastal SACs, coastal Special Protection Areas (SPAs) and potential Sites of Community Importance (SCIs) and Sites of Special Scientific Interest (SSSI).	Designated nature conservation sites within the physical processes study area have been described in paragraph 2.7.32 to 2.7.34 (for the array area) and paragraph 2.7.63 for the OECC. The predicted changes to physical processes have been considered in relation to indirect effects on other receptors elsewhere in the ES, in particular in Volume 2, Chapter 5: Benthic Ecology (Document Ref: 6.2.5) and within the Thanet Extension MCZ assessment (Volume 4, Annex 5-3 (Document Ref: 6.4.5.3)).
NPS EN-1	Paragraph 5.5.11: The Secretary of State (SoS) should not normally consent new development in areas of dynamic shorelines where the proposal could inhibit sediment flow or have an adverse impact on coastal processes at other locations. Impacts on coastal processes must be managed to minimise adverse impacts on other parts of the coast. Where such proposals are brought forward consent should only be granted where the SoS is satisfied that the benefits (including need) of the development outweigh the adverse impacts.	A cable landfall assessment is presented in Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1). This assessment considers the nature of ongoing shoreline change at the landfall and the potential for cables and other project infrastructure to impact coastal processes. Summary details with regards to the coastal processes setting at the landfall are provided in paragraph 2.7.57 onwards.

Policy/ legislation	Key provisions	Section where provision addressed
		The significance of effects to coastal morphology are subsequently presented in paragraph 2.10.54 onwards (for the construction phase), paragraph 2.11.92 onwards (for the O&M phase) and paragraph 2.12.8 onwards (for the decommissioning phase).
NPS EN-1	Section 4.8: The resilience of the project to climate change (such as increased storminess) should be assessed in the Environmental Statement accompanying an application.	Potential changes in climate are described in the existing environment section (paragraph 2.7.1 onwards) and are considered alongside predicted changes described in the assessment sections (paragraph 2.10.1 onwards).
NPS EN-3	Paragraph 2.6.81: An assessment of the effects of installing cable across the intertidal zone should include information, where relevant, about: • Any alternative landfall sites that have been considered by the applicant during the design phase and an explanation for the final choice; • Any alternative cable installation methods that have been considered by the applicant during the design phase and an explanation for the final choice; • Potential loss of habitat; • Disturbance during cable installation and removal (decommissioning);	Predictions of change to physical processes that could arise from the construction, and O&M of Thanet Extension are presented in paragraph 2.10.1 to 2.11.106. A cable landfall assessment is also presented in Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1). This assessment considers the nature of ongoing shoreline change at the landfall and the potential for cables and other project infrastructure to impact coastal processes. Details regarding alternative landfall sites that have been considered during the design phase and an explanation for the final choice are provided in Volume 1, Chapter 4: Site Selection and Alternatives (Document Ref: 6.1.4).

Policy/ legislation	Key provisions	Section where provision addressed
	• Increased suspended sediment loads in the intertidal zone during installation; and • Predicted rates at which the intertidal zone might recover from temporary effects.	
NPS EN-3	Paragraph 2.6.113: Where necessary, assessment of the effects on the subtidal environment should include: • Environmental appraisal of array and cable routes and installation methods; • Habitat disturbance from construction vessels' extendible legs and anchors; • Increased suspended sediment loads during construction; and • Predicted rates at which the subtidal zone might recover from temporary effects.	Predictions of change to physical processes that could arise from the construction, O&M and decommissioning of Thanet Extension are presented in paragraph 2.10.3 to 2.12.12.
NPS EN-3	Paragraph 2.6.190: Assessment should be undertaken for all stages of the lifespan of the proposed wind farm in accordance with the appropriate policy for offshore wind farm EIAs.	The impact of the proposed project on coastal processes and geomorphology is considered in paragraph 2.10.3 onwards (for the construction phase), paragraph 2.11.3 onwards (for the O&M phase) and paragraph 2.12.3 onwards (for the decommissioning phase).
NPS EN-3	Paragraph 2.6.191 and 2.6.192: The Applicant should consult the Environment Agency, Marine Management Organisation (MMO) and Centre for Environment, Fisheries and Aquaculture Science (Cefas) on	Consultation on approach to assessment for physical processes has been carried out with the Environment Agency, MMO, Cefas and Natural England. Details of the

Policy/ legislation	Key provisions	Section where provision addressed
	methods for assessment of impacts on physical processes.	approach to consultation are provided in Table 2.2.
NPS EN-3	Paragraph 2.6.192: Mitigation measures which the Infrastructure Planning. Commission (IPC) (now the Planning Inspectorate (PINS)) should expect the applicants to have considered include the burying of cables to a necessary depth and using scour protection techniques around offshore structures to prevent scour effects around them. Applicants should consult the statutory consultees on appropriate mitigation.	The built-in mitigation relating to cable burial and scour are set out in section 2.9 (paragraph 2.9.1 onwards). Consultation is ongoing with statutory consultees and other interested parties.
NPS EN-3	Paragraph 2.6.193: Geotechnical investigations should form part of the assessment as this will enable the design of appropriate construction techniques to minimise any adverse effects.	Geotechnical data has informed the assessment and project design of Thanet Extension. Details are provided in Table 2.4.
NPS EN-3	Paragraph 2.6.194: 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.	Predictions of change to physical processes that could arise from the construction, and O&M of Thanet Extension are presented in paragraph 2.10.3 - 2.11.106
NPS EN-3	Paragraph 2.6.195: The direct effects on the physical environment can have indirect effects on a number of other receptors. Where indirect effects are predicted, the IPC (now the Planning Inspectorate (PINS) should refer to relevant Sections of this NPS and EN 1.	The predicted changes to the physical environment have been considered in relation to indirect effects on other receptors elsewhere in the ES, in particular within Volume 2, Chapter 5: Benthic Ecology (Document Ref: 6.2.5) and in Volume 2, Chapter 3: Marine Water and Sediment Quality (Document Ref: 6.2.3).

Policy/ legislation	Key provisions	Section where provision addressed
NPS EN-3	Paragraph 2.6.196: The methods of construction, including use of materials should be such as to reasonably minimise the potential for impact on the physical environment.	The project has proposed designs and installation methods that seek to minimise significant adverse effects on the physical environment where possible. Where necessary, the assessment has set out mitigation to avoid or reduce significant adverse effects.
NPS EN-3	Paragraph 2.6.197: Mitigation measures which the SoS should expect the applicants to have considered include the burying of cables to a necessary depth and using scour protection techniques around offshore structures to prevent scour effects around them. Applicants should consult the statutory consultees on appropriate mitigation.	The built-in mitigation measures relating to cable burial and scour are set out in section 2.9 (paragraph 2.9.1 onwards).

2.2.3 Thanet Extension is located within the South East Marine Plan Area. The plan is currently under development (with final drafts due by May 2019) and therefore no specific policies have currently been put forward which require consideration within the ES.

2.2.4 Other key guidance which is of relevance to the assessment includes:

- ‘Environmental impact assessment for offshore renewable energy projects.’ (BSI, 2015);
- ‘Review of environmental data associated with post-consent monitoring of licence conditions of offshore wind farms.’ MMO Project No: 1031. (Fugro-Emu, 2014);
- 'Advice Note Seven: Environmental Impact Assessment, Preliminary Environmental Information, screening and scoping' (The Planning Inspectorate, 2015a);
- 'Advice Note Nine: Using the Rochdale Envelope' (The Planning Inspectorate, 2012);
- 'Advice Note Twelve: Transboundary Impacts ' (The Planning Inspectorate, 2015b);
- 'Guidelines for Data Acquisition to Support Marine Environmental Assessments of Offshore Renewable Energy Projects'. (Cefas, 2011);
- 'General advice on assessing potential impacts of and mitigation for human activities on Marine Conservation Zone features, using existing regulation and legislation' (JNCC and Natural England, 2011);
- 'National Policy Statement EN-1 - Overarching National Policy Statement for Energy' (DECC, 2011a);
- 'National Policy Statement EN-3 - National Policy Statement for Renewable Energy Infrastructure' (DECC, 2011b);
- ‘Further review of sediment monitoring data’. (COWRIE ScourSed-09).’ (ABPmer, HR Wallingford and Cefas, 2010);
- ‘Coastal Process Modelling for Offshore Wind farm Environmental Impact Assessment: Best Practice Guide’. ABPmer and HR Wallingford for COWRIE, 2009, [http://www.offshorewindfarms.co.uk];
- 'Guidelines in the use of metocean data through the lifecycle of a marine renewables development' (ABPmer *et al*., 2008a);
- ‘Review of Cabling Techniques and Environmental Effects applicable to the Offshore Wind Farm Industry.’ Department for Business Enterprise and Regulatory Reform in association with Defra. (BERR, 2008);
- 'Review of Round 1 Sediment process monitoring data - lessons learnt. (Sed01)' (ABPmer *et al*., 2007);
- 'Dynamics of scour pits and scour protection - Synthesis report and recommendations. (Sed02)' (HR Wallingford *et al*., 2007);
- 'Offshore Windfarms: Guidance note for Environmental Impact Assessment in Respect of FEPA and CPA requirements'. (Cefas, 2004);
- 'Potential effects of offshore wind developments on coastal processes' (ABPmer and METOC, 2002);
- ‘Scoping the environmental impacts of coastal defence, including beach nourishment’ (Environment Agency, 2002); and
- ‘Beach management manual – second edition’ (CIRIA, 2010).

2.2.5 Monitoring evidence compiled during the construction, and O&M of earlier offshore wind farm developments (including TOWF) is also available. Some of this information is contained within the COWRIE ScourSed-09 publication (ABPmer *et al*., 2010), whilst a number of monitoring reports and previous offshore wind farm ESs are hosted on The Crown Estate Marine Data Exchange website (www.marinedataexchange.co.uk/).

2.3 Consultation and scoping

2.3.1 As part of the EIA process for Thanet Extension, a formal Scoping Opinion (PINS 2017) was sought from PINS following submission of the Scoping Report (VWPL, 2016).

2.3.2 Ongoing consultation has taken place through the development of the Thanet Extension Evidence Plan (the Evidence Plan) within which agreement has been sought as to the suitability of available evidence, assessment methodologies, and forthcoming guidance where appropriate.

2.3.3 Consultation responses and responses received through the development of the EIA Evidence Plan have been important in informing this ES chapter and in the development of the technical supporting annexes.

2.3.4 Responses relating to physical processes are addressed throughout this chapter. Table 2.2 provides a summary of key points raised, and describes how they have been addressed.

Table 2.2: Summary of consultation relating to Marine Geology, Oceanography and Physical Processes

Date and consultation phase/ type	Consultation and key issues raised	Section where provision addressed
June 2017 Evidence Plan consultation (MMO)	The MMO reiterates the assessment should emphasise data and modelling evidence wherever possible to support both the outcome of the desk based assessments and the tools used.	Baseline field data, monitoring evidence from other operational wind farms (including TOWF) and numerical modelling of changes to physical processes undertaken to support other Offshore Wind Farm (OWF) EIA studies have all been used to inform the assessments presented in paragraph 2.10.1 onwards.
February 2017 Scoping (Secretary of State)	Additional survey efforts should target any areas of seabed within the Thanet Extension array area not covered by the existing TOWF geophysical, geotechnical and benthic surveys.	A wide range of project-specific surveys has been carried out involving the collection of geophysical, geotechnical and benthic data. These provide 100% coverage of the Thanet Extension array area and the majority of the OECC (section 0; paragraph 2.4.13 onwards).
February 2017 Scoping (Secretary of State)	The ES should provide details of all models and methods used to inform the assessment and explain the assumptions and limitations. Where ‘expert based assessment’ has been undertaken, the SoS will expect this to be based on applicable and up to date information.	Full details of the methodological approach for assessing changes to physical processes is set out in Section 0. This approach is consistent with the latest guidance and best practice set out in section 2.2 (paragraph 2.2.4 onwards). Justification for not undertaking additional numerical modelling is set out in detail within Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1). This has been agreed through The Evidence Plan.
February 2017 Scoping (Secretary of State)	The ES should provide full justification as to the link between surge events and other topic areas included within the scope of the EIA.	A description of surge events within the study area is provided in the baseline section (paragraph 2.7.5 and 2.7.10), along with a description of their relevance to other EIA topic areas. The potential for surge events to be modified by the presence of project infrastructure (especially Wind Turbine Generator (WTG) foundations) is discussed in the assessment of potential changes to tides (paragraph 2.11.3 onwards).

Date and consultation phase/ type	Consultation and key issues raised	Section where provision addressed
February 2017 Scoping (Secretary of State)	The ES should include an assessment of the effects to relevant designated sites resulting from impacts to Marine Geology, Oceanography and Physical Processes.	An assessment of associated impacts to marine ecological receptors arising from morphological changes to the seabed are considered elsewhere within the ES, in particular within: • Volume 2, Chapter 4: Marine Ornithology (Document Ref: 6.2.4); • Volume 2, Chapter 5: Benthic Ecology (Document Ref: 6.2.5); • Volume 2, Chapter 6: Fish and Shellfish (Document Ref: 6.2.6); and • Volume 2, Chapter 7: Marine Mammals (Document Ref: 6.2.7).
February 2017 Scoping (Secretary of State)	There is minimal reference to the intertidal area within Section 2.2 of the Scoping Report.	A description of the intertidal area at the landfall is provided in paragraph 2.7.57 onwards and within Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1).
February 2017 Scoping (Natural England)	The need for scour protection should be appropriately justified through robust evidence base and assessed accordingly.	The anticipated requirements for scour protection is set out in the project design statement (Volume 2, Chapter 1: Project Description - Offshore (Document Ref: 6.2.1)). A full assessment of the potential seabed changes arising from the installation of scour protection is set out in paragraph 2.11.42 to 2.11.57.

Date and consultation phase/ type	Consultation and key issues raised	Section where provision addressed
February 2017 Scoping (Maritime & Coastguard Agency)	Particular attention should be paid to cabling routes and where appropriate burial depth for which a Burial Protection Index study should be completed and, subject to the traffic volumes, an anchor penetration study may be necessary.	A full cable burial risk assessment will be undertaken post-consent and pre-construction to ensure appropriate levels of conservatism are factored into the cable installation plan.
February 2017 Scoping (Secretary of State)	It is not clear what the term 'expert based empirical and conceptual assessment methods' implies and further definition should be provided in the assessment method.	Full details of the methodological approach for assessing changes to physical processes are set out in Section 0. A range of assessment techniques has been used: these techniques have typically relied upon the use of empirical equations as well as expert judgement to develop a detailed conceptual understanding of each potential issue.
February 2017 Scoping (Natural England)	A full review of lessons learnt should be used to inform a realistic worst-case assessment in the ES of achievable burial depths, and associated methodology including required sand wave clearance and need for cable and scour protection.	An assessment of sand wave clearance and the requirement for cable protection is presented in paragraph 2.10.32 onwards. The assessment includes consideration of the sand wave clearance work undertaken at Race Bank offshore wind farm. A detailed Cable Burial Assessment for the Thanet Extension project will be undertaken following consent to inform appropriate burial depth.
February 2017 Scoping (Natural England)	Visible and persistent chalk plumes from cable installation at Rampion OWF: the potential for similar effects at this project should be considered.	A quantitative assessment of changes in Suspended Sediment Concentration (SSC) and bed levels has been carried out, as presented in paragraph 2.10.3 to 2.10.42.

Date and consultation phase/ type	Consultation and key issues raised	Section where provision addressed
February 2017 Scoping (Natural England)	Expert based assessment implies there will be no further data collection or modelling. If this is the case, we advise that the existing data presented must be the most applicable and up to date.	A wide range of project-specific surveys has been carried out involving the collection of geophysical, geotechnical and benthic data (paragraph 2.4.13 onwards). Justification for not undertaking additional numerical modelling of changes to flows and waves is set out in detail within Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1).
February 2017 Scoping Expert Working Group (Natural England)	The ES should address the issue of persistent sediment plumes seen in aerial photographs and satellite images at TOWF. The cause and any associated impacts on the biological environment should be presented.	A full discussion of 'turbid wake' features has been provided in Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1). The potential for associated changes to ecological receptors is considered elsewhere in the ES.
February 2017 Scoping (Port London Authority)	The edge of the Thanet Extension site is now much closer to South Falls bank than TOWF. The potential for change to the bank should therefore be fully assessed.	South Falls is considered as a physical processes receptor (paragraph 2.5.2 onwards) (see Figure 2.1).

Date and consultation phase/ type	Consultation and key issues raised	Section where provision addressed
January 2018 Section 42 (MMO)	The volume of material to be removed due to sand waves for the installation of the export cable should be fully defined in the ES. The extent and nature of any specific dredging activities is not currently clear. Disposal sites should be identified. Any cleared sandwave material should ideally be deposited upstream in order to allow natural reworking of the material.	The Maximum Design Scenario table (Table 2.16) has been updated to include volumes of material which may potentially be removed during sand wave clearance activities. Up to 1,440,000 m^3 may be dredged during pre-sweeping activities. A deemed Marine Licence will be sought for the OECC to include characterisation of a disposal site, with material removed during sand wave clearance activities being disposed of this in this area, in the vicinity of the excavation location.
January 2018 Section 42 (MMO)	The degree of cable protection measures proposed should be fully justified.	The extent of cable protection measures is set out in the Maximum Design Scenario table (Table 2.16Table 2.16) and has been informed by (amongst other things) previous experience from TOWF.
January 2018 Section 42 (MMO)	The southern loop to the export cable corridor should be given full categorisation and attention in any ensuing ES. In addition, a consistent particle size grading system (e.g. Folk and Ward) should be used; "Fine to Coarse sand" is not a recognised "particle size unit".	Potential impacts associated with cable installation in the southern loop have been assessed in full, both within the ES (paragraph 2.10.322.10.32 onwards) and within Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1). A consistent particle size grading system has been applied to Figure 2.14.

Date and consultation phase/ type	Consultation and key issues raised	Section where provision addressed
January 2018 Section 42 (MMO)	Please show where there is a risk of chalk being exposed (dredging for construction, cabling, sand wave temporary removal) as well as drill cuttings if monopiles are used.	On the basis of the available geophysical and geotechnical information, chalk could potentially be disturbed by construction related activities anywhere within the southern half of the Thanet Extension array. The presence of chalk is also inferred from geophysical data collected from the north of the array although the chalk is typically found at depths below the seabed greater than 30 m (which equates to the average anticipated drilling depth). In almost all areas of the OECC, chalk is either found at or very close (i.e. <0.5 m) to the seabed (noting that the internal reflectors are often not clearly defined.) Chalk could therefore be exposed/disturbed by cable trenching and/or sand wave clearance activities.
January 2018 Section 42 (MMO)	The creation of spoil berms in the shallow waters of Pegwell Bay could be significant in terms of changes to wave characteristics and subsequently sediment transport. This worst-case change, and any associated impacts, must be considered in the ES.	Trenching activities in Pegwell Bay have the potential to result in spoil berms. The Maximum Design Scenario for this activity is set out in Table 2.16, whilst an assessment is presented in paragraph 2.11.59 onwards.
January 2018 Section 42 (MMO)	It would be helpful to show the methodology for the indicated ~2.5% change in wave height and also graphically.	The approach for determination of the maximum adverse scenario for wave and current blockage is set out within Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1). The approach used employs standard empirical equations for the determination of blockage and the results are consistent with numerical modelling of similar sized structures at other UK wind farm locations. The method determines the maximum reduction in wave height along the downwind boundary. Because these values are found to be small in absolute and relative terms, they present no concern with regards to changes in sediment transport at the coast. Accordingly, it was not considered necessary to determine or illustrate the rates or patterns of wave recovery in the lee of the wind farm.
January 2018 Section 42 (MMO)	Whilst the height of cable protection measures above the natural seabed may only be 0.5 m, this may inhibit natural bedload transport especially when the cable is perpendicular to the transport pathway.	The potential for cable protection measures to influence patterns of sediment transport is considered in paragraph 2.11.352.11.35 onwards. Given understanding of both the design characteristics of the protection measures and the mechanisms by which sediment is transported across the seabed, it is considered that any protection measures will only result in localised changes.

Date and consultation phase/ type	Consultation and key issues raised	Section where provision addressed
January 2018 Section 42 (MMO)	Long-term sediment winnowing by the virtually continuous suspended sediment plumes will be a slow process but is potentially significant. Detail on where and when the MES Ltd 2013 sediment samples were taken should be provided along with any estimates that can be made of the rate of winnowing to determine when (and if) a significant change in particle size can be measured.	The MES Ltd samples were collected in August 2012 and are now shown in Figure 2.2. A description of the changes associated with turbid wakes is presented in paragraph 2.11.582.11.58 onwards. The extent to which winnowing is evident in the MES (2013) data is considered in paragraph 2.11.742.11.74 onwards. It is not possible to determine potential rates of long-term change with any confidence as short-term baseline rates of sediment erosion and deposition (causing seabed texture to vary naturally on timescales of hours or less) will vary over flood-ebb, spring-neap, seasonal, and other cycles. Changes to surficial texture by natural process (modified or not by turbid wakes) are likely to be limited to the upper few millimetres or centimetres of the seabed. The potential significance of a change to a coarser surficial substrate will be considered within the benthic ecology chapter.
January 2018 Section 42 (MMO)	Consideration must be given to all relevant in-combination effects on the marine environment including the proposed 132 kV cable replacement project for the existing Thanet OWF.	All relevant cumulative and in-combination effects on the marine environment have been considered. The Thanet Cable Replacement project is no longer being pursued and as such a cumulative impact assessment is not required.
January 2018 Section 42 (MMO)	The MMO would welcome development of a Scour Protection Plan linked with the proposed Cable Protection Plan to determine the likely scour depth and volumes associated with the final design and to justify proposed mitigation measures.	A full cable burial risk assessment will be undertaken post consent and pre construction to ensure appropriate levels of conservatism are factored into the cable installation plan (including the requirements for and design of cable protection).
January 2018 Section 42 (MMO)	The removal of 9,600 m^3 is required for each suction caisson – an explanation of how this figure is calculated is required.	An explanation of how this figure is arrived at is set out in the Maximum Design Scenario table (Table 2.16).Table 2.16). The area of seabed preparation per foundation could be up to 3,200 m^2 and the depth of seabed preparation could be up to 3 m).
January 2018 Section 42 (MMO)	A diagram showing the size and orientation of the theoretical "80 diameters" impact on turbulence is recommended along with clarification as to whether this extends beyond the proposed Project area.	A 2.4 km (80x diameter) buffer around the turbines is now shown in Figure 2.5.Figure 2.5. This change could theoretically extend outside of the Thanet Extension array area. However, the buffer is a conservative representation as it assumes that change of this magnitude change could occur in all flow directions.
January 2018 Section 42 (MMO)	The MMO wish to have clarity on how the natural variability of the sandbanks has been determined; further detail of this should be provided e.g. expert judgement or by observation.	Our understanding of sandbank variability is informed by available literature (e.g. Kenyon and Cooper, 2005), as well as expert judgement. This clarification has been added to paragraph 2.11.892.11.89.

Date and consultation phase/ type	Consultation and key issues raised	Section where provision addressed
January 2018 Section 42 (MMO)	Please explain the differences between DTM (Digital Terrain Model) and DSM (Digital Surface Model) and how this impacts on the interpretation.	A Digital Terrain Model (DTM) describes the earth surface without any surface objects (including vegetation) whereas a Digital Surface Model (DSM) includes objects. The differences between these two models are potentially relevant when considering morphological change in areas containing surface vegetation (such as saltmarshes). This is clarified within Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1).
January 2018 Section 42 (MMO)	The Partrac Metocean study and the Vattenfall (2017) interpretation should be explored in detail in the EIA. For instance, what are the physical driving process for the extreme tidal events?	Outputs from the Partrac metocean measurement campaign have been used to inform baseline understanding of the hydrodynamic and wave regime and this has been reported in paragraph 2.7.42.7.4 onwards. Further discussion of the surge related influence is provided in paragraph 2.7.5 onwards.
January 2018 Section 42 (MMO)	Volume 4, Annex 2-1 Technical Report para 7.4. Table 23 shows four different water depths for the assessment. Further clarification should be provided whether this is 4 different Acoustic Wave and Current meters (AWAC) deployments or if the data has been interpolated onto different water depths.	The water depths in the table do not relate to AWAC deployments. These depths are illustrative of the range of water depths encountered within the array and are used to determine nearbed orbital current velocities. These are of relevance in the determination of bed shear stress and sediment mobility.
January 2018 Section 42 (MMO)	Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1). Consideration should be given to presenting the AWAC data.	Appendix A within Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1) summarises the results of a search for pre-existing relevant data/ literature to support the investigation. As such, we have not included the results of the project-specific surveys in this Appendix.
January 2018 Section 42 (Dover District Council)	The land take involved during the construction process and during operation is significant and is likely to have a long-term effect. Have these effects been qualified, have different scenarios been considered. Will these permeant changes to the coastline shape have an effect of tide patterns, mudflats and movement of sediment?	An assessment of potential changes to coastal and seabed morphology was presented in the PEIR and has been refined (using the latest project design information) for the ES. This concludes that construction and operation of the wind farm will not result in significant effects for marine geology, oceanography and physical processes. Any resulting changes to tides, waves and sediment transport will be limited in magnitude and highly localised, and so will not result in wider morphological changes.
January 2018 Section 42 (Port London Authority)	The PEIR doesn't appear to address the PLA's concern (regarding the potential impacts to Northeast Spit) in either the physical processes or navigation chapters	Although Northeast Spit is located approximately only 2.5 km from the Thanet Extension array area, it is considered very unlikely that the morphology of this feature would be altered by the presence of turbine foundations. The reasons for this are set out in paragraph 2.11.772.11.77 onwards. In brief, this is because the morphology of the feature will be primarily determined by tidal currents and sediment supply, neither of which will be influenced at this distance from the Thanet Extension Array Area.

Date and consultation phase/ type	Consultation and key issues raised	Section where provision addressed
January 2018 Section 42 (Port London Authority)	A key concern for the PLA is that the project would result in adverse impact on the coastal processes, reducing the amount of room within the navigational channel for vessels to pass through, and on this basis objection is raised.	For the reasons set out in paragraph 2.11.772.11.77 onwards, it is considered very unlikely that the morphology of Northeast Spit would be altered as a result of the operational presence of the project.
January 2018 Section 42 (Port London Authority)	The presented sediment samples are quite old and mobile sediment may be very different now as a result of changes in environmental factors. These must be updated.	The assessment has been informed through a combination of project-specific surveys (including) newly collected grab samples and ground truthed side-scan), augmented by pre-existing regional scale mapping under taken by the BGS. This combination of information is considered sufficiently robust to inform the assessment.
January 2018 Section 42 (Natural England)	A full assessment is required into the potential physical processes effects of extending the sea wall and country park.	The larger landfall extension option ('Option 1' in the PEIR) has been removed from the project description assessed for the ES. Therefore, the transition joint bays will be in/ on the Pegwell Bay Country Park rather than in the intertidal area. Notwithstanding this, some modification to the existing sea wall will be required and these are assessed in paragraph 2.10.592.10.59 onwards.
January 2018 Section 42 (Natural England)	Although no major significant effects have been assessed, we disagree that mitigation will not be necessary for certain aspects associated with intertidal and onshore works	The landfall proposals have been revised since PEIR and an assessment is presented in paragraph 2.10.59 onwards. Whilst no significant impacts have been identified for marine physical processes, the significance of the small-scale loss of saltmarsh habitat is considered in Volume 2, Chapter 5: Benthic Ecology (Document Ref: 6.2.5), alongside the requirement for any mitigation.
January 2018 Section 42 (Natural England)	Installation techniques and scour prevention: Further detail and justification is required regarding the following: a) the proposed installation techniques in areas including seabed ridges and rocky outcrops; b) the need for scour prevention; c) the assumptions made for material during the jetting of inter array cable (including 50% release of material); d) sandwave clearance, disposal of dredged material and sediment plumes; and e) the permanent loss of saltmarsh, and increasing the sea wall seaward.	a) Proposed installation techniques for cable installation in areas of rocky outcrops and seabed ridges are described in Volume 2, Chapter 1: Project Description - Offshore (Document Ref: 6.2.1). b) The requirement (or otherwise) for scour protection is an engineering design consideration, which will be informed through robust analysis of (amongst other things) hydrodynamic and seabed conditions. It will also be informed by scour observations at the adjacent TOWF site. Full details of the maximum required scour protection are described in Volume 2, Chapter 1: Project Description - Offshore (Document Ref: 6.2.1) and summarised in Table 2.16. c)The assumptions made for material release during jetting are based on the findings of field monitoring (e.g. BERR, 2008; BOEM, 2017). d) Full details regarding the assessment of sandwave clearance, disposal of dredged material and sediment plumes are provided within Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1). e) The potential impacts to marine processes arising from re-alignment of the existing sea wall are assessed in paragraph 2.10.59 onwards.

Date and consultation phase/ type	Consultation and key issues raised	Section where provision addressed
January 2018 Section 42 (Natural England)	What does this net increase in SPM concentrations caused by turbid wakes mean for ecological receptors in the vicinity of this area? Is there any link between these turbid wakes and increased sediment transport within the array area, especially when coupled with strong tidal currents.	It is important to note that whilst SPM might be relatively reduced closer to the seabed and relatively increased higher in the water column due to the turbid wake effect, there will be no net increase in total (depth averaged) SPM, for the reasons set out within Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1). The implications for ecological receptors due to the redistribution of suspended material through the water column is discussed in Volume 2, Chapter 5: Benthic Ecology (Document Ref: 6.2.5). There is (theoretically) potential for higher rates of sediment transport through the array due to the fact that a greater proportion of material will be transported higher in the water column where water is moving faster. However, these changes will be small in absolute terms and within the range of natural variability observed within/ nearby to the array.
January 2018 Section 42 (Natural England)	Natural England advise that impacts to the Goodwin Sands rMCZ are assessed.	Impacts on morphological features (sand banks) within Goodwin Sands rMCZ as a consequence of the operational presence of the Thanet Extension project have been assessed in paragraph 2.11.77 onwards. Potential impacts to ecological receptors within the Goodwin Sands rMCZ as a result of elevated levels of SSC and associated deposition during the construction phase are assessed in Volume 2, Chapter 5: Benthic Ecology (Document Ref: 6.2.5). The habitats and their sensitivities are presented for the rMCZ in the MCZ assessment (Volume 4, Annex5-3: MCZ Assessment (Document Ref: 6.4.5.3), noting that an MCZ assessment for the rMCZ has not been undertaken.
January 2018 Section 42 (Natural England)	Natural England would like to see more detail on how cables will be installed in these areas of 'Numerous seabed ridges and outcrops that can be seen throughout the OECC where the underlying chalk geology is present at the seabed.	Proposed installation techniques for cable installation in areas of rocky outcrops and seabed ridges are described in Volume 2, Chapter 1: Project Description – Offshore (Document Ref: 6.2.1).
January 2018 Section 42 (Natural England)	Seabed protection for approximately 25% of the [export cable] route seems quite high. How has this been assessed?	The maximum extent of cable protection measures is set out in the Maximum Design Scenario table (Table 2.16) and has been informed by (amongst other things) previous experience from TOWF. The assessment of potential changes to hydrodynamics and sediment transport in response to the presence of cable protection measures has been undertaken using a desk based assessment approach that considers (amongst other things) baseline rates of potential sediment transport, the angle of repose for the bed material and the height of the cable protection measures.
January 2018 Section 42 (Natural England)	Disposal of any dredged material will have to be carefully placed to avoid any habitats of conservation importance within the array area. Consideration of where any sediment plumes may migrate to in relation to nearby protected sites must also be assessed.	A full assessment of sediment plume characteristics is provided within Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1). The implications of changes in SSC on ecological receptors is assessed elsewhere within the ES, especially in Volume 2, Chapter 5: Benthic Ecology (Document Ref: 6.2.5).

Date and consultation phase/ type	Consultation and key issues raised	Section where provision addressed
January 2018 Section 42 (Natural England)	Are the largest structures the worst-case for turbid wakes? What about the impact of a higher number of smaller structures?	Consideration of the potential spatial extent of the turbid wakes is provided within Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1). This semi-quantitative assessment does consider the potential for an array comprising a higher number (34) of smaller foundations.
January 2018 Section 42 (Natural England)	If the equilibrium of scour can be reached or determined relatively quickly, and the effects of the current scour are not severe, the preferred option would be not to use additional scour protection and monitor the situation more closely to see how the scour progresses.	This is acknowledged. If consented the applicant will ensure that scour protection is only deployed where required and in line with the scour protection management plan which will be submitted post-consent
January 2018 Section 42 (Natural England)	What are the SSC/ SPM background levels [within the Thanet array area]? What percentage elevation does this 10-30 mg/l increase represent?	Background levels in SPM/ SSC are highly variable, both in space (horizontally and vertically) and in time. Accordingly, the percentage elevation above background levels will vary greatly and therefore it is not appropriate to quote a fixed value. Moreover, any increase is only relevant to the upper water column/ surface layers. (At or close to the bed there would be an equivalent reduction)

2.4 Scope and methodology

2.4.1 The Thanet Extension physical processes study area within which baseline conditions and potential changes have been considered is shown in Figure 2.1 and is defined as:

- The Thanet Extension array area;
- The Thanet Extension OECC;
- The Thanet Extension export cable landfall in Pegwell Bay; and
- The seabed and water column surrounding these areas that may be influenced by changes to physical processes due to the proposed development.

2.4.2 The study area extent has been defined using expert judgement, taking into consideration characteristics of the baseline physical environment (e.g. spring tidal excursion ellipse distances) as well as understanding developed from similar infrastructure project assessments.

2.4.3 To aid description, the OECC has been sub-divided into four separate areas:

- Nearshore Area (water depths less than ~ -5 m Lowest Astronomical Tide (LAT));
- Inshore Area (water depths between ~ -5 and -10 mLAT);
- Midshore Area (water depths between ~ -10 and -20 mLAT); and
- Offshore Area (water depths greater than ~ -20 m LAT).

Assessment approach

2.4.4 The assessment of effects on physical processes has been considered in terms of a source-pathway-receptor model whereby:

- The source is the initiator event;
- The pathway is the link between the source and the receptor impacted by the effect (e.g. sediment transport processes); and
- The receptors are the receiving entities as defined in paragraph 2.5.2 onwards.

2.4.5 A receptor can only be exposed to change if a pathway exists through which an effect can be transmitted between the source activity and the receptor.

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

- The 'evidence base' containing monitoring data collected during the construction and O&M of other OWF developments, in particular the adjacent operational TOWF. This evidence base also includes numerical modelling and desk based analyses undertaken to support other analogous OWFEIAs;
- Analytical assessments of project-specific data; and
- Standard empirical equations describing the relationship between (for example) hydrodynamic forcing and sediment transport or settling and mobilisation characteristics of sediment particles released during construction activities (e.g. Soulsby, 1997).

2.4.7 The assessment has been undertaken in accordance with industry best practice and guidance, as previously described (paragraph 2.2.4). Full details of the methodological approach are set out in Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1).

2.4.8 Details regarding the extent of data available from the proposed development are provided within the 'baseline data' Section (paragraph 2.4.13 onwards). This includes project specific geophysical, geotechnical, benthic and metocean data along with other publicly available datasets.

2.4.9 The assessment also considers likely naturally occurring variability in, or long-term changes to, physical processes within the project lifetime due to natural cycles and/ or climate change (e.g. sea level rise). This is important as it enables a reference baseline level to be established against which the potentially modified physical processes can be compared, throughout the project lifecycle. Baseline conditions are described in detail within the 'Existing environment' section (paragraph 2.7.1 onwards) and include for the potential effects of climate change.

Temporal and Spatial Scales of Assessment

2.4.10 The assessment of impacts on the marine physical environment has been considered over two spatial scales. These are:

- Far-field. Defined as the area surrounding the Thanet Extension array area and corridor over which indirect changes may occur (i.e. the study area); and
- Near-field. Defined as the footprint of the Thanet Extension array area and corridor.

2.4.11 The far-field extent is shown in Figure 2.1.

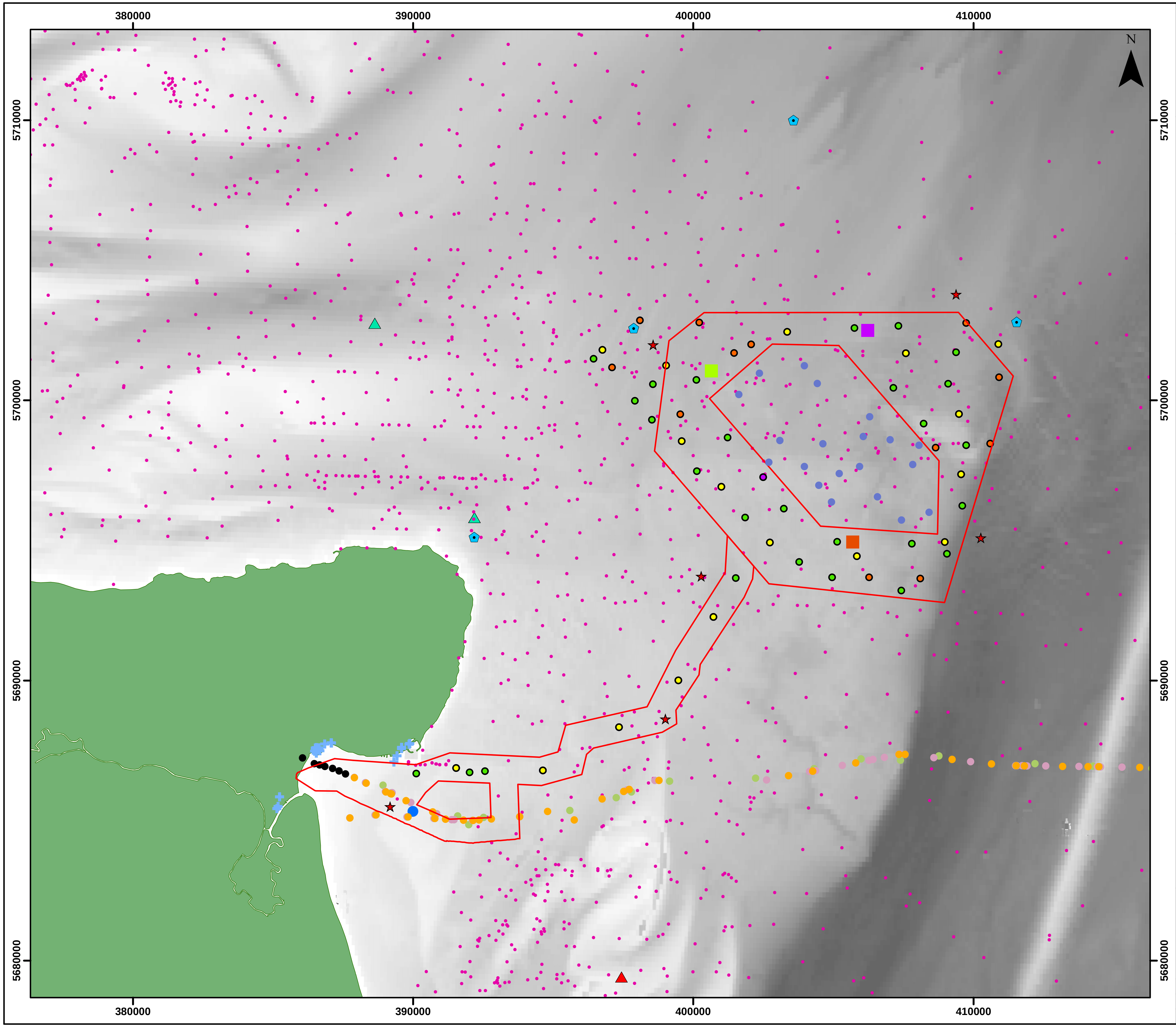
2.4.12 In terms of temporal scales, the assessment has considered changes associated with the three main phases of development. These are:

- Offshore construction (up to 28 months);
- O&M (30 years but may increase by the time the project nears decommissioning as technology/ maintenance improves); and
- Offshore decommissioning (similar duration to construction).

Baseline data

2.4.13 Information on physical processes within the study area was collected through a detailed desktop review of existing studies and datasets. These are summarised at Table 2.3 with location information shown in Figure 2.2.

2.4.14 A gap analysis of the existing dataset was undertaken by ABPmer in 2016 (see Appendix A of Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1)) which assisted in the design and implementation of a detailed programme of project-specific surveys. These are described in Table 2.4 with data locations shown in Figure 2.2. Together, the project and non-project specific data have been used to develop a detailed understanding of the existing baseline environment (paragraph 2.7.1 onwards).



ABPmer VATTENFALL

THANET EXTENSION OFFSHORE WIND FARM

Figure 2.2

Data Locations

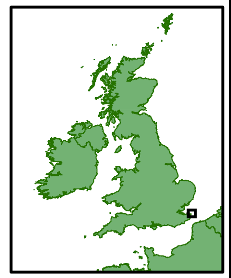
Legend

- Offshore Red Line Boundary
- Cone Penetration Test
- Camera
- Grab Sample
- Grab & Camera
- Vibrocore
- Location A1 (Modelled Water Levels)
- Location A2 (AWAC)
- Location A3 (AWAC)
- MES Ltd Grab Sample
- ABPmer SEASTATES (Wave Hindcast)
- ABPmer SEASTATES wave data
- Thames REC Grab Sample
- Nemo Link Borehole
- Nemo Link Cone Penetration Test
- Nemo Link Vibrocore Sample
- Nemo Link Grab Sample
- BGS Grab Sample
- BGS Borehole
- BODC Current Data
- CCO Wave Data
- NTLSF Water Level
- WaveNet Wave site
- Environment Agency Coastal Flood Boundary

Bathymetry (m CD)

6.0 -11.8 -29.5 -47.3 -65.1

Datum: ETRS 1989
Projection: UTM31N



1:135,000 — 0 1.5 3 km; 0 0.75 1.5 nm

Drg No	003_ES_Fig2.2_Data_Locations		
Rev	1	Date	24/05/2018
By	AMC	Layout	N/A

Figure 2.2

Table 2.3: Summary of key existing reports and datasets

Title	Source/ Author	Year
General		
Thanet Environmental Statement: Hydrodynamics and Geomorphology (including supporting annexes and survey reports)	Thanet Offshore Wind Limited	2005
Outer Thames Regional Environmental Characterisation	Emu *et al.*	2009
Outer Thames Estuary Marine Aggregate Regional Environmental Assessment	Thames Estuary Dredging Associated (TEDA)	2010
Nemo Link interconnector Geophysical and Geotechnical data	Nemo Link	2011
Water levels and currents		
Admiralty tide tables	United Kingdom Hydrographic Office (UKHO)	2017
Observational water level records	National Tide and Sea Level Facility (NTSLF) (https://www.ntslf.org/)	2017
Atlas of UK Marine Renewable Energy Resources	ABPmer *et al.* (www.renewables-atlas.info/.)	2008
Observational current records	British Oceanographic Data Centre (BODC) (https://www.bodc.ac.uk/)	2016
Winds and waves		
Observational wave records	Cefas (http://cefasmapping.defra.gov.uk/TextSummary)	2017
Hindcast wind and wave data (1979 to 2015)	ABPmer SEASTATES (www.seastates.net/)	2016
Sediments and geology		
TOWF array area and cable corridor geophysical survey	EGS International Ltd	2005
British Geological Survey (BGS) Offshore GeoIndex	(http://www.bgs.ac.uk/geoindex)	2017
The geology of the southern North Sea.	Cameron *et al.* (British Geological Survey (BGS) United Kingdom offshore regional report)	1992
North Sea Geology	Balson *et al.* (Strategic Environmental Assessment – SEA2 & SEA3)	2002
Seabed sediment, Quaternary geology and solid geology maps	BGS 1:250,000 map series	1987-1991
Satellite derived Suspended Particulate Matter (SPM) observations	Dolphin *et al.*	2011
Observational records of SSC	Huntley *et al.*	2000
Suspended Sediment Climatologies around the UK	Cefas	2016
Southern North Sea Sediment Transport Study Phase 2 (SNS2)	HR Wallingford *et al.*	2002
The effect of monopile-induced turbulence on local suspended sediment patterns around UK wind farms	Forster	2017
Sand banks, sand transport and offshore wind farms	Kenyon and Cooper	2005
The effect of monopile-induced turbulence on local suspended sediment patterns around UK wind farms	Forster	2017

Title	Source/ Author	Year
Seabed geomorphology		
TOWF array area and cable corridor geophysical survey	EGS International	2005
UK Hydrographic Office INSPIRE portal	UKHO http://aws2.caris.com/ukho/mapViewer/map.action	2017
Harmonised Digital Terrain Model (DTM) for the European sea regions	EMODnet Bathymetry partnership (www.emodnet-hydrography.eu/)	2017
Seabed mobility in the Greater Thames Estuary	Burningham, H. and French, J.	2009
Landfall geomorphology		
Regional coastal monitoring data (including aerial photography, beach topographic data and Light Detection and Ranging (LiDAR) data	South East Regional Coastal Monitoring Programme (http://www.channelcoast.org)	1995 - present
LiDAR	Environment Agency contemporary and historic LiDAR	1999 – present
National Coastal Erosion Mapping	Environment Agency mapping http://maps.environment	2011
Isle of Grain to South Foreland Shoreline Management Plan SMP2	South East Coastal Group (SECG)	2010

Table 2.4: Summary of project-specific survey data

Title	Overview	Reference
Bathymetric and geophysical survey	Sidescan sonar (SSS), Single Beam Echo Sounder (SBES), Multi Beam Echo Sounder (MBES), Sub Bottom Profiler (SBP) pinger, Ultra High Resolution (UHR) multichannel and Magnetometer (MAG) survey carried out within the Thanet Extension array area and OECC between July and September 2016.	Fugro (2016a,b)
Geotechnical survey	Seabed cone penetration test (CPT) and vibrocores sampling operations were performed 12th - 16th September 2016. A total of 18 test locations were investigated in the Thanet Extension array area (10 CPT, 8 vibrocore). A total of two test locations were investigated in the Thanet Extension array area 1 CPT, 1 vibrocore).	Fugro (2016c)
Benthic survey	Survey undertaken 11th – 14th November 2016. Particle Size Analysis (PSA) carried out on 28 grab samples. Drop down video acquired at 39 stations.	Fugro (2017)
Oceanographic survey	Wave, current, water and sediment data at two locations within the Thanet Extension array area. Two 600 kHz Nortek Acoustic Wave and Current meters (AWAC), a Datawell Waverider and two Optical Back Scatter (OBS) sensors were deployed on 16th and 17th December 2016 and recovered on 16th and 17th February 2018 (1 year and 2 months of data)	Partrac (2017)

2.5 Assessment criteria and assignment of significance

2.5.1 For the most part physical processes are not in themselves receptors but are instead 'pathways'. However, changes to physical processes have the potential to indirectly impact other environmental receptors (Lambkin *et al*., 2009). For instance, the creation of sediment plumes (which is considered in the physical processes assessment) may lead to settling of material onto benthic habitats. The potential significance of this particular change is assessed in Volume 2, Chapter 5: Benthic Ecology (Document Ref: 6.2.5). This distinction between assessments of pathways and receptors is summarised in Table 2.5, for each of the potential impacts/ changes identified considered within the assessment section.

2.5.2 Whilst physical processes can largely be considered as pathways, a small number of features have been identified as potentially sensitive physical processes receptors. These are:

- Designated coastal features (Saltmarshes, intertidal flats and dune systems – see paragraph 2.7.63 for details);
- Sand banks (South Falls, Goodwin Sands and Margate Sands) (Figure 2.1); and
- Designated chalk features (cliffs, platforms and reefs – see paragraph 2.7.63 for details)

2.5.3 These receptors have been identified on the basis of:

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

2.5.4 Where these receptors have the potential to be affected by changes to physical processes, a full impact assessment (i.e. assigning sensitivity, magnitude and significance) has been carried out.

2.5.5 The assessment of effects upon physical processes receptors is a systematic process that is determined by taking into account the 'Sensitivity and importance of the receptor 'and the 'Magnitude of the impact'. These assessment criteria are described in more detail within this section.

2.5.6 The importance and sensitivity of each receptor has been assessed using expert judgement and described with a standard semantic scale using the terms Very Low, Low, Medium, High and Very High. Definitions for each term are provided in Table 2.6. These expert judgements regarding receptor sensitivity/ importance are closely guided by the conceptual understanding of regional-scale physical processes, developed during the baseline characterisation process (paragraph 2.7.1 onwards).

Table 2.5: Summary of potential impacts/ changes considered in the physical processes assessment

Potential impact/ change	Pathway (P)/ Receptor (R)
Construction	
Increases in SSC and deposition of disturbed sediments to the seabed due to dredging for seabed preparation prior to foundation installation.	P
Increases in SSC and deposition of disturbed sediments to the seabed due to the release of drill arisings during foundation installation.	P
Increases in SSC and deposition of disturbed sediment to the seabed due to cable installation within the Thanet Extension array area and within the OECC.	P
Sand wave crest level preparation resulting in a change to local hydrodynamic, wave and sediment transport processes.	P
Impacts to sand bank receptors (due to construction activities).	R
Impacts to designated coastal feature receptors (due to construction activities).	R
Operation and Maintenance	
Changes to the tidal regime.	P
Changes to the wave regime.	P
Changes to sediment transport and sediment transport pathways.	P
Scour of seabed sediments.	P
Development of turbid wake features.	P
Impacts to sand bank receptors (due to wind farm operation).	R
Impacts to designated coastal feature receptors (due to wind farm operation).	R
Impacts to designated chalk feature receptors (due to wind farm operation).	R
Decommissioning	
Increases in SSC and deposition of disturbed sediment to the seabed within the Thanet Extension array area and the OECC.	P
Impacts to designated coastal feature receptors (due to decommissioning activities).	R
Cumulative	
Cumulative temporary increases in SSC and seabed levels as a result of Thanet Extension export cable installation and dredge disposal activities.	P
Cumulative temporary increases in SSC and seabed levels as a result of Thanet Extension export cable installation and aggregate dredging activities.	P

Table 2.6: Sensitivity/ importance of the environment

Receptor sensitivity/ importance	Description/ reason
Very high	No capacity to accommodate the proposed form of change; and/ or receptor designated and/ or of international level importance. Likely to be rare with minimal potential for substitution. May also be of very high socioeconomic importance.
High	Very low capacity to accommodate the proposed form of change; and/ or receptor designated and/or of national level importance. Likely to be rare with minimal potential for substitution. May also be of high socioeconomic importance.
Medium	Moderate to low capacity to accommodate the proposed form of change; and/ or receptor designated and/ or of regional level importance. Likely to be relatively rare. May also be of moderate socioeconomic importance.
Low	Moderate to high capacity to accommodate the proposed form of change; and/ or receptor not designated but of district level importance.
Very low	High capacity to accommodate the proposed form of change; and/ or receptor not designated and of local level importance.

2.5.7 The magnitude of impact describes the extent or degree of change that is predicted to occur to a receptor. It has been assessed using expert judgement and described qualitatively with a standard semantic scale. Definitions for each term are provided in Table 2.7. These expert judgements regarding the magnitude of effect relative to baseline conditions have been made by experienced marine physical process specialists and formed following consideration of a range of information sources including:

- Available survey data and supporting reports/ publications described in the summary of available baseline data (paragraph 2.4.13 onwards);
- The existing evidence base from other Offshore Wind Farms (OWFs) and similar projects; and
- Standard empirical equations e.g. for the assessment of scour, sediment transport and settling.

Table 2.7: Magnitude of impact

Magnitude	Definition
Very high	Permanent changes across the near- and far-field to key characteristics or features of the particular environmental aspect's character or distinctiveness.
High	Permanent changes, over large parts of the near- and far-field, to key characteristics or features of the particular environmental aspect's character or distinctiveness.
Medium	Noticeable, temporary (for part of the project duration) change, or barely discernible change for any length of time, encountered within the near-field and parts of the far-field, to key characteristics or features of the particular environmental aspect's character or distinctiveness.
Low	Noticeable, temporary (for part of the project duration) change, or barely discernible change for any length of time, restricted to the near-field and immediately adjacent far-field areas, to key characteristics or features of the particular environmental aspect's character or distinctiveness.
Very low	Changes which are not discernible from background conditions.

2.5.8 The significance of potential effects has been determined by taking into account the Sensitivity and importance of the receptor and the Magnitude of the impact as applied to construction, O&M and decommissioning stages of the project (Table 2.8).

Table 2.8: Significance of potential effects

		Sensitivity/ importance				
		Very high	High	Medium	Low	Very low
Adverse Magnitude	Very high	*Major*	*Major*	*Moderate*	*Minor*	*Minor*
	High	*Major*	*Moderate*	*Minor*	*Minor*	*Negligible*
	Medium	*Moderate*	*Minor*	*Minor*	*Negligible*	*Negligible*
	Low	*Minor*	*Minor*	*Negligible*	*Negligible*	*Negligible*
	Very low	*Minor*	*Negligible*	*Negligible*	*Negligible*	*Negligible*
Beneficial Magnitude	Very low	*Minor*	*Negligible*	*Negligible*	*Negligible*	*Negligible*
	Low	*Minor*	*Minor*	*Negligible*	*Negligible*	*Negligible*
	Medium	*Moderate*	*Minor*	*Minor*	*Negligible*	*Negligible*
	High	*Major*	*Moderate*	*Minor*	*Minor*	*Negligible*
	Very High	*Major*	*Major*	*Moderate*	*Minor*	*Minor*

Note: shaded cells are defined as significant effects in respect of the EIA.

2.5.9 It is noted here that a distinction is made throughout the assessment between the magnitude, extent and duration of 'impacts' and the resulting significance of the 'effects' upon physical processes receptors. Various actions may result in impacts: for instance, the installation of the export cable at the landfall, causing a localised and short-term change to intertidal morphology (which is defined as a physical processes receptor). The significance of effect associated with the impact will be dependent upon the sensitivity/ importance of the receptor, with particular consideration given to the receptor's ability to tolerate and recover from the impact, as well as status.

2.5.10 Mitigation is prescribed only to reduce 'significant' effects. Under EIA guidelines, 'Moderate' and Major' effects are regarded as being significant (Table 2.8). Mitigation measures that were identified and adopted as part of the evolution of the project design (embedded into the project design) are described separately, in section 2.9 (paragraph 2.9.1 onwards).

2.6 Uncertainty and technical difficulties encountered

2.6.1 Uncertainty exists with regards to characterisation of the future baseline. Key areas of uncertainty include the extent to which future changes in storminess may occur and the potential associated changes to the wave regime. There is also considerable uncertainty with regards to exactly how the coast may respond to a modified wave climate acting in combination with higher than present sea levels.

2.6.2 In addition to the uncertainty described above with the future baseline, there is some uncertainty associated with the assessment of sediment plumes and accompanying changes to bed levels due to construction related activities. This arises due to uncertainty regarding how the seabed geology will respond to drilling and jetting. The exact volume of material entrained into the water column will be dependent upon a number of factors including the type of drilling/ cable installation equipment used and the mechanical properties of the geological units. In the absence of detailed information, a series of potential release scenarios have been considered. Together, these scenarios capture the worst-case impacts in terms of the highest concentration suspended sediment plumes, the most persistent suspended sediment plumes, the maximum changes in bed level elevation and the greatest spatial extent of change in bed level.

2.7 Existing environment

2.7.1 Physical processes have been sub-divided into the following categories:

- Water Levels;
- Currents;
- Wind and wave climate;
- Sediments and geology;
- Seabed bathymetry and geomorphology; and
- Designated sites.

2.7.2 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 upon which impacts from the project can be assessed against. Many of the datasets used to inform the baseline post-date the construction of TOWF and therefore any localised changes associated with the operational TOWF are captured within the baseline for Thanet Extension.

2.7.3 A technical report and ES Chapter were produced for the area of the Thanet array (Thanet Offshore Wind Limited, 2005). A review of the key findings from that study has been incorporated into the description of the existing environment. It is not intended to repeat or to carry out any additional assessment of impacts within the array boundary.

Thanet Extension array area

Water levels

2.7.4 The Thanet Extension array area is located within a semi-diurnal tidal environment with a macro-tidal range (Figure 2.3; Table 2.9). Water levels throughout the array generally increase in range from north-east to south-west. The typical spring tide range is 4.3 - 4.8 m, with a neap range of 2.4 - 2.6 m (VWPL, 2015; ABPmer *et al*., 2008b).

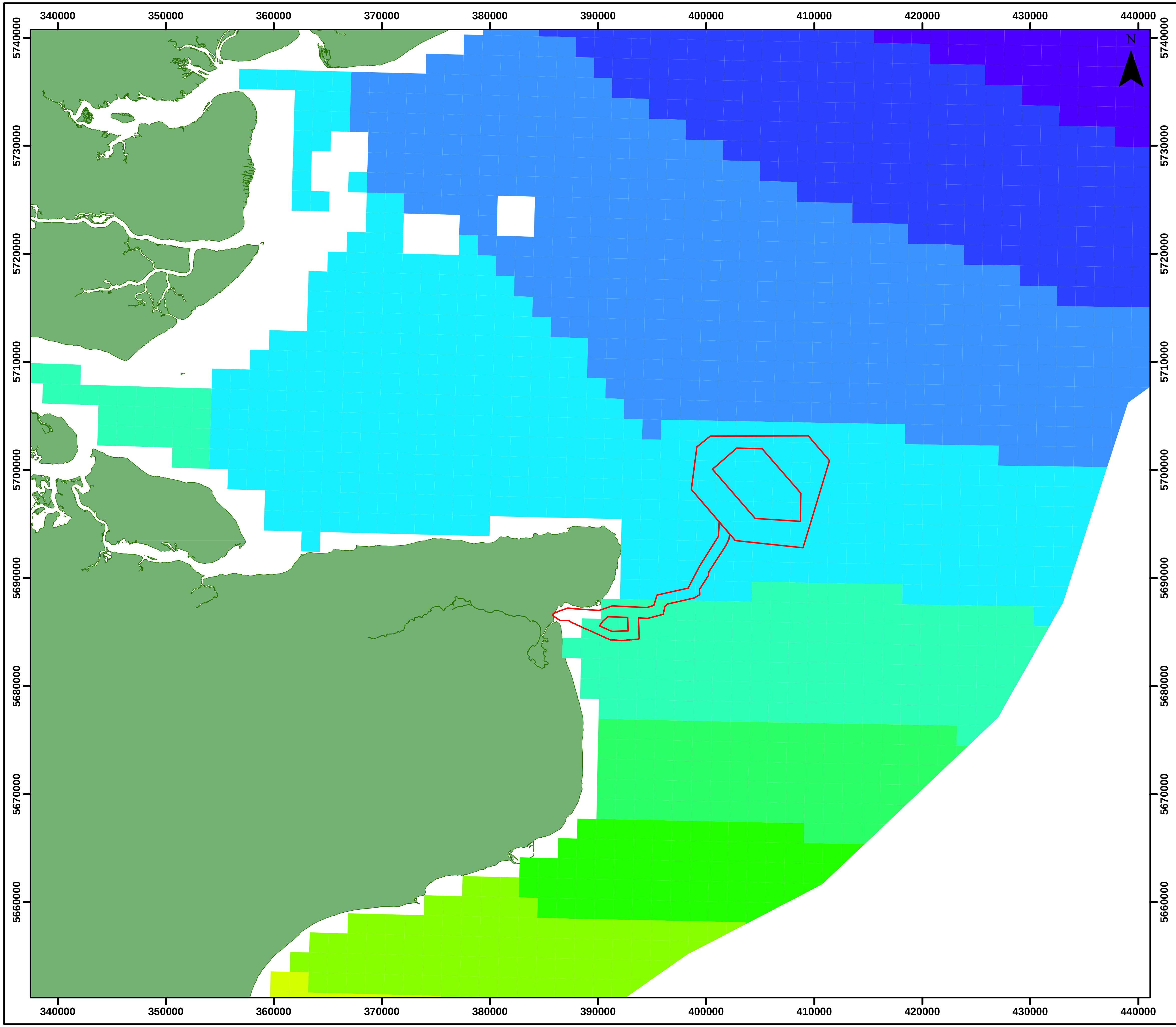
Table 2.9: Standard water levels at three locations around Thanet Extension (height values quoted relative to LAT in metres)

Datum*	Description	Site A1	Site A2	Site A3
HAT	Highest Astronomical Tide	5.38	5.50	5.88
MHWS	Mean High Water Spring	4.81	4.84	5.24
MHWN	Mean High Water Neap	3.84	3.85	4.15
MSL	Mean Sea Level	2.63	2.65	2.86
MLWN	Mean Low Water Neap	1.42	1.45	1.57
MLWS	Mean Low Water Spring	0.45	0.46	0.48
LAT	Lowest Astronomical Tide	0.00	0.00	0.00
	Tidal Range			
HAT - LAT	Largest Tidal Range	5.38	5.50	5.88
MSR	Mean Spring Range	4.36	4.38	4.76
MNR	Mean Neap Range	2.42	2.40	2.58
* See Figure 2.2 for A1, A2 and A3 locations				

Source: VWPL (2015)

2.7.5 Extreme water levels at the proposed development typically result from storm surge propagation within the North Sea. The processes associated with storm surge propagation in the North Sea are generally well understood, having been extensively studied. In brief, a storm surge is produced when high winds build up a wall of water, further exacerbated by the effects of atmospheric pressure (Prichard, 2013). Whilst the AWAC deployments from the Thanet Extension array area provide a relatively long period (1 year and 2 months) of measured non-tidal influences on water levels, these limited duration records cannot be used directly to derive robust longer return period estimates of extreme water levels (beyond a few years return period). Instead, this information has been obtained from hydrodynamic modelling which utilises long-term hindcast wind records (VWPL, 2015). This analysis suggests storm surge elevations within the Thanet Extension array area are between 2.65 and 2.80 m for a 1:50 year event (VWPL, 2015).

2.7.6 Mean sea level is likely to rise during the 21st Century as a consequence of either vertical land (isostatic) movements or changes in eustatic sea level. It is predicted in UKCP09 that by 2050, relative sea level will have risen by approximately 0.35 m above 1990 levels (medium emissions scenario) at the landfall with rates of change increasing over time (Lowe *et al*., 2009). A rise in sea level may 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.



THANET EXTENSION OFFSHORE WIND FARM

Figure 2.3

Variation in Water Levels Across the Marine Physical Processes Study Area

Legend

Offshore Red Line Boundary

Mean Spring Range (m)

- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- 4.5 to 5.0
- 5.0 to 5.5
- 5.5 to 6.0
- 6.0 to 6.5
- 6.5 to 7.0

Datum: ETRS 1989
Projection: UTM31N

1:350,000 — 0, 4, 8 km; 0, 2, 4 nm

Drg No	003_ES_Fig2.3_Atlas_Water_Levels		
Rev	1	Date	24/05/2018
By	AMC	Layout	N/A

Figure 2.3

Currents

2.7.7 Data from the first service visit of the metocean survey (Partrac, 2017) provides information about flows at two locations in Thanet Extension; one site is in the northern section (Site A2, at around 22 m depth) and the other in the southern section (Site A3, at around 17 m depth) (Figure 2.4). Regional-scale information on tidal currents is also available from the UK Atlas of Marine Renewable Energy Resources (ABPmer *et al*., 2008b) (Figure 2.5). The following can be noted from the depth-average flows derived from the metocean measurements;

- Flows are slightly stronger at the southern metocean deployment (Site A3), as might be expected due to a location which has a slightly higher tidal range. This site is also under the influence from the tide moving towards the Dover Straits where tidal velocities are also increased by the narrowing section of water;
- Depth averaged mean spring currents within the Thanet Extension array area are in the approximate range 0.7 - 1.2 m/s, with equivalent neap flows of between approximately 0.4 - 0.7 m/s; and
- The axis of tidal flows at Site A3 is south (flood) to north (ebb), and fairly aligned with the adjacent coastline. Site A2 is at a location further north of the north Kent coast and consequently comes under the influence of the tidal exchange with the Outer Thames. This influence leads to a re-orientation of the flood tide to the south-south-west and the ebb set to north-north-east.

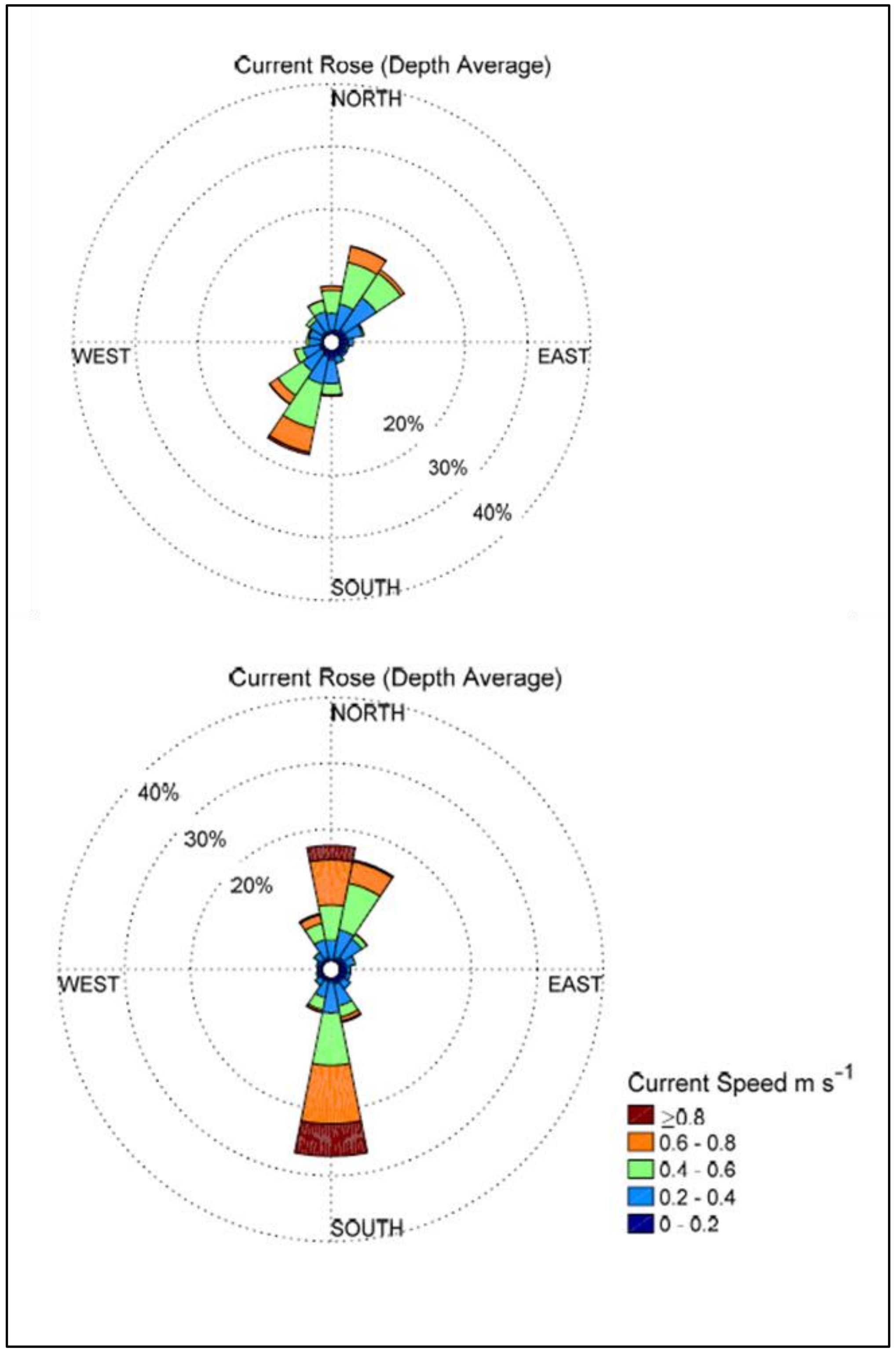
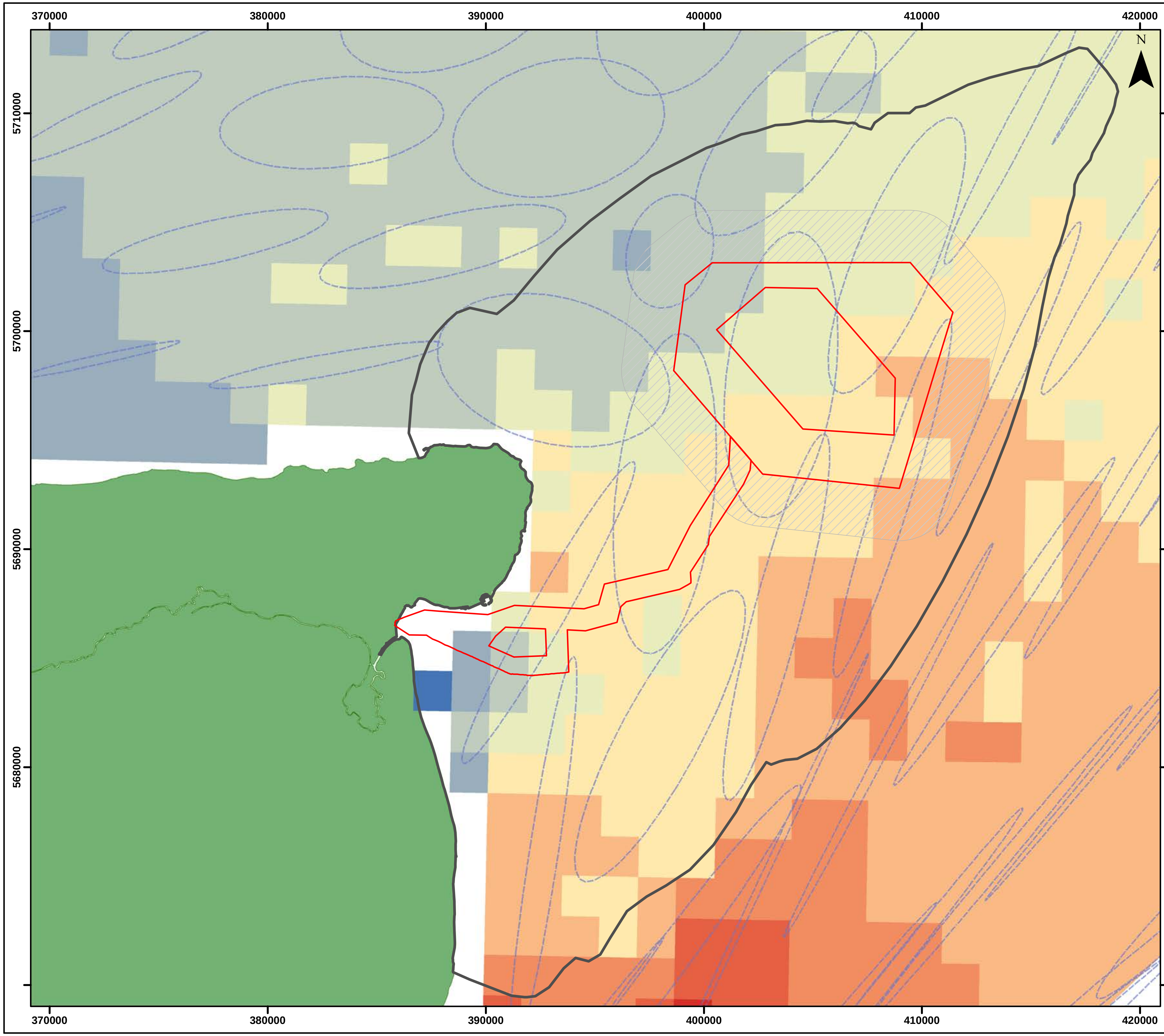


Figure 2.4: Current roses from metocean deployments A2 (top) and A3 (bottom), December 2016 to March 2017 (Partrac, 2017).



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THANET EXTENSION OFFSHORE WIND FARM

Figure 2.5

Variation in Tidal Current Speed Across the Marine Physical Processes Study Area

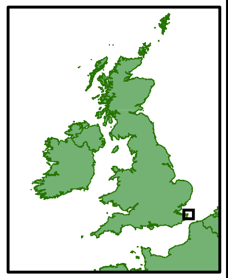
Legend

- Offshore Red Line Boundary
- 2.4 km Buffer
- Spring Tide Excursion Buffer
- Spring Tidal Ellipse

Mean Spring Peak Current Speed (m/s)

- <0.2
- 0.2 to 0.4
- 0.4 to 0.6
- 0.6 to 0.8
- 0.8 to 1.0
- 1.0 to 1.2
- 1.2 to 1.4
- 1.4 to 1.6
- 1.6 to 1.8
- >1.8

Datum: ETRS 1989
Projection: UTM31N



1:175,000 — 0 2 4 km; 0 1 2 nm

Drg No	003_ES_Fig2.5_Atlas_Currents		
Rev	1	Date	24/05/2018
By	AMC	Layout	N/A

Figure 2.5

2.7.8 Tidal ellipses within western and central sections of the Thanet Extension array area are generally aligned north to south, with more of a north-east to south-west alignment within the eastern section (Figure 2.5). This results in a generally southerly orientated flood tide, with the ebb in a north-north-east direction.

2.7.9 Information on the longer term net tidal current drift rate and direction is available from the tidal flow modelling presented within the TOWF ES (Thanet Offshore Wind Limited, 2005). Patterns of net tidal current drift are both temporally and spatially variable although they are typically in a southerly direction during spring tides and in a northerly direction during neap tides. During spring tides net tidal current drift rates are relatively high (up to approximately 0.2 m/s), which is also associated with potentially high rates of southerly sediment transport in parts of the Thanet Extension array area (paragraph 2.7.22 onwards).

2.7.10 The maximum extreme (surface) current speeds throughout the Thanet Extension array area (which includes the influence of meteorologically caused residual surge currents) are summarised in Table 2.10, based on modelling outputs from a project specific metocean study (VWPL, 2015). This data demonstrates that flow may be greatly enhanced by meteorological forcing factors. During the oceanographic survey campaign (16/12/2016 to 14/03/2017) maximum surface flows speeds of 1.3 m/s and 1.7 m/s were recorded at Site A2 and A3, respectively. On the basis of the return period analyses presented in Table 2.10, it is not unusual for flow speeds of this magnitude to be encountered within the Thanet Extension array area.

Table 2.10: Extreme omni-directional current speeds within the Thanet Extension array area (values in m/s)

Location	Return period (years)		
	1:1	1:10	1:50
Site A1	1.30	1.38	1.43
Site A2	1.74	1.95	2.12
Site A3	1.86	2.11	2.30

Source: VWPL (2015)

Wind and wave climate

2.7.11 Hindcast data from ABPmer's SEASTATES database has been used to characterise wind and wave conditions within the Thanet Extension array area (ABPmer, 2016), along with observational wave records from the wider study area available from the Channel Coastal Observatory. At the time of writing, < 6 months of wave data was available from the project specific metocean survey and this is of insufficient duration to fully characterise the wave regime. SEASTATES is a fully spectral wave model which provides thirty eight years of hindcast data (1979-2016) for the North Atlantic and European shelf seas. The model is driven by the spatially and temporally varying CFSR (Climate Forecast System Reanalysis) wind fields developed by NOAA (National [American] Oceanic and Atmospheric Administration). The SEASTATES hindcast has been previously validated against 28 buoys within UK and European waters (ABPmer, 2013).

2.7.12 Wind conditions throughout the proposed array are shown in Figure 2.6 (based on hindcast wind data from NCEP for the period 1979 to 2016). An analysis of the hindcast records shows that the predominant wind direction is south-westerly, with approximately 20% of all winds originating from this direction. Wind speeds of between 5 - 10 m/s account for around half of the record whilst the maximum observed speed was 27.3 m/s. HSE (2002) provide estimates of extreme wind speed return periods within the vicinity of the Thanet Extension array area, with the estimated extreme wind speed for a 1:50 return of approximately 30 - 32 m/s.

2.7.13 The dominant wave directions within the Thanet Extension array area are from the north-east (Figure 2.7, based on hindcast wave data from ABPmer SEASTATES for the period 1979 – 2016) due to large fetch lengths in this direction within the North Sea, and from the south-west due to the predominant south-westerly winds and wave propagation from the English Channel through the Dover Straits (to the south). Wave heights are generally smaller in the western side of the Thanet Extension array area due to sheltering from both North and South Foreland. Within the Thanet Extension array area, significant wave heights (Hs) are in the range 0 - 1 m for approximately 65 - 80% of the time whilst waves between 1 - 2 m in height occur for approximately 20 - 30% of the time. The maximum significant wave height throughout the 38 year record is 5.84 m. Mean wave periods (Tm) are typically in the range 3 - 6 seconds and are indicative of a setting in which wind waves generally dominate. However, longer period (> ~8 seconds) swell waves are also encountered which are associated with waves propagating southwards through the North Sea and northwards from the English Channel via the Dover Straits. The largest and longest period waves are encountered during winter months with calmer conditions generally prevailing during the summer months. Indeed, analysis of the hindcast wave data from the array area shows that average significant wave heights are approximately 60% larger in winter compared with summer. Similarly, mean wave periods are around 20% longer during winter months than summer months.

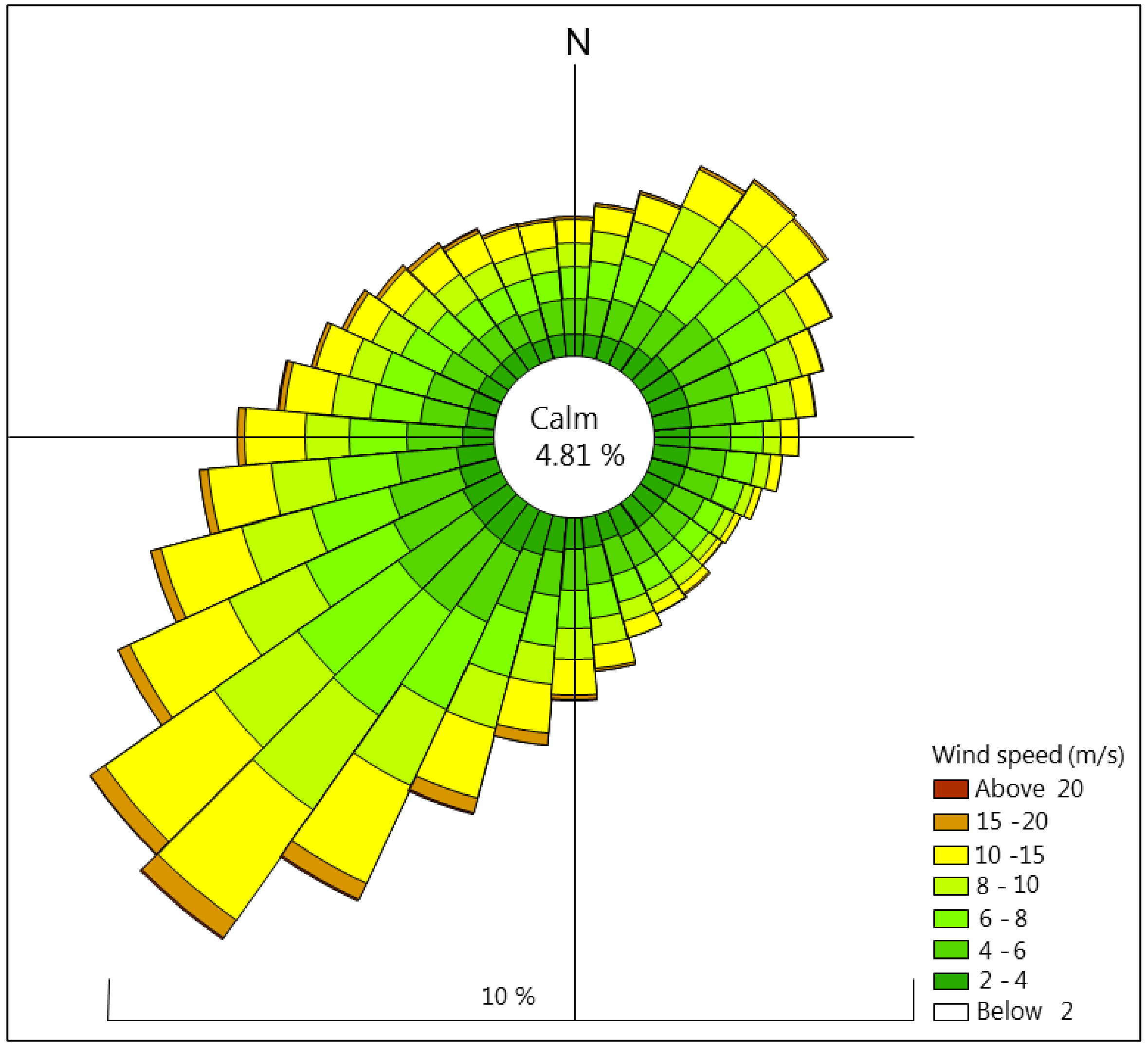
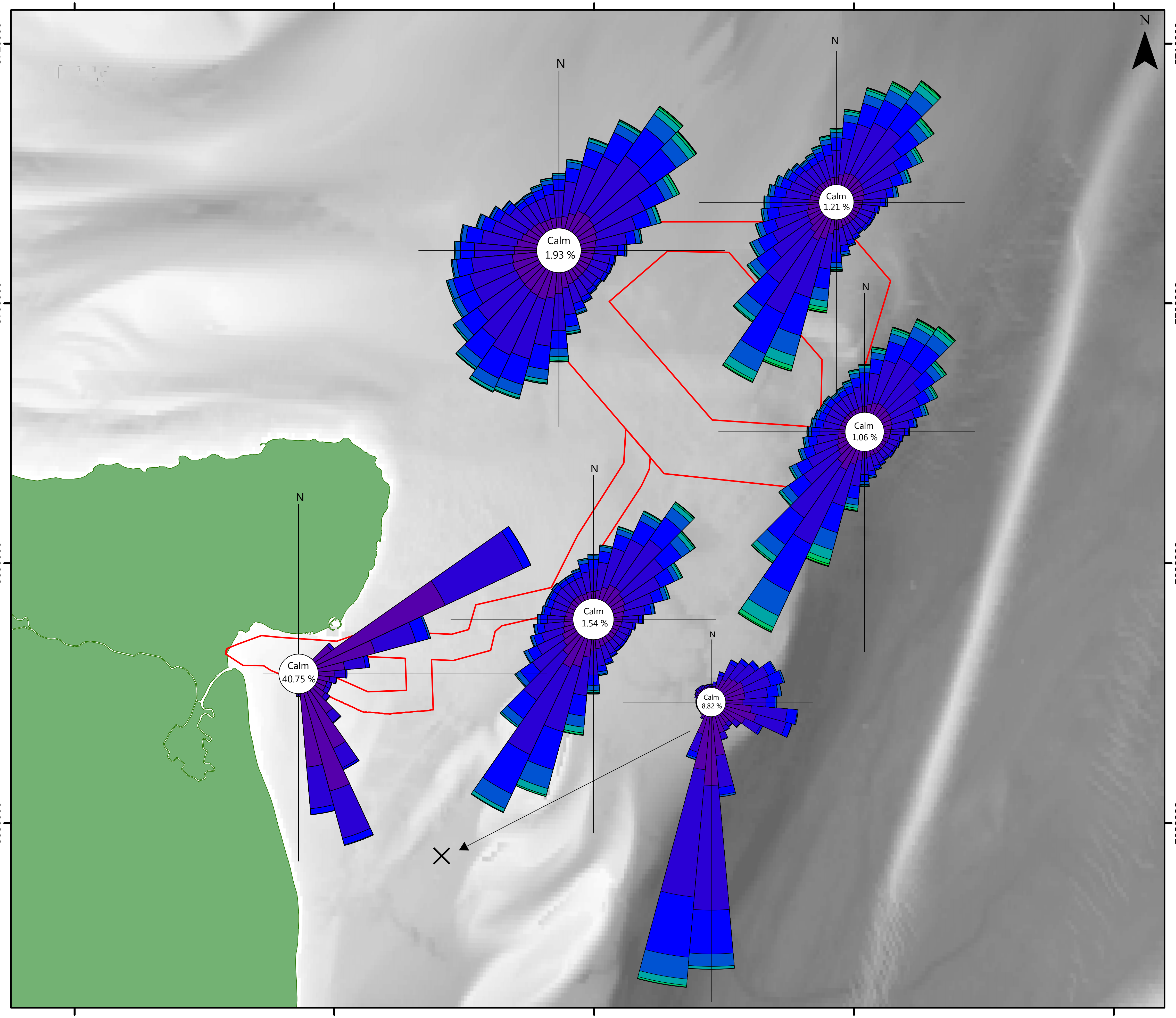


Figure 2.6: Wind rose for the Thanet Extension Offshore Wind Farm array area.



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THANET EXTENSION OFFSHORE WIND FARM

Figure 2.7

Variation in Wave Conditions Across the Marine Physical Processes Study Area

Legend

Offshore Red Line Boundary

CCO Goodwin Sands Wave Buoy

Significant Wave Height (m)

- Above 5.50
- 5.00 - 5.50
- 4.50 - 5.00
- 4.00 - 4.50
- 3.50 - 4.00
- 3.00 - 3.50
- 2.50 - 3.00
- 2.00 - 2.50
- 1.50 - 2.00
- 1.00 - 1.50
- 0.50 - 1.00
- 0.25 - 0.50
- Below 0.25

Bathymetry (m CD)

6.0, -11.8, -29.5, -47.3, -65.1

Datum: ETRS 1989
Projection: UTM31N

Wave data based on hindcast wind data from NCEP for the period 1979 to 2016.

1:150,000 — 0, 1.5, 3 km; 0, 0.85, 1.7 nm

Drg No	003_ES_Fig2.7_Wave_Climate		
Rev	1	Date	24/05/2018
By	AMC	Layout	N/A

Figure 2.7

2.7.14 Information on extreme wave conditions in the vicinity of the Thanet Extension array area is available from extremes analysis of modelled wave data within VWPL (2015). Findings are summarised in Table 2.11. These extreme waves predominantly occur from the north-easterly and south-westerly directions.

Table 2.11: Omni-directional extreme wave height and zero crossing period (Hs values in m; Tz in s)

	Return period (years)					
	1:1		1:10		1:50	
	Hs	Tz^	Hs	Tz	Hs	Tz
Site A1	3.0	6.3	3.9	7.3	4.6	7.9
Site A2	3.7	6.9	4.7	7.7	5.3	8.2
Site A3	3.4	6.7	4.4	7.6	5.1	8.2
^ Tz is defined as the mean time interval between upward or downward zero crossings on a wave record						

Source: VWPL (2015)

Sediments and geology

2.7.15 *O*n the basis of the available grab sample data (Fugro, 2017) and interpreted multi-beam backscatter and side-scan sonar data (Fugro 2016a; Thanet Offshore Wind Limited, 2005), it is found that sediments within the Thanet Extension array area mainly consist of sand and gravel with variable contributions of silt and/ or clay (Figure 2.8). The north-west of the array consists of mainly fine to medium sand, with clayey/ silty sand also present. Close to the TOWF array, the presence of sub-cropping tertiary sediments results in an irregular and poorly sorted seabed with cobble and boulder clusters frequently present. The north and east of the Thanet array area consists of fine to coarse sand of varying proportions, with individual pockets of clay/ silt and sand/ gravel. Often the surficial sediments are present as thin veneers immediately overlying larger geological features.

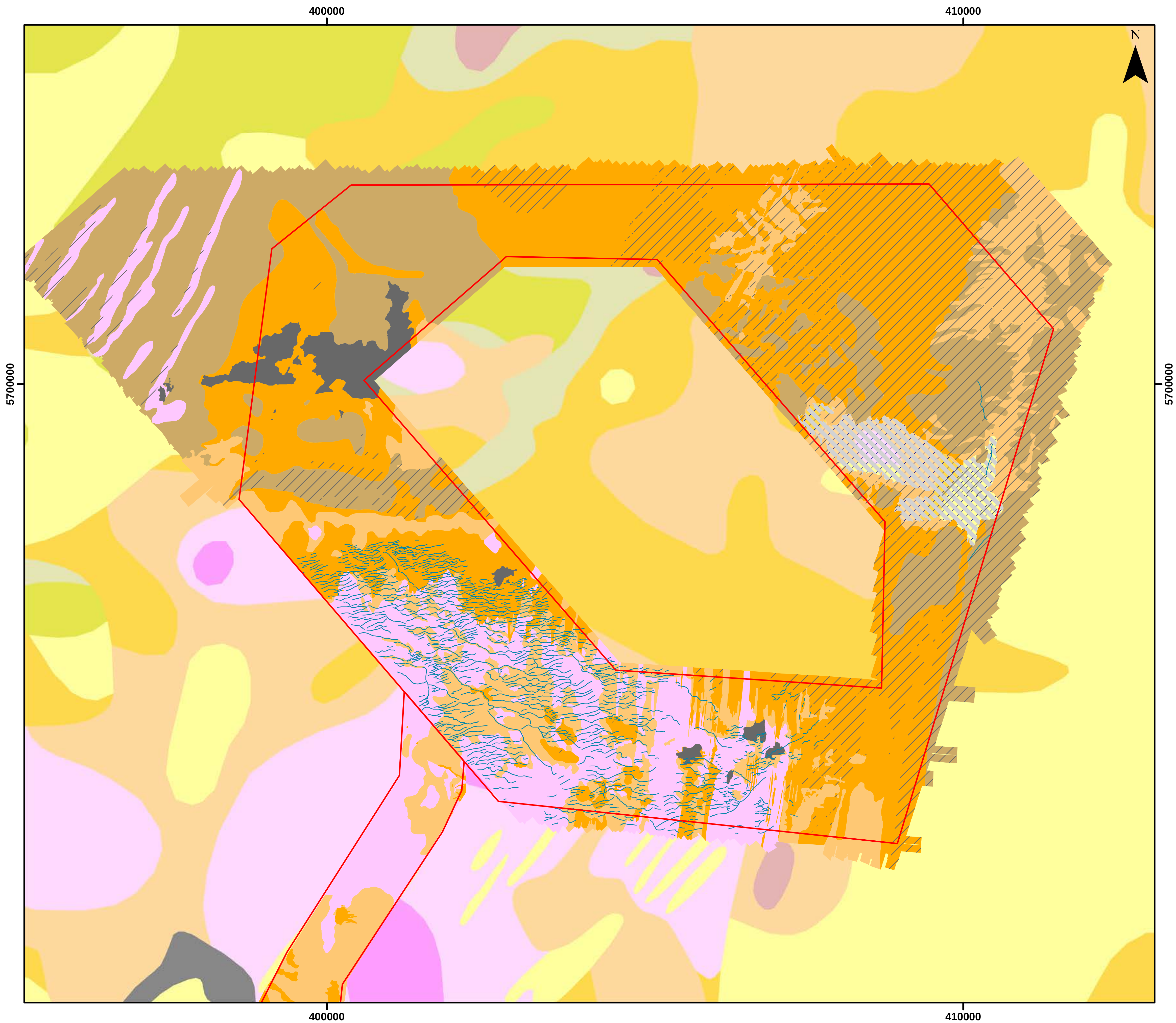

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Figure 2.8

Seabed Sediment and Bedform Distribution Within the Thanet Extension Array Area

Legend

Offshore Red Line Boundary

Seabed Sediments
- 'Clayey to Silty Sand' (Fugro, 2016a)
- 'Fine to Coarse Sand' (Fugro, 2016a)
- Gravel
- Gravelly Muddy Sand
- Gravelly Sand
- Muddy Gravel
- Muddy Sand
- Rock
- Sand
- Sandy Gravel
- Slightly Gravelly Muddy Sand
- Slightly Gravelly Sand

Seabed Features (Fugro, 2016a)
- Small to Medium Sand Waves
- Ridge Crest
- Reef

Datum: ETRS 1989
Projection: UTM31N

Sediment distribution within the array area from Fugro (2016a); surrounding areas from BGS seabed mapping

1:60,000 — 0 0.65 1.3 km; 0 0.3 0.6 nm

Drg No	003_ES_Fig2.8_Sediments_Bedforms_Array		
Rev	1	Date	24/05/2018
By	AMC	Layout	N/A

Figure 2.8

2.7.16 Interpretation of underlying geology within the Thanet Extension array area is provided from seabed cone penetration tests and vibrocore sampling (Fugro 2016c) (Figure 2.2), as well as outputs from the project-specific geophysical survey (Fugro, 2016a). A summary of the interpreted geology is presented in Table 2.12 whilst the mapped distribution of the interpreted units is provided in Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1).

2.7.17 Geological properties throughout the southern North Sea have been strongly influenced by successive eustatic sea level variations. Extensive areas of Cretaceous chalk are covered by varying thicknesses of Tertiary marine sediments throughout the Thanet Extension array area, such as mudstones and fine grained muddy sands which are suggested to have high organic contents. Sporadic presence of quaternary shallow-water and deltaic sediments are also present (mainly in the north and west of the array area), and are suggested to be a result of channel formations throughout interglacial periods (Fugro, 2016a).

Table 2.12: Summary of interpreted geology throughout Thanet Extension array area

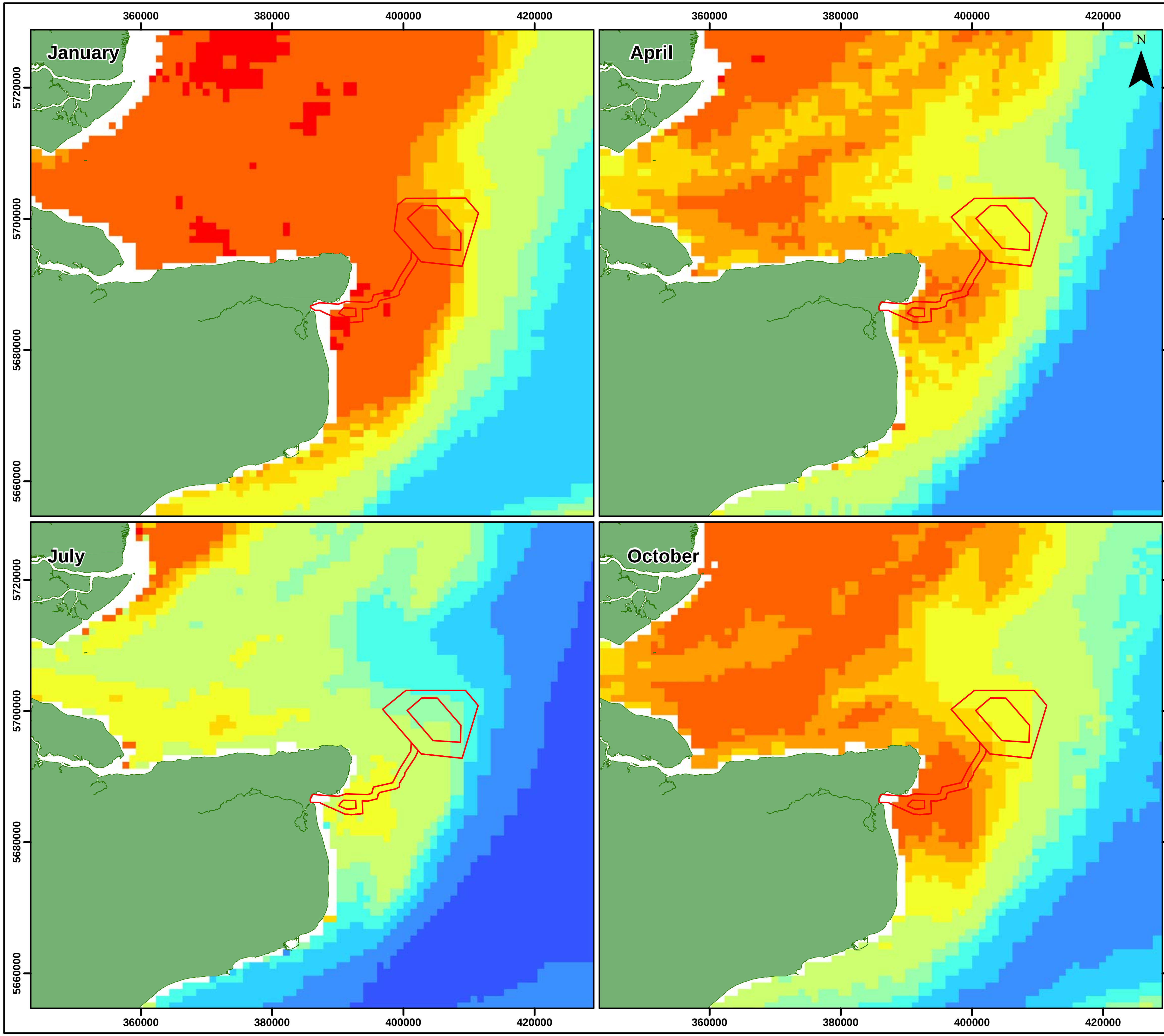
Unit	Base of unit below seabed (m)	Indicative lithology	Depositional environment	Formation	Age
A	0 to 13.2	Coarse sand, with shells and shell fragments, rare silt and clay laminae and rare gravel	Marine	Southern Bight	Holocene
B	0 to 20.1	Variable sand, silt, clay and organic materials	Channel deposit	Partly Elbow	Early Holocene/ Pleistocene
C	1 to 50	Sand overlain by marine silty clays, clayey and sandy silts, and subordinate sands, pebble beds,	Marine/ Shallow Marine	London Clay, Harwich, Woolwich, Upnor	Eocene/ Paleocene
D	1 to 74	Glaucinitic sands, silts and silty clay with basal flint conglomerate	Shallow marine	Thanet Formation	Paleocene
E	67 to 164	White chalk with flint and gravels/cobbles	Marine	Upper Chalk	Late Cretaceous
F	83 to 178	Chalk with sand, silt and clay	Shallow marine	Upper Chalk	Late Cretaceous
G	138 to 253	Marly Chalk with flint	Marine	Middle Chalk	Late Cretaceous
H	N/A	Shaly marl Chalk, hard comminuted shell-bed, calcareous clay and glauconitic marl	Marine	Lower Chalk	Late Cretaceous

Source: Fugro (2016c)

2.7.18 The southern North Sea is characterised by a high degree of spatial and temporal (both annual and inter-annual) variability in SSC. In general, there exists an inshore to offshore gradient in SSC, with the highest concentrations observed close, and especially at the mouths, to large estuaries such as the Thames (Cefas, 2016).

2.7.19 The Thanet Extension array area is located close to the Thames Estuary, an area characterised by naturally high levels of turbidity, primarily in response to the input of fine grained sediments from fluvial sources, erosion of soft cliff coasts and the frequent re-suspension of mobile material from shallow seabed settings. It is situated at the boundary between the turbid Thames Estuary and the clearer North Sea, in a region known as the East Anglian Plume (Cefas, 2016). The East Anglian Plume extends from the East coast of the UK across the southern North Sea towards the Danish coastline and has an important role in transporting sediment across the North Sea (Dyer and Moffat, 1998) (Figure 2.9).

2.7.20 Monthly averaged satellite imagery of Suspended Particulate Matter (SPM) suggests that within the Thanet Extension array area average (surface) SPM is generally greater than 10 mg/l, increasing markedly throughout winter months to values between 30 - 80 mg/l (Eggleton *et al*., 2011; Cefas, 2016), occasionally reaching up to 100 mg/l. Higher values are anticipated during spring tides and storm conditions, with the greatest concentrations encountered close to the bed.



THANET EXTENSION OFFSHORE WIND FARM

Figure 2.9

Average Surface Suspended Particulate Matter Concentration for the Period 1998-2015

Legend

- Offshore Red Line Boundary

Suspended Particulate Matter (1998-2015) mg/l

- 0-1
- 1-2
- 2-4
- 4-6
- 6-8
- 8-10
- 10-20
- 20-30
- 30-40
- 40-50
- 50-100
- >100

Datum: ETRS 1989
Projection: UTM31N

1:581,695 — 0, 6, 12 km — 0, 3.5, 7 nm

Drg No	003_ES_Fig2.9_SPM_maps		
Rev	1	Date	24/05/2018
By	AMC	Layout	N/A

Figure 2.9

2.7.21 Turbid wakes have been observed at the Thanet, London Array and Greater Gabbard OWFs in the outer Thames estuary in aerial (e.g. VWPL, 2017), satellite imagery (e.g. Vanhellemont and Ruddick, 2014; NASA, 2016) (Figure 2.10) as well as directly via field measurements (Forster, 2017). The turbid wake features are aligned with the tidal stream locally, are typically 30 - 150 m wide and extend 'one or more' kilometres downstream from each WTG (and for 'more than 10 km' at TOWF) (Vanhellemont and Ruddick, 2014). Absolute SPM concentrations are typically a few 10's of mg/l above background levels and are reported as being 'probably dependent upon sea-floor sediment type and water depth' (Vanhellemont and Ruddick, 2014). The cause of these features is discussed in detail within paragraph 2.11.58 onwards.

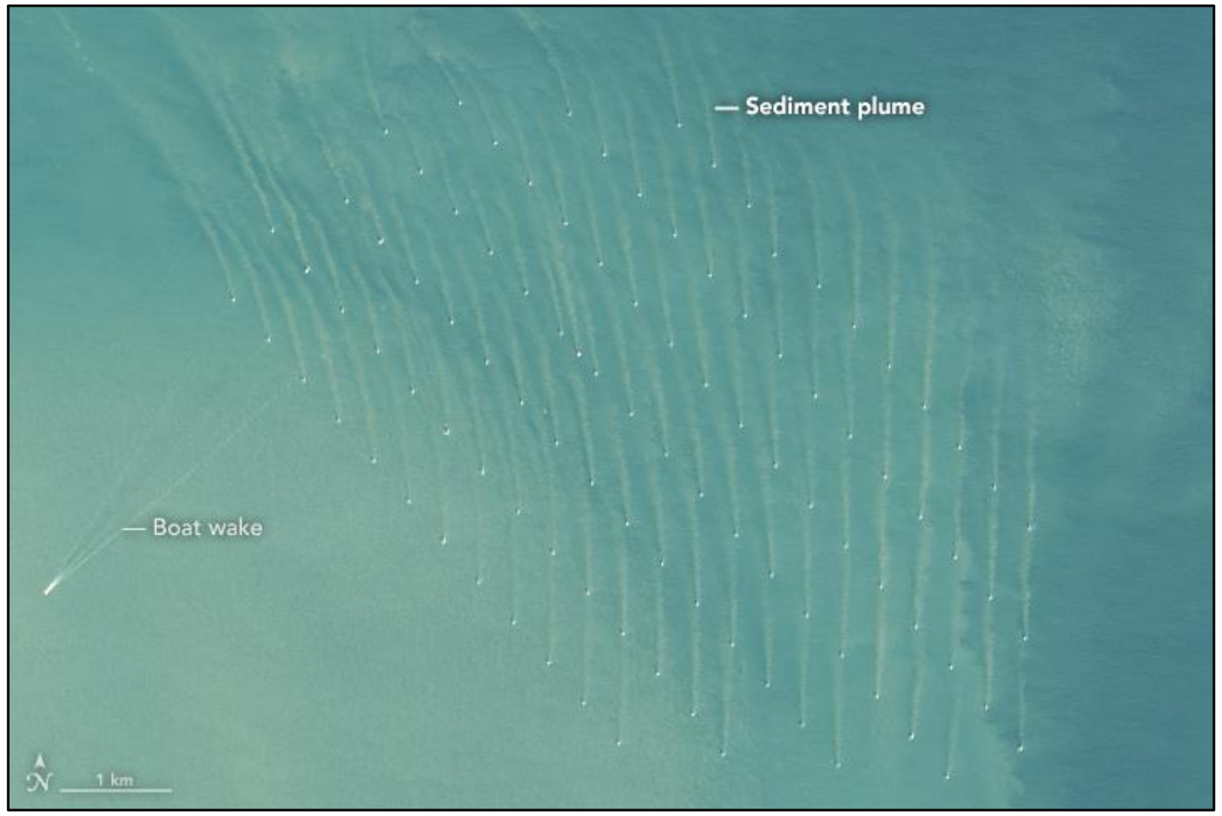


Figure 2.10: Landsat 8 satellite imagery of TOWF, acquired 30/06/2015. (NASA, 2016).

2.7.22 Analysis of satellite observed (sea surface) SPM concentrations suggests that collectively, the turbid wake features have resulted in a net increase in average surface SPM within and nearby to the TOWF array area, with a notable increase in the frequency with which SPM in the range 10 - 20 mg/l is encountered. Annual mean SPM has risen from 26.7 - 30.1 mg/l, whilst the 50% exceedance has increased from 19.2 - 22.2 mg/l (Forster, 2017).

2.7.23 The main influence on sediment transport within the Thanet Extension array area is tidal currents. Using the empirical relationships described in Soulsby (1997), it is found that granule sized gravel material (up to approximately 2,500 µm) is expected to be mobile and during neap tides the largest material that is expected to be mobilised is medium to coarse sized sand (up to approximately 500 µm). Wave action may contribute to enhanced bed shear stress although its influence on the direction of net sediment transport will be limited to shallower areas of the OECC and at the proposed cable landfall.

2.7.24 On the basis of the existing regional scale mapping of sediment transport presented in Kenyon and Cooper (2005), it is suggested that the net (bedload) sediment transport is to the south-west across the Thanet Extension array area, with more complex patterns of sediment transport just to the east of the Thanet Extension array area associated with the South Falls sand bank. The suggestion of a general southerly movement of sediment across the array area is supported by several independent lines of evidence (Figure 2.11):

- A comparison of the available multi-beam bathymetry data from 2012 and 2016 from within the Thanet Extension array area shows that southerly sand wave migration of between 25 - 50 m occurred in the north and east area of the Thanet Extension array area equating to an approximate migration rate of between 6 - 12 m/year (Fugro 2016a);
- Progressive vector analyses of the Site A2 and A3 AWAC records, combining information on tidal currents, associated levels of bed shear stress for fine to medium sand (250 µm) and thresholds of motion for sediment at the bed (Soulsby, 1997) suggest net southerly sediment transport at both measurement locations; and
- Sediment transport modelling presented in Thanet Offshore Wind Limited (2005) considered the potential for transport of very fine sand. This modelling suggests high potential rates of net sediment transport in a southerly direction across the Thanet Extension array area during mean spring tides with much lower rates (of varying direction) during neap tides.

2.7.25 However, whilst the separate lines of evidence described above all suggest general southerly transport across much of the Thanet Extension array area, the geophysical survey data from the Thanet Extension array area suggests that this may not be the case within the north-west of the Thanet Extension array area. Here, the asymmetry of the mapped bedforms is clearly indicative of a north-westerly direction of transport, towards the Thames Estuary.

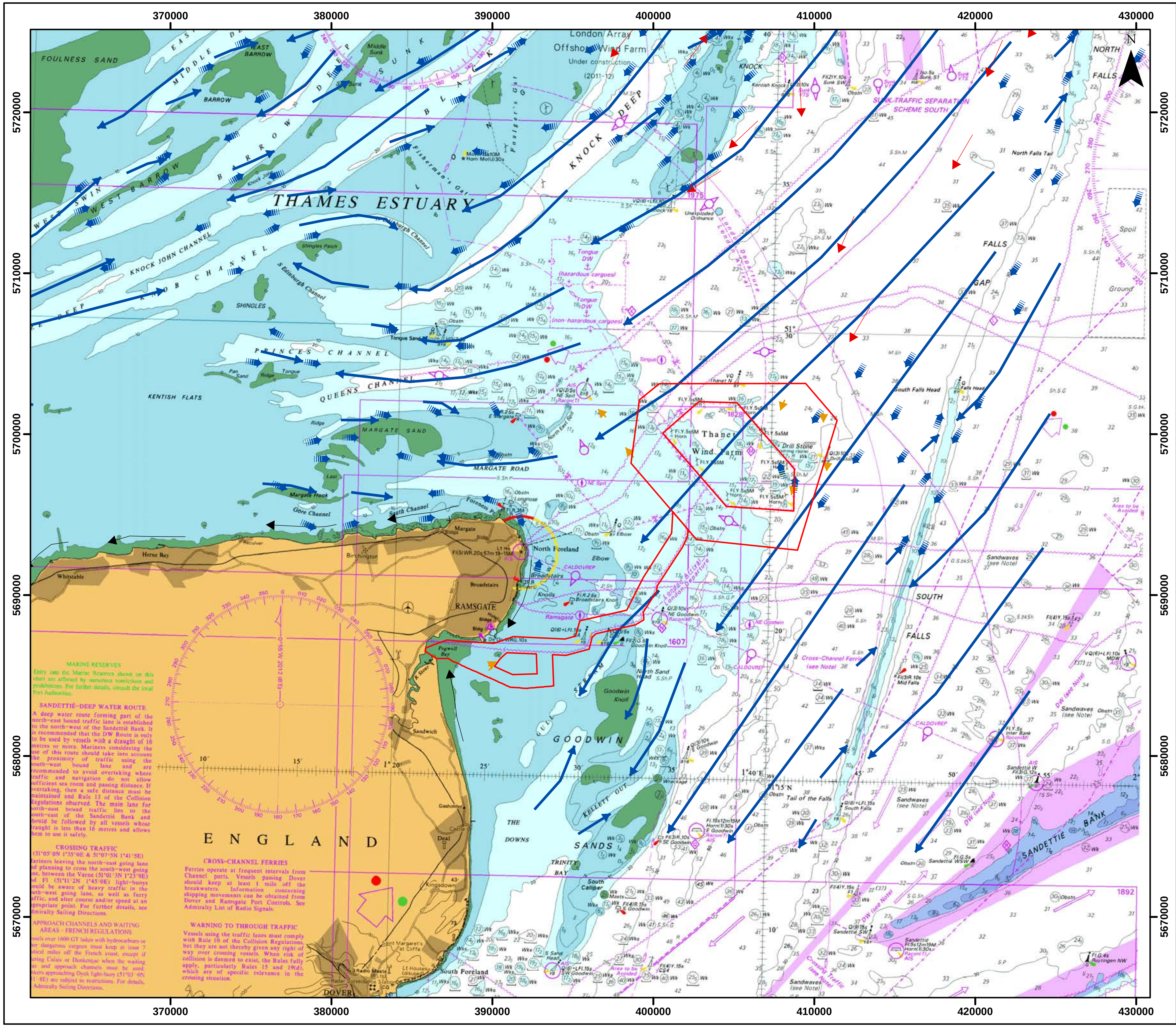


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Figure 2.11

Sediment Transport Pathways Across the Marine Physical Processes Study Area

Legend

Offshore Red Line Boundary

Bedload Sediment Transport

- (this study)
- HR Wallingford et al. (2002)
- Outer Thames REC (Emu, 2009)
- Kenyon & Cooper (2005)

Longshore Sediment Transport

- Kenyon & Cooper (2005)

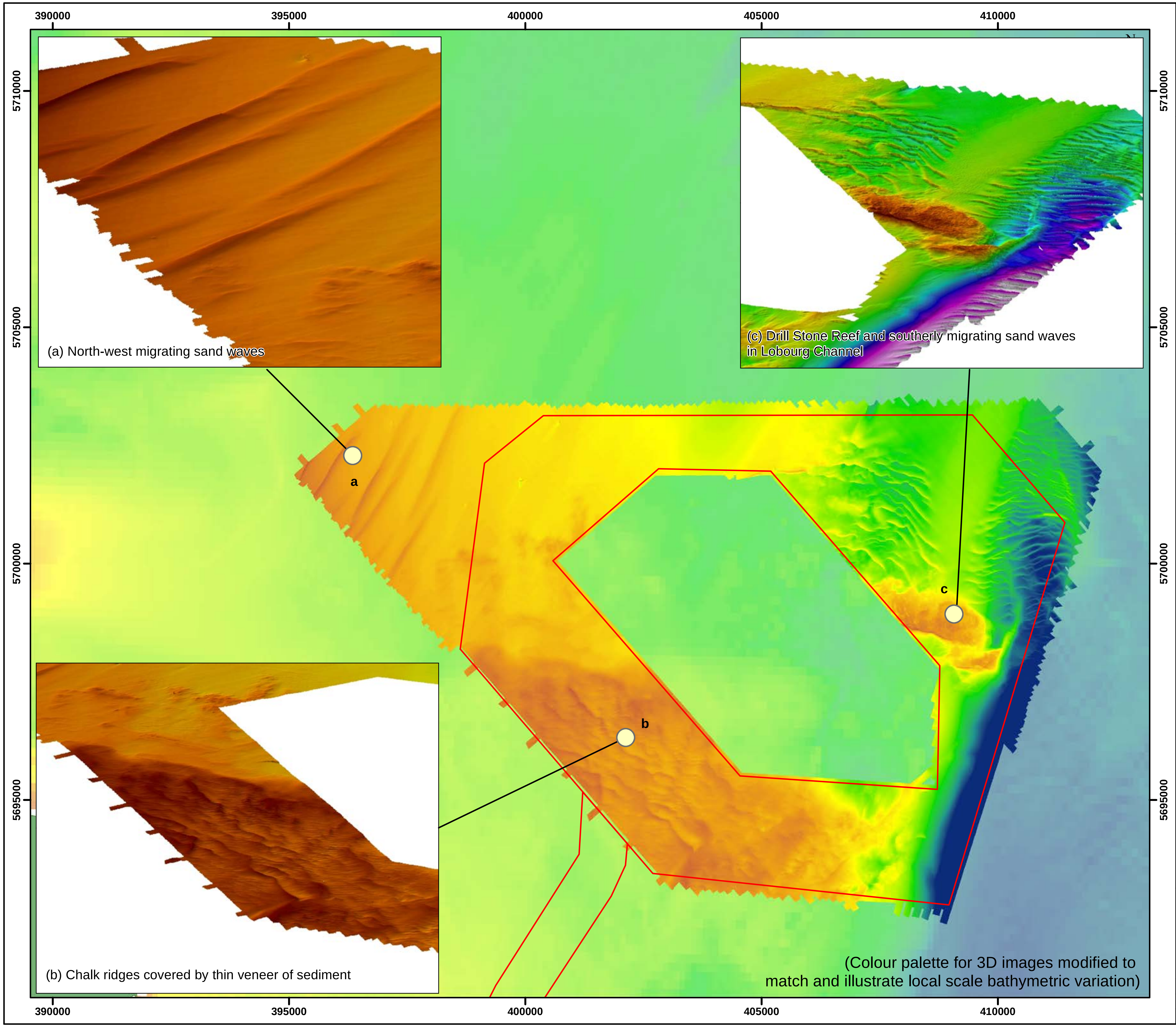
Datum: ETRS 1989
Projection: UTM31N

1:235,000 — 0 2.5 5 km; 0 1 2 nm

Drg No	003_ES_Fig2.11_Sediment_Transport			Figure 2.11
Rev	1	Date	24/05/2018	
By	AMC	Layout	N/A	

Seabed bathymetry and geomorphology

2.7.26 Throughout the array area water depths range between -11.5 and -45 mLAT (Fugro 2016a) (Figure 2.12). Eastern and north-eastern areas of the array are generally deeper, with the greatest water depths encountered along the south-east margin of the array area. This area of seabed corresponds with the western margin of the Lobourg channel, a very large (relict) palaeovalley feature which previously drained much of north-west Europe and south-east Britain when the southern North Sea was subaerially exposed during Pleistocene (2.65 Ma to 11.7 Ka BP) glacial periods.



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THANET EXTENSION OFFSHORE WIND FARM

Figure 2.12

Detailed Bathymetry of the Thanet Extension Array Area

Legend

Offshore Red Line Boundary

Bathymetry (m LAT)

-11.7, -17.2, -22.6, -28.0, -33.3, -48.7

Bathymetry within the array area from Fugro (2016 a,b); surrounding area from Oceanwise, derived from UKHO datasets

Datum: ETRS 1989
Projection: UTM31N

1:80,000 — 0, 0.85, 1.7 km — 0, 0.45, 0.9 nm

Drg No	003_ES_Fig2.12_Bathymetry_Array		
Rev	1	Date	24/05/2018
By	AMC	Layout	N/A

Figure 2.12

2.7.27 Seabed gradients within the array area are generally small (< 5 degrees), although the sand wave formations in the north-east of the site are associated with considerably higher (up to 32 degrees) gradients.

2.7.28 A potential core reef/ persistent reef structure (Drill Stone Reef) (thought to be formed by *S. spinulosa*) exists in the north-east of the Thanet Extension array area. The reef stretches over approximately 3.5 km in a west-north-west to east-south-east direction with a maximum width of approximately 1.3 km including a slightly detached part in the south-east. Its south edge is marked by a relatively sharp and steep decline of up to 30 degrees with water depths decreasing from approximately -13 m to -23 mLAT over a distance of approximately 100 m (Fugro 2016a).

2.7.29 In many locations, the seabed relief reflects the surface expression of the underlying geology (Figure 2.8; Figure 2.12). Relict seabed lineations (or longitudinal furrows) are found in three areas: at the east and west side of the reef complex and in the south-south-east. They usually extend over several hundreds of metres in a north-south direction with widths of 5 - 12 m and heights between 0.1 - 0.6 m. Their presence appears to be limited to areas of elevated seabed. These lineations may be linked to the outburst of glacial meltwaters normal to the ice margin. Ridge features are also widespread, especially in south-easterly parts of the array area. Although similar in appearance to the sedimentary bedform features (described below) these features are not related to currents but present the surface expression of the underlying geological unit (Fugro 2016a).

2.7.30 Much of the seabed within the Thanet Extension array area is characterised by the presence of active current-induced bedforms which are perpendicularly aligned to the main axis of flow. These bedforms comprise sand waves and megaripples of varying height and spacing. These bedforms have been grouped into the following categories by Fugro (2016a), with the location of mapped bedform fields shown in Figure 2.8:

- Very large sand waves of wavelengths 300 - 600 m and a height of up to 6 m. These are predominantly found within the north-west corner of the array. Individual waves have straight lee faces and are generally orientated north-north-east to south-south-west;
- Large to very large sand waves of wavelengths 50 - 300 m and a height of up to 8 m. This category is predominantly found in the north-east area of the array, and has a mixture of straight and irregularly shaped crests. General orientation varies between north-north-west to south-south-west and north-east to south-west depending on the local seabed morphology; and
- Small to medium megaripples of wavelengths 3 - 13 m and heights of 0.1 - 1.5 m. These dunes occupy around a third of the array, either superimposed on the crests of larger sand waves or as sole bedform features. With the latter, they are generally orientated in southerly directions.

2.7.31 In addition to the bedforms within the array area described above, there are also several large sand bank features located relatively close (less than approximately 10 km) to the array area (Figure 2.1). These features have been identified as physical processes receptors (paragraph 2.5.2 onwards) and are briefly described below:

- **Margate Sand** is an estuary-mouth type sand bank located in the outer Thames estuary, approximately 3 km to the west of the Thanet Extension array area. The bank is composed of well-sorted sandy sediments and is understood to be a dynamic feature, with large movements of the bank edges over time (JNCC, 2017a);
- **South Falls** is an open shelf linear sand bank located approximately 6 km to the east of the Thanet Extension array area. It is orientated north-north-east to south-south-west and is understood to be active under present day hydrodynamic conditions (Defra *et al*., 2009). The bank is understood to have a core of material which was swept into position in the earliest stages of the Flandrian transgression of the sea at the end of the last ice age (Venn and D'Oliver, 1983); and
- **Goodwin Sands** is located approximately 2 km to the south of the Thanet extension OECC, approximately 10 km off the Kent coast. The bank is a (near coast) sinuous bank located at a bedload convergence where no overall (net) bedload transport is anticipated (Kenyon and Cooper, 2005).

Designated sites

2.7.32 The eastern side of Thanet extension array area lies within the southern North Sea Candidate Special Area of Conservation (cSAC) (Figure 2.13). However, the primary reason for selection is for Harbour porpoise, rather than the presence of geomorphological features and/ or habitats (JNCC 2017b).

2.7.33 The Thanet extension array area also lies in close proximity (approximately 3 km east) of the Margate and Long Sands SAC. The site contains a number of Annex I sand bank features that are mainly submerged with the crests protruding at low tide, supporting a high diversity of benthic fauna and fish species (JNCC 2017a).

2.7.34 The Goodwin Sands recommended Marine Conservation Zone (rMCZ) is located around 4 km south of the Thanet extension array area. This is being considered for a future inclusion as an MCZ due to the presence of complex reef and mussel bed systems that stabilise mobile sediments whilst additionally providing habitat niches.

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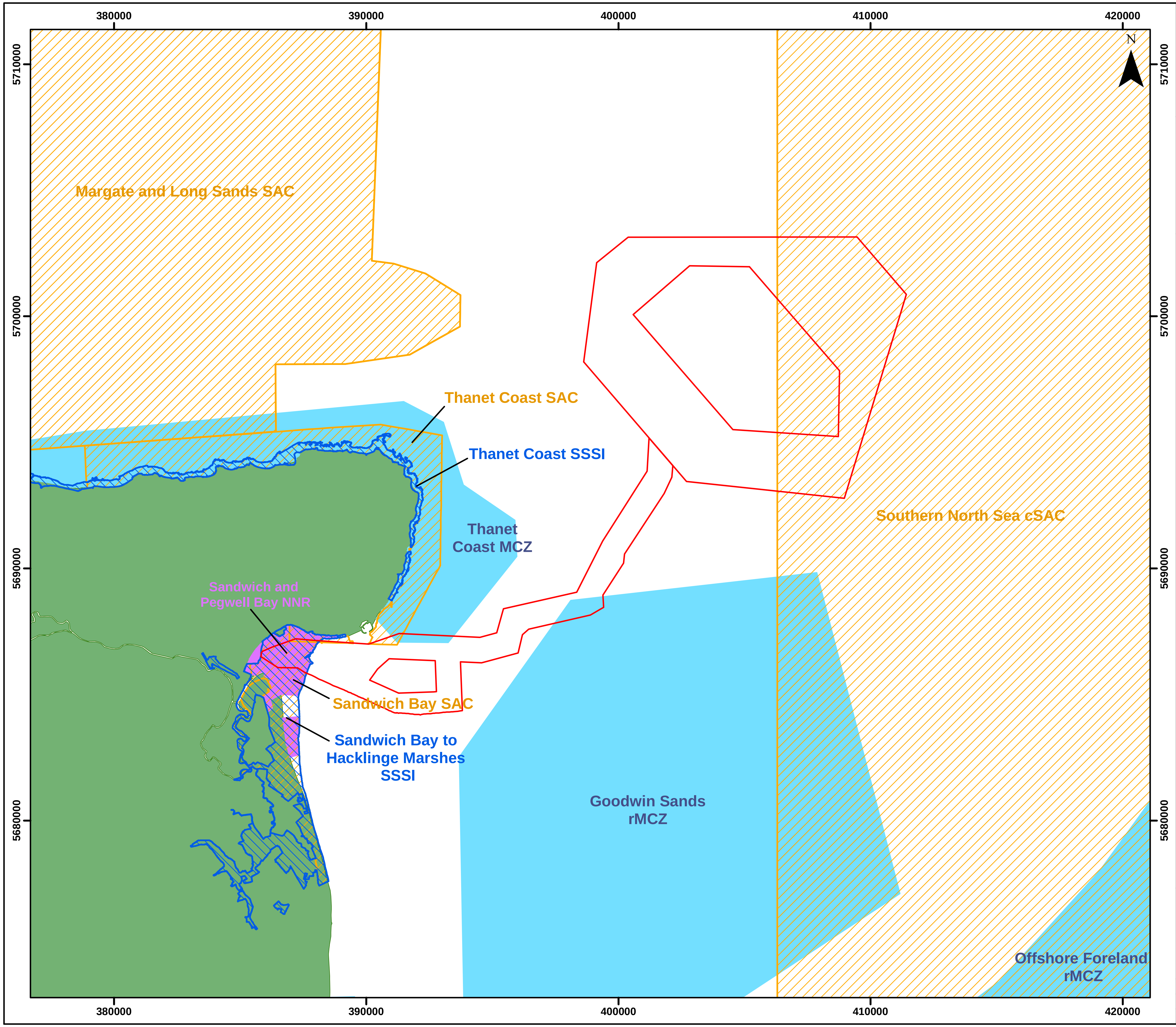
Figure 2.13

Designated Sites Referred to Within the Marine Physical Processes Assessment



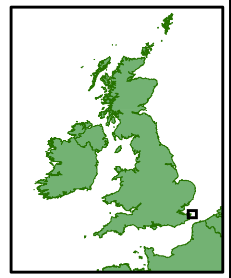
Legend

- Offshore Red Line Boundary

Designated Sites

- Site of Special Scientific Interest (SSSI)
- Special Area of Conservation (SAC)
- Marine Conservation Zone (MCZ)
- National Nature Reserve (NNR)

Datum: ETRS 1989
Projection: UTM31N



1:150,000 — 0 1.5 3 km — 0 0.85 1.7 nm

Drg No	003_ES_Fig2.13_Designations			Figure 2.13
Rev	1	Date	24/05/2018	
By	AMC	Layout	N/A	

Offshore Export Cable Corridor

Water levels

2.7.35 Tidal water levels along the OECC and at the landfall have been characterised using outputs from the UK Atlas of Marine Renewable Energy Resources (ABPmer *et al*. 2008b) (Figure 2.3) and UKHO gauge measurements at the Port of Ramsgate (Table 2.13). Tidal range generally increases along the OECC with greater proximity to the coast, increasing from approximately 4.2 m where the OECC meets the array to approximately 4.6 m at the landfall.

Table 2.13: Tidal characteristics for the Port of Ramsgate (values in mLAT)

Location	Level							Range	
	HAT	MHWS	MHWN	MSL	MLWN	MLWS	LAT	Spring	Neap
Ramsgate (mLAT)	6.0	5.5	4.3	3.0	1.7	0.9	0	4.6	2.6
ODN at Ramsgate is 2.88 m above LAT.									

Source: UKHO (2017)

2.7.36 The Environment Agency Coastal Flood Boundary Dataset (CFBD) provides an assessment of extreme water levels within nearshore and inshore sections of the OECC (Figure 2.2). Extreme water level return periods (appropriate for the 30 year lifespan of the project) are shown in Table 2.14.

Table 2.14: Extreme water level statistics for nearshore and inshore sections of the OECC (including the landfall) (values in mLAT)

Return period (base year 2008)						
1:1	1:2	1:5	1:10	1:20	1:25	1:50
6.5	6.6	6.8	6.9	7.0	7.0	7.2

Source: Environment Agency (2011)

2.7.37 It is predicted that the 1-year total extreme positive water level within inshore areas of the OECC is 6.5 mLAT whilst the 50-year prediction is 7.2 mLAT.

Currents

2.7.38 Throughout inshore and offshore parts of the OECC mean spring peak currents are predominantly between approximately 0.9 - 1.1 m/s but reach approximately 1.3 m/s in localised areas (Figure 2.5, ABPmer *et al*., 2008b). In general the tidal ellipses within eastern sections of the OECC are aligned north to south, rotating around North Foreland to become more north-east to south-west aligned. Within Pegwell Bay and nearshore areas of the OECC, peak current speeds are typically less than 0.5 m/s, with the flow axis having a general east to west alignment.

Wind and wave climate

2.7.39 The wave regime along the OECC has been characterised using observational wave records available through the Channel Coastal Observatory (CCO) (Goodwin Sands wave buoy) (2010 - 2016) and hindcast wave data from ABPmer's SEASTATES database (ABPmer 2013, 2016). This hindcast data covers the period 1979 to 2016 although the extracted data from within Pegwell Bay only covers the 20 year period between 1995 and 2015. A summary of the wave climate is shown in Figure 2.7.

2.7.40 In offshore sections of the OECC, the wave regime is dominated by waves from the north-east and south-west. However closer inshore the OECC becomes increasingly sheltered from westerly waves that propagate through the Thames Estuary such that within Pegwell Bay prevailing waves are almost entirely from the north-east and south-east. As waves move into shallower water, refraction, shoaling (wave steepening) and potentially wave breaking may occur, modifying individual waves and the collective wave climate. Indeed, within Pegwell Bay the maximum Hs value extracted from the hindcast is 2.25 m (in comparison to ~5.8 m for offshore areas within the array area), with the vast majority (over 95%) of the hindcast record containing waves between 0 - 0.5 m in height.

2.7.41 Across shallow areas, maximum wave heights will become 'depth limited' with the potential for wave breaking to occur during storm events and/ or around low tide. As a consequence of the above processes, the wave regime within inshore and nearshore areas will exhibit a degree of spatial variability owing to the sheltering effect of the banks including Goodwyn Knoll, Cross Ledge and South Falls (Figure 2.1).

2.7.42 In offshore areas, waves will tend to only periodically stir the bed and will not contribute regularly to the net transport of sediment. However, in shallower nearshore areas they have a more important role to play in alongshore and cross-shore sediment transport and will play a key role in driving morphological change.

Sediments and geology

2.7.43 As for the Thanet Extension array area, information has been provided from available grab sample data (Fugro, 2017) and interpreted side-scan sonar data (Fugro 2016b; Thanet Offshore Wind Limited, 2005).

2.7.44 Seabed sediments along the OECC are predominantly characterised by sands and gravels with varying contributions of each (Fugro 2016b; Nemo Link, 2011) (Figure 2.14). The north-eastern extent of the OECC (close to the Thanet Extension array area) comprises mixed sand/ gravel. Increasing contributions of sand and clay occurs within mid sections, with further fine sand and clay contributions within inshore and nearshore areas. The surficial sediment layer varies in thickness throughout the OECC, although it predominantly acts as a mobile surface layer on top of underlying geological features.

2.7.45 Sediments in Pegwell Bay comprise fine to very fine sands (Rees Jones ,1998; Dussart and Rodgers, 2002). Within the bay, fine surface sediments are re-suspended, moved around in the water column as the tide ebbs and flows and eventually deposited elsewhere.

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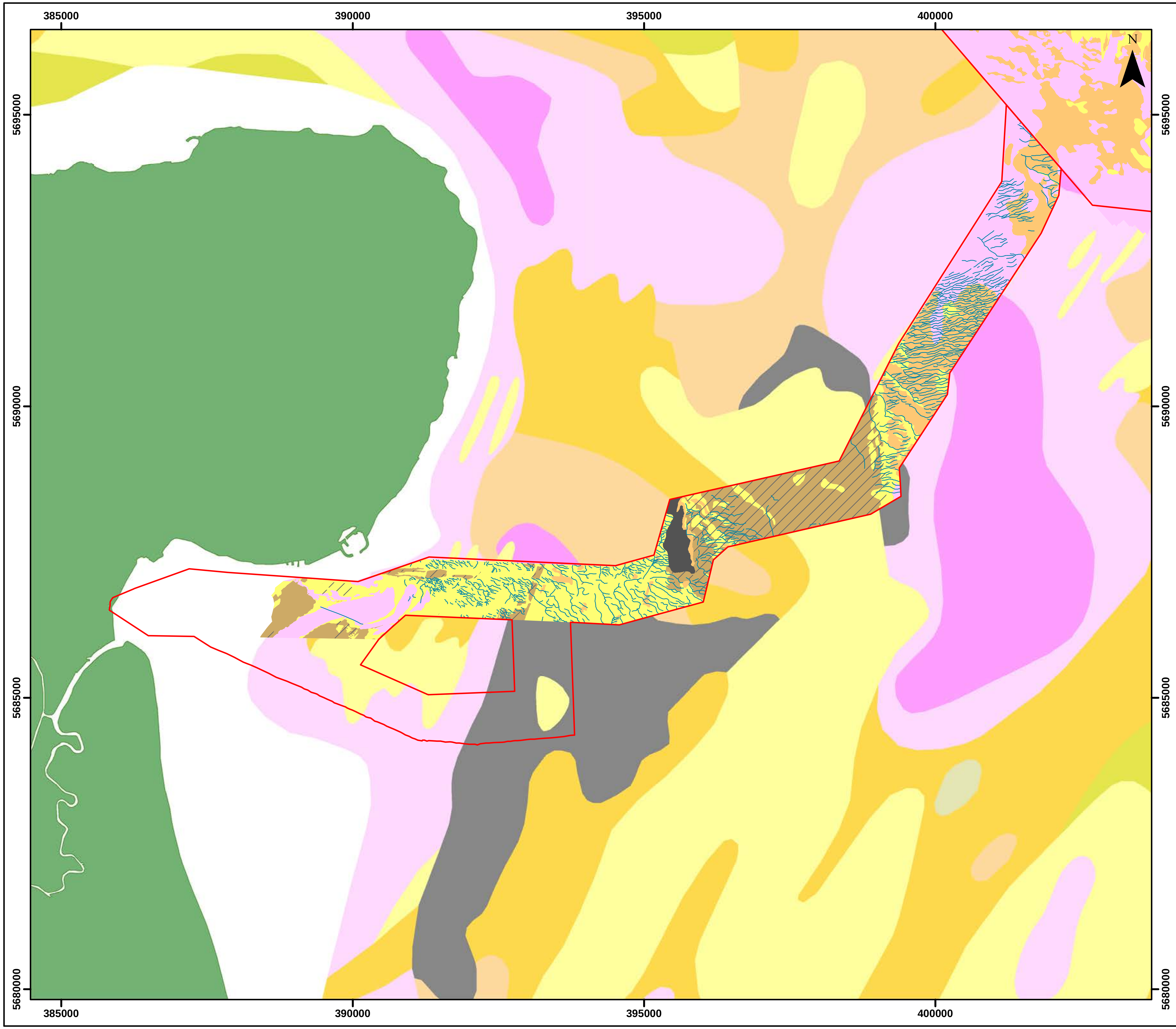
Figure 2.14

Seabed Sediment and Bedform Distribution Within the Thanet Extension OECC



Legend

Offshore Red Line Boundary

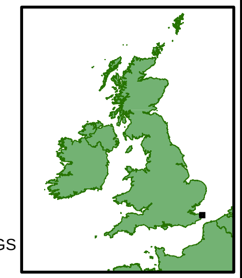
Seabed Sediments

- 'Fine to Coarse Sand' (Fugro, 2016c)
- Gravel
- Gravelly Sand
- Muddy Sand
- Rock
- Sand
- Sandy Gravel
- Slightly Gravelly Muddy Sand
- Slightly Gravelly Sand

Seabed Features

- Small to Medium Sand Waves
- Ridge Crest

Datum: ETRS 1989
Projection: UTM31N



Sediment distribution within the cable corridor from Fugro (2016b); surrounding areas from BGS seabed mapping

1:65,000 — 0 0.7 1.4 km — 0 0.35 0.7 nm

Drg No	003_ES_Fig2.14_Sediments_Bedforms_ECR			Figure 2.14
Rev	1	Date	24/05/2018	
By	AMC	Layout	N/A	

2.7.46 Interpretation of underlying geology along the OECC is provided by analysis of seabed cone penetration test and vibrocore sampling (Fugro 2016c) as well as outputs from the project-specific geophysical survey (Fugro, 2016b). A summary of the interpreted geology is presented in Table 2.15.

Table 2.15: Summary of underlying geology throughout the OECC

Unit	Base of unit below seabed (m)	Indicative lithology	Depositional environment	Formation	Age
A	1.4 to 7.8	Coarse sand, with shells and shell fragments, rare silt and clay laminae and rare gravel	Marine	Southern Bight	Holocene
D	1 to 74	Sands, silts and silty clay with basal flint	Shallow Marine	Thanet Formation	Palaeocene
E	67 to 164	White Chalk with flint and gravels/cobbles	Marine	Upper Chalk	Late Cretaceous

Source: Fugro (2016b)

2.7.47 Extensive areas of Cretaceous chalk are encountered at or close to the surface although are overlain in places by tertiary sediments belonging to the Thanet Formation. Quaternary sediments in the form of Holocene deposits are also present and are generally expected to be mobile, creating various types of bedforms (paragraph 2.7.56). Both the Tertiary and Quaternary sediment groups vary in thickness along the OECC, with mobile Holocene deposits reaching a thickness of up to approximately 3 m where bedform features are present.

2.7.48 Suspended sediment concentrations are found to increase with greater proximity to the coast and are at their highest within nearshore and inshore areas of the OECC (Figure 2.9). This is likely due to a combination of enhanced re-suspension from wave activity within shallower water and fluvial input of sediment. In general average (surface) SPM remains above 10 to 20 mg/l throughout summer months and above 40 mg/l during winter (Eggleton *et al*., 2011).

2.7.49 Regional scale mapping of sediment transport presented in Kenyon and Cooper (2005) suggests that the outer extent of the OECC experiences net south-westerly bed load transport, with convergence of sediment transport in the vicinity of Goodwin Sands, to the south of the OECC (Figure 2.11). The observational evidence (in the form of bedform asymmetry analysis) from the OECC geophysical survey (Fugro, 2016b) is limited although tentative evidence for a general northerly migration of bedforms is present just to the north of Goodwin Sands, approximately 3 km offshore in the outer reaches of Pegwell Bay.

2.7.50 Within the approaches to Pegwell Bay, mapped sand waves immediately to the north of Cross Ledge suggest a general easterly migration of bedforms. However, it should be noted that the effects of wave shoaling and wave breaking during extreme conditions can further influence the sediment transport processes in shallow inshore/ nearshore areas, leading to a highly dynamic environment in which geomorphological features can vary throughout a single winter season (Thanet Offshore Wind Limited, 2005). Furthermore, the reduced current speeds within western sections of OECC are suggested to be a driver for more episodic migration of seabed features (Fugro 2016b).

2.7.51 Pegwell Bay receives a natural supply of sediment from updrift, offshore and fluvial sources (SECG, 2010). Material is transported southwards across the Bay from Ramsgate harbour, of which the construction of harbour structures has significantly altered the natural longshore movement of sediment. In contrast, transport is generally northward in direction along the gravel barrier between South Foreland and the Stour estuary mouth. However during storm conditions this northerly transport may reverse, switching to a predominantly southerly orientated drift back down the barrier (SECG, 2010).

2.7.52 Much of the intertidal at the mouth of the River Stour has been accreting over time, with gradual channel evolution (Figure 2.15). The gravel spit on the eastern side of the river channel has historically lengthened due to an overall south to north littoral drift along the gravel barrier. This is reflected in sediment budget estimates, with negative rates (i.e. erosion) beyond Sandwich and a residual rate of *circa* 3,000 m^3/yr northwards approaching the end of the barrier in 2013 (EKEP, 2013).

2.7.53 Tidal currents bring in sand and silt as suspended load into Pegwell Bay (Motyka and Brampton, 1993). However, the majority of sediment transport throughout Pegwell Bay occurs during storm surge conditions (SECG, 2010). Topographic profiles (for the period March 2013 to February 2014) show significant amount of shingle movement throughout periods of known storm activity, with a flattening of the lower profile of up to 0.5 m at around 1 mODN (3.88 m above LAT), and a berm accumulation of 0.3 - 0.7 m between 2 and 3 mODN (4.88 - 5.88 m above LAT). This is described in greater detail within Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1).

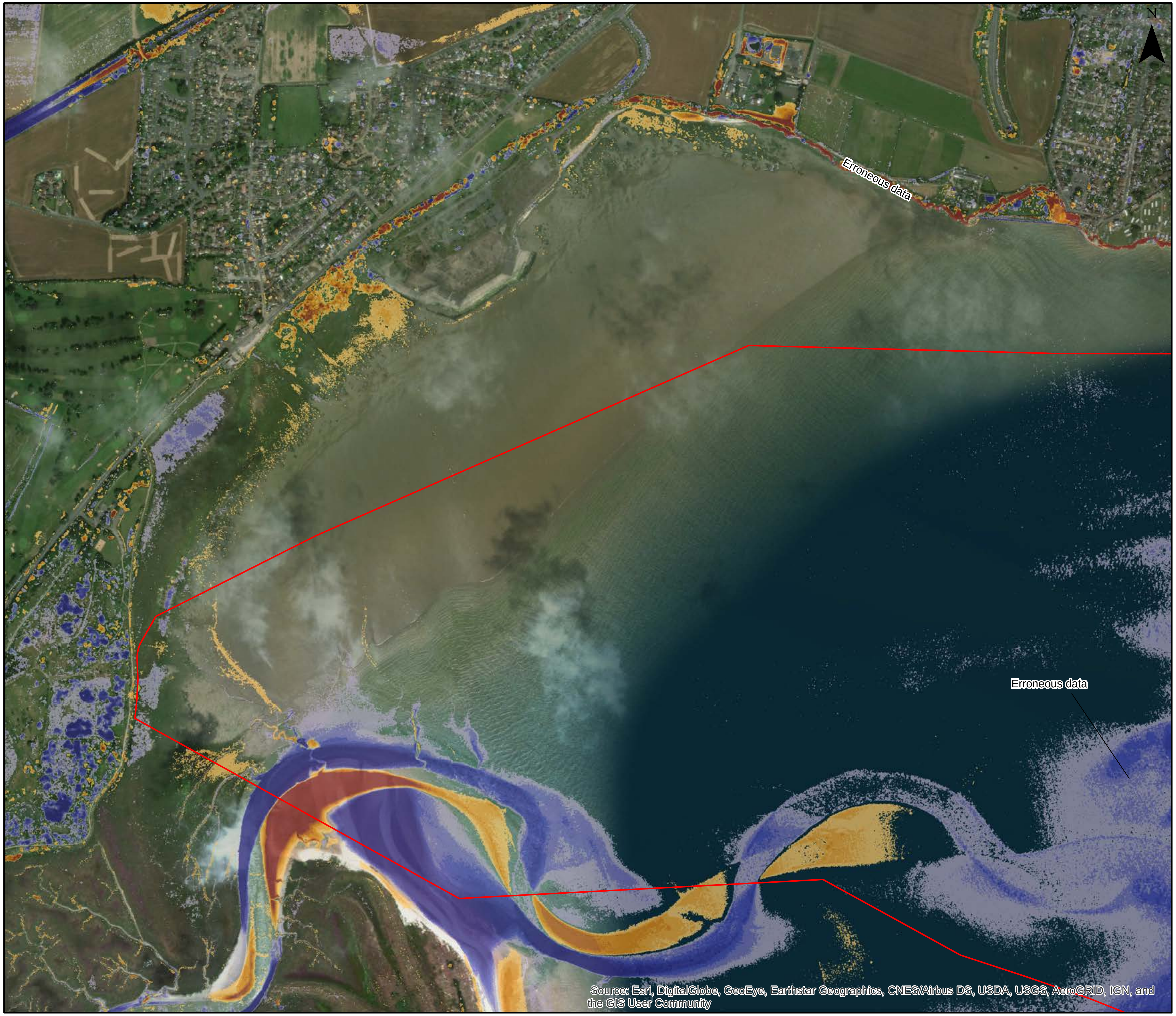


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Figure 2.15

Elevation Differences at the Landfall Between 2007 to 2013, Based on LiDAR

Legend

- Offshore Red Line Boundary
- > 1.20
- 1.00 to 1.20
- 0.80 to 1.00
- 0.60 to 0.80
- 0.40 to 0.60
- 0.20 to 0.40
- 0.00 to 0.20
- -0.20 to 0.00
- -0.40 to -0.20
- -0.60 to -0.40
- -0.80 to -0.60
- -1.00 to -0.80
- -1.20 to -1.00
- < -1.20

Accretion

Erosion

Datum: OSGB 1936
Projection: BNG

1:8,500 — 0, 0.085, 0.17 km — 0, 0.045, 0.09 nm

Drg No	003_ES_Fig2.15_LiDAR_Diff		
Rev	1	Date	24/05/2018
By	AMC	Layout	N/A

Figure 2.15

Seabed bathymetry and geomorphology

2.7.54 Water depths throughout the OECC range between 0 and -18.0 mLAT (Fugro 2016b, Figure 2.16), and generally increase south-west to north-east from the coastline to the boundary with the array area. Bed slope gradients are typically less than 5 degrees; however a number of localised ridges are significantly steeper (up to 35 degrees), mainly associated with plateau-like outcrops and seabed ridges within central and western sections of the OECC.

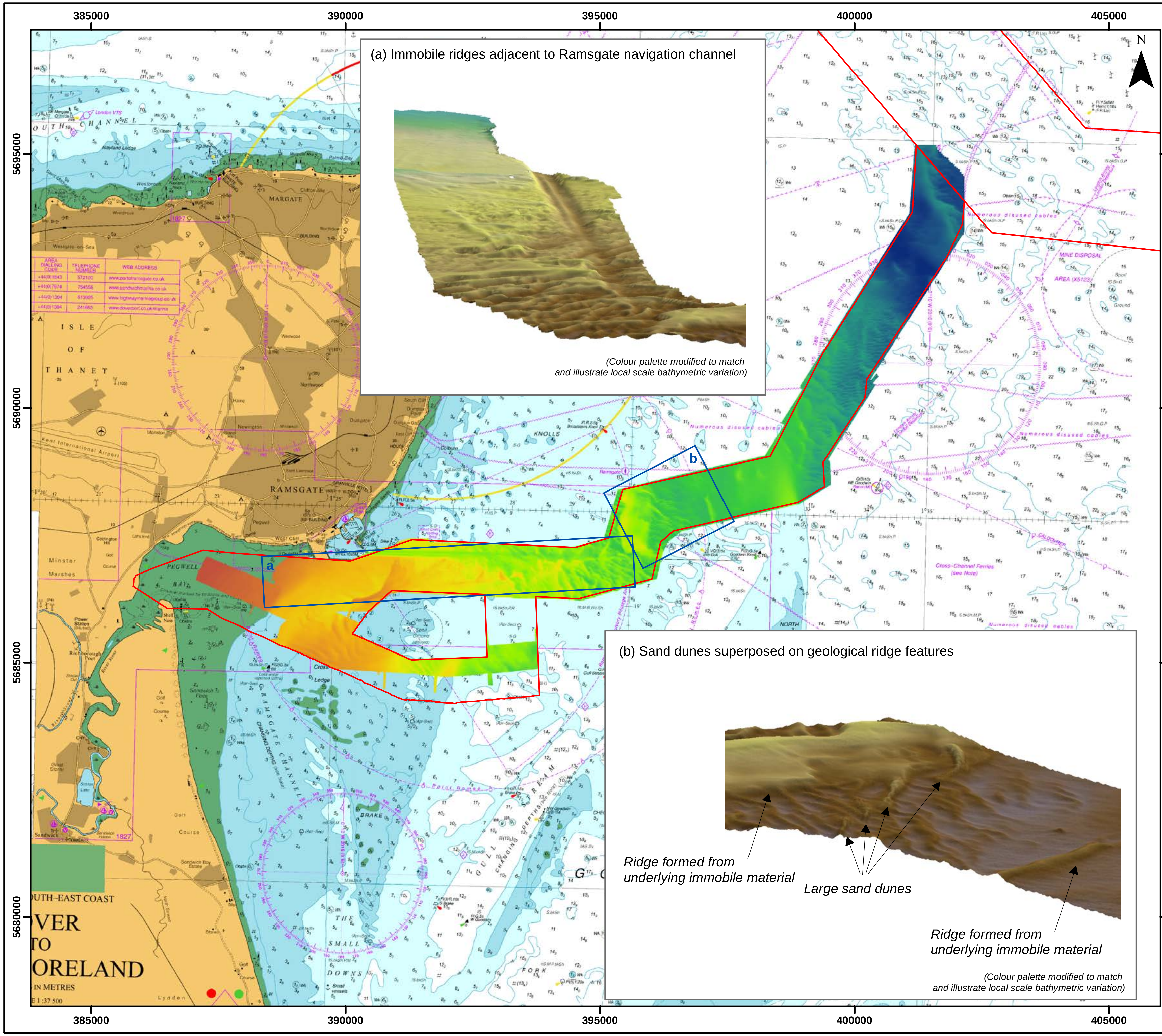

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Figure 2.16

Detailed Bathymetry of the Thanet Extension OECC

Legend

Offshore Red Line Boundary

Bathymetry (m LAT)

2.73, 0.09, -2.55, -5.19, -7.83, -10.47, -13.11, -15.76, -18.40

Datum: ETRS 1989
Projection: UTM31N

1:75,000 — 0, 0.8, 1.6 km — 0, 0.4, 0.8 nm

Drg No	003_ES_Fig2.16_Bathymetry_ECR			Figure 2.16
Rev	1	Date	24/05/2018	
By	AMC	Layout	N/A	

2.7.55 Numerous seabed ridges and outcrops can be seen throughout the OECC where the underlying chalk geology is present at the seabed. These ridges may be several metres high and are typically associated with scatted boulder clusters. These features are frequently encountered throughout north-eastern and western sections. A plateau-like outcrop stretching around 600 m is present in central sections.

2.7.56 As with the array area, mobile current-induced sediment bedform features are present throughout the OECC, although the maximum dimensions of these features (both height and wave length) are smaller within the OECC than in the array area. The mapped sand wave bedforms along the OECC have been divided into three individual categories (Fugro 2016b): these are described below and shown in Figure 2.14:

- Sand waves of wavelengths 200 - 250 m and a height of between 1 - 3 m. These are predominantly found within south-western sections, along with isolated individuals throughout central sections. These features generally have straight lee faces and are orientated south-west to north-east in line with the axis of tidal ellipses throughout Pegwell Bay and along the coast of North Foreland;
- Sand waves of wavelengths 8 - 25 m and heights in excess of 2 m. This category has a mixture of straight and irregularly shaped crests. The general location is within south-west sections, and orientation is south-west to north-east; and
- Sand waves of wavelengths 3 - 10 m and heights of 0.1 - 0.6 m. These small waves have a mixture of straight and irregularly shaped crests, and are found throughout the OECC where the surficial sediment layer is sufficiently thick. Orientation of this category is predominantly south-west to north-east, but is highly variable and portrays the varying current regimes throughout the OECC.

Landfall geomorphology

2.7.57 The south-western part of Pegwell Bay where the cable makes landfall is predominantly low-lying intertidal saltmarsh and mud/ sand flats located adjacent to the River Stour which meanders and exits into the Bay. The intertidal is protected from easterly waves by a shingle spit at Shell Ness (just to the east of the landfall), of which the barrier is between 100 - 175 m wide and 4 to 4.5 mODN (6.88 - 7.38 m above LAT) high. The spit has a highly dynamic morphology and is dependent on seasonal variations in the local wave climate entering the Bay. The morphology of the River Stour channel is similarly dynamic, with migration of several tens of metres observed between 2007 and 2013 (Figure 2.15).

2.7.58 The existing cliff line within the northern section of the Bay is predominantly chalk, giving way to softer sandstone just to the north of Cliffsend. This likely provides a source of material for the foreshore within the inner bay. Considerably finer material exists within the saltmarsh intertidal through which the River Stour exits in the south of the bay, at the landfall. Such material is likely to have built up in the lee of the mixed sand/ shingle spit and ultimately provides a platform upon which the spit can migrate over time (SECG, 2010).

2.7.59 Large sections of the neighbouring coastline to Pegwell Bay have been historically developed, with coastal defence schemes preventing cliff and/ or beach erosion. This has resulted in a low supply of sediment within the nearshore, limiting rates of beach accretion (SECG, 2010). The removal of such structures in future could lead to instability of the existing shoreline position, with the potential for a breakdown of the existing beaches and an increased risk of inundation of low lying areas (SECG, 2010). The lack of sediment supply may also lead to a reduction in the accretion rate seen within the Stour estuary mouth, modifying the morphology of the channel and the surrounding saltmarsh intertidal.

Shoreline management and coastal defences

2.7.60 The proposed landfall at Pegwell Bay lies within SMP unit 4b20: 'Ramsgate Harbour (west) to north of the River Stour' (SECG, 2010). The current strategy throughout all three management epochs (i.e. the next 100 years) is to Hold the Line (HTL), with No Active Intervention (NAI) throughout undefended sections.

2.7.61 Coastal defences in Pegwell are discontinuous, reflecting variations in geology, elevation and proximity to coastal development. In the vicinity of the cable landfall, an embankment of height 4.5 - 5.5 mODN (7.38 - 8.38 m above LAT) runs from the central Bay in a southerly direction for approximately 1 km. This protects parts of the frontage which are exposed to wave action and inundation during extreme events. No defences are present to the east of the landfall, around Shell Ness (SMP policy unit 4b21).

2.7.62 Under the current SMP2 strategy, most change is expected in the medium epoch (2020 - 2050). The low-lying areas within the bay are anticipated to be inundated in response to sea level rise. This could result in a breach of the spit further south, just to the south of the landfall boundary. The low-lying areas within Pegwell Bay will be increasingly vulnerable to coastal flooding. The shingle spit is expected to roll back naturally due to Sea Level Rise (SLR) which may expose the centre of the bay to greater wave attack from easterly conditions, therefore reducing accretion rates throughout the estuary mouth due to greater volumes of finer material remaining in suspension.

Designated sites

2.7.63 Sections of the OECC and landfall overlap (or are in very close proximity to) several existing and recommended designated sites. These are summarised below, with locations shown in Figure 2.13).

- **Thanet Coast SAC** contains an example of Annex I reefs on soft chalk with sublittoral chalk platforms that extend into the littoral and form chalk cliffs. These platforms extend offshore in a series of steps dissected by gullies. The site also contains the Annex I habitat 'submerged or partially submerged sea caves' with many caves, stack and arch formations. Some caves extend for up to 30 m into the cliffs and reach 6 - 10 m in height, although many are much smaller (JNCC, 2017c);
- **Sandwich Bay SAC** contains a largely inactive dune system with site selection due to the presence of a range of Annex I dune habitats (JNCC, 2017d);
- **Thanet Coast MCZ** protects several varied habitats including subtidal chalk, subtidal coarse sediment, subtidal mixed sediments and subtidal sand;
- **Sandwich Bay to Hacklinge Marshes SSSI** contains the most important sand dune system and sandy coastal grassland in South East England and also includes a wide range of other habitats such as mudflats, saltmarsh and chalk cliffs;
- **Sandwich and Pegwell Bay National Nature Reserve (NNR)** is considered to be one of the most important coastal nature conservation areas in Britain, containing a complex mosaic of habitats including chalk cliffs, sand dunes, sand and mud flats, as well as saltmarsh (Natural England, 2017); and
- **Goodwin Sand rMCZ** is being considered for a future inclusion as an MCZ due to the presence of complex reef and mussel bed systems that stabilise mobile sediments whilst additionally providing habitat niches (The Wildlife Trusts, 2017). At the time of drafting this ES Goodwin Sand rMCZ has not been brought forward for consultation and as such there is an absence of defined Conservation Objectives, Advice on Operations, or Management Measures against which to consider a detailed assessment of potential effects on the MCZ.

2.7.64 It is noted here that the Thanet Coast and Sandwich Bay SPA overlaps with the landfall boundary. However, potential effects on birds within these designated sites is considered elsewhere within the ES.

2.8 Key parameters for assessment

2.8.1 This section identifies the maximum adverse scenario from the marine physical environment, defined by the project design envelope (Volume 2, Chapter 1: Project Description - Offshore (Document Ref: 6.2.1)). The method adopted is in accordance with the requirements of the Rochdale Envelope approach to environmental assessment as set out in the PINS Advice note nine: 'Using the Rochdale Envelope' (The Planning Inspectorate, 2012). In essence, the design envelope is a series of projected maximum extents to the project for which the significant effects are assessed. The detailed design of the project can then vary within this envelope without rendering the EIA inadequate. Thus, this approach also provides a conservative method to understanding the potential worst-case effects of the proposed project.

2.8.2 The maximum adverse scenarios assessed for the marine physical environment are described in Table 2.16. It is noted here that three WTG sizes are currently under consideration (8 MW, 10 MW and 12 MW). Subject to final design it is possible that an alternative, larger capacity, WTG (i.e. >12MW) type may be selected. In this scenario the overall project capacity will remain at 340MW and the physical parameters such as maximum blade tip height, rotor diameter, and height of nacelle will remain within the maximum envelope described in this chapter and subsequent technical assessment chapters.

Table 2.16: Maximum design scenario assessed

Potential change/ effect	Maximum adverse scenario assessed	Justification
Construction		
Increases in SSC and deposition of disturbed sediments to the seabed due to dredging for seabed preparation prior to foundation installation.	Greatest volume of sediment disturbed and released from a single foundation location • Largest WTG quadropod suction caisson foundation (12 MW), associated base diameter of four caisson cans 20 m, associated bed preparation area 3,200 m^2, average dredge depth 3 m, spoil volume per foundation 9,600 m^3; • Disposal of material on the seabed within the array area; • Dredging carried out using a representative trailer suction hopper dredger (11,000 m^3 hopper capacity with split bottom for spoil disposal); and • Disposal of material on the seabed within the array area. Greatest volume of sediment disturbed and released across the entire array area • Project comprising 28 large (12 MW) quadropod suction caisson foundations, associated base diameter of four caisson cans 20 m, associated bed preparation area 3,200 m^2, average dredge depth 3 m, spoil volume for entire array area 268,800 m^3; • 1x Offshore Substation (OSS) quadropod suction caisson foundation, associated base diameter of four caisson cans 15 m, associated bed preparation area 3,200 m^2, average dredge depth 3 m, total spoil volume 9,600 m^3; • 1x met mast quadropod suction caisson foundation, associated base diameter of four caisson cans 20 m, associated bed preparation area 3,200 m^2, average dredge depth 3 m, total spoil volume 9,600 m^3; • Disposal of material on the seabed within the array area; • Dredging carried out using a representative trailer suction hopper dredger (11,000 m^3 hopper capacity with split bottom for spoil disposal); and • Construction phase lasting up to 28 months (but anticipated to be around 12 working months spread over a minimum of two summer seasons).	Seabed preparation works would only be required prior to installation of quadropod suction caisson foundations (if at all). Two maximum adverse scenarios are identified, corresponding to the greatest volume of sediment disturbance locally (from a single foundation) and across the entire array (from all foundations). The greatest sediment disturbance from a single quadropod suction caisson foundation location is associated with the largest diameter caisson cans. The greatest volume of sediment release for the entire array area is associated with a layout comprising a smaller number of large (12 MW) WTG foundations.
Increases in SSC and deposition of disturbed sediments to the seabed due to the release of drill arisings during foundation installation.	Greatest volume of sediment disturbed and released from a single foundation location • Largest WTG monopile foundations (12 MW), associated drill diameter 7.5 m, drilling to an average of 30 m penetration depth, spoil volume per foundation 1,325 m^3; • Drilling rate of up to 5 m/hour (based on 6 hours to each foundation); and • Disposal of drill arisings at or above water surface within the array. Greatest volume of sediment disturbed and released across the entire array area • Project comprising 34 (10 MW) monopile foundations, associated drill diameter 7 m, drilling to an average of 30 m penetration depth, up to 50% of foundations may be drilled, spoil volume for entire array area 19,627 m^3;	Although the volumes of material released via drilling are less than for seabed preparation via dredging, drilling has the potential to release larger volumes of relatively finer sediment. Two maximum adverse scenarios are identified, corresponding to the greatest volume of sediment disturbance locally (from a single foundation) and across the entire array (from all foundations). The greatest volume of drill arisings from a single foundation location is associated with the largest diameter monopile foundation whereas the greatest volume of drill arisings for

Potential change/ effect	Maximum adverse scenario assessed	Justification
	• 1x OSS monopile foundation, associated drill diameter 6 m, drilling to an average of 30 m penetration depth, total spoil volume 900 m^3; • 1x met mast monopile foundation, associated drill diameter 7.5 m, drilling to an average of 30 m penetration depth, total spoil volume 1,325 m^3; • Drilling rate of up to 5 m/hour (based on 6 hours to each foundation); • Disposal of drill arisings at or above water surface; and • Construction phase lasting up to 28 months (but anticipated to be around 6 working months).	the entire array area is associated with a layout comprising a smaller number of large (12 MW) quadropod foundations.
Increases in SSC and deposition of disturbed sediment to the seabed due to cable installation within the Thanet Extension array area and within the OECC.	<u>Inter-array cables</u> • Installation method: jetting; • Total length 64 km; • V-shape trench; width = 1 m; depth = 3 m; • Assume up to 50% of material is actually ejected from the trench. The rest is retained as sediment cover within the trench; • Total volume of disturbance= (64 km x 1 m x 3 m x 0.5 x 50% = 48,000 m^3; • Assumed installation rate of up to approximately 450 m/hr; • Construction phase lasting up to 28 months; and • Sand wave clearance via dredging <u>HVAC export cables</u> • Installation method: jetting; • Up to four export cable trenches; each up to 30 km in length from array area boundary to landfall (120 km in total); • V-shape trench; width = 10 m; depth = 3 m; • Assume up to 50% of material is actually ejected from the trench. The rest is retained as sediment cover within the trench; • Volume of disturbance = (120 km x 10 m x 3 m x 0.5 x 50% = 900,000 m^3 in total); • Minimum spacing between (pairs) of cables 120 m; • Assumed installation rate of up to approximately 450 m/hr; and • Construction phase lasting up to 28 months.	Cable installation may involve (*inter alia*) jetting, ploughing, trenching and/or cutting installation techniques. Of these, jetting will most energetically disturb the greatest volume of sediment in the trench profile and as such is considered to be the maximum adverse scenario for sediment dispersion. Sand wave clearance may potentially be required and would be carried out using a jetting tool.
Sand wave crest level preparation resulting in a change to local hydrodynamic, wave and sediment transport processes.	• Sandwave clearance via dredging • Assume 20% of HVAC export cable route (24 km); • Pre-sweeping dredging width of corridor of 20 m; • Pre-sweeping area of 0.48 km^2; • Assumed 60 m^3/m of sand wave clearance; • Pre-sweeping volume of dredging corridor will be up to 1,440,000 m^3; and • Material disposed of within the Thanet Extension array area and OECC.	The volume of material to be cleared from individual sand waves will vary according to the local dimensions of the sand wave (height, length and shape) and the level to which the sand wave must be reduced (also accounting for stable sediment slope angles and the capabilities and requirements of the cable burial tool being used). These details are not fully known at this stage, however, based on the available geophysical data, it is anticipated that the bedforms requiring clearance are likely to be in the range 1 - 8 m in height.

Potential change/ effect	Maximum adverse scenario assessed	Justification
Impacts to sand bank receptors (due to construction activities).	• Sand wave clearance via jetting; • Volume of sediment requiring removal to be confirmed; and • Material disposed of within the Thanet Extension array area and OECC.	During the construction phase the primary means by which sand banks could be impacted is through interruption of sediment transport patterns via sand wave clearance activities.
Impacts to designated coastal feature receptors (due to construction activities).	Trenching (Options 2 and 3) • Landfall approached from the offshore side using open-cut trenching through a short area of saltmarsh and intertidal mud; • Up to four cable trenches across intertidal; • Burial depth 3 m below seabed; • Trenching working area up to 31 m wide (based on four cables and associated separation and spoil) in the lower inter-tidal; and • Trenches to be open for a period of days to a few weeks. HDD (Option 1) • Up to 4x temporary HDD exit pits; • Each exit pit 20 m x 20 m footprint; • Located at least 100 m seaward of existing sea wall; • Containment of all drilling mud (i.e. no release into coastal receiving waters); and • Exit pits to be open for a period of a few weeks. Cofferdam (Options 2 and 3) • One temporary cofferdam structure; • Maximum of 25 m long in a seaward direction, by 165 m wide; • Constructed of sheet piles; • Installation and removal period of up to 33 days; and • Cofferdam in place for a period of a few months, then removed. Re-aligned sea wall (Option 2) • New (permanent) sea wall constructed up to 18.5 m seawards of existing defences along approximately 155 m of frontage ; • Maximum inter-tidal area permanently affected 1398.9 m^2; and • Defences comprising rock armour.	The primary means by which the morphology of the landfall could potentially be impacted during the construction phase is through: • Disturbance of sediments during (open-cut) cable trenching and HDD exit pit excavation within the inter-tidal, resulting in associated changes to bed levels and modification of hydrodynamic/ sediment transport processes; • Modification of marine processes through re-configuration of the existing sea wall and/or presence of temporary cofferdam structure; and • Modification of the coastline and a local intertidal area by installation of the rock armour sea wall.
Operation[1]		
Changes to the tidal regime.	Foundations • Array comprising the largest (12 MW) quadropod suction caisson foundations for WTGs (up to 28 structures with four 20 m suction cans), one OSS and one met mast; • Minimum foundation spacing of 716 m x 480 m; and	The greatest total in-water column blockage to currents, waves and sediment transport processes is presented by an array comprising the largest (12 MW) quadropod suction caisson foundations.
Changes to the wave regime.		

Potential change/ effect	Maximum adverse scenario assessed	Justification
Changes to sediment transport and sediment transport pathways.	• O&M phase lasting ~30 years (may increase by the time the project nears decommissioning as technology/maintenance improves). Cable protection measures (all) • Options include rock placement, concrete mattresses, frond mattresses and/ or Uraduct; • Sloped profile above seabed level: Up to 7 m (HVAC cable) and 5 m (Inter-array cables) overall width and 0.5 m maximum height; and • Total length of cables which may potentially require seabed protection anticipated to be up to approximately 25% of route. Cable crossings • Number of export cable crossings/ cable = 20 per cable; • Number of inter-array cable crossings/ cable = 12; • Use of concrete mattressing; total height above bed (including cable) = 0.5 m; • Area per crossing = 1000 m^2; • Total area of all crossings = 92,000 m^2 (12 inter-array cable crossings + (4 export cables x 20 cable crossings) x 1,000 m^2 per crossing)	This combination was determined via calculations that quantitatively compare the blockage presented by a range of minimum and maximum sizes of varying foundation types and numbers (see Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1)).
Scour of seabed sediments.	(Maximum adverse scenario is defined on the basis of the outputs of the scour assessment (see Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1) for results)	Each foundation type may produce different scour patterns therefore monopiles and quadropod foundations have both been considered. The foundation type, size and number producing the greatest area and/ or volume of influence cannot be identified in advance of the assessment.
Development of turbid wake features.	• Array comprising the largest (12 MW) quadropod suction caisson foundations for WTGs (up to 28 structures with four 20 m suction cans), one OSS and one met mast; • Minimum foundation spacing of 716 m x 480 m; and • O&M phase lasting ~30 years (but may increase by the time the project nears decommissioning as technology/maintenance improves).	Different foundation types will produce differing patterns of turbulence and therefore potentially slightly different turbid wake footprints. However, suction caissons provide the greatest blockage and have the potential to cause greatest turbulence.
Impacts to sand bank receptors (due to wind farm operation).	• Array comprising the largest (12 MW) quadropod suction caisson foundations for WTGs (up to 28 structures with four 20 m suction cans), one OSS and one met mast; • Minimum foundation spacing of 716 m x 480 m; and • O&M phase lasting ~30 years (but may increase by the time the project nears decommissioning as technology/maintenance improves).	The greatest total in-water column blockage to currents, waves and sediment transport processes is presented by an array comprising the largest (12 MW) quadropod suction caisson foundations.
Impacts to designated coastal feature receptors (due to wind farm operation). Impacts to designated chalk feature receptors (due to wind farm operation).	• Array comprising the largest (12 MW) quadropod suction caisson foundations for WTGs (up to 28 structures with four 20 m suction cans) one OSS and one met mast; • Target burial depth to be determined pending the outcome of the site investigation works at landfall and nearshore.	Greatest blockage of tides, waves and sediment transport therefore greatest potential for morphological change. Minimum cable burial depth (and therefore the greatest risk of cable exposure due to erosion).

Potential change/ effect	Maximum adverse scenario assessed	Justification
		Closest distance to the beach for cable related infrastructure (e.g. substations) therefore greatest potential for impact associated with beach roll back. (Potential impacts in relation to the realignment of the seawall are assessed in the construction phase assessment – see paragraph 2.10.54 onwards.)
Decommissioning		
Increases in SSC and deposition of disturbed sediment to the seabed within the Thanet Extension array area and the OECC.	• Array comprising the largest number of foundations (34); • Buried cables to be cut and left *in situ* (but to be determined in consultation with key stakeholders as part of the decommissioning plan and following best practice at the time); • Scour and cable protection left *in situ*; and • Decommissioning activities lasting approximately one year.	When removing foundations, the greatest disturbance will be associated with the layout containing the greatest number of structures.
Impacts to designated coastal feature receptors (due to decommissioning activities).	• Removal of export cables from trenches within intertidal/ shallow subtidal; • Filling of HDD ducts; • Decommissioning activities lasting approximately one year.	Maximum disturbance of seabed resulting from removal of cable(s) and filling of HDD ducts.
Cumulative effects		
Cumulative temporary increases in SSC and seabed levels as a result of Thanet Extension export cable installation and dredge disposal activities.	• Maximum adverse scenario for Thanet Extension Project construction phase (as previously defined); and • Two dredge disposal sites (Pegwell Bay – TH140 and Nemo Disposal Site C – TH152).	Meaningful sediment plume interaction generally only has the potential to occur if the activities generating the sediment plumes are located within one spring tidal excursion ellipse from one another and occur at the same time. Accordingly, only those activities located within one spring tidal excursion ellipse of the project have been considered within the assessment. Operational wind farms within the study area (Thanet and London Array) are not considered within the cumulative effects section as they are recognised as being part of the baseline environment and hence are taken into consideration within the project-alone assessment (paragraph 2.10.1 to 2.12.12).

Potential change/ effect	Maximum adverse scenario assessed	Justification
Cumulative temporary increases in SSC and seabed levels as a result of Thanet Extension export cable installation and aggregate dredging activities.	• Maximum adverse scenario for Thanet Extension Project construction phase (as previously defined); and • One aggregate extraction site dredge disposal site (Goodwin Sands – Area 521).	Meaningful sediment plume interaction generally only has the potential to occur if the activities generating the sediment plumes are located within one spring tidal excursion ellipse from one another and occur at the same time. Accordingly, only those activities located within one spring tidal excursion ellipse of the project have been considered within the assessment.

[1]A range of O&M activities have been identified in the project design statement (Volume 2, Chapter 1: Project Description - Offshore (Document Ref: 6.2.1)) and some of these have the potential to cause short-term localised changes to physical processes (e.g. cable re-burial). However, changes associated with all of these activities are of comparable or lesser magnitude than those already assessed for the construction phase.

2.9 Embedded mitigation

2.9.1 Mitigation measures that were identified and adopted as part of the evolution of the project design (embedded into the project design) and that are relevant to physical processes are listed in Table 2.17. General mitigation measures, which would apply to all parts of the electrical transmission works, are set out first. Thereafter mitigation measures that would apply specifically to physical processes issues associated with the proposed development are described separately. The assessment stage of the EIA (presented in paragraph 2.10.1 - 2.13.27) is based on the 'mitigated' design described in Table 2.17.

Table 2.17: Embedded mitigation relating to physical processes

Parameter	Mitigation measures embedded into the project design
General	
Project design	Careful routing of the offshore cable route to largely avoid areas of designated seabed.
Construction	
Landfall	Duration of time between trench excavation, cable lay and trench backfill operations at the landfall is to be kept to a minimum (i.e. where possible to be undertaken within one tidal cycle) so as to limit disruption to coastal processes.
Offshore cable	The Cable Installation Plan will set out measures to minimise adverse impacts to potentially sensitive receptors. It will also set out appropriate cable burial depth in accordance with industry good practice, minimising the risk of cable exposure.
Operation and Maintenance	
Offshore cable	Where burial depth cannot be achieved, cable armouring will be implemented (e.g. mattressing, rock placement etc). The suitability of installing rock or mattresses for cable protection will be investigated, based on (*inter alia*) the seabed current data at the location of interest and the assessed risk of impact damage.
WTG foundations	Where scour protection is absent and where the hydrodynamic/ seabed geology allow, scour has the potential to form around WTG foundations. This may lead to the release of material into suspension (higher turbidity) and a change to seabed habitat immediately adjacent to the structure. This will be reduced with the introduction of scour protection, where necessary.
Decommissioning	
N/A	N/A

2.10 Environmental assessment: construction phase

2.10.1 The changes to physical processes in response to construction of the Thanet Extension have been described in this section. The maximum adverse scenario against which each construction phase change has been assessed is set out in Table 2.16.

2.10.2 Within this section, an assessment of pathways is presented first followed by the assessments of potential impacts to receptors. The assessments of potential change to pathways are not accompanied by a conclusion regarding the significance of effect. The potential for changes to impact other EIA receptor groups are considered elsewhere within the ES. References to other relevant Chapters are provided at the end of each assessment.

Increases in SSC and deposition of disturbed sediments to the seabed due to dredging for seabed preparation prior to foundation installation

Overview

2.10.3 Seabed preparation may be required prior to the installation of suction caisson foundations (Table 2.16). Two potential sources of sediment release associated with bed preparation activities have been assessed:

- Overspill during the dredging of sediment from the seabed; and
- The disposal of dredged sediment back to the seabed at a nearby location.

2.10.4 The sediment release rate from overspill during dredging will be much smaller than that from dredge spoil disposal, and will be more quickly dispersed by tidal currents. Accordingly, the focus of the assessment in this section is on the highest concentration increases in SSC associated with dispersion from dredge spoil disposal activities.

2.10.5 In order to inform the assessment of potential changes to suspended sediment concentrations and bed levels arising from dredging, a number of spreadsheet based numerical models have been developed, taking into consideration information on:

- Flow speed;
- Direction;
- Lateral dispersion;
- Settling velocities; and
- Sediment properties (seabed and sub-seabed).

2.10.6 The results from these assessments have been validated against numerical modelling and monitoring from other analogous activities. Full results are provided in Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1).

Conceptual understanding of change

2.10.7 It is assumed that dredging would be undertaken with a dredger with a hopper volume of ~11,000 m^3 and disposal of dredged material is assumed to take place nearby (i.e. within a few hundred metres) of the seabed preparation site, within the array area.

2.10.8 As described in Table 2.16, two maximum design scenarios are identified corresponding to the greatest volume of sediment disturbance locally (from a single foundation) and across the entire array (from all foundations). In both instances, the maximum design scenario involves dredging by hopper suction dredger with a split bottom for disposal (i.e. release of material at the water surface).

2.10.9 Across much of the array area, the seabed sediment comprises coarse sand and gravel, with varying quantities of fines present (Figure 2.8). Dredging of the coarse sediment units would not create persistent plumes as the coarse material would quickly settle to the seabed. However, the disturbance of the finer grained sediments has the potential to give rise to more persistent plumes that settle out of suspension over a wider area than for coarse grained sediments.

2.10.10 The dredger will operate at a given location until the required volume has been dredged or the hopper is sufficiently full. The dredged material (spoil) will then be returned to the seabed nearby as a relatively sudden release from under the vessel. If the volume to dredge at a given location is greater than the hopper capacity (11,000 m^3) then multiple dredging and disposal cycles will be required. It will take the equivalent of:

- 1 dredging cycle for one (large) 12 MW WTG; and
- 26.5 dredging cycles for all 28 (larger) MW WTGs, the OSS and met mast.

2.10.11 When the dredged material is released from the hopper, approximately 90% will fall directly to the bed as a single mass (termed the dynamic phase of the plume). The remaining approximately 10% will become more dispersed and stay in suspension (termed the passive phase of the plume). The grain size distribution of material in each phase will be representative of the grain size distribution of the dredged material, which may vary.

2.10.12 The scale of change associated with the dynamic phase of the plume from a single full hopper dredge spoil disposal event can be summarised as follows:

- Duration within the water column - order of seconds to minutes;
- Duration at the seabed - order of seconds to minutes before becoming part of the background sedimentary environment;
- Spatial extent in the water column - order of tens of metres (both laterally and vertically); and
- SSC levels in the water column will be very high in the dynamic phase (far in excess of natural ranges), however these high concentrations will only last for the duration of time taken for the material to fall to the bed and settle (i.e. order of seconds to minutes).

2.10.13 The scale of change associated with the passive phase of the plume from a single full hopper dredge spoil disposal event can be summarised as follows:

- Sand sized material could remain in suspension for up to approximately 15 minutes. During this time, the sediment in suspension could be transported (advected) up to approximately 0.5 km at representative peak tidal current speeds. This distance will, however, typically be less during non-peak flows or during neap tidal periods. The footprint and concentration of the plume would spread and dilute slightly due to diffusion and dispersion with time and distance. The overall direction of transport would be to the north during the ebb tide or to the south during the flood tide;
- SSC levels in the water column within the footprint of the plume may possibly be in excess of natural ranges over this short timescale (approximately 15 minutes);
- Finer sediment fractions (i.e. fine sand or less) present in the passive phase would have a slower settling velocity than the medium sized sands described above and may persist in suspension for longer (i.e. order of hours to days), increasing the extent and duration of change; and
- Away from the release locations (i.e. order of hundreds of metres to a few kilometres), elevations in SSC above background levels are relatively low (i.e. less than ~20 mg/l) and are within the range of natural variability. After 24 hours, elevations in SSC will typically be less than 5 mg/l.

2.10.14 Monthly averaged satellite imagery of SPM suggests that within the Thanet Extension array area average (surface) SPM is generally greater than 10 mg/l, increasing markedly throughout winter months to values between 30 - 80 mg/l (Eggleton *et al*., 2011), occasionally reaching up to 100 mg/l. Higher values are anticipated during spring tides and under storm conditions, with the greatest concentrations encountered close to the bed. Localised increases in SSC of up to several hundred mg/l in the immediate vicinity of the release location will be considerably higher than background levels but are very localised and last for a very short period of time (less than two hours).

2.10.15 Over longer timescales, net movement of any fine grained material persisting in suspension would generally be in an approximate southerly (south-easterly through south-westerly) direction across most of the array area in accordance with the direction of net tidal current drift in this area.

2.10.16 In terms of bed level changes associated with installation of a single WTG foundation, it is found that:

- The actual shape and thickness of the seabed deposit resulting from the release of material from the dredger at the water surface cannot be predicted accurately in advance and in any case is likely to vary. A range of possible configurations of area and thickness are presented in Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1). From this range, the following examples represent a relatively widely spread deposit which is the maximum design scenario for the area of seabed affected (by a nominal average thickness of 0.05 m). In practice, the deposit may comprise several individual releases from multiple dredging cycles and the deposits are likely to be relatively thicker, with a correspondingly smaller area of effect;
- If up to 9,600 m^3 of material is displaced during the installation of one suction caisson foundation (for a 12 MW WTG), OSS or met mast, an area measuring 192,000 m^2 (nominally 438 x 438 m) could potentially be covered by an average thickness of 0.05 m;
- A greater average thickness of material would lead to a smaller area of impact and vice versa. For example, a 0.10 m average thickness deposit would affect an area two times smaller than that described above (for an average deposition thickness of 0.05 m); and
- Deposits resulting from fine sediment that is much more widely dispersed in the passive phase of the plume will have an average thickness less than the diameter of a grain of sand, and therefore would not be measurable in practice. Furthermore, this material would be readily re-mobilised and dispersed and transported further away from the release location, in the direction of the ambient tidal flow.

2.10.17 In terms of bed level changes associated with dredging for installation of all foundations (up to 28 WTGs, one OSS and one met mast), it is found that:

- If the total volume of dredge spoil from all foundations (291,200 m^3) was distributed equally across the array area (73 km^2), the average increase in bed elevation would be 0.004 m;
- An area equal to approximately 0.2% of the array area could potentially be covered by an average thickness of 0.05 m of material; and
- In practice, the change will comprise a series of discrete deposits (smaller overlapping or non-overlapping deposits, potentially from multiple dredging cycles around each dredged area), distributed throughout the parts of the array area that WTGs are located. Individual deposits are likely to be relatively thicker on average than the example value of 0.05 m, with a correspondingly smaller area of effect.

2.10.18 If multiple activities causing sediment disturbance (such as dredging, drilling or cable installation) are undertaken simultaneously at two or more locations that are aligned in relation to the ambient tidal streams, then there is potential for overlap between the areas of effect on SSC and sediment deposition. The effect on SSC in areas of overlap will be additive if the downstream activity occurs within the area of effect from upstream (i.e. sediment is disturbed within the sediment plume from the upstream location). The effect on SSC will not be additive (i.e. the effects will be as described for single occurrences only) if the areas of effect only meet or overlap downstream following advection or dispersion of the effects. Effects on sediment deposition will be additive if and where the footprints of the deposits overlap. Given that the minimum spacing between foundations is 480 m, it is unlikely that coarse sands or gravels put into suspension will be dispersed far enough (i.e. between adjacent foundation locations) to cause any overlapping effects before being redeposited to the seabed. In general, only relatively fine sediment (e.g. clay, silt and fine sand sized material) is likely to be advected far enough to potentially cause overlapping effects on SCC.

Assessment of significance

2.10.19 All of the identified physical processes receptors are insensitive to elevated levels of SSC and localised changes in bed level. However, the potential for these changes to impact other EIA receptor groups are considered elsewhere within the ES, in particular:

- Volume 2, Chapter 3: Marine Water and Sediment Quality (Document Ref: 6.2.3);
- Volume 2, Chapter 4: Offshore Ornithology (Document Ref: 6.2.4);
- Volume 2, Chapter 5: Benthic Ecology (Document Ref: 6.2.5);
- Volume 2, Chapter 6: Fish and Shellfish (Document Ref: 6.2.6); and
- Volume 2, Chapter 7: Marine Mammals (Document Ref: 6.2.7).

Increases in SSC and deposition of disturbed sediments to the seabed due to the release of drill arisings during foundation installation

Overview

2.10.20 Monopile foundations and pin-piles for quadropod foundations will be installed into the seabed using standard piling techniques. In some locations, the particular geology may present some obstacle to piling, in which case, some or all of the seabed material might be drilled from within the pile footprint to assist in the piling process. Up to 50% of WTG foundations may require drilling to assist with installation. It is noted here that all monopile foundations were successfully installed at TOWF using piling alone with no drilling required.

2.10.21 The impact of drilling operations mainly relates to the release of drilling spoil at or above the water surface which will put sediment into suspension and the subsequent re-deposition of that material to the seabed. The nature of this disturbance will be determined by the rate and total volume of material to be drilled, the seabed and subsoil material type, and the drilling method (affecting the texture and grain size distribution of the drill spoil).

2.10.22 The same spreadsheet based models used to consider changes in SSC and bed levels associated with dredging have been used to inform the drill arisings assessment. Full results are provided in Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1).

Conceptual understanding of change

2.10.23 Two maximum adverse scenarios are identified in Table 2.16, corresponding to the greatest volume of drilled sediment disturbance locally (from a single monopile foundation) and across the entire array (from 34 medium sized (10 MW) monopile foundations, one OSS and one met mast).

2.10.24 The distribution of grain/ clast sizes in the drill arisings is not known in advance, so results are provided separately in Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1) for scenarios where 100% of the material is assumed to be either fines, sands or gravels. In practice, depending on the actual ground conditions and drilling tools used, the distribution of grain/clast size in the spoil will be some variable mixture of these with a corresponding intermediate duration, extent and magnitude of change.

2.10.25 The following observations based on the spreadsheet based numerical model results are consistent with similarly modelled patterns of change in assessments for other wind farms, and the wider monitoring evidence base.

2.10.26 Assuming that a mixture of sediment grain sizes are present, the overall spatial pattern of change due to drilling of a single monopile foundation is summarised as follows:

- SSC will be increased by tens to hundreds of thousands of mg/l at the point of sediment release, which is at or near the water surface;
- SSC of low tens of mg/l will be present in a narrow plume (tens to a few hundreds of metres wide, up to one tidal excursion in length (~13 km on spring tides and ~7 km on neap tides) aligned to the tidal stream downstream from the source;
- If drilling occurs over more than one flood or ebb tidal period, the plume feature may be present in both downstream and upstream directions;
- Outside of the area up to one tidal excursion upstream and downstream of the foundation location, SSC less than 10 mg/l may occur more widely due to ongoing dispersion and dilution of material;
- Sufficiently fine sediment may persist in suspension for hours to days or longer, but will become diluted to very low concentrations (< 5 mg/l, indistinguishable from natural background levels and variability) within timescales of around one day; and
- Over longer timescales, net movement of any fine grained material persisting in suspension would generally be in an approximate southerly (south-easterly through south-westerly) direction across most of the array area in accordance with the direction of net tidal current drift in this area.

2.10.27 Sediment deposition as a result of drilling for a single foundation installation are characterised as follows:

- Deposits of mainly coarse grained and clastic sediment deposits will be concentrated within an area in the order of approximately 10 - 100 m downstream/ upstream and a few tens of metres wide from individual foundations, with an average thickness in the order of one to ten metres (limited to realistically likely values);
- Deposits of mainly sandy sediment deposits will be concentrated within an area in the order of approximately 150 - 500 m downstream/ upstream and tens to one hundred metres wide from individual foundations, with an average thickness in the approximate order of tens of centimetres to approximately one metre;
- Fine grained material will be dispersed widely within the surrounding region and will not settle with measurable thickness; and
- The absolute width, length, shape and thickness of local sediment deposition as a result of drilling are estimated above but cannot be predicted with certainty and are likely to vary due to the nature of the drill spoil, the local water depth and the ambient environmental conditions during the drilling activity. Other possible combinations of shape, area and thickness of sediment deposition are provided in Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1).

2.10.28 The local patterns of change to SSC and sediment deposition are described above, as a result of drilling activities for individual foundations of any type. In the array area, up to 17 (50% of 34) 10 MW monopile foundations for WTGs may be installed using drilling, as well as one OSS and one met mast. The total sediment volume potentially released by drilling of all foundations has also been assessed with respect to the total potential extent and thickness of sediment deposition, as summarised below.

2.10.29 The actual shape, width, length and thickness of local or regional sediment deposition as a result of drilling cannot be predicted with certainty and is likely to vary according to the final distribution of foundations, the local nature of the drill spoil, the local water depth and the ambient environmental conditions during the drilling activity. However, the maximum total volume that could theoretically be released from drilling 50% of all foundations (17 monopile WTG foundations and 1 monopile OSS foundation) is 21,852 m^3 and it is found that:

- If the total volume of drill arisings from all foundations was distributed equally across the array area (73 km^2), the average increase in bed elevation would be 0.0005 m (assuming a packing density of the deposited material of 0.6);
- An area equal to approximately 1.0% of the array area could potentially be covered by an average thickness of 0.05 m of material (assuming a packing density of the deposited material of 0.6); and
- In practice, the change will comprise a series of discrete deposits (smaller overlapping or non-overlapping deposits), distributed throughout the parts of the array area that WTGs are located. Individual deposits are likely to be relatively thicker on average than the example value of 0.05 m, with a correspondingly smaller area of effect.

2.10.30 If multiple activities causing sediment disturbance (such as drilling, dredging or cable installation) are undertaken simultaneously at two or more locations that are aligned in relation to the ambient tidal streams, then there is potential for overlap between the areas of effect on SSC and sediment deposition. The potential for in-combination effects on SSC and sediment deposition are discussed in paragraph 2.10.18.

Assessment of significance

2.10.31 All of the identified physical processes receptors will be insensitive to elevated levels of SSC and localised changes in bed level. However, the potential for these changes to impact other EIA receptor groups are considered elsewhere within the ES, in particular:

- Volume 2, Chapter 3: Marine Water and Sediment Quality (Document Ref: 6.2.3);
- Volume 2, Chapter 4: Offshore Ornithology (Document Ref: 6.2.4);
- Volume 2, Chapter 5: Benthic Ecology (Document Ref: 6.2.5);
- Volume 2, Chapter 6: Fish and Shellfish (Document Ref: 6.2.6); and
- Volume 2, Chapter 7: Marine Mammals (Document Ref: 6.2.7).

Increases in SSC and deposition of disturbed sediment to the seabed due to cable installation within the Thanet Extension array area and within the OECC

Overview

2.10.32 The impact of cable burial operations mainly relates to a localised and temporary re-suspension and subsequent settling of sediments (BERR, 2008). The exact nature of this disturbance will be determined by the soil conditions within the Thanet Extension array area and OECC, the length of installed cable, the burial depth and burial method.

2.10.33 The maximum adverse scenario for cable installation involves jetting into a V-shaped cable trench measuring, on average, 10 m wide by 3 m deep (Table 2.16). In addition, localised sand wave clearance may be required prior to cable installation. This would involve the displacement of material via jetting tool. The potential for increases in SSC and deposition of disturbed sediment to the seabed due to these activities have been calculated using the previously described spreadsheet based numerical model, with results presented in detail within Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1). These results have subsequently been validated using modelling and monitoring from other analogous activities.

Conceptual understanding of change

2.10.34 In terms of cable installation, jetting techniques represent the maximum design scenario, as it has the greatest potential to energetically fluidise and eject material from the trench into suspension. By contrast, the other cable installation techniques described in the project design statement (Volume 2, Chapter 1: Project Description - Offshore (Document Ref: 6.2.1)) are expected to re-suspend a smaller amount of material into the water column. Due to spatial variation in the geotechnical properties of the underlying geology within this region, it is possible that a combination of techniques may be used.

2.10.35 It is impractical to capture the full detail of sediment heterogeneity within the array area and along the offshore cable corridor within the context of assessing changes in SSC. Instead, the assessment has considered a series of worst-case 'end-member' scenarios. These are:

- Jetting through 100% (coarse) gravel (15,000 µm);
- Jetting through 100% (medium) sand (375 µm); and
- Jetting through 100% (fine) silt (10 µm).

2.10.36 These three scenarios represent the full potential range of change both in terms of the duration, spatial extent of change to SSC, and maximum thicknesses of sediment deposition. In practice, a release comprising entirely fines is very unlikely.

2.10.37 Results are presented in Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1) for a range of representative current speeds, noting that sand wave clearance/ cable burial will continue through all states of the tide, including current speeds lower than the highest locally possible (peak) value. Because of the uncertainty with regards to how high into the water column from the bed material may be ejected or re-suspended, results are provided for a realistic range of heights (1, 5 and 10 m). A greater height of ejection will lead to a potentially longer plume duration and a greater distance of influence, but also a corresponding reduction in SSC and deposition thickness.

2.10.38 In summary:

- Due to the expected low height of ejection, the effect of sand and gravels on SSC and deposition will be spatially limited to within metres (up to approximately 20 m) downstream of the cable for gravels and within tens of metres (up to a few hundred metres) for sands; and
- Finer material will be advected away from the release location by the prevailing tidal current. High initial concentrations (similar to sands and gravels) are to be expected but will be subject to rapid dispersion, both laterally and vertically, to near-background levels (tens of mg/l) within hundreds to a few thousands of metres of the point of release. In practice, only a small proportion of the material disturbed is expected to be fines, with a corresponding reduction in the expected levels of SSC.

2.10.39 Irrespective of sediment type, the volumes of sediment being displaced and deposited locally are relatively limited (up to 7.5 m^3 per metre of cable burial with 50% release of sediments) which also limits the combinations of sediment deposition thickness and extent that might realistically occur. Fundamentally, the maximum distance from each metre of cable trench over which 7.5 m^3 of sediment can be spread to an average thickness of 0.05 m is 150 m; any larger distance would correspond to a smaller average thickness. The assessment suggests that the extent and so the area of deposition will normally be smaller for sands and gravels (although leading to a greater average thickness of deposition in the order of tens of centimetres to a few metres) and that fine material will be distributed much more widely, becoming so dispersed that it is unlikely to settle in measurable thickness locally.

2.10.40 If cable burial, or any other activity causing sediment disturbance, is undertaken simultaneously at two or more locations that are aligned in relation to the ambient tidal streams, then there is potential for overlap between the areas of effect on SSC and sediment deposition.

Assessment of significance

2.10.41 The potential for sand wave clearance activities to adversely impact sand bank receptors via alteration of sediment transport pathways is considered in paragraph 2.10.49 onwards.

2.10.42 All of the identified physical processes receptors will be insensitive to elevated levels of SSC and localised changes in bed level. However, the potential for these changes to impact other EIA receptor groups are considered elsewhere within the ES, in particular:

- Volume 2, Chapter 3: Marine Water and Sediment Quality (Document Ref: 6.2.3);
- Volume 2, Chapter 4: Offshore Ornithology (Document Ref: 6.2.4);
- Volume 2, Chapter 5: Benthic Ecology (Document Ref: 6.2.5);
- Volume 2, Chapter 6: Fish and Shellfish (Document Ref: 6.2.6); and
- Volume 2, Chapter 7: Marine Mammals (Document Ref: 6.2.7).

Sand wave crest level preparation resulting in a change to local hydrodynamic, wave and sediment transport processes.

Overview

2.10.43 Within some parts of the Thanet Extension array area and OECC, large (up to 8 m high) mobile bedforms are present (paragraph 2.7.30). To ensure effective burial below the level of the stable bed, it may (in places) be necessary to first remove sections of sand waves through the use of a jetting tool, before trenching into the underlying bed. This section considers the potential for seabed recovery as well as longer term changes to patterns of sediment transport. The assessment is based on the analyses presented in Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1) which is informed by the maximum adverse scenario set out in Table 2.16.

Conceptual understanding of change

2.10.44 The volume of material to be cleared from individual sand waves will vary according to the local dimensions of the sand wave (height, length and shape) and the level to which the sand wave must be reduced (also accounting for stable sediment slope angles). The total volume that could be dredged due to sand wave clearance activities will be up to 1,440,000 m^3.

2.10.45 The rate of recovery would vary in relation to the rate of sediment transport processes, faster infill and recovery rates will be associated with higher local flow speeds and more frequent wave influence. The shape of the bedform following recovery might recover to its original condition (e.g. rebuilding a single crest feature, although likely displaced in the direction of natural migration) or it might change (e.g. a single crest feature might bifurcate or merge with another nearby bedform). All such possible outcomes are consistent with the natural processes and bedform configurations that are already present in the study area and would not adversely affect the onward form and function of the individual bedform features.

2.10.46 The levelled areas are not considered likely to create a barrier to sediment movement. Evidence drawn from aggregate dredging activities indicates that if any changes occur to the flow conditions or wave regime, these are localised in close proximity to the dredge pocket. However, the aggregate dredge pockets concerned had widths and lengths of several kilometres. The proposed works will be at a much smaller scale and footprint, with trench widths expected to be in the order of a few tens of metres. This means there is likely to be little to no influence on the flow or wave regime, which in turn means no change to the regional scale sediment transport processes across the array area and OECC.

2.10.47 The proposed jetting activities will only locally displace the disturbed sediment volume, which will remain the same sediment type as the surrounding seabed. No sediment volume will be removed from the sedimentary system.

Assessment of significance

2.10.48 The changes described in this section are to 'pathways' as opposed to receptors. The significance of potential impacts to sand banks arising either directly or indirectly from sand wave clearance activities is considered within paragraph 2.10.49 onwards.

Impacts to sand bank receptors (due to construction activities).

Overview

2.10.49 Of the impact pathways considered within this section for the construction phase, the only means by which the three sand banks could be affected by construction related activities associated with Thanet Extension is through sand wave clearance, which could theoretically interrupt the supply of material to adjacent sand bank systems. The potential for impacts to sand banks is considered here, drawing upon the findings of the assessment of potential changes to sediment transport associated with sand wave clearance (summarised in paragraph 2.10.43 to 2.10.48 and presented in more detail within Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1)).

Conceptual understanding of change

2.10.50 Levelled areas of sand waves are not considered likely to create a barrier to sediment movement and displaced material will not be removed from the sedimentary system. More generally, the bedforms along which bed levelling may be required will be part of a much larger dynamic bedform field including (in places) active sand waves along the OECC belonging to the Goodwin Sands rMCZ bank system. The patterns of processes governing the overall evolution of the systems (the flow regime, water depths and sediment availability) are at a much larger scale than, and so would not be affected by, the proposed local works. As a result, the proposed levelling is not likely to influence the overall form and function of the system and eventual recovery via natural processes is therefore expected.

Assessment of significance

2.10.51 Using the criteria presented in Table 2.6, the sand banks within the study area are considered to be of High sensitivity/ importance. Margate sand bank is internationally designated whilst the Goodwin sand banks are within the Goodwin Sands rMCZ. South Falls is immediately adjacent to the Dover Straits shipping lane and therefore any modification to the position of the feature is potentially of particular concern. However, these sand banks within close proximity to the Thanet Extension array area are understood to be naturally dynamic features which will be insensitive to such minor changes in tidal and wave conditions.

2.10.52 The magnitude of impact to sand banks is predicted to be Very low. This assessment is based on the fact that no sediment will be removed from the system and therefore the rate at which sediment is supplied to the adjacent banks will remain unaltered.

2.10.53 The overall level of effect significance has been assessed according to the EIA methodology set out in section 2.5 (paragraph 2.5.1 onwards). Effect significance has been determined by combining the assigned rating for receptor sensitivity/ importance and impact magnitude, as shown in Table 2.8. Overall, the effect on sand banks is **Negligible** adverse.

Impacts to designated coastal feature receptors (due to construction activities).

Overview

2.10.54 The export cable will make landfall in the south-west of Pegwell Bay, to the west of the mouth of the River Stour (Figure 2.17). The location is characterised by the presence of (designated) saltmarsh across the upper intertidal, with muddy/ sandy sediments present in the lower intertidal/ shallow subtidal. The most pronounced naturally occurring morphological changes are dominated by migration of Shell Ness, the River Stour and associated tributary channels (Figure 2.15).

2.10.55 Three options have been identified for installation of the export cables at the landfall. These three options assume that the outcome of site investigation works indicate that trenching and/or HDD are possible within the historic landfill. Only one of the three options will be implemented. A description of the three landfall options is given below:

- Option 1: Locate the Transition Joint Bays (TJBs) below ground within the Country Park and install the offshore cables by HDD. This Option requires a larger onshore temporary works compound to house the HDD rig and associated equipment but does not require excavation and reinstatement of the sea wall. Under this Option HDD would be undertaken from land to sea, with an initial bore undertaken prior to a wider drill profile and installation of ducts to house the cables. The HDD ducts would be installed from the TJB location, out to a punch-out location at least 100 m seaward of the sea wall. The cables would be trenched through the upper intertidal area to the HDD exit pits and drawn through the duct to the TJB.
    - As a result of the uncertainty associated with the contents of the landfill there may be a need to control the HDD works in order to prevent the introduction of a pathway for the contaminants present. Whilst the detailed design will be subject to the outcomes of the site investigation works, and any additional SI works that may be required post-consent, there are a number of methods that could be applied to control the release of contaminants from the landfill. This may include excavating down through the landfill and lining it with plastic or other material (depending on depth), or installation of casing through the first section of the HDD bore (within the initial landfill area) to seal it (disposing of the excavated material appropriately) before continuing the bore out to the punch out/receptor pit in clean ground.
- Option 2: Locate the TJBs above ground within the Country Park. This requires installation of a temporary cofferdam within the upper intertidal/ saltmarsh area before extending the existing sea wall. As with Option 1, the cables would be trenched through the upper intertidal area to the seawall extension. The seawall extension is required to allow for the vertical transition from buried offshore cables to the above ground TJBs and onward surface laid onshore cables. For the purposes of assessment, it is assumed that the temporary cofferdam will be installed using normal piling techniques and will take a duration of 16 days, assuming active piling for 70% of the 12 hour working day (noting construction works between 0700 and 1900, 6 days per week). After construction of the seawall extension and installation of the cables the cofferdam would be removed, and the seawall extension reinstated.
- Option 3: Locate the TJBs below ground within the Country Park before trenching the remainder of the route. As described in relation to Option 2 this requires installation of a temporary cofferdam before excavating through from the upper intertidal, through the existing sea wall. The offshore cables would be trenched from the intertidal through this cofferdam and seawall area onshore into the TJB area. The cofferdam would be removed, and the seawall reinstated. No extension to the existing seawall is required with this option.

2.10.56 Available details of the maximum adverse scenario are presented in Table 2.16 whilst more detailed descriptions of the three landfall options are described in the project description chapter (Volume 4, Chapter 1: Project Description - Onshore (Document Ref: 6.4.1).

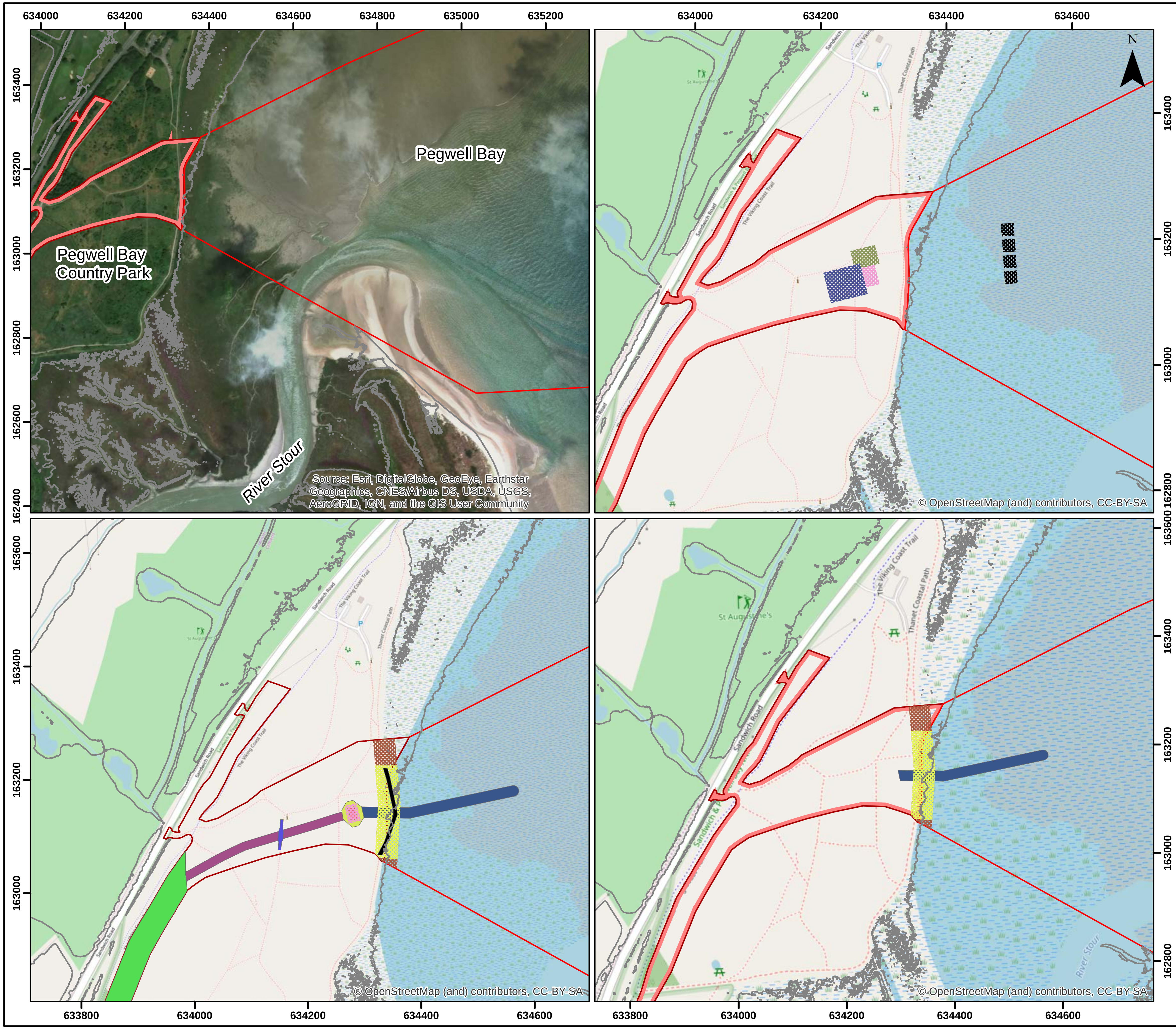
2.10.57 Although only one of the three options will be implemented, all options have the potential to influence physical processes (and hence coastal morphology) in slightly different ways. These design aspects are summarised below and assessed in this section:

- Re-alignment of the existing sea wall (Option 2);
- Temporary use of cofferdam structure (Option 2 and 3);
- Excavation of HDD exit pits (Option 1); and
- Disturbance of sediments during (open-cut) cable trenching across the inter-tidal (All options although length of trenching varies between HDD/ non-HDD options).

2.10.58 A more detailed discussion of the potential for changes to hydrodynamics, sediment transport and beach morphology at the landfall is presented in Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1).

THANET EXTENSION OFFSHORE WIND FARM

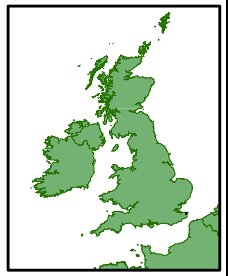
Figure 2.17
Aerial Imagery of the Export Cable Landfall (2011)



Legend

- Offshore Red Line Boundary
- Onshore Red Line Boundary
- MHWST Contour
- HDD exit pits
- Sea defence extension cofferdam extent
- Sea defence extension possible area
- Temporary work area for HDD
- Temporary works area
- Temporary works area trenching
- Transition pit cofferdam extent
- Above ground stabilisation area -15m
- Cable corridor
- KWT crossing 5x54m
- Subsea cable installation area -19m
- Transition pit area -12x46m
- Transition pit -12x22m
- Rock armour replacement area

Datum: OSGB 1936
Projection: BNG



1:7,000

0 0.07 0.14 km

0 0.035 0.07 nm

Drg No	003_ES_Fig2.17_Landfall_Aerial		
Rev	1	Date	24/05/2018
By	AMC	Layout	N/A

Figure 2.17

Conceptual understanding of change

2.10.59 **Re-alignment of the sea wall:** Where the OECC makes landfall in Pegwell Bay, it will be necessary to re-align (extend) a small section of the sea wall which is currently in place at the seaward limit of Pegwell Bay Country Park. The re-aligned sea wall would involve the use of rock armour along an approximately 155 m long stretch of (north-south orientated) frontage, with the new position of the defence up to 18.5 m seaward of the existing defence (Figure 2.17). Whilst this modification of the existing defence will result in a small loss of saltmarsh habitat (1398.9 m^2 - which is independently assessed in Volume 2, Chapter 5: Benthic Ecology (Document Ref: 6.2.5)), the potential for wider changes in marine physical processes is considered to be very small. The reasons for this are set out below:

- The toe of the existing sea wall is located at approximately the HAT mark (circa 3.1 m ODN) and the toe of the new defence is located at approximately the MHWS mark (circa 2.6 m ODN). Accordingly, the amount of time that water levels are high enough that currents or waves will have the potential to interact directly with the new structure is and will remain very limited (estimated to be approximately 1.3% of time, based on an analysis of 18 years of hindcast tide and residual surge water levels from Pegwell for the period 1980 to 1997).
- Flows within Pegwell Bay are generally weak and this will especially be the case in an upper saltmarsh setting where flows are further reduced by the presence of vegetation. Accordingly, the potential for measurable changes to flows in the vicinity of the new defence will be very limited.
- Because the toe of the defence may be slightly lower in the tidal frame than the existing sea wall, it is possible that waves may interact with the structure slightly more frequently than is currently the case. This may result in some additional turbulence from wave breaking or localised scour in the immediate vicinity of the armour units at the toe of the structure (order of a few metres extent). However, it is important to note that this could only occur infrequently for limited periods of time (only around high water during larger spring tides and when waves are present).

2.10.60 **Use of temporary cofferdam structures:** Prior to works commencing, a temporary cofferdam would be installed at the seaward interface of the landfall works to act as a barrier to tidal inundation and waves, and as a preventative barrier to contain any already present contaminants released from the landfill area. The cofferdam will be installed in such a way as to permit open trenching from the intertidal to the sea wall extension, allowing a dry working area below the high water mark on the saltmarsh in the area east of the Country Park. This cofferdam would extend a maximum of 25 m in a seaward direction, along up to 165 m of the frontage, and would be constructed of sheet piles.

2.10.61 Given the similarities in scale and location within the inter-tidal zone, the cofferdam will interact with marine physical processes in a similar manner to the re-aligned sea wall (described in paragraph 2.10.59 onwards, above). It follows from this that the potential for modification to inter-tidal morphology will be similarly limited. In fact, any changes are expected to be even less than for the re-aligned wall as the cofferdam will be a temporary structure that is in place for only a few months.

2.10.62 **Excavation of HDD exit pits:** If HDD is used to install the export cables at the landfall, up to four HDD exit pits may be excavated on the mud/ sand flat in the inter-tidal, approximately 100 m seaward of the saltmarsh. The dimensions of the HDD exit pits will be up to 20 m x 20 m, with a depth of a few metres. This corresponds to a total volume of excavated material of a few thousand cubic metres for all four pits (estimated volume of circa 5000 m^3, based on an average excavation depth of 3 m).

2.10.63 It is anticipated that, if possible, the excavated material would be stored nearby as temporary spoil mounds. Depending upon the position of the pits and mounds in the inter-tidal (and hence the water depth in which they are situated), they may have the potential to modify the nearshore wave regime and therefore seabed/ inter-tidal morphology. In particular, localised changes in water depth over the pits and mounds could in theory allow greater or differently distributed transmission of wave energy to the coast resulting in a localised morphological response.

2.10.64 It is noted here that the individual morphological elements within Pegwell Bay may have differing sensitivities and responses to any small-scale and localised changes to the wave regime. For instance, wave driven sediment transport is a key process at Shell Ness whereas tidal processes (including the settling of fine grained sediments) will be particularly influential in the saltmarsh setting at the landfall. However, the HDD exit pits (and any associated spoil mounds) would be temporary features and it is anticipated that they would only be present for a short period (up to a few weeks) before the excavated material was used to back fill the pits. Accordingly, the potential for longer term morphological change arising from changes to the hydrodynamic and/or wave regime is considered to be very small. Moreover, if the pits were located relatively high up the inter-tidal, they would only be inundated infrequently and as such, there would be very limited potential for interaction with waves.

2.10.65 **Trenching:** trenching across the intertidal/ shallow subtidal could be achieved using several techniques although ploughing would displace the greatest volume of material out of the trench and therefore is considered to represent the maximum design scenario. Excavation of the trench with a plough would result in the formation of berms either side of the trench. The size of these berms will be dependent upon the trench width, cable burial depth and nature of the disturbed sediments.

2.10.66 The disturbed sediments are anticipated to comprise organic-rich saltmarsh sediments along with fine sand whilst the likely trench dimensions are not presently known. These will be established once more knowledge of the site has been gathered and processed (from ongoing intrusive Site Investigations) and a detailed Cable Burial Assessment for Thanet Extension cable corridor has been performed. Notwithstanding the above, taking a 3 m burial depth as the probable maximum case, the width resulting for a ploughed trench of 30 degrees would be 10 m. Should the subsequent spoil berms be taken into account, the whole width would be 28 m whilst the spoil berm height would be approximately 2.1 m. Importantly, trenches (and associated spoil berms) of this dimension would only be present in sub-tidal areas. Within the inter-tidal, the spacing between the four trenches would narrow (to circa 5 m) and the width of individual trenches would also reduce, to approximately 1 m. Accordingly, the overall amount of disturbance would be limited (4,703 m^2).

2.10.67 It is possible that whilst the trenches are open, the material in the berms could be mobilised by the action of tidal currents and waves and locally redistributed. Accordingly, the potential extent of change to beach/ intertidal morphology could extend across a wider area than the immediate footprint of the trench and berms. However, it is anticipated that the berms adjacent to the trench would only be present on the seabed/ beach for a very short period of time and therefore the extent to which this redistribution of material could occur is anticipated to be limited. Furthermore, given that the berms would only be present for a very short period of time, any changes to hydrodynamics and sediment transport would also be highly localised and there would be no potential for longer term change to coastal morphology.

2.10.68 Within the lower intertidal/ shallow subtidal, it is anticipated that reworking by currents and/ or waves will quickly (in the order of days to several weeks) redistribute and smooth any remaining local disturbances after the trench has been backfilled, returning the area of the trench (and associated works) to a natural state (e.g. elevation and sediment type) that will be in equilibrium with the baseline environment. However, recovery of the adjacent saltmarsh may be expected to take much longer (period of years). Direct impacts may include disturbance (removal) of the saltmarsh within the working footprint of the works. Although the local topography will largely be restored following the activity, the original saltmarsh habitat may be expected to recover to the pre-construction condition in the area of the impact within two to three years. This is in line with the recovery recorded for the existing TOWF cable installation within the Pegwell Bay saltmarsh habitat. The potential significance of this change is considered in Volume 2, Chapter 5: Benthic Ecology (Document Ref: 6.2.5).

2.10.69 In addition to the above, because the trench will be back-filled using the excavated organic-rich saltmarsh deposits the surface elevation of the trench could theoretically lower over time due to sediment compaction. If the rate of sedimentation doesn't keep pace with the rate of compaction, this could potentially result in a change in vegetation type from baseline conditions, owing to the change in inundation frequency/ local salinity regime. These changes would be restricted to the footprint of the trench and therefore could be in the order of several hundred m^2. (This is based on four cables being installed across a distance of approximately 100 m of saltmarsh, with trenches narrowing to a width of approximately 1 m). However in terms of overall morphology the form/ function and stability of the wider saltmarsh would not be affected.

2.10.70 It is noted here that open-cut trenching methods were used to install the TOWF export cables at a location just to the north of the petrol station located at the west of Pegwell Bay on the A256 (Figure 2.1). Comparison of aerial photography from before (2008) and after (2013 and 2016) installation shows that changes to the intertidal associated with cable installation were localised and predominantly of short-term duration. Morphological change is restricted to the area of the trench itself and by 2016 the location of the trench is barely discernible.

2.10.71 In theory, the installation of any cable protection measures could cause a morphological response via (for instance) modification of the local nearshore wave regime and associated patterns of sediment transport. However, it is assumed that if cable protection was installed at the landfall it would be installed with a sufficiently low profile relative to the surrounding bed to present minimal barrier to the passage of waves and so cause no change to long-term patterns of sediment transport.

Assessment of significance

2.10.72 Using the criteria presented in Table 2.8, the coastal features at the landfall are considered to be of High sensitivity/ importance. Although both nationally and internationally designated, this is a dynamic setting which is typically subject to natural change under baseline conditions. Accordingly, it is assessed to have some capacity to recover from disturbance.

2.10.73 The magnitude of impact to coastal features which could occur via some or all of the potential impact pathways described in this section occurring together is predicted to be Low. This assessment is based on the fact that any impacts will be localised in extent albeit (in the case of the re-alignment of the sea wall) of long-term duration.

2.10.74 The overall level of effect significance has been assessed according to the EIA methodology set out in section 2.5 (paragraph 2.5.1 onwards). Effect significance has been determined by combining the assigned rating for receptor sensitivity/ importance and impact magnitude, as shown in Table 2.8. Overall, the effect on the coast is **Minor** adverse.

2.11 Environmental assessment: O&M phase

2.11.1 The changes to physical processes in response to construction of the Thanet Extension have been described in this section. The maximum adverse scenario against which each operational phase change has been assessed is set out in Table 2.16.

2.11.2 Within this section, an assessment of pathways is presented first followed by the assessments of potential impacts to receptors. The assessments of potential change to pathways are not accompanied by a conclusion regarding the significance of effect. Instead the significance of effect is considered in the various relevant receptor Chapters.

Changes to the tidal regime

Overview

2.11.3 The interaction between the tidal regime and the foundations of the wind farm infrastructure will result in a general reduction in current speed and an increase in levels of turbulence locally due to frictional drag and the shape of the structure. Resistance posed by the array (due to the sum of all foundation drag) to the passage of water at a large scale may also distort the progression of the tidal wave, also potentially affecting the phase and height of tidal water levels. The potential for such changes to the tidal regime to occur in response to the presence of the Thanet Extension array area (recognising the existing operational TOWF) is considered in this section.

2.11.4 Changes to the tidal regime may also indirectly impact seabed morphology (including bedforms) in a number of ways. In particular, there exists a close relationship between flow speed and bedform type (e.g. Belderson *et al*., 1982) and thus any changes to flows have the potential to alter seabed morphology over the lifetime of the project. The potential for such changes to nearby sand banks is considered within paragraph 2.10.49 to 2.10.53.

Conceptual understanding of change

2.11.5 **Currents:** the presence of foundations in the sea will interfere locally with the passage of tidal flows as a consequence of blockage effects, which will lead to the development of a turbulent wake with a reduced time-mean flow speed extending downstream (Figure 2.18). The wake signature naturally dissipates to near background levels by a distance in the order of several tens the diameter of the obstacle downstream (e.g. Li *et al*., 2014; Cazaneve *et al*., 2016; Rogan *et al*., 2016). In an array of multiple structures, the changes can be considered as the sum of all individual effects.

Figure 2.18: Turbine wake observed at foundation E01, TOWF (Forster, 2017).

2.11.6 The worst-case foundation option for Thanet Extension has been determined as the larger four-legged quadropod structure required for the 12 MW turbine (Table 2.16; Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1)). For the 12 MW WTG, there will only be 28 quadropod structures required across the 72.8 km^2 array area. The realistic worst-case minimum turbine spacing is 716 m x 480 m.

2.11.7 In contrast, the operational TOWF contains 100 monopile foundations with diameters varying between 4.1 - 4.9 m, which are spread across a 35 km^2 array area with spacing of 0.5 km along the rows and 0.8 km between rows. Each of these foundations has a local scale effect on the tidal flows through drag forces and wake formation, the immediate consequence of which is the development of vortices around the structure which can lead to scouring of the local seabed. The wider effects of TOWF on the tidal regime is partly revealed by the presence of turbid wakes (paragraph 2.1.1), noting that the visible sediment plume is considerably longer than the measurable flow wake feature.

2.11.8 For Thanet Extension, similar tidal and sediment plume type effects are anticipated on the tidal regime as those observed at TOWF, but with some notable contrasts;

- Depending on the final design option, there will only be up to 34 foundations (or 28 foundations for the 12 MW case) and one OSS which will introduce additional local disturbance to flows around those already occurring at the 100 WTG foundations within TOWF;
- The worst-case foundation option under consideration is a quadropod structure rather than a monopile as this has been assessed to result in the greatest amount of local blockage to the tidal flows. The immediate consequence of this structure is to create a more disturbed local flow across the larger incident width. This disturbed flow can be expected to lead to local scour at sites without appropriate seabed protection (paragraph 2.11.42 to 2.11.57), and the encouragement of similar, but proportionally wider, turbid wakes for areas with active seabed transport of fine sediments;
- The lateral extents of modification to tidal flows in the wake are likely to be proportionally larger due to the increased width of the individual structures. Li *et al*. (2014) found that the wake field will extend a distance of up to approximately 80 times the diameter of the foundation. Taking a mid-depth width of 30 m for the 12 MW quadropod foundation, it follows that a likely extent of a measurable/ detectable wake is estimated to be in the order of 2.4 km (at times of peak flow) and along the axis of flows as measured in the metocean deployments (paragraph 2.7.7). A 2.4 km buffer around the Thanet Extension array area is shown in Figure 2.5. (This buffer is a conservative representation as it assumes that change of this magnitude could occur in all flow directions, rather than in just the direction of peak flow); and
- The source of each wake feature will be spaced further apart than within TOWF due to increased separations between the larger rated WTGs, so the potential of interaction of wakes between foundations is much reduced, further limiting any potential for array scale effects.

2.11.9 On the flood tide, only the foundations located in the northern sector of Thanet Extension will create wake effects that have the potential to also overlap with TOWF. For an indicative layout in which WTGs are distributed evenly throughout the array area, there are estimated to be around six locations close enough to TOWF where this might occur.

2.11.10 On the ebb tide, only the foundations located in the southern part of Thanet Extension will create wake effects that have the potential to overlap with TOWF. There are estimated to be around seven locations close enough to TOWF where this might occur.

2.11.11 Ebb and flood flows through the east and western parts of Thanet Extension are unlikely to overlap with TOWF.

2.11.12 However, even taking into consideration the potential for flow disturbance from both the Thanet Extension and TOWF array area acting together, if the changes to flows described above occurred from the outer limits of the Thanet extension array area, they remain too short to reach the adjacent coastlines, any other windfarm in the study area along the same axis of flow, and/ or any adjacent sand bank features.

2.11.13 **Water levels:** Although foundations within the Thanet Extension (and TOWF) array area may be expected to cause some very minor redistribution of current speeds, there will be minimal overall net change in the rate at which water passes through the array area. As such, patterns of natural variability in local and regional water levels are not expected to be affected by the presence of the Thanet Extension (and TOWF) array areas. This includes both tidal and non-tidal (surge) contributions to water levels. This conclusion is consistent with numerical modelling studies previously undertaken to inform a wide range of other (much larger) Round 3 developments (e.g. East Anglia Offshore Wind, 2012; Moray Offshore Renewables Ltd, 2012, Navitus Bay Development Ltd, 2014).

Assessment of significance

2.11.14 The changes described in this section are to ‘pathways’ as opposed to receptors. The significance of potential impacts to physical processes receptors (most notably sand banks) arising from modification of the tidal regime is considered within paragraph 2.11.77 onwards.

Changes to the wave regime

Overview

2.11.15 Modification of the wave regime could occur in response to the presence of:

- WTG (and OSS) foundations; and/ or
- Cable protection measures.

2.11.16 The influence of a single structure on individual waves is not easily measurable in practice but the combined influence of many structures is generally accepted to be a slight reduction of wave energy (height and period) which may extend across the far-field. Where the wave climate is persistently modified, these changes may potentially alter the frequency of sediment mobilisation and rates of transport and deposition in offshore areas, and/ or the rate and direction of longshore sediment transport at exposed coastlines. These potential changes to the sediment transport regime are discussed separately, in paragraph 2.11.26 to 2.11.41, whilst the potential for associated impacts to sand banks and the coast are discussed in paragraph 2.11.77 onwards.

Conceptual understanding of change

2.11.17 **WTG foundations:** An array comprising 28 large (12 MW) quadropod suction caisson foundation represents the maximum adverse scenario for the blockage of waves through the array area. Further details regarding the maximum adverse scenario are provided in Table 2.16, whilst full justification for the determination of the maximum adverse scenario is presented in Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1).

2.11.18 The presence of the foundations in the sea, plus the swept radius of WTG blades in the air, can collectively modify the wave and wind wave regime passing through an OWF. The primary effects on waves are caused by (Christensen, *et al*., 2013):

- Drag forces against passing waves in contact with the foundation;
- Reflection (and scattering) of wave energy off the face of the foundation;
- Diffraction of wave energy around the structure; and
- Modified wind field within and leeward of the OWF as a consequence of WTG blades, reducing local wind-wave development across the leeward fetch.

2.11.19 At the foundation scale, the ratio of the diameter (or width) (D) of the structure relative to the incident wavelength (L) is important when considering the potential for wave-structure interaction. When D/L > 0.2 then interactions between a structure and the incident wave become relevant. Taking the full width of the 12 MW quadropod at mean depth as D = 30 m, D/L exceeds 0.2 for both 'typical' wave conditions and 'large' waves conditions observed in the observed and hindcast wave records from the study area.

2.11.20 Given the above, quantitative assessment of the potential for modification of the wave regime has therefore been undertaken. It is noted here, that in relation to the adjacent operational TOWF, D/L for the largest diameter monopile of 4.9 m produces results for D/L up to 0.13 at most i.e. the wave interactions with the smaller monopiles in TOWF array area are negligible at each foundation and depth and therefore negligible for the total array for these waves. This finding is entirely consistent with the numerical assessment of waves presented in the original TOWF ES which demonstrates that any changes to waves will be negligible outside the array area (Thanet Offshore Wind Limited, 2005). Similarly, D/L for the largest diameter monopiles at the closest operational wind farms, namely London Array (~11 km to the north; up to 5.7 m diameter monopiles) and Greater Gabbard (~34 km to the north-east; up to 6.3 m diameter monopiles) is also < 0.2. Accordingly, any changes to waves will be highly localised and will not extend to the Thanet Extension array area.

2.11.21 The summation of the array-scale changes from Thanet Extension on waves from the north-east (which are developed across the longest fetch and are most pertinent for the consideration of potential impacts to the adjacent Kent coast) is estimated below, with full details of the calculations set out in Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1):

- Drag – a 10% energy reduction per WTG, summed for each row through which waves travel and weighted by relative blockage per row;
- Reflections and scattering – a 65% energy reduction per WTG for "typical" waves and 70% for "large" waves, summed for each row and weighted by relative blockage per row;
- Diffraction – it has previously been established through field survey that monopile foundations are not considered to pose a significant risk of causing measurable wave diffraction (e.g. Cefas, 2005). As shown above (paragraph 2.11.20), the relatively small diameter of individual quadropod members relative to wavelength mean these are also not expected to cause measurable diffraction; and
- Wind – a 5% energy reduction across width of array.

2.11.22 On the basis of the above, the maximum reduction in wave energy attributed to waves passing through multiple rows in Thanet Extension (and TOWF) is around 10%, averaged across the leeward side. As wave energy is proportional to the square of wave height, these reductions translate to a reduction of the incident 1.5 m 'typical' wave to 1.46 m (i.e. a reduction of ~2.7%), and the incident 'large' wave from 2.5 - 2.44 m (i.e. a reduction of ~2.4%) along the downwind margin of the Thanet Extension array area. These very small changes in wave height will also dissipate over distance towards the coast (which is 8 km away).

2.11.23 Only very slight influences are expected to spectral wave period where the structures have relatively greater influence on short period waves than longer period waves. This conclusion is supported by numerical modelling undertaken to inform a wide range of other OWF developments (e.g. East Anglia Offshore Wind, 2012; Moray Offshore Renewables Ltd, 2012, Navitus Bay Development Ltd, 2014).

2.11.24 **Cable protection measures:** in terms of the potential for the cable protection to modify the wave regime, it is considered that any interruption of inshore and nearshore wave processes would be minimal and highly localised. This is because the cable protection would likely occupy a low profile (~ 0.5 m) within the water column relative to the water depth (Table 2.16). As such, the cable protection would present a minimal cross section of interference to the passage of incoming waves.

Assessment of significance

2.11.25 The changes described in this section are to 'pathways' as opposed to receptors. The significance of potential impacts to physical processes receptors arising from modification of the wave regime is considered within paragraph 2.11.77 onwards.

Changes to sediment transport and sediment transport pathways

Overview

2.11.26 Modification of existing sediment transport pathways could occur in response to changes in the wave and tidal regime resulting from the presence of:

- WTG (and OSS) foundations; and/ or
- Cable protection measures.

2.11.27 The presence of cable protection measures may also have the potential to cause a direct (albeit localised) blockage of sediment transport. The above changes could potentially occur over a range of timescales, depending on location and the specific project infrastructure that is interacting with the sediment transport regime.

2.11.28 Details of the maximum adverse scenario are presented in Table 2.16 and a comprehensive discussion of the potential for changes to sediment transport and sediment transport pathways is presented in Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1). The potential impacts associated with changes to patterns of sediment transport on physical processes receptors are discussed in paragraph 2.11.77 onwards.

Conceptual understanding of change

2.11.29 ***WTG and OSS foundations:*** *transport at the coast*: On the basis of the quantitative analysis of potential changes to the wave regime (paragraph 2.11.15 onwards), it is found that there will be no measurable reduction in wave height at adjacent coastlines in response to the presence of the WTG foundations since reductions in wave height along the downwind margin of the array area will be no greater than ~2.7%. Changes in wave height of this magnitude are small in both relative and absolute terms. Such small differences are not measurable in practice and would be indistinguishable from normal short-term natural variability in wave height (both for individual wave heights and in terms of the overall seastate). Accordingly, these changes are not predicted to have any measurable influence on longshore sediment transport.

2.11.30 *Bed load transport*: Across the Thanet Extension array area and offshore sections of the offshore cable corridor, sediment transport is dominated by the action and asymmetry of tidal currents. Potential changes to currents have previously been described in paragraph 2.11.3 to 2.11.14. In brief, current speed will be reduced in a narrow wake extending downstream from each foundation and potentially also increased (by a lesser magnitude but in a slightly wider corridor than the area experiencing decreased flow) between the rows of foundations. This results in limited net difference in the total flow rate of water through the array area, with measurable changes largely restricted to the footprint of the array area.

2.11.31 The extent to which these continuous but localised changes in flow speed could influence rates of bedload transport within and nearby to the array area will depend upon the magnitude of change relative to sediment mobilisation thresholds. In places, it is probable that localised flow reductions will lessen the frequency with which sediment particles are mobilised and therefore rates of transport may also be similarly reduced. Conversely, marginally greater rates of sediment transport may be experienced where localised flow accelerations are found. The overall result of these slight changes in flow speed could potentially be a very small reduction in the net volume of material transported as bedload through the array area.

2.11.32 *Suspended sediment transport*: As stated in paragraph 2.11.3 to 2.11.14, changes to tidal currents (which control the rate and direction in which suspended sediment is transported) due to the operational presence of the array area are assessed to be very limited in absolute magnitude and spatially restricted to the array area plus a small distance downstream in the main flood and ebb directions.

2.11.33 During large storm events, waves may stir the seabed within shallower parts of the array area, naturally causing an additional short-term contribution to SSC levels locally. The maximum adverse scenario layout will potentially cause a small reduction in wave heights within and nearby to the array area and it is therefore possible that there will be a corresponding small reduction in the rate at which sediment is locally re-suspended from the seabed.

2.11.34 The change described above would only be apparent during larger storm events (if at all) and would potentially slightly reduce SSC from that which would have occurred in the baseline condition. However, levels of SSC will remain dominated by regional scale inputs that are not affected by the presence of the wind farm. No measurable changes to SSC outside the range of natural variability are expected to occur within or nearby to the array area.

2.11.35 **Cable protection measures:** installation of cable protection could result in a local elevation of the seabed profile by up to 0.5 m (Table 2.16). Cable protection would be placed onto the seabed surface above the cable and therefore could directly trap sediment, locally impacting down-drift locations.

2.11.36 Following installation and under favourable conditions, an initial period of sediment accumulation would be expected to occur, creating a smooth slope against the cable protection. The process of wedge formation may take place over a period of a few weeks to months, depending on rates of sediment transport.

2.11.37 Sandy sediments are transported in two modes: bedload and saltation. Saltation is the process by which sands are moved up into the water column. These suspended sands would be expected to move relatively freely over the top of the armour although to begin with would regularly be deposited upon it, filling void spaces. Once any void spaces have been infilled, saltation is expected to be largely unaffected by the presence of the cable protection such that existing transport process (including bed form migration) will remain unaffected.

2.11.38 The process of void infilling is expected to occur relatively quickly (in the order of a few months). This is due to saltation as well as the anticipated high rates of transport in areas of mobile seabed (which is where much of the cable protection is anticipated).

2.11.39 Bedload is the process by which sands move while still in contact with the seabed. Bedload will be temporarily affected up until such time that the armour is covered by sand and the slope gradient either side has been reduced in response to the accumulation of a sediment wedge with stable slope angles (approximately 30 degrees). Following this, bedload will continue because the slope angle presented by sections of protected cable would be within the natural range of bed slope angles associated with bed forms mapped within the OECC.

2.11.40 Accordingly, for all areas in which cable protection is used (including where sand waves are present), it is not expected that the presence of the cable protection devices will continuously affect patterns of sediment transport following the initial period of accumulation. It follows that any changes on seabed morphology away from the cable protection will also be very small. The extent of the cable protection measures does not constitute a continuous blockage along the cable route corridor.

Assessment of significance

2.11.41 The changes described in this section are to ‘pathways’ as opposed to receptors. The significance of potential impacts to physical processes receptors arising from modification of the sediment transport regime is considered within paragraph 2.11.77 onwards.

Scour of seabed sediments.

Overview

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

- Obstacle (dimensions, shape and orientation);
- Ambient flow (depth, magnitude, orientation and variation including tidal currents, waves, or combined conditions); and
- Seabed sediment (geotextural and geotechnical properties).

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

2.11.44 Scour assessment for EIA purposes is considered here for two foundation types: monopiles and piled quadropod foundations (a four legged jacket). Each foundation type may produce different scour patterns and represent different realistic worst-case options depending upon the metric of interest (e.g. maximum scour footprint per foundation, maximum scour footprint for the entire array area, maximum volume of eroded sediment per foundation and so on). Accordingly, both monopiles and quadropod foundations have been considered. Suction caisson foundations (for quadropods) have not been considered in the assessment below because these will fall within the envelope of change associated with the other two foundation types. Indeed, local scour around each suction bucket will be limited (largely owing to the fact that they will only have limited protrusion above the seabed), with the total spatial extent of local scour expected to be less than the extent of group scour for quadropod foundations.

2.11.45 The concerns under consideration include the seabed area that may become modified from its natural state (potentially impacting sensitive receptors through habitat alteration) and the volume and rate of additional sediment resuspension, as a result of scour. The seabed area directly affected by scour may be modified from the baseline (pre-development) or ambient state in several ways, including:

- A different (coarser) surface sediment grain size distribution may develop due to winnowing of finer material by the more energetic flow within the scour pit;

- A different surface character will be present if scour protection (e.g. rock protection) is used;
- Seabed slopes may be locally steeper in the scour pit; and
- Flow speed and turbulence may be locally elevated.

2.11.46 The magnitude of any change will vary depending upon the foundation type, the local baseline oceanographic and sedimentary environments and the type of scour protection implemented (if needed). In some cases, the modified sediment character within a scour pit may not be so different from the surrounding seabed; however, changes relating to bed slope and elevated flow speed and turbulence close to the foundation are still likely to apply. As such, depending upon the sensitivities of the particular ecological receptor, not all scouring necessarily corresponds to a loss of habitat. This is discussed further in Volume 2, Chapter 5: Benthic Ecology (Document Ref: 6.2.5).

Conceptual understanding of change

2.11.47 In order to quantify the area of seabed that might be affected by scour, the following provides an estimate of the theoretical maximum depth and extent of scour. This assessment is based upon empirical relationships described in Whitehouse (1998) and is a summary of a more detailed assessment presented in Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1). Consideration is also given to the monitoring evidence considering scour pit development around foundations within TOWF. Importantly, the estimates of scour presented in this section are highly conservative as they assume an unlimited depth of erodible sediment and the absence of erosion resistant geology.

2.11.48 Results conservatively assume an unlimited depth of erodible sediment to be present, allowing the maximum equilibrium scour depths to form symmetrically around the perimeter of the structure. Derivative calculations of scour extent, footprint and volume assume an angle of internal friction = 32 degrees. Scour extent is measured radially from the structure's edge. Scour footprint therefore excludes the footprint of the structure itself. Scour pit volumes for monopile foundation structures are calculated as the volume of an inverted truncated cone, minus the volume of the structure itself; scour pit volume for the quadropod foundations are similarly calculated but as the sum of that predicted for each of the corner piles.

2.11.49 In the following section, the term 'local scour' refers to the local response to individual structure members. 'Global scour' refers to a region of shallower but potentially more extensive scour associated with a multi-member foundation resulting from the change in flow velocity through the gaps between members of the structure and turbulence shed by the entire structure. Global scour does not imply scour at the scale of the wind farm array.

2.11.50 Key findings are summarised below and in Table 2.18 and Table 2.19:

- Scour development within the Thanet Extension array area is expected to be dominated by the action of tidal currents;
- The greatest area of local scour effect (per foundation) is associated with the largest (12 MW) monopiles (10 m diameter), with an area of 2,013 m^2 susceptible to scour development;
- The greatest potential volume of scoured material from a single foundation is associated with the largest monopile (10 m diameter), with a scoured volume of 10,141 m^3 per foundation;
- For the Thanet Extension array as a whole, the greatest extent of local scour would be associated with an array comprising 28 large sized (12 MW) monopile foundations (and 1 OSS and 1 met mast). The potential spatial extent of this scour (excluding the footprint of the foundations) is 60,400 m^2: this would represent approximately 0.08% of the total Thanet Extension array area;
- For the Thanet Extension array as a whole, the greatest extent of global scour would be associated with an array comprising 28 large quadropod foundations (and 1 OSS and 1 met mast). The potential spatial extent of this scour (147,111 m^2) would represent approximately 0.2% of the total Thanet Extension array area; and
- Erosion resistant (pre-Holocene) material is present at or close to the seabed in several areas of the Thanet Extension array area and this is likely to lead to a natural limitation of scour depth and a related reduction in the footprint and volume of seabed affected by scour, both for individual foundations and for the array as a whole.

2.11.51 The assertion that the estimates of scour provided in Table 2.18 and Table 2.19 are conservative (i.e. an over estimate) is strongly supported by the post-construction monitoring of scour from TOWF (Figure 2.19). Indeed, scour pits (associated with monopile foundations measuring 4.1 - 4.9 m in diameter) measured between 3.7 - 4.4 m deep in 2013 (by which time the vast majority of scour would have occurred) (Titan, 2013). In contrast, the equilibrium scour depth for monopile foundations measuring 4.1 - 4.9 m in diameter estimated using empirical relationships (presented in Table 2.18 and Table 2.19) is between 5.3 - 6.4 m, i.e. up to approximately 2 m greater than observed. This difference almost certainly relates to the relatively erosion resistant nature of the surficial geology which inhibits scour development.

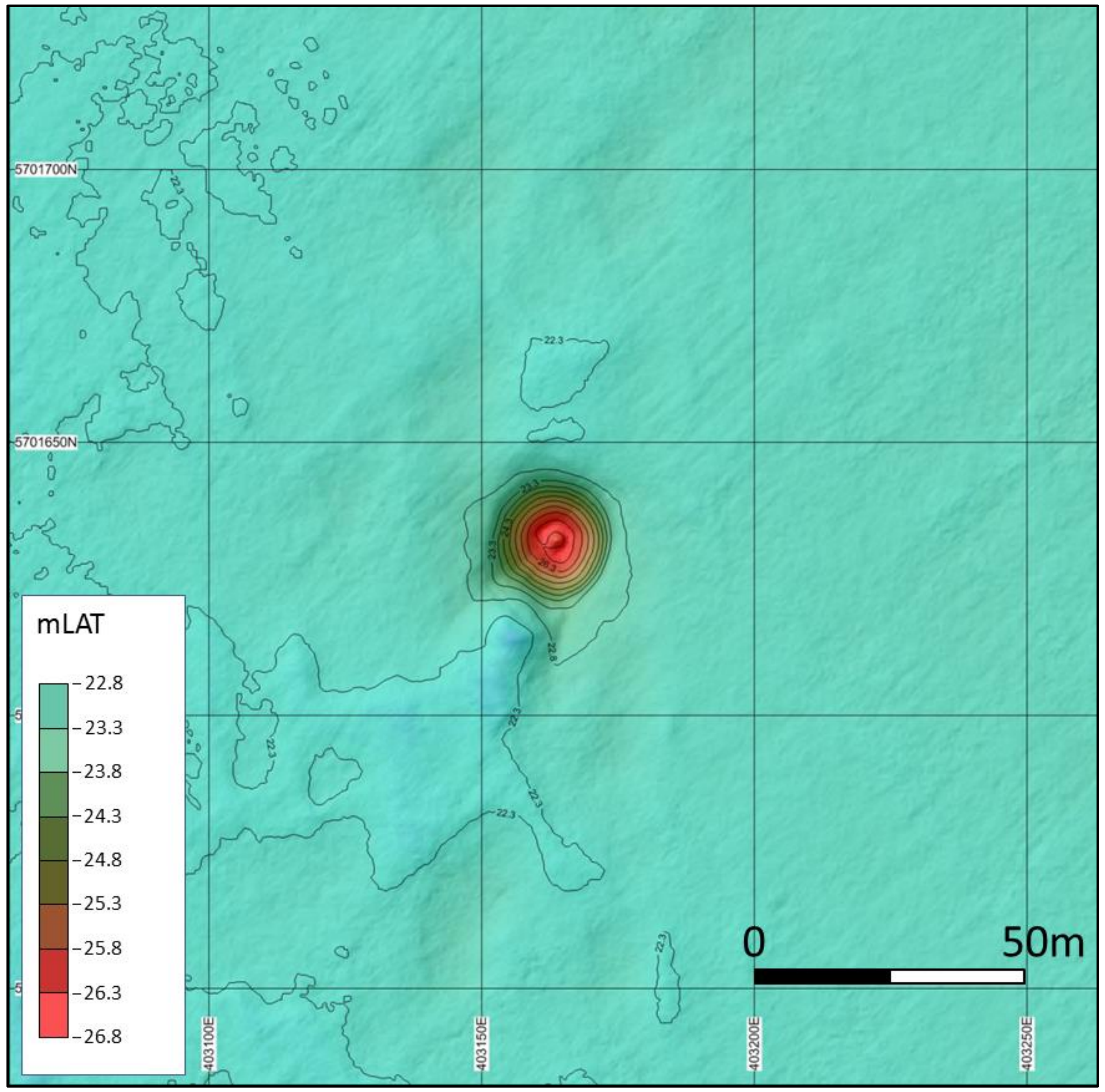


Figure 2.19: WTG E01 within TOWF with circular scouring (Titan, 2013).

2.11.52 Within the assessed scour pits from the TOWF array area, the substrate was found to comprise a mixture of coarse sediments ranging from muddy sandy gravels to cobbles. On average these sediments were coarser than those recorded from samples throughout the TOWF site (MES Ltd, 2013). Given the similarities in the physical environmental setting, it is a reasonable to assume that similar subtle changes in substrate will occur within any scour pits that develop within the Thanet Extension array area.

2.11.53 Scour depth can vary significantly under combined current and wave conditions through time (Harris *et al*., 2010). The post-construction monitoring evidence from TOWF generally suggests that the vast majority of scour had been accomplished by the start of the monitoring campaign (in spring 2012). This finding is entirely consistent with monitoring of scour development around other monopile foundations in UK OWF sites which suggests that the time-scale to achieve equilibrium conditions can be of the order of 60 days in environments where the seabed is relatively mobile (Harris *et al*., 2011). These values account for tidal variations as well as the influence of waves. (Near) symmetrical scour will only develop following exposure to both flood and ebb tidal directions.

2.11.54 Under waves or combined waves and currents an equilibrium scour depth for the conditions existing at that time may be achieved over a period of minutes, whilst typically under tidal flows alone equilibrium scour conditions may take several months to develop.

2.11.55 The greatest influence on local scour depth would arise from the installation of scour protection. If correctly designed and installed, scour protection will essentially prevent the development of local primary scour as described in this section. The dimensions and nature of scour protection may vary between designs but, given its purpose, would likely cover an area of seabed approximately similar to the predicted extent of the scour.

2.11.56 Any elevation in SSC as a consequence of scour will be short lived, localised and within the range of natural variability.

Table 2.18: Summary of predicted maximum scour dimensions for largest individual WTG foundation structures

Parameter		Foundation type	
		Monopile (10 m diameter)	4 legged quadropod (40 m x 40 m x 4.0 m legs)
Equilibrium Scour Depth (m)	Steady current	13.0	5.2
	Waves	Insufficient for scour	Insufficient for scour
	Waves and current	13.0	5.2
	Global scour	N/A	1.6
Extent from foundation* (m)	Local scour	20.8	8.3
	Global scour	N/A	40.0
Footprint [a] (m^2)	Structure alone	79	50
	Local scour (exc. structure)	2,013	1,289
	Global scour (exc. structure)	N/A	4,976
Volume [a] (m^3)	Local scour (exc. structure)	10,141	2,596
	Global scour (exc. local scour and structure)	N/A	7,962
	Drill arisings or bed preparation	1,325	1,257

[a] Based upon the scour depth for steady currents. Footprint and volume values are per foundation.

Table 2.19: Total seabed footprint of the different WTG foundation types with and without scour

Parameter	Monopiles		4 Legged Quadropod	
	(9.0 m diameter)	(10 m diameter)	(30 m base)	(40 m base)
Maximum number of foundations	34 (+1 OSS & 1 met mast)	28 (+1 OSS & 1 met mast)	34 (+1 OSS & 1 met mast)	28 (+1 OSS & 1 met mast)
Seabed footprint of all foundations (m^2)	2,305	2,356	1,018	1,486
Proportion of Thanet Extension array area occupied by foundations [a] (%)	< 0.1%	< 0.1%	< 0.1%	< 0.1%
Seabed footprint of all local scour (m^2)	59,091	60,400	26,093	38,092
Proportion of Thanet Extension array area potentially affected by scour [a] (%)	< 0.1%	< 0.1%	< 0.1%	< 0.1%
Seabed footprint of all foundations + local scour (m^2)	61,397	62,756	27,111	39,578
Proportion of Thanet Extension array area occupied/ potentially affected by foundations and scour [a] (%)	< 0.1%	< 0.1%	< 0.1%	< 0.1%
Seabed footprint of all global scour (m^2)	N/A	N/A	100,770	147,111
Proportion of Thanet Extension array area potentially affected by global scour [a] (%)	N/A	N/A	0.14	0.20

All scour dimensions are based upon the scour depth for steady currents.
[a] Corresponding proportion of the Thanet Extension array area (72.8 km^2).

Assessment of significance

2.11.57 All of the identified physical processes receptors will be insensitive to localised changes in bed levels around the WTG foundations, as well as any associated localised and short-term elevated levels of SSC. However, an assessment of significance with regards to the potential alteration of seabed habitat associated with the scour pits is presented in Volume 2, Chapter 5: Benthic Ecology (Document Ref: 6.2.5).

Development of turbid wake features

Overview

2.11.58 Turbid wakes (wake features additionally characterised by an elevated level of turbidity relative to water immediately outside of their local footprint) have been observed at the Thanet, London Array and Greater Gabbard OWFs in the outer Thames estuary. Similar features have also been noted for other OWFs in the waters of Germany, The Netherlands and Belgium, suggesting that this is a general phenomenon associated with the placement of these structures in the sea (Forster, 2017).

2.11.59 This section assesses the potential for turbid wakes to develop in association with the operational presence of the Thanet Extension array and describes their likely:

- Cause;
- Spatial extent (horizontal and vertical);
- Level of change in SSC (relative to naturally present background levels and ranges);
- Duration, frequency and/ or persistency; and
- Effect on seabed sediment texture.

2.11.60 The assessment is based on a maximum adverse scenario of an array comprising 28 large (12 MW) quadropod foundations (Table 2.16). Results presented in this section summarise the findings of a more detailed analysis of turbid wakes presented within Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1).

Conceptual understanding of change

2.11.61 There is now a wide range of evidence regarding turbid wakes at TOWF (and other wind farms). The evidence includes remote sensing data (e.g. Vanhellemont and Ruddick, 2014; NASA, 2016), aerial photography (e.g. VWPL, 2017) and local field studies (Forster, 2017). Analysis of satellite observed (sea surface) SPM concentrations suggests that these features have resulted in a net increase in average surface SPM within and nearby to the TOWF array area, with a notable increase in the frequency with which SPM in the range 10 - 20 mg/l is encountered. The field evidence collected by Forster (2017) from TOWF shows that plumes are caused by re-distribution of suspended sediment in the water column due to increased vertical mixing in the monopile wake. Not only are suspended sediment concentrations higher at the surface, but the evidence shows that the near-bed concentration of sediment is actually lower within the plume. This indicates that a re-distribution of suspended material from the near-bed to the surface is caused by the increased turbulence within the wake.

2.11.62 A previously considered hypothesis was that turbid wakes might be the result of ongoing local scouring of seabed sediments. This hypothesis was considered and discounted by Forster *et al*. (2017), on the basis of a range of field survey evidence. Calculations of the mass/volume of sediment required to create the observed turbid wakes (set out in Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1)) also show that extensive scouring would be required for active local scour to cause turbid wakes, however, no such erosion was observed in post-construction monitoring of scour at TOWF (Titan, 2012a, b; 2013).

2.11.63 The spatial footprint of the turbid wakes will primarily be dependent upon:

- The ambient tidal conditions;
- The characteristics of the sediment within the near bed turbid layer; and
- The dimensions/ characteristics of the foundation structures.

2.11.64 Accordingly, the extent of the turbid wakes will fluctuate over tidal cycles (ebb/ flood, spring/ neap) and also possibly in response to seasonal influences (e.g. input of finer grained sediment from fluvial discharge).

2.11.65 On the basis of the satellite imagery covering the TOWF array area, turbid wakes are typically 30 - 150 m wide, extending downstream for a distance of over 10 km during spring tides (Vanhellemont and Ruddick, 2014). The widest plumes in this range appear to be the result of two or more individual wakes intersecting and combining to produce a single wider feature. It is noted here that the largest monopiles proposed for the Thanet Extension array area are 10 m in diameter which is over twice the diameter of the largest monopile within the TOWF array area (4.9 m in diameter). Larger monopiles are likely to be associated with more extensive (both in the x and y axis) turbulent wake field (e.g. Rogan *et al*., 2016). However, whilst the dimensions of individual turbid wakes in the Thanet Extension array area are most likely to be larger than those presently observed in the TOWF, it is considered very unlikely that they will be double the footprint:

- The maximum length to which the turbid wake features could theoretically extend is limited by the spring tidal excursion distance (Figure 2.5). The maximum mean spring tidal excursion distance is approximately 13 km from the array area, which is consistent with the maximum observed extent of turbid wake features from the TOWF array (up to 10 km), as described by Vanhellemont and Ruddick (2014). At any given time, up to approximately 10% of the footprint of the spring tidal excursion ellipse buffer could be influenced by the presence of turbid wake features.
- Levels of elevated turbulence in the wake behind monopiles are highest immediately behind the structure and recover at an exponential rate towards ambient conditions. Where levels of turbulence are sufficiently elevated in the wake, sediment will be actively re-suspended and maintained in suspension throughout the height of the water column. For coarser sediment, resettlement will start at relatively higher levels of turbulence (at a smaller distance from the foundation) and the response will be more rapid (a shorter time/ distance is required from the point that sediment begins to settle out, to the point that turbidity actually decreases). For finer sediment, a lower level of turbulence is required to maintain suspension and, even when the turbulent effect ceases, the concentration of sediment in surface waters may take a longer time to reduce due to slow rates of settlement. Accordingly, the effect of doubling the foundation diameter (from approximately 5 - 10 m) may only partially increase the extent of the area where turbulence is elevated (from approximately 400 - 800 m for an elevation of two or more times the ambient value (Rogen *et al*., 2016)), while the distance for recovery through settlement would remain the same or similar.

2.11.66 Given the proximity of the Thanet Extension array area to the operational TOWF site, it is very likely that, where foundations are tidally aligned, turbid wake features from the two wind farms may overlap or coalesce. The resulting combined turbid wake(s) may appear wider and/ or longer than individual non-overlapping turbid wake features, but (based on the underlying processes) there is no reason why the overall extent should be wider or longer than a superimposition of the individual contributing features. This is consistent with the satellite derived images of overlapping turbid wakes at the TOWF (Vanhellemont and Ruddick, 2014).

2.11.67 As a logical conclusion of the processes likely controlling turbid wakes (described in paragraph 2.11.58 onwards) and the field evidence provided by Forster (2017), depth averaged SSC (i.e. the total mass of sediment in suspension) within the Thanet Extension array area will not change either locally or regionally as a result of turbid wakes, as no additional sediment is being eroded from the seabed as part of the process. However, the vertical distribution of sediment in suspension will be affected, becoming more uniformly distributed throughout the water column. Therefore, within the turbid wake features, surface SSC is expected to increase relative to the baseline distribution, with a corresponding decrease in nearbed SSC.

2.11.68 According to the *in situ* measurements from Forster (2017) as well as the satellite data presented in Vanhellemont and Ruddick (2014) the SSC/ SPM in the surface waters of the turbid wakes at TOWF is typically between about 10 - 30 mg/l above background levels. The relative contrast in SSC between inside and outside of the turbulent wakes is likely to vary, in response to natural variability in the naturally present magnitude and vertical distribution of SSC both nearbed and elsewhere in the water column.

2.11.69 Because the naturally present distribution of SSC is expected to be broadly similar between the Thanet Extension and TOWF array areas, it is reasonable to assume that the magnitude of elevated SSC in turbid wakes at Thanet Extension will be broadly similar to those observed at TOWF at any given time.

2.11.70 Given the proximity of the Thanet Extension array area to the operational TOWF site, it is very likely that, where foundations are tidally aligned, turbid wake features from the two wind farms may overlap or coalesce. However, based on the underlying processes there is no reason why SSC should be locally higher than that of the contributing features considered individually (i.e. a non-additive effect). This is consistent with the satellite derived images of overlapping turbid wakes at the TOWF (Vanhellemont and Ruddick, 2014).

2.11.71 The development and persistence of turbid wake features will be dependent upon a range of factors including:

- The particle size distribution of material in suspension;
- The ambient flow conditions; and
- The extent to which material in suspension is mixed throughout water column, before entering the Thanet Extension array area.

2.11.72 Areas inside of the Thanet Extension array area that are downstream of foundations on both ebb and flood tides might theoretically be affected up to 100% of the time. Other parts of the array area and areas outside of the Thanet Extension array area that are downstream of foundations on either ebb or flood tides might theoretically be affected by turbid wake features for up to 50% of the time due to current direction reversal.

2.11.73 In practice, it is unlikely that the turbid wakes will be continually present. A period of 'no plume present' is apparent in satellite images acquired between one and two hours into the ebb tide (i.e. following tidal reversal and at relatively low current speeds) although further evidence is required to confirm this (Forster, 2017). Similarly, it is likely that during the stormier winter months, turbid wake features will be either less pronounced or absent due to naturally enhanced mixing of sediment through the water column in the ambient environment.

2.11.74 The patterns of turbulence elevation and recovery, and the associated patterns of sediment resuspension and resettlement, may result in selective transport and deposition patterns for sediment of different grainsizes.

- The effect on relatively coarse grained (e.g. sand sized) material is likely to be limited as the additional distance (proportional to the time needed for grains to settle through the water column) is relatively small; as such, coarser sediment will be present at normal ambient concentrations near bed and will be redeposited in normal quantities when conditions are suitable (e.g. around slack water).
- Potential effects on fine grained material may have a greater extent due to the relatively slower settling rate; as such, the nearbed concentration of finer sediments may be relatively lower than ambient levels in parts of the wake, especially closer to the foundation, and so would be deposited in smaller quantities when conditions are suitable. This may cause net winnowing of finer material from the seabed in the footprint of turbid wakes, due to a slightly reduced rate of supply or deposition over long time periods.

2.11.75 Field evidence from particle size distribution analysis of 12 discrete grab samples, from within and outside of the TOWF in 2005, 2007 and 2012 (MES Ltd, 2013) does not show any clear evidence of such fine sediment winnowing. The proportion of silt to sand both increases and decreases at different locations within the site. The number and distribution of grab samples are, however, limited.

Assessment of significance

2.11.76 All of the identified physical processes receptors will be insensitive to localised changes in surface SSC and seabed sediment distribution. However, significance of effect assessments associated with the presence of the turbid wake features characterised in this section are carried out and presented in the following ES topic Chapters:

- Volume 2, Chapter 4: Offshore Ornithology (Document Ref: 6.2.4);
- Volume 2, Chapter 5: Benthic Ecology (Document Ref: 6.2.5);
- Volume 2, Chapter 6: Fish and Shellfish (Document Ref: 6.2.6); and
- Volume 2, Chapter 7: Marine Mammals (Document Ref: 6.2.7).

Impacts to sand bank receptors (due to wind farm operation)

Overview

2.11.77 Within the study there are several large sand bank features located relatively close (less than approximately 10 km) from the Thanet Extension array area. These are Margate, Goodwin and South Falls sand banks (Figure 2.1). The eastern end of Margate Sand ‘Northeast Spit’ is also of particular interest from a navigational perspective, since it represents a potential hazard to navigation.

2.11.78 Sand banks are tidally induced bedforms, with sand bank formation principally governed by sediment availability and the prevailing tidal current regime. However, waves may also influence sand bank morphology by determining the maximum height (minimum depth) to which they can accumulate (Kenyon and Cooper, 2005).

2.11.79 The potential for alteration of these features via changes to tidal currents and/or waves in response to the presence of foundations within the array area is considered in the following section. The potential for cable protection measures to influence sand banks is not discussed in this section since it has been established that any associated changes to tidal currents and/or waves will be extremely localised and not extend more than a few hundred metres (paragraph 2.11.35 - 2.11.40; Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1)).

Conceptual understanding of change

2.11.80 **Influence of changes to the tidal regime:** the potential for changes to the tidal regime has been discussed in paragraph 2.11.3 to 2.11.14. In summary, the maximum spatial extent across which measurable changes to tidal currents could theoretically occur is approximately 2.4 km (Figure 2.5). Margate sand bank and Goodwin sand bank are located approximately 2.5 km and 7 km from the array area, respectively, whilst South Falls is 6 km away. At this distance from the array area, no measurable changes in current speed are expected and mean spring peak tidal currents (which are an important determinant of bedform distribution - Belderson *et al*. (1982) will remain unaltered.

2.11.81 **Influence of changes to the wave regime:** the assessment of potential changes to the wave regime (presented in paragraph 2.11.15 to 2.11.25 and in Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1)) suggests that in the vicinity of Margate, Goodwin and South Falls sand banks maximum (instantaneous) reductions in wave heights will be extremely small (< ~2%) occurring intermittently throughout the lifetime of the project. In theory, a reduction in wave heights could result in an increase in the elevation of sand bank crests since the propagation depth of orbital currents beneath the modified waves would be reduced.

2.11.82 However, for the following reasons it is considered extremely unlikely that these changes to wave conditions would result in a corresponding morphological change to the sand banks in the form of a small increase in crest elevation:

2.11.83 The wave events that are likely to cause the greatest effects on offshore sand banks occur during low-frequency high-intensity storm conditions (e.g. 1 in 10 year return period). Whilst some reductions in wave heights under calm conditions (high-frequency low-intensity wave events) may be expected, larger storm waves will be comparatively less affected by the presence of the foundation structures as wavelengths will be comparatively large relative to structure diameter. Accordingly, the key wave events that influence sand banks do not correspond to the wave events anticipated to undergo the greatest change; and

2.11.84 Even if very small reductions in wave heights were to occur across nearby sand banks, it is extremely unlikely these would manifest in changes to sand bank crest elevation. This is because these sand banks are also influenced by large waves from other directional sectors which will not have travelled through the Thanet Extension array area (Figure 2.7). These unaffected waves will also contribute to flattening of the crests, thereby maintaining their existing (baseline) elevation.

2.11.85 **Influence of changes to the sediment transport regime:** within the study area, sediment transport in offshore areas is dominated by the action of tidal currents, with wave driven sediment transport only becoming important in shallow coastal waters, distant to the array area. As set out in the assessment of tides (paragraph 2.11.3 to 2.11.14), the presence of the WTG foundations will cause very small localised changes (both increases and decreases) in average flow speed within the array and across a narrow region just outside of the array boundary.

2.11.86 The extent to which these continuous but localised changes in flow speed could influence rates of bedload transport within and nearby to the array will depend upon the magnitude of change relative to sediment mobilisation thresholds. In places, it is possible that localised flow reductions will lessen the frequency with which sediment particles are mobilised and therefore rates of transport may also be similarly reduced. Conversely, marginally greater rates of sediment transport may be experienced where localised flow accelerations are found.

2.11.87 The overall result of these slight changes in flow speed could potentially be a very small reduction in the net volume of material transported as bedload through the array area. However, baseline rates of sediment transport across the array area are understood to be high (paragraph 2.7.24) and therefore the potential for wider (indirect) morphological change to the surrounding seabed is considered to be very limited. This also holds true for nearby sand banks, including Northeast Spit at the eastern tip of Margate Sand.

2.11.88 It is also noted here that on the basis of the available local- and regional-scale sediment transport pathway information presented in Figure 2.11 and described in paragraph 2.7.22 onwards, there is limited connectivity between the Thanet extension array area and Margate sand banks and South Falls sand bank. Goodwin sand bank is down drift of the array area; however at this distance away (~7 km) changes in rates of net sediment transport are not expected.

Assessment of significance

2.11.89 Using the criteria presented in Table 2.6, the sand banks within the study area are considered to be of High sensitivity/ importance. Margate sand bank is internationally designated whilst the Goodwin sand banks are within the Goodwin Sands rMCZ. South Falls is immediately adjacent to the Dover Straits shipping lane and therefore any modification to the position of the feature is potentially of particular concern. However, these sand banks within close proximity to the Thanet Extension array area are understood to be naturally dynamic features which area insensitive to minor changes in tidal and wave conditions. (This understanding is informed by available literature (e.g. Kenyon and Cooper, 2005), as well as expert judgement).

2.11.90 The magnitude of impact to sand banks is predicted to be Very Low. This assessment is based on the fact that whilst very small changes to the tidal and wave regime could theoretically occur over the lifetime of the project, the scale of the change will be insufficient to cause physical alterations of the sand banks outside of the expected range of natural variability.

2.11.91 The overall level of effect significance has been assessed according to the EIA methodology set out in section 2.5 (paragraph 2.5.1 onwards). Effect significance has been determined by combining the assigned rating for receptor sensitivity/ importance and impact magnitude, as shown in Table 2.8. Overall, the effect on sand banks is **Negligible** adverse.

Impacts to designated coastal feature receptors (due to wind farm operation)

Overview

2.11.92 The primary means by which the coast could be impacted by the operational presence of Thanet Extension are:

- Modification of the wave regime due to WTG foundations within the Thanet Extension array area, causing associated changes in longshore transport;
- Exposure of buried export cables and associated infrastructure, locally modifying nearshore hydrodynamic, wave and sediment transport processes; and
- The presence of cable protection measures in shallow nearshore areas, locally modifying hydrodynamic, wave and sediment transport processes.

2.11.93 The potential for the above to impact the shoreline is assessed within this section, through consideration of the maximum adverse scenario presented in Table 2.16.

Conceptual understanding of change

2.11.94 **WTG foundations:** on the basis of the discussion of potential changes to waves (set out in paragraph 2.11.15 to 2.11.25) and within Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1), the maximum reduction in wave energy attributed to waves passing through multiple rows in the Thanet Extension (and TOWF) array area is around 2.5%. These very minor changes to wave height will also dissipate over distance towards the coast (which is 8 km away) and will be immeasurable. Accordingly, there are not expected to be any detectable changes to the rate (and direction) of net longshore sediment transport at the coast and therefore there will be no associated morphological changes to any of the identified coastal feature receptors set out in paragraph 2.5.2 (i.e. saltmarsh, intertidal flats or dunes).

2.11.95 This is consistent with the fact that, to the best of our knowledge no adverse morphological impacts (such as increased coastal change) have occurred to the Kent coast that can be attributed to the operational presence of TOWF. TOWF has been operational since 2010 (eight years at the time of writing).

2.11.96 **Exposure of cables:** once buried, the only way in which the cables could influence intertidal morphology during operation would be if they became exposed as a consequence of natural change. Detailed understanding of the likely temporal variability in intertidal topography throughout the lifetime of the Project is therefore critical for informing appropriate target burial depths.

2.11.97 Arguably the most robust means by which to understand the potential for future variability at the landfall is through detailed consideration of the observed longer term morphological behaviour which has taken place. This assessment approach is followed here, with a full analysis presented in within Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1).

2.11.98 In summary, historical morphological analysis of Pegwell Bay has been undertaken using:

- Google Earth historical satellite and aerial imagery (period 1940 to 2017) (Figure 2.20),
- Environment Agency LiDAR topographic surveys (period 2007 to 2013);
- South East Regional Coastal Monitoring Programme bathymetric surveys (period 2003 to 2016); and
- Bathymetric analyses previously presented in the TOWF Environmental Statement for the period 1955 to 2005 (Thanet Offshore Wind Limited, 2005).

Figure 2.20: Historic evolution of Pegwell Bay covering the period 1940 to 2017.

2.11.99 Key findings are set out below:

- Historically, the area in the vicinity of the landfall has experienced notable change throughout the period 1940 to present, associated with anthropogenic modification of the coast, movement in the position of the River Stour channel and migration of Shell Ness;
- Whilst overall the saltmarsh and adjacent mud/ sand flat has been relatively stable over the past decade or so, the eastern margin has been greatly eroded by westerly migration of the Stour river channel. Here, elevation changes are in the approximate range ±3 m;
- The River Stour channel exhibits significant migration across the intertidal. This is particularly notable in the data between 2010 and 2016 where the channel has migrated several hundred metres to the north. The relative depth of the channel below the surrounding seabed level at this location is approximately 0.3 - 1.0 m, but is deeper (up to 1.6 m) higher up the intertidal and closer to the spit where the channel is above the tidal water level for more of the time;
- The River Stour channel is also known to have shifted historically (over the period 1955 to 2005), probably in response to changes to the Goodwin Sands, Brake Bank and Shell Ness. The channel may also have been influenced by port extension at Ramsgate (Thanet Offshore Wind Limited, 2005); and
- Shell Ness is experiencing consistent progradation towards the north. From the 1940's to present, the spit has prograded northwards at an average rate of approximately 4 m per year. This indicates a surplus of sediment supply to the spit from marine or fluvial sources and a net northerly transport of sediment along the western margin of the bay.

2.11.100 These changes will continue to occur during the operational phase of the wind farm and will be factored into a detailed engineering assessment of cable burial depth which will minimise the risk of cable exposure in this time. This cable burial assessment will give consideration to the potential impacts of climate change on intertidal shallow subtidal morphology.

2.11.101 Provided a thorough cable burial risk assessment is undertaken, it is considered unlikely that cables will become exposed throughout the lifetime of the project. However, even if a section of cable were to become exposed, it might locally influence intertidal processes and morphology at a scale proportional to the diameter of the cable (order of a few tens of centimetres) and the length of the exposed section. The cable may become naturally reburied although could require reburial using similar techniques to that set out in the assessment of SSC and bed level changes associated with cable installation activities (paragraph 2.10.32 onwards).

2.11.102 If more than one section of cable is exposed at any one time, the potential impacts of each cable are likely to be localised to a distance much smaller than the separation distance between them.

2.11.103 **Cable protection measures:** cable protection measures could be installed in shallow subtidal locations near to the landfall potentially influencing nearshore wave conditions and patterns of sediment transport in the immediate vicinity of the cable. However, it is assumed that if and where cable protection measures are used in the shallow subtidal near to the landfall, they would be installed with a sufficiently low profile relative to the surrounding bed to present minimal barrier to the passage of waves and so cause no change to patterns of longshore sediment transport.

Assessment of significance

2.11.104 Using the criteria presented in Table 2.8, the designated coastal feature receptors within the study area (paragraph 2.5.2) are considered to be of High sensitivity/ importance. Although many areas are either nationally or internationally designated, this coast is a dynamic environment which is typically subject to natural change under baseline conditions. Accordingly, it is assessed to have some capacity to recover from disturbance.

2.11.105 The magnitude of impact to coastal features which could occur via some or all of the potential impact pathways described in this section occurring together is predicted to be either Low or Very Low. This assessment is based on the fact that in most areas the anticipated changes will not be discernible from background levels which themselves are constantly changing over short, medium and long-term timescales. Where change could potentially be observed (e.g. immediately adjacent to an exposed cable), the impact will be extremely localised in extent.

2.11.106 The overall level of effect significance has been assessed according to the EIA methodology set out in section 2.5 (paragraph 2.5.1 onwards). Effect significance has been determined by combining the assigned rating for receptor sensitivity/ importance and impact magnitude, as shown in Table 2.8. Overall, the effect on the coast is no greater than **Minor** adverse. Depending upon the pathway or combination of pathways under consideration, effects could occur over differing temporal and spatial scales and be of varying severity:

- The blockage of waves through the array area could potentially cause extremely small changes to the nearshore wave regime at a *regional* scale for the duration of the operational period (i.e. a *long* period of time). However, any associated effects to coastal morphology are anticipated to be indiscernible from naturally occurring background levels of variability and therefore be of negligible significance;
- Exposed cables could give rise to minor adverse effects at a *local* scale for a *short* period of time; and
- The presence of cable protection measures could cause minor adverse effects at a local scale for the duration of the operational period (i.e. a *long* period of time).

Impacts to designated chalk feature receptors (due to wind farm operation)

Overview

2.11.107 The Thanet Coast SAC and Thanet Coast MCZ are designated for containing supra-, inter- and subtidal chalk features including cliffs, platforms and reefs. Of the impact pathways considered within this section for the operation phase, the only means by which the chalk features could be impacted is through enhanced erosion associated with modification of the wave and/ or tidal regime caused by the presence of WTG foundations within the array area.

2.11.108 The potential for cable protection measures to influence patterns of erosion is not discussed in this section since it has been established that any associated changes to tidal currents and waves will be extremely localised and not extend more than a few hundred metres (paragraph 2.11.35 to 2.11.40; Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1)).

Conceptual understanding of change

2.11.109 On the basis of the discussion of potential changes to waves (set out in paragraph 2.11.15 to 2.11.25) and within Volume 4, Annex 2-1: Marine Geology, Oceanography and Physical Processes Technical Annex (Document Ref: 6.4.2.1), the operational presence of the array area may potentially cause an extremely small reduction in wave height of approximately 2.5% at the down-wind boundary of the array. This change will dissipate with distance from the array area. The chalk features at the seabed or at the coast will be entirely insensitive to changes in wave height of this magnitude and as such, no morphological change is expected.

2.11.110 Changes to the tidal currents will be restricted to a distance of approximately 2.4 km from the array area (paragraph 2.11.8); Figure 2.5. Both the Thanet Coast SAC and Thanet Coast MCZ which contain designated chalk features are located approximately 6 km away. Accordingly, there is no potential for enhanced erosion of the seabed associated with modification of the tidal regime as there is no connection between source and receptor.

Assessment of significance

2.11.111 Using the criteria presented in Table 2.6, the chalk features within the study area are considered to be of High sensitivity/ importance as all are covered by international nature conservation designations and have no potential for substitution/ recovery.

2.11.112 The magnitude of impact to chalk features is predicted to be Very Low. This assessment is based on the fact that there will be no measurable increase in erosion of the chalk and therefore changes will not be discernible from background conditions.

2.11.113 The overall level of effect significance has been assessed according to the EIA methodology set out in section 2.5 (paragraph 2.5.1 onwards). Effect significance has been determined by combining the assigned rating for receptor sensitivity/ importance and impact magnitude, as shown in Table 2.8. Overall, the effect on chalk features is **Negligible** adverse.

2.12 Environmental assessment: decommissioning phase

2.12.1 The changes to physical processes in response to construction of the Thanet Extension have been described in this section. The maximum adverse scenario against which each decommissioning phase change has been assessed is set out in Table 2.16.

2.12.2 Within this section, an assessment of pathways is presented first followed by the assessments of potential impacts to receptors. The assessments of potential change to pathways are not accompanied by a conclusion regarding the significance of effect. Instead the significance of effect is considered in the various relevant receptor Chapters.

Increases in SSC and deposition of disturbed sediment to the seabed within the Thanet Extension array area and the OECC

Overview

2.12.3 The following decommissioning activities could potentially give rise to increases in SSC and associated deposition of material with in the Thanet Extension array area and the OECC:

- Removal of foundation structures;
- Cutting off of monopiles and quadropod foundation legs; and
- (Possible) removal of cables from the intertidal zone.
- Conceptual understanding of change

2.12.4 The removal of WTG foundations is expected to result in some localised seabed disturbance accompanied by temporary increases in SSC. It is possible that quadropod pin-piles could be left *in situ* although piles would probably be cut off a few metres below the bed, causing a localised disturbance of the bed and a temporary increase in SSC.

2.12.5 For the purposes of the EIA it has been assumed that all cables will be removed from the intertidal zone during decommissioning. It is probable that equipment similar to that which is used to install the cables could be used to reverse the burial process and expose the cables. Accordingly, the area of seabed impacted during the removal of the cables would be similar as the area impacted during the installation of the cables.

2.12.6 For all of the above, the changes in SSC and accompanying changes to bed levels associated with decommissioning activities are expected to be of a lesser magnitude than that associated with construction. Further information is provided in the construction phase assessment (paragraph 2.10.1 to 2.10.48).

Assessment of significance

2.12.7 All of the identified physical processes receptors will be insensitive to elevated levels of SSC and localised changes in bed level. However, the potential for these changes to impact other EIA receptor groups are considered elsewhere within the ES, in particular:

- Volume 2, Chapter 4: Offshore Ornithology (Document Ref: 6.2.4);
- Volume 2, Chapter 5: Benthic Ecology (Document Ref: 6.2.5);
- Volume 2, Chapter 6: Fish and Shellfish (Document Ref: 6.2.6); and
- Volume 2, Chapter 7: Marine Mammals (Document Ref: 6.2.7).

Impacts to designated coastal feature receptors (due to decommissioning activities)

Overview

2.12.8 The maximum adverse scenario in terms of the potential for impacts to coastal feature receptors would be the total removal of all cables and associated infrastructure at the landfall. The removal of all cables and infrastructure would cause very short-term morphological changes at the landfall although these would be localised in nature and no greater in magnitude than for the construction phase.

Conceptual understanding of change

2.12.9 Should the cable system require removal at the end of its operational life, it will be removed through the same soils and sediments disturbed during installation. This process could result in short-term elevations in SSC and localised changes in bed level (i.e. within the near-field). It is anticipated that the working areas for removal will also be restricted to the area used for installation; accordingly, any impacts would be no greater in magnitude than for the construction phase. If the cables are left in the seabed at the end of the Project lifespan, impacts will be the same as those described previously for the operation phase.

Assessment of significance

2.12.10 The coastal features at the landfall are considered to be of High sensitivity/ importance. Although internationally designated, this is generally a dynamic environment which is typically subject to natural change under baseline conditions. Accordingly, it is assessed to have some capacity to recover from disturbance.

2.12.11 The magnitude of impact to the coast is predicted to be Low. This assessment is based on the fact that any changes would be temporary and restricted to the near-field.

2.12.12 Overall, the effect on the coast is adverse but will only occur for a *short* period of time and be experienced at a *local* scale. The level of effect significance is therefore **Minor** adverse.

2.13 Environmental assessment: cumulative effects

2.13.1 Cumulative effects refer to effects upon receptors arising from the Thanet Extension when considered alongside other proposed developments and activities and any other *reasonably foreseeable project(s)* proposals. In this context the term *projects* is considered to refer to any project with comparable effects and is not limited to offshore wind projects.

2.13.2 The approach to cumulative assessment for Thanet Extension takes into account the Cumulative Impact Assessment Guidelines issued by RenewableUK in June 2013, together with comments made in response to other renewable energy developments within the southern North Sea, and the Planning Inspectorate (PINS) ‘Advice Note 9: Rochdale Approach’. The renewable energy developments that have informed this approach have been agreed within the Scoping Opinion, the suggested tiers, and the Cumulative Impact Assessment conducted for the Thanet Extension.

2.13.3 In assessing the potential cumulative impact(s) for Thanet Extension, it is important to bear in mind that for some projects, predominantly those ‘proposed’ or identified in development plans etc. may or may not actually be taken forward. There is thus a need to build in some consideration of certainty (or uncertainty) with respect to the potential impacts which might arise from such proposals. For example, relevant projects/ plans that are already under construction are likely to contribute to cumulative impact with Thanet Extension (providing effect or spatial pathways exist), whereas projects/ plans not yet approved or not yet submitted are less certain to contribute to such an impact, as some may not achieve approval or may not ultimately be built due to other factors.

2.13.4 For this reason, all relevant projects/ plans considered cumulatively alongside Thanet Extension have been allocated into ‘Tiers’, reflecting their current stage within the planning and development process. This allows the cumulative impact assessment to present several future development scenarios, each with a differing potential for being ultimately built out. Appropriate weight may therefore be given to each scenario (Tier) in the decision making process when considering the potential cumulative impact associated with Thanet Extension Offshore Wind Farm (e.g., it may be considered that greater weight can be placed on the Tier 1 assessment relative to Tier 2).

2.13.5 The projects and plans selected as relevant to the assessment of impacts to Marine Geology, Oceanography and Physical Processes are based upon an initial screening exercise undertaken on a long list. Each project, plan or activity has been considered and scoped in or out on the basis of effect–receptor pathway, data confidence and the temporal and spatial scales involved. For the purposes of assessing the impact of the Thanet Extension on Marine Geology, Oceanography and Physical Processes in the region the cumulative impact technical note submitted with the Scoping Report screens in the projects and activities listed in the following paragraphs and Tables.

2.13.6 The proposed tier structure, that is intended to ensure that there is a clear understanding of the level of confidence in the cumulative assessments provided in the Thanet Extension ES, is as follows:

Tier 1

2.13.7 Thanet Extension considered alongside other projects/ plans currently under construction and/ or those consented but not yet implemented, and/ or those submitted but not yet determined where data confidence for the projects falling within this category is high.

2.13.8 Built and operational projects will be included within the cumulative assessment where they have not been included within the environmental characterisation survey, i.e. they were not operational when baseline surveys were undertaken, and/ or any residual impact may not have yet fed through to and been captured in estimates of 'baseline' conditions or there is an ongoing effect.

Tier 2

2.13.9 All projects included in Tier 1 plus other projects/ plans consented but not yet implemented and/ or submitted applications not yet determined where data confidence for the projects falling into this category is medium.

Tier 3

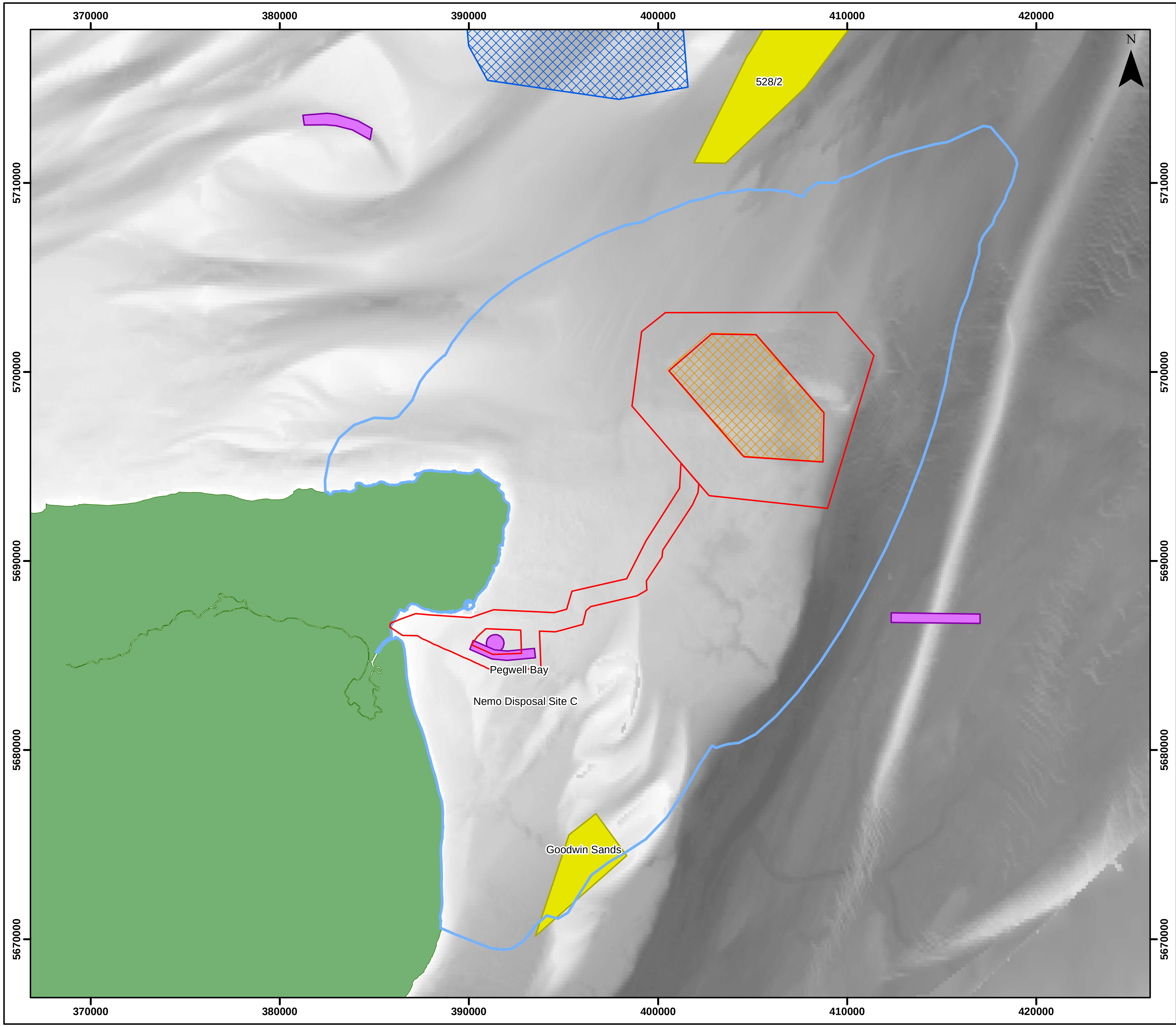
2.13.10 The above plus projects on relevant plans and programmes (the PINS Programme of Projects and MMO 'Marine Case Management System' being the source most relevant for this assessment). Specifically, all projects where the developer has advised PINS in writing that they intend to submit an application in the future were considered. This includes, for example, East Anglia Four for which Scoping Reports have been submitted and data availability is limited and/ or data confidence is low.

2.13.11 The specific projects scoped into this cumulative impact assessment, and the tiers into which they have been allocated are presented in Table 2.20 below, whilst the locations of these projects is shown in Figure 2.21. A small number of operational projects within the study area are not captured within the baseline characterisation (section 2.7; paragraph 2.7.1 onwards) and as such, are included in Table 2.20.

2.13.12 As previously stated, operational wind farms within the study area (TOWF and London Array) are not considered within the cumulative effects section as they are recognised as being part of the baseline environment and hence have already been taken into consideration within the project-alone assessment (paragraph 2.10.1 to 2.12.12).

2.13.13 The Thanet Cable Replacement project is no longer being pursued and as such a cumulative impact assessment is not required.

2.13.14 Finally, installation of the Nemo Link interconnector cable will be complete by the end of 2017/ start of 2018 (i.e. in advance of the Thanet Extension construction period). Accordingly, it has not been considered further in the cumulative assessment for Marine Geology, Oceanography and Physical Processes.



ABPmer VATTENFALL

THANET EXTENSION OFFSHORE WIND FARM

Figure 2.21

Aggregate Extraction Areas, Disposal Sites & Offshore Wind Farms within the Study Area

Legend

- Offshore Red Line Boundary
- Spring Tide Excursion Buffer

Offshore Wind Farm

- Thanet
- London Array

Aggregate Extraction

- Aggregate Exploration and Option Area

Dredge Disposal

- Operational Site

Bathymetry (m CD)

6.0 -11.8 -29.5 -47.3 -65.1

Datum: ETRS 1989
Projection: UTM31N

1:200,000 — 0 2 4 km — 0 1 2 nm

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Rev	1	Date	24/05/2018	
By	AMC	Layout	N/A	

Table 2.20: Projects for cumulative assessment

Development type	Project	Status	Data confidence assessment/ phase	Tier
Disposal Site	Pegwell Bay (TH140) Nemo Disposal Site C (TH152)	Operational	High – Operational.	Tier 1
Aggregate Exploration/ Option Area	Goodwin Sands (Area 521)	Planned 2017 to 19	High.	Tier 1
Aggregate Exploration/ Option Area	Hanson (Area 528/2)	Pre-consent exploration	Low	Tier 3

2.13.15 The cumulative Rochdale Envelope considered in the assessment is summarised in Table 2.21.

Table 2.21: Cumulative Rochdale Envelope

Impact	Scenario	Justification
Cumulative temporary increases in SSC and seabed levels as a result of Thanet Extension export cable installation and dredge disposal activities.	Maximum adverse scenario as described for construction phase of Thanet Extension (for export cable installation) assessed cumulatively with the following dredge disposal sites: • Pegwell Bay (TH140); and • Nemo Disposal Site C (TH152).	Maximum potential for interaction of increased suspended sediment concentrations within one tidal excursion as this includes the maximum area of potential overlap for suspended sediments.
Cumulative temporary increases in SSC and seabed levels as a result of Thanet Extension export cable installation and aggregate dredging activities.	Maximum adverse scenario as described for construction phase of Thanet Extension (for export cable installation) assessed cumulatively with the following dredge disposal sites: • Goodwin Sands (Area 521). Assessment assumes aggregate extraction at Goodwin Sands using a large (c.4500 to 500 m^3 hopper) Trailing Suction Hopper Dredger (TSHD), with multiple dredgers simultaneously in operation.	

Cumulative temporary increases in SSC and seabed levels as a result of Thanet Extension export cable installation and dredge disposal activities

Overview

2.13.16 The Thanet Extension OECC is approximately 120 m from the Pegwell Bay (TH140) disposal site and overlaps with the Nemo Link Interconnector (TH152) disposal site (Figure 2.21). Should export cable installation be occurring at the same time as dredge disposal activities at these sites, there could be the potential for cumulative changes in SSC and bed levels.

2.13.17 The disposal site TH140 is situated 1.8 km offshore, south-east of the entrance to Ramsgate Harbour. The site is considered suitable only for the disposal of dispersive maintenance dredging material and is largely used for the disposal of sandy muds dredged from Ramsgate Harbour (Cefas, 2001). Between 1986 to 2012, average disposal of (maintenance) dredged material of *circa* 80,000 (wet) tonnes/year (Cefas, 2014).

2.13.18 Disposal site TH152 is only to be used for the dredge arisings from sand banks excavated during installation of the Nemo Link Interconnector. Although the Nemo Link Interconnector should be installed in 2017/18 (i.e. in advance of the Thanet Extension construction period), it is theoretically possible that some disposal activities could still take place here after this date (e.g. for remedial works etc).

Conceptual understanding of change

2.13.19 The interaction between sediment plumes generated by Thanet Extension export cable installation activities and those from nearby dredge disposal operations could occur in two ways:

- Where plumes generated from the two different activities meet and coalesce to form one larger plume; or
- Where a vessel or barge is disposing of material within the plume generated by Thanet Extension construction activities (or *vice versa*).

2.13.20 Given the very close proximity of the two activities, it is considered that both types of plume interaction could occur. However, it is noted that in line with UNCLOS (The United Nations Convention on the Law of the Sea) cable installation vessels typically request a 1 nautical mile (c. 1.85 km) vessel safety zone when installing or handling cables. Accordingly, whilst plume interaction may still occur, the potential for much higher concentration and more persistent plumes than that previously described in the project-alone assessments of SSC (paragraph 2.10.3 to 2.10.42) is considered to be small.

2.13.21 Cumulative increases in bed level could also occur. However, it is noted that this location has been chosen for the disposal of dispersive dredged material and therefore disposed material is expected to be regularly re-worked. It is anticipated that in the long-term material will be transported away from the area in a north-easterly direction (Cefas, 2001) (Figure 2.11).

Assessment of significance

2.13.22 All of the identified physical processes receptors will be insensitive to elevated levels of SSC and localised changes in bed level. However, the potential for these changes to impact other EIA receptor groups are considered elsewhere within the ES, in particular:

- Volume 2, Chapter 4: Offshore Ornithology (Document Ref: 6.2.4);
- Volume 2, Chapter 5: Benthic Ecology (Document Ref: 6.2.5);
- Volume 2, Chapter 6: Fish and Shellfish (Document Ref: 6.2.6); and
- Volume 2, Chapter 7: Marine Mammals (Document Ref: 6.2.7).

Cumulative temporary increases in SSC and seabed levels as a result of Thanet Extension export cable installation and aggregate dredging activities

Overview

2.13.23 The Thanet Extension OECC is within a distance of one spring tidal excursion ellipse from the Goodwin Sands aggregate option area (Figure 2.21). Accordingly, it is necessary to consider the potential for cumulative changes in SSC and bed levels.

2.13.24 Dover Harbour Board is proposing to dredge up to 2.5 million m^3 of aggregate (generally comprising fine to coarse sand) from South Goodwin Sands, located approximately 10 km to the south of the Thanet Extension OECC. Dredging will be undertaken using one or two TSHDs. The proposed dredge area covers an area of 3.9 km^2 and dredging would be carried out over an approximate 2 year period, between 2017 and 2019 (DHB, 2016).

Conceptual understanding of change

2.13.25 On the basis of the spreadsheet based modelling considering potential changes in SSC associated with export cable installation (paragraph 2.10.32 to 2.10.42), it is found that any fine grained sediment plume will be subject to rapid dispersion, both laterally and vertically, to near-background levels (tens of mg/l) within hundreds to a few thousands of metres at the point of release. Similarly, on the basis of the numerical plume modelling undertaken for the Goodwin Sands Aggregate Dredging Environmental Statement, it is found that peak increases of suspended fine sand in excess of 10 mg/l are restricted to within a distance of approximately 1.5 to 2 km to the north of the proposed dredge area shown on Figure 2.21 (DHB, 2016).

2.13.26 Given the above information and that the two sediment disturbance activities are located approximately 10 km apart, any cumulative increase in either the spatial footprint or peak concentration of sediment plumes will be indistinguishable from background levels. Any associated changes in bed level will also be immeasurable.

Assessment of significance

2.13.27 All of the identified physical processes receptors will be insensitive to elevated levels of SSC and localised changes in bed level. However, the potential for these changes to impact other EIA receptor groups are considered elsewhere within the ES, in particular:

- Volume 2, Chapter 4: Offshore Ornithology (Document Ref: 6.2.4);
- Volume 2, Chapter 5: Benthic Ecology (Document Ref: 6.2.5);
- Volume 2, Chapter 6: Fish and Shellfish (Document Ref: 6.2.6); and
- Volume 2, Chapter 7: Marine Mammals (Document Ref: 6.2.7).

2.14 Inter-relationships

2.14.1 The term 'Inter-relationship' takes into account the environmental interactions ('inter-relationships') with other receptors within the Project. This term and the relevant legislation are described in Volume 2, Chapter 14: Inter-relationships (Document Ref: 6.2.14).

2.14.2 The different physical processes studied are already inter-related; in particular, sediment transport is dependent on currents and waves and therefore these linked processes have already been considered within the assessment. In turn, this information on changes to physical processes has been used to inform other ES topics such as Marine Ornithology (Volume 2, Chapter 4 (Document Ref: 6.2.4)) and Benthic Ecology (Volume 2, Chapter 5 (Document Ref: 6.2.5)). Assessments have been undertaken separately within these individual topic Chapters and are not reported here as additional inter-relationships. A full assessment of inter-relationships between topics is presented in Volume 2, Chapter 13 (Document Ref: 6.2.14) of the ES.

2.15 Mitigation

2.15.1 All of the potential effects to physical processes receptors are identified as Not Significant in terms of the EIA Regulations (Volume 1; Chapter 3 (Document Ref: 6.1.3)). Accordingly, no mitigation has been put forward as there are no significant effects which require mitigation.

2.16 Transboundary statement

2.16.1 No transboundary effects have been identified. This is because the predicted changes to the key physical process pathways (i.e. tides, waves, and sediment transport) are not anticipated to be sufficient to influence identified receptors at this distance from the Project.

2.17 Summary of effects

2.17.1 This chapter has investigated potential changes to marine physical processes arising from the Thanet Extension project. The range of potential impacts and associated effects considered has been informed by scoping responses (Table 2.2) as well as reference to existing policy and guidance.

2.17.2 The assessment has been undertaken in three stages. These are:

- The determination of the maximum adverse scenario from the Project Description (Volume 2, Chapter 1: Project Description - Offshore (Document Ref: 6.2.1));
- The determination of the baseline physical environment (including potential changes over the Project lifetime due to natural variation); and
- Assessment of changes to physical processes arising from the maximum adverse scenario both for Thanet Extension on its own and in conjunction with other built and consented projects.

2.17.3 In order to assess the potential changes relative to the baseline (existing) coastal and marine environment, a combination of complementary approaches have been adopted for the Thanet Extension physical processes assessment. These include:

- The 'evidence base' containing monitoring data collected during the construction and operation of other OWF developments, in particular the operational TOWF. The evidence base also includes results from numerical modelling and desk based analyses undertaken to support other OWF EIAs;
- Analytical assessments of project-specific data, including the use of rule based numerical models; and
- Standard empirical equations describing the relationship between (for example) hydrodynamic forcing and sediment transport or settling and mobilisation characteristics of sediment particles released during construction activities (e.g. Soulsby, 1997).

2.17.4 A wide range of potential changes to physical processes have been considered, including short-term sediment disturbance due to construction activities, scour around foundations and the potential for changes to the coast arising from the blockage of waves and tides.

2.17.5 For the most part, physical processes are not in themselves receptors but are, instead, 'pathways'. However, changes to marine processes have the potential to indirectly impact other environmental receptors. Notwithstanding this, three specific physical processes receptors were identified within the Thanet Extension study area, namely:

- Designated coastal features (Saltmarshes, intertidal flats and dune systems)
- Sand banks (South Falls, Goodwin Sands and Margate Sands); and
- Designated chalk features (cliffs, platforms and reefs).

2.17.6 Even using the conservative Rochdale Envelope approach to EIA, it has been found that for all receptor groups, the level of effect significance is either **Negligible** or **Minor** adverse for all phases of development (Table 2.22). Accordingly, all of the potential effects to physical processes receptors are therefore Not Significant in terms of the EIA Regulations (Volume 1, Chapter 3: Approach to EIA (Document Ref: 6.1.3)).

Table 2.22: Summary of predicted changes and effects of the Thanet Extension Offshore Wind Farm.

Description of impact	Change/ Effect	Possible mitigation measures	Residual effect
Construction			
Increases in SSC and deposition of disturbed sediments to the seabed due to dredging for seabed preparation prior to foundation installation.	(Pathway)	(No mitigation measures necessary)	(Pathway)
Increases in SSC and deposition of disturbed sediments to the seabed due to the release of drill arisings during foundation installation.	(Pathway)	(No mitigation measures necessary)	(Pathway)
Increases in SSC and deposition of disturbed sediment to the seabed due to cable installation within the Thanet Extension array area and within the OECC.	(Pathway)	(No mitigation measures necessary)	(Pathway)
Sand wave crest level preparation resulting in a change to local hydrodynamic, wave and sediment transport processes.	(Pathway)	(No mitigation measures necessary)	(Pathway)
Impacts to sand bank receptors (due to construction activities).	**Negligible** adverse	(No mitigation measures necessary)	**Negligible** adverse
Impacts to designated coastal feature receptors (due to construction activities).	**Minor** adverse	Completion of cable specification and installation plan	**Minor** adverse
Operation and Maintenance			
Changes to the tidal regime.	(Pathway)	(No mitigation measures necessary)	(Pathway)
Changes to the wave regime.	(Pathway)	(No mitigation measures necessary)	(Pathway)
Changes to sediment transport and sediment transport pathways.	(Pathway)	(No mitigation measures necessary)	(Pathway)
Scour of seabed sediments.	(Pathway)	(No mitigation measures necessary)	(Pathway)
Development of turbid wake features.	(Pathway)	(No mitigation measures necessary)	(Pathway)
Impacts to designated coastal feature receptors (due to construction activities).	**Negligible** adverse	(No mitigation measures necessary)	**Negligible** adverse
Impacts to designated coastal feature receptors (due to wind farm operation).	**Minor** adverse	Completion of cable specification and installation plan	**Minor** adverse

Description of impact	Change/ Effect	Possible mitigation measures	Residual effect
Impacts to designated chalk feature receptors (due to wind farm operation).	**Negligible** adverse	(No mitigation measures necessary)	**Negligible** adverse
Decommissioning			
Increases in SSC and deposition of disturbed sediment to the seabed within the Thanet Extension array area and the OECC.	(Pathway)	(No mitigation measures necessary)	(Pathway)
Impacts to designated coastal feature receptors (due to decommissioning activities).	**Minor** adverse	(No mitigation measures necessary)	**Minor** adverse
Cumulative effects			
Cumulative temporary increases in SSC and seabed levels as a result of Thanet Extension export cable installation and dredge disposal activities.	(Pathway)	(No mitigation measures necessary)	(Pathway)
Cumulative temporary increases in SSC and seabed levels as a result of Thanet Extension export cable installation and aggregate dredging activities.	(Pathway)	(No mitigation measures necessary)	(Pathway)

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