East Anglia Offshore Wind

VATTENFALL

SCOTTISHPOWER RENEWABLES

East Anglia THREE

Chapter 7

Marine Geology, Oceanography and Physical Processes

Environmental Statement

Volume 1

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Author – Royal HaskoningDHV
East Anglia THREE Limited

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7 MARINE GEOLOGY, OCEANOGRAPHY AND PHYSICAL PROCESSES

7.1 Introduction

1. This chapter of the Environmental Statement (ES) describes the physical environment of the proposed East Anglia THREE project, covering the East Anglia THREE site and the offshore cable corridor, including its landfall at Bawdsey on the Suffolk coast.

2. The chapter provides a summary description of key aspects relating to the existing marine geology, oceanography and physical processes, recognising that the baseline physical environment is not static, but is subject to considerable natural variability and could, potentially, be sensitive to change.

3. The chapter continues with an assessment of the magnitude and significance of the effects upon the baseline conditions resulting from the construction, operation and decommissioning of the proposed East Anglia THREE project, as well as those effects resulting from cumulative interactions with other existing or planned projects. Also provided are considerations with regard to potential mitigation measures, where appropriate.

4. This chapter was written by Royal HaskoningDHV, on behalf of East Anglia THREE Limited (EATL), and incorporates results from other contributors, including the Centre for Environment, Fisheries and Aquaculture Science (Cefas), Deltares, Fugro EMU Ltd., Geotechnical Engineering and Marine Surveys (GEMS) and Marine Ecological Surveys Ltd. (MESL).

5. This chapter also draws on findings of earlier studies undertaken to inform the East Anglia Zonal Environmental Appraisal (ZEA) (GL Noble Denton 2011; ABPmer 2012a) and the ES of the consented East Anglia ONE project (ABPmer 2012b).

6. The assessment process has been informed by the following:

- Interpretation of field data specifically collected for the proposed East Anglia THREE project;
- Consideration of the existing evidence base regarding the effects of offshore windfarm developments on the physical environment;
- Empirical assessments of scour formation around wind turbine foundations;
- Cross-reference to previous detailed numerical modelling studies undertaken for both the East Anglia ZEA and the ES of the East Anglia ONE project;

- Discussion and agreement with key stakeholders; and
- Application of expert-based judgement.

7. The potential effects upon marine geology, oceanography and physical processes have been assessed conservatively using realistic 'worst case' characteristics for the proposed East Anglia THREE project. The worst case has been revisited since the Preliminary Environmental Information Report (PEIR) to take account of updates to the project design and comments received during the Section 42 consultation in 2014.

8. The assessment of potential effects has been made with specific reference to the relevant National Policy Statements (NPS). These are the principal decision-making documents for Nationally Significant Infrastructure Projects (NSIP). Those relevant to Marine Geology, Oceanography and Physical Processes are:

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

9. Relevant aspects of EN-1 and EN-3 are presented later in section 7.4.1. This chapter of the ES either directly addresses these issues or provides information which enables these issues to be directly addressed in other, more relevant chapters, most notably: Chapter 8 Marine Water and Sediment Quality; Chapter 10 Benthic Ecology; Chapter 11 Fish and Shellfish Ecology; Chapter 14 Commercial Fisheries; Chapter 15 Shipping and Navigation; and Chapter 17 Offshore Archaeology and Cultural Heritage.

10. All figures referred to in this chapter are provided in **Volume 2** of the ES.

11. This chapter should be read in conjunction with *Appendices 7.1, 7.2, 7.3*, *7.4* and *7.5*, which are presented in Volume 3 of this ES.

7.2 Consultation

12. The Scoping Report for the proposed East Anglia THREE project was published on the Planning Inspectorate website in November 2012. None of the formal scoping responses received relate specifically to marine geology, oceanography or physical processes.

13. However, the various responses previously received in relation to the physical environment in response to the Scoping Report for the East Anglia ONE project have

provided useful information about the type of physical process issues that would need to be considered for the proposed East Anglia THREE project.

14. In addition to the Scoping Report, a Physical Processes Background Paper was submitted to Natural England (NE) and Cefas in September 2013 as part of the Evidence Plan process (an explanation of the Evidence Plan process is provided in section 6.3.3 of Chapter 6 Environmental Impact Assessment (EIA) methodology). That document provided a Method Statement for the assessment of potential effects on the baseline marine geology, oceanography and physical processes from the proposed East Anglia THREE project and is provided for reference in *Appendix 7.1* of this ES.

15. The Physical Processes Background Paper (*Appendix 7.1*) was discussed by EATL, Royal HaskoningDHV, Cefas and Natural England at a meeting on 13th September 2013 and has since been amended and mutually agreed as a proportionate means of assessing the potential effects on the baseline physical environment within the PEIR. A further Evidence Plan meeting was held between EATL, Royal HaskoningDHV, Cefas and Natural England in June 2014, after PEIR submission, to discuss the findings of the assessment and enable refinement before ES submission. The responses received during consultation on the Physical Processes Background Paper and the PEIR are summarised in *Table 7.1* with full detail provided in Annex D of *Appendix 7.1*.

Table 7.1 Consultation Responses

Consultee	Date /Document	Comment	Response / where addressed in this ES
Cefas and Natural England	Meeting 13/09/2013	Both organisations are content with an expert judgement based approach (i.e. no need for project-specific modelling) because of the strong evidence base that is in place from previous detailed assessments for the East Anglia Zone Environmental Appraisal and the Environmental Statement for the proposed East Anglia ONE project, subject to benthic and fish experts within Cefas and Natural England also being content with this approach.	Appendix 7.1 and Section 7.6
Cefas and Natural England	Meeting 13/09/2013	Both organisations are content that the work previously undertaken for the offshore cable corridor and cable landfall	Sections 7.3.2.8 and 7.6.1.8

Consultee	Date /Document	Comment	Response / where addressed in this ES
		proposed for the East Anglia ONE project is re-evaluated in the context of different timings of construction/ decommissioning for the proposed East Anglia THREE project, given that installation approaches and cable corridor will be identical near to shore and at the landfall.	
Cefas and Natural England	Meeting 13/09/2013	Both organisations are content that the assessment of effects on the wave and current regimes should draw from the well-established evidence base that exists across the offshore windfarm industry.	Sections 7.6.2.1 and 7.6.2.2
Cefas	Meeting 13/09/2013	Given that the proposed East Anglia THREE project has some areas of different water depth compared to the previously assessed East Anglia ONE project, this will need to be taken into consideration in the expert-based assessments. In relation to this, it would be useful to schematically illustrate a 'zone of potential effect' around the project boundary.	*Figure 7.7* and *Figure 7.8*
Cefas and Natural England	Meeting 13/09/2013	It remains important that an empirical assessment is made of the potential scour hole formation around the wind turbine foundations to inform the subsequent assessments of either: (i) fate of scoured material; or (ii) footprint of scour protection works on the sea bed.	Appendix 7.3, Table 7.7 and Section 7.6.2.5
Cefas and Natural England	Meeting 13/09/2013	Given an initial assumption of up to 10% of cables requiring protection (an assumption that subsequently has been further refined), it is accepted that if these areas are in deeper water, beyond the active closure depth for sediment transport in the beach / foreshore zone, then	Section 7.3.2.7

Consultee	Date /Document	Comment	Response / where addressed in this ES
		desk-based assessment will suffice. If, however, these areas of protected cable are inshore of the 'closure depth' of the shore profile (i.e. within the inter-tidal or nearshore zones) where they could potentially interrupt littoral sediment transport, then further dialogue with Cefas and Natural England is required on the methods for assessment.	
Cefas and Natural England	Meeting 13/09/2013	Further dialogue will be needed with Cefas and Natural England when more detail is available on engineering proposals for cable crossings.	Section 7.3.2.7
Cefas and Natural England	Meeting 13/09/2013	It is acceptable for the cumulative effects to be assessed using proportionate and high-level assessments.	Section 7.4.4
Section 42 Consultation on the PEIR			
Marine Management Organisation (MMO)	East Anglia THREE PEIR response (July 2014)	In general the evidence used is appropriate, proportionate, consistent with other similar projects and incorporates key data sources. Impacts are accurately described and we are content with the cumulative impact assessment (CIA) with respect to the physical environment.	Chapter 7
MMO	East Anglia THREE PEIR response (July 2014)	The PEIR does not include information regarding monitoring requirements. We would expect such detail to be included in the ES and we would welcome the opportunity to discuss such requirements prior to the submission of EA3 application.	EATL have produced an In Principle Monitoring Plan this includes monitoring provisions such as a survey to detect changes in seabed topography, including scour processes. Requirements for monitoring have been discussed with NE, MMO & Cefas and would be finalised with these organisations prior to construction.
MMO	East Anglia THREE PEIR	Vol. 2, Figure 7.7 – Clarification is required as to why there is no	*Figure 7.7* has been changed to *7.8* and has been

Consultee	Date /Document	Comment	Response / where addressed in this ES
	response (July 2014)	potential change to the wave regime in the north west corner of the EA3 zone shown in the figure.	amended to show influence on wave regime in the north west corner.
Suffolk County Council (SCC), Mid Suffolk District Council (MSDC), Suffolk Coastal District Council (SCDC)	East Anglia THREE PEIR response (July 2014)	Paragraph 76 suggests that techniques other than HDD may be used at the landfall, including open trenching (there are no coastal defences at the landfall). We continue to support HDD and preferably long HDD (see above) at the landfall.	Sections 7.3.2.8 and 7.6.1.8
SCC, MSDC, SCDC	East Anglia THREE PEIR response (July 2014)	We note the conclusions on the likely magnitude of effect associated with the installation of the cables at landfall (Impact 8). As with EA ONE we would nevertheless require there to be appropriate monitoring provisions in the DCO/DML with a mechanism to trigger mitigation as need be (this is referred to in section 19.2.1). Please refer to earlier comments on decommissioning.	As the cables for the proposed East Anglia THREE project at landfall would be placed in ducts which will have been installed by East Anglia ONE, the provisions made in the Development Consent Order (DCO) for that project are considered sufficient to mitigate any impacts caused by the presence of the East Anglia THREE cables.
Natural England	East Anglia THREE PEIR response (July 2014)	Note that Natural England comments below have been summarised. Natural England made initial comments on the PEIR which were discussed at a workshop on 3rd July 2014, before providing final comments. The full comments are available in Annex D of *Appendix 7.1*	Provided below
Natural England	East Anglia THREE PEIR response (July 2014)	NE-24: Further information is required on the cable landfall and cable crossings.	Sections 7.3.2.7 and 7.3.2.8 (information) Sections 7.6.2.6 and 7.6.2.7 (impacts assessment)
Natural England	East Anglia THREE PEIR response (July	NE-25: Further information is required on the mounds created by disposal of drilling spoil.	Section 7.6.1.2.1

Consultee	Date /Document	Comment	Response / where addressed in this ES
	2014)		
Natural England	East Anglia THREE PEIR response (July 2014)	NE-26: Further information is required on the worst case scenario for scour.	Section 7.3.2.3
Natural England	East Anglia THREE PEIR response (July 2014)	NE-27: Further information is required on cable protection for inter array cables and cable crossings.	Volume II *Figure 5.4* and *Diagram 5.17* in Chapter 5 Description of the Development illustrates this.
Natural England	East Anglia THREE PEIR response (July 2014)	NE-28: The hierarchal approach to selecting the most appropriate cable protection in order to reduce impacts to sensitive receptors is welcomed by NE. When will this be determined and presented?	Section 7.3.2.6 - The hierarchy is: (1) to bury cables in all cases where practicable to do so; (2) at crossings or where seabed conditions prevent burial, the preferred protection method is via mattressing.
Natural England	East Anglia THREE PEIR response (July 2014)	NE-29: Further information is required on cable crossings.	Sections 7.3.2.7 (information) Sections 7.6.2.6 and 7.6.2.7 (impacts assessment)
Natural England	East Anglia THREE PEIR response (July 2014)	NE-30: Further information is required on the cable landfall	Sections 7.3.2.8 and 7.6.1.8
Natural England	East Anglia THREE PEIR response (July 2014)	NE-31: Further information is required on impacts on the tidal regime.	Section 7.6.2.1 and *Figure 7.7*
Natural England	East Anglia THREE PEIR response (July 2014)	NE-32: Further information is required on 'temporary works'.	Section 7.6.2.9
Natural England	East Anglia THREE PEIR response (July 2014)	NE-33: Further information is required on impact from the presence of foundation structures.	Section 7.6.2.5
Natural England	East Anglia THREE PEIR response (July 2014)	NE-34: Cross-referencing is required on impacts to other receptors.	Section 7.9
Natural	East Anglia THREE PEIR	NE-35: Further information is	Sections 7.6.2.6 and 7.6.2.7

Consultee	Date /Document	Comment	Response / where addressed in this ES
England	response (July 2014)	required on cable protection.	
Natural England	East Anglia THREE PEIR response (July 2014)	NE-36: Further information is required on sea bed levelling before the cable can be installed.	Section 7.6.2.7
Natural England	East Anglia THREE PEIR response (July 2014)	NE-37: Further information is required on cable protection (especially on export cable).	Section 7.6.2.7
Natural England	East Anglia THREE PEIR response (July 2014)	NE-38: Further information is required on cable landfall.	Sections 7.3.2.8 and 7.6.1.8. Note: all landfall duct operations would be undertaken by East Anglia ONE
Natural England	East Anglia THREE PEIR response (July 2014)	NE-40: Further information is required on decommissioning of cables.	Chapter 5
Natural England	East Anglia THREE PEIR response (July 2014)	NE-41: The PEIR notes "Indeed, the wave conditions across the East Anglia THREE site are more severe, suggesting that the passive plume would be similar or lower in concentration than that previously considered for East Anglia ONE." I am not sure I understand why waves would result in less of a plume. *Clarification to be provided within the ES.*	Previous modelling for East Anglia ONE was based on passive plume dispersion by tidal currents only. When wave action is also applied it is possible that the plume would not only be dispersed in the direction of the tidal flow, but also in the direction of the wave train, making the volume of material spread over a wider area (if the two directional axes are not concurrent) but at lower concentrations. However, it is acknowledged that this sentence is unclear and therefore it has been removed from the text.
Natural England	East Anglia THREE PEIR response (July 2014)	NE-42: Cross-referencing is required on impacts to other receptors.	Section 7.9
Natural England	East Anglia THREE PEIR	NE-43: Further information is required on the evidence-base	Section 7.6.1.1.1

Consultee	Date /Document	Comment	Response / where addressed in this ES
	response (July 2014)	obtained from research into the physical impacts of marine aggregate dredging on sediment plumes and sea bed deposits.	
Natural England	East Anglia THREE PEIR response (July 2014)	NE-44: Further information is required on the areas where the very small increases in sea bed were observed from East Anglia ONE modelling.	Section 7.6.1.2.1
Natural England	East Anglia THREE PEIR response (July 2014)	NE-56: Further information is required on the routes of the export cables for East Anglia ONE, East Anglia THREE and East Anglia FOUR.	Export cable corridors for East Anglia THREE and East Anglia ONE are presented in *Figure 5.3* in Volume 2 of this ES. The location of export cables for future projects within the East Anglia Zone is currently unknown.
Natural England	East Anglia THREE PEIR response (July 2014)	NE-49: Further information is required on cable landfall and what activities are covered by East Anglia ONE.	Sections 7.6.1.8 and 7.6.2.8
Natural England	East Anglia THREE PEIR response (July 2014)	NE-50: Further information is required on shoreline set-back distances.	Section 7.5.7.4. Note: Set back is approx. 180m from the cliff
Natural England	East Anglia THREE PEIR response (July 2014)	NE-53: Further information is required on impacts on the 'non designated sandbanks'	Section 7.6.2.2
Natural England	East Anglia THREE PEIR response (July 2014)	NE-54: Further information is required on scour protection	Chapter 5 Description of the Development
Natural England	East Anglia THREE PEIR response (July 2014)	NE-55: Further clarification is needed on the statement "In the case of no scour protection being provided, the scour hole would respond dynamically …"	Section 7.6.2.5
Natural England	East Anglia THREE PEIR response (July 2014)	NE-54: Further information is required on cable decommissioning, including any length of cable through the cliff	Chapter 5 Description of the Development

Consultee	Date /Document	Comment	Response / where addressed in this ES
		face.	
English Heritage, now known as Historic England	East Anglia THREE PEIR response (July 2014)	Modelling scour assessments for the different foundation options. We note that the calculations assume water depths of 35m although deeper water exists in the majority of the project offshore area (as described in paragraphs 40 and 42 with addition models assuming a 45m water depth). However, as foundations and spacings of the turbines have not yet been decided, these calculations will need to be re-done to take the decisions into account, and be linked to the marine archaeology sections to address potential impacts with particular reference to the worst case scenario (e.g. conical gravity foundations).	The greatest scour hole development is associated with gravity base structures of the maximum potential diameter in shallowest water zones. This has now been assessed in the shallow water zone for a 60m diameter gravity base structure (previously 40m diameter was used in this shallow water zone) and the results have been taken as a worst case in the assessments. In reality, the scour hole development for a given foundation size would reduce in deeper water areas because of less wave-induced stirring at the sea bed. Scour volumes, even under these worst case arrangements, remain below the values of sediment that would be disturbed by sea bed preparation for foundation installation. The impacts on archaeological receptors is presented in Chapter 17.
Eastern IFCA	East Anglia THREE PEIR response (July 2014)	Whilst the authority welcomes the inclusion of all Special Protection Area sites within its district for consideration under the HRA process, we seek assurance that the scoping out of the two Special Areas of Conversation sites is justified. The proximity, in particular, of the Orfordness-Shingle Street SAC to the intertidal section of the proposed works is of concern and the authority seeks assurance that the potential for associated works to overlap with the SAC is	Habitat Regulations Assessment (HRA) Report

Consultee	Date /Document	Comment	Response / where addressed in this ES
		recognised and mitigated for.	
Natural England	Response to Phase III report (consultation), July 2015	We do not have any detailed comment to make at this time but look forward to receiving the revised environmental assessment and the detail contained therein of how the changes to the project may affect the outcome of the receptor specific assessments.	The impact assessment takes into consideration all changes that have been made to the project, specifically sections 7.3.2 and 7.6.1 which both consider the Single Phase and the Two Phased approaches.
Consultation on Draft ES Chapter			
Natural England	27/8/2015	[Comment on paragraph 40] Natural England understands this point, but note that volumes of material released due to scour would be in addition to those from seabed preparation and therefore impacts should be considered as cumulative and ongoing.	Sediment dredged from the sea bed in preparation for foundation installation would rapidly (tens of minutes) settle out of suspension. Impacts from this activity would not overlap with scour around the foundation which would be installed several days later. Therefore these impacts are assessed separately in sections 7.6.1.1 and section 7.6.2.4. As both of these impacts were assessed as having no impact there cumulative effect is likely to be at worst of negligible significance.
Natural England	27/8/2015	[Comment on paragraph 61] Seabed levelling – The requirement for this means the seabed is mobile. What measures will therefore be taken to ensure cables stay buried in these areas?	The target depth of cable burial would be determined by sea bed conditions and would be agreed with the relevant authorities in the Cable Specification and Installation plan.
Natural England	27/8/2015	[Comment on paragraph 64] What about where seabed levelling has taken place? Reasonable likelihood cable protection would be required here due to mobility as mentioned above. Natural England would prefer cable protection to be limited in all	EATL's first preference would be to bury cables. Where this is not possible cable protection would be kept to a minimum due to reduce the magnitude of impacts. As the sea bed across the

Consultee	Date /Document	Comment	Response / where addressed in this ES
		areas, including exposed bedrock. Consideration should be given to using cable protection most similar to the natural environment and methods that reduce footprint and impact such as cutting cable into bedrock and letting trench provide protection if the footprint of this would be smaller than using cable protection over exposed cables.	East Anglia THREE site and offshore cable corridor is predominantly sediment (mainly sand) as shown in section 7.5.7.1 no cable protection is likely to match the natural environment. The cable protection requirement would be determined in the Cable Specification and Installation Plan.
Natural England	27/8/2015	[Comment on paragraph 65] Natural England is unsure what bridging is? Could a brief explanation be provided be here? Why are concrete mattresses the preferred option? Further justification should be provided here. Please note that during the Dogger Bank Creyke Beck examination it was highlighted by Forewind that the ropes holding concrete mattresses together are likely to fail during the lifespan of a windfarm, therefore making these harder to remove on decommissioning than other forms of scour protection.	Note that the reference to bridging has now been removed from the chapter and project description as EATL do not believe this would be required. Mattresses are the preferred option as they are stable, easy to install and remove and create the smallest footprint.
Natural England	27/8/2015	[Comment on paragraph 68] Further information should be provided here as to how the height for cable protection measures has been worked out and what this consists of.	Section 5.5.14.5 and diagram 5.17 in Chapter 5 Description of the Development.
Natural England	27/8/2015	[Comment on paragraph 83] Natural England welcome installation of scour protection during construction for both gravity bases and monopiles where this can be demonstrated to reduce overall volumes of scour protection needed.	EATL note this.
Natural England	27/8/2015	[Comment on paragraph 87] Please note that the target depth	This is assessed in Chapters 9 Underwater Noise and

Consultee	Date /Document	Comment	Response / where addressed in this ES
		for minimising EMF impacts is 1.5m. The minimum target depth given here is 0.5m though we understand that it may not be possible to achieve 1.5m in all ground types. It would be helpful to understand where the areas of hard ground are that may require cable protection.	EMF and Chapter 11 Fish and Shellfish Ecology. The areas hard ground would be determined in preconstruction geotechnical surveys.
Natural England	27/8/2015	[Comment on paragraph 113] Impacts from cable reburial and remedial scour protection should be considered if these activities are to be covered by the DML. Otherwise a separate license will be required should these be necessary. It is NE's experience that these activities have been necessary at almost all offshore windfarms to date.	The total amount of cable protection considered (i.e. 10% of all cables) is highly conservative and therefore allows for any additional protection that would be required during operation. The Outline Offshore Operation and Management Plan (OOOMP) considers several maintenance activities including cable reburial and repair. The OOOMP has been submitted as part of the DCO application.
Natural England	27/8/2015	[Comment on paragraph 119] Removal of scour and cable protection should be included here where relevant. Current advice and best practise dictates that scour and cable protection should be removed on decommissioning in order to allow the seabed to recover to its pre-construction state. Therefore removability should be a key consideration in selection of scour and cable protection types. Further discussion at the time of decommissioning will enable the best decisions to be made at the time.	Removal of scour and cable protection have now been included. As discussed in section 7.6.3 removal of infrastructure would follow best practice at that time which would be subject to discussion with the relevant authorities.
Natural England	27/8/2015	[Comment on paragraph 220] Would release at surface from the dredger be at the turbine location where seabed is dredged or	It is likely that disposal would be in the vicinity of the wind turbine location.

Consultee	Date /Document	Comment	Response / where addressed in this ES
		further away?	
Natural England	27/8/2015	[Comment on paragraph 234] Consideration should be given (perhaps in other chapters) as to whether deposition of drill arisings would change the nature of the seabed due to different sediment composition. Size and persistence of drill arising mounds should also be considered.	This is now described in full in section 7.6.1.2.2
Natural England	27/8/2015	[Comment on paragraph 259] It would be useful to see height and width of mounds as well as volume and assessment of if/ how the mounds would winnow over time.	Section 7.6.1.2.2 provides estimations for the predicted dimensions of the mounds.
Natural England	27/8/2015	[Comment on *Table 7.19*] Natural England queries why duration is negligible for seabed level effect in near field? Surely this depends on how long disposal or seabed preparation mounds persist? Reversibility is also linked to persistence. This could be better justified.	Section 7.6.1.2.2. The assessment to which this comment refers now provides separate assessments of magnitude for the disposal scenario and the mounds scenario.
Natural England	27/8/2015	[Comment on paragraph 285] If seabed recovers from sandwave clearance due to natural processes what does this mean for continuing cable burial?	The cable would be below the level of the sea bed and therefore it is unlikely that the cable would become exposed as the sea bed recovers.

Consultee	Date /Document	Comment	Response / where addressed in this ES
Natural England	27/8/2015	[Comment on section 7.6.1.6.1] Where sandwave clearance is likely to occur in nearer shore areas on the export cable route some assessment should be presented of any likely impacts of sandwave clearance on the wave climate and therefore on coastal processes. Natural England does not currently feel this has been sufficiently considered.	Section 7.6.1.6.1 and *Figure 7.6* illustrates that very few steep sandwaves exist in the near shore areas of the offshore cable corridor; therefore it is unlikely that significant amounts of sea bed levelling would be required. However, if it is required then clearing a trench through sandwaves would not cause a significant morphological effect and therefore would have no knock-on effect on wave propagation reaching the shore. A Cable Specification and Installation plan would contain further detail on the locations and extent of necessary sea bed levelling.
Natural England	27/8/2015	[Comments on *Tables 7.25*, 7.37 and 7.4] Whilst we appreciate this is potentially covered in other sections of the ES, assessments of impacts on N2K sites should be done against the conservation objectives for the site and using the site attributes, not using generic EIA matrices. If this is covered elsewhere it should be cross referenced here. We realise that due to the location of these projects there are unlikely to be significant impacts on designated sandbanks sites.	This chapter uses a source pathway receptor impact model to assess the project potential impacts on receptors; this is not intended as a HRA assessment. The HRA screening used the work in this chapter in order to screen out Physical processes impacts upon designated sites. This conclusion was agreed with Cefas and Natural England at an Evidence Plan Meeting on 13/9/2013
Natural England	27/8/2015	[Comment on paragraph 384] As per our comment on the PEI further detail should be provided on this if possible or cross-referenced to other chapters.	Chapter 5 provides outline information available at the current time. Note that the ducts would be installed by the East Anglia ONE project .

Consultee	Date /Document	Comment	Response / where addressed in this ES
Natural England	27/8/2015	[Comment on paragraph 400] The issue of secondary scour around scour protection if used is not discussed here. It would be useful if it could be included.	Section 7.6.2.5.1 now considers secondary scour.
Natural England	27/8/2015	[Comment on paragraph 409] It would be helpful if further justification and evidence could be provided that cable protection will not significantly affect bedload transport patterns.	Section 7.6.2.6 includes further justification.
Natural England	27/8/2015	[Comment on paragraph 426] Natural England appreciates the efforts to reduce cable protection needs in the inshore area due to potential interruption to coastal processes. We feel that potential impacts are not well quantified or evidenced and therefore could do with further clarification, particularly in relation to impacts on designated sites.	There is a commitment from EATL to limit the cable protection in the inshore area of the offshore cable corridor (see section 7.3.3), until pre-construction geotechnical work is undertaken, it is not possible to further quantify effects. Cable protection would be detailed within the Cable Specification and Installation Plan.
Natural England	27/8/2015	[Comment on paragraph 450] Removal of scour/ cable protection should be included here.	Section 7.6.3 now includes further detail on what would be removed during decommissioning.
Natural England	27/8/2015	[Comment on paragraph 461] The assessment relies on EA1 and EA3 not being constructed at the same time. This should be reflected somewhere, maybe in license otherwise assessment is not valid.	East Anglia ONE is currently in the pre-construction stage having secured a Contract for Difference and is likely to commence operation in 2019. The proposed East Anglia THREE project would not commence construction until 2020 at the earliest. Therefore there would be no overlap.
Natural England	27/8/2015	[Comment on paragraph 466] The assessment of cumulative impacts on N2K sites needs to be better detailed and justified. If this is done elsewhere then it should be cross-referenced here. If not, then	The assessment is intended to describe the impact to the physical characteristics of the N2K receptors; it is not intended as a HRA assessment. The

Consultee	Date /Document	Comment	Response / where addressed in this ES
		it should be done here.	assessments of reliance to the features of the sites are presented in Chapter 10 Benthic Ecology and Chapter 13 Offshore Ornithology and conclusion with regard to HRA are in the HRA Screening. This is now referenced in the text.

7.3 Scope

7.3.1 Study Area

16. The East Anglia THREE site is located in the southern North Sea, encompassing a sea bed area of approximately 305km^2. At its closest point to shore, the East Anglia THREE site is approximately 69km offshore from Lowestoft on the Suffolk coast (*Figure 7.1*).

17. Water depths across the East Anglia THREE site typically range from 35m below Lowest Astronomical Tide (LAT) to 45m below LAT, but the extreme depths range from a minimum of 25m below LAT to a maximum of 49m below (*Table 7.2*).

Table 7.2 Summary of East Anglia THREE site characteristics

Description	Area (km^2)	Area (%)
Total site	304.8	100.0
Water depth <35m	47.5	15.6
Water depth 35-45m	243.3	79.8
Water depth >45m	14.0	4.6
Water depth >50m	0.0	0.0

18. The export cable corridor covers an area of sea bed of 454km^2, with a maximum length of 166km. The inshore section and landfall of the export cable corridor (at Bawdsey in Suffolk) are identical to that previously assessed for the East Anglia ONE project (*Figure 5.3*). In addition, the interconnector cable corridor covers an area of seabed of 238km^2; due to an area of overlap with the export cable corridor the combined sea bed area within the offshore cable corridor (interconnector and export cable corridors) is 571km^2. The interconnector cable provides the ability to connect

the proposed East Anglia THREE project with the consented East Anglia ONE project (Chapter 5 Description of the Development).

19. The assessment of effects on marine geology, oceanography and physical processes considers the direct footprint of the proposed East Anglia THREE project (near-field) and the wider areas of sea bed and shoreline that potentially could be affected (far-field).

7.3.2 Worst Case

20. It should be noted that the detailed design of the proposed East Anglia THREE project (including numbers of wind turbines, layout configuration, requirement for scour protection, electrical design etc.) is not yet determined, and may not be known until sometime after the Development Consent Order (DCO) has been granted. Therefore, realistic worst case assumptions in terms of potential effects upon marine geology, oceanography and physical processes have been adopted (see Chapter 3 Policy and Legislative Context section 3.5 for more information on the Project Design Envelope).

21. Definition of the worst case assumptions has been made from consideration of the detail about the proposed East Anglia THREE project that is presented in Chapter 5 Description of the Development, alongside the mitigation measures that have been embedded in the design (section 7.3.3).

7.3.2.1 Phasing

22. EATL are currently considering constructing the project in either a Single Phase or in a Two Phased approach. Under the Single Phase approach the project would be constructed in one single build period and under a Two Phased approach the project would be constructed in two phases each consisting of up to 600MW. Indicative programmes for both Single Phase and Two Phased approaches are shown in *Tables 5.34* and *5.37* of Chapter 5 Description of the Development. In summary, the offshore components of the Single Phase construction would last for 41 months, with the offshore components of the Two Phased approach lasting for 45 months (due to an overlap between the two construction phases under this approach).

7.3.2.2 Layout

23. Within the East Anglia THREE site, up to three different sizes of wind turbine could be used, but in any case the minimum and maximum sized wind turbines would be within the range 7 to 12MW.

24. This means that in order to achieve the 1,200MW installed capacity, there could be a minimum of 100 12MW wind turbines or a maximum of 172 7MW wind turbines, or

a combination of numbers and wind turbine ratings in between. Under a Two Phased approach, it has been assumed that approximately half of the wind turbines would be installed in Phase 1 and half in Phase 2.

25. Under either the Single Phase or Two Phased approach the wind turbines would be arranged in blocks with regular rows, with a minimum spacing between adjacent wind turbines of 675m within each row and a minimum spacing of 900m between rows.

7.3.2.3 Foundations

26. There could be only one foundation type used or alternatively a combination of types and sizes could be used across the windfarm site. Some types and sizes of foundation are more favourable for certain water depths, ground conditions or wind turbine models and the final arrangements would be confirmed during detail design considerations.

27. Accordingly, to ensure the proposed East Anglia THREE project is adequately assessed for the purposes of EIA, foundation sizes covering the range from 7MW to 12MW wind turbines, and including monopiles, tripod jackets or quadropod jackets with either pin piles or suction buckets, suction caisson and gravity base structures have been considered to determine the worst case assumptions.

28. Due to their presence on the sea bed and in the water column, wind turbine foundations have the potential to cause the following principal effects on the physical environment:

- Blockage effects – the presence of a foundation may modify the progression of certain physical characteristics (waves, tidal currents, sediment transport) over the lifetime of a project.
- Sediment disturbance effects – foundations may lead to disturbance of the sea bed sediments due to dredging or piling operations during the construction phase or scour hole formation during the operation phase.

29. In respect of blockage effects, there is now a considerable evidence base across the offshore windfarm industry derived from numerous Environmental Statements that are available in the public domain (confirmed by a review of modelling studies from around 30 wind farms in the UK and European waters presented in Seagreen, 2012) which indicates that the greatest potential effect is associated with conical gravity base structures. This is because these structures occupy a significant proportion of the water column as a solid mass (as opposed to an open lattice of slender columns and cross-members, found in jackets or tripods, or a single slender column like a

monopile). They do, therefore, have the potential to affect wave propagation and near-surface tidal currents in a manner that other foundation types do not.

30. In addition, conical gravity base structures have by far the greatest footprint area at the base of the structure of all potential options (*Table 7.3*) and this influences near-bed currents and sea bed sediment transport processes.

Table 7.3 Worst Case Assumptions for wind turbine Foundation Footprints

Foundation Type	Wind Turbine rating (MW)	Foundation Dimensions (m)	Foundation Footprint (m^2)
Gravity base structure	7	40 (basal diameter)	1,257
	12	60 (basal diameter)	2,828
Jacket with pin piles*	7	33.5 x 33.5	1,123
	12	43.5 x 43.5	1,893
Jacket with suction caissons*	7	38 x 38	1,444
	12	50 x 50	2,500
Suction caisson	7	25 (diameter)	491
	12	30 (diameter)	707
Monopile	7	10 (diameter)	79
	12	12 (diameter)	113

* Dimensions are distances between leg centres based on a square footprint

31. In respect of sediment disturbance effects, these can be considered separately for the construction phase, the operation phase and the decommissioning phase.

32. During the construction phase, it is probable that there would be a need for some sea bed preparation associated with all foundation types. This has potential to disturb sediments at or near the surface of the sea bed (down to relatively shallow depths below the sea bed), hereafter called near-surface sediments.

33. The greatest quantities of near-surface sediment disturbance due to sea bed preparation activities during construction would be associated with conical gravity base structures. Conservative average dredging volumes associated with conical gravity base structures of the maximum diameter for both the 7MW and 12MW wind turbines are provided in *Table 7.4*. To ensure a conservative approach to the assessment of effects, it has been assumed that these values apply everywhere across the East Anglia THREE site.

Table 7.4 Worst Case Assumptions for Near-Surface Sediment Disturbance during Construction

Foundation Type	Maximum no.	Foundation Dimensions (m)	Ave. Volume of Sea Bed Preparation per Foundation (m^3)*
Gravity base structure for 7MW wind turbine	172	40 (basal diameter)	17,500
Gravity base structure for 12MW wind turbine	100	60 (basal diameter)	26,000
Jacket structure for offshore platforms	6	103 × 155	73,225
Jacket or Gravity base structure for meteorological masts	2	20m	10,375

* Assumptions behind these calculations are provided in section 5.5.4.2.2 of Chapter 5 Description of the Development

34. In addition, there is potential that the installation of monopiles and jackets (using 3 or 4 pin piles) may require drilling (although the preference is for driving the piles wherever it is feasible to achieve this). Any drilling of piles into the sea bed would have the greatest potential to release sediments from notable depths (tens of metres) below the sea bed surface, hereafter called sub-surface sediments, into the water column (to depths of up to 40m below the sea bed for monopiles and up to 50m below the sea bed for pin piles) (*Table 7.5*). These sub-surface sediments have a different physical composition to near-surface sediments and therefore may be more widely dispersed by tidal currents (i.e. the drill arisings may be overall finer than the near-surface sediments).

Table 7.5 Worst Case Assumptions for Sub-Surface Sediment Disturbance during Construction

Foundation Type	Drilling Depth (m)	Foundation Dimensions (m)	Max. Sediment Volume per foundation structure (m^3)*
Jackets (with pin piles)	50	3.5 (diameter piles, 4 no.)	1,924
Monopiles for wind turbines	40	10 (diameter pile for 7MW turbines, 1 no.)	3,142
	40	12 (diameter pile for 12MW turbines, 1 no.)	4,524
Monopiles for meteorological masts	40	8	2,011

*These calculations are based on the volume of material which would be displaced by each foundation type.

35. During the operational phase, there is potential, if no scour protection is provided, for the presence of the foundations to cause scour hole formation in the sea bed adjacent to the foundation due to flow acceleration in the immediate vicinity (tens of metres) of the foundation.

36. As the need for scour protection would not be determined until the wind turbine locations and the associated foundation types are known, the worst case assessments need to consider both the formation of scour holes in the absence of scour protection (and the associated fate of the scoured sea bed material) and, as a corollary, the extent of scour protection that would be required if it is deemed necessary to limit scour hole development.

37. Scour assessments have been performed using metocean data derived from earlier modelling studies (GL Noble Denton 2011) and both zone-wide and project-specific (*Appendix 7.5*) field surveys (water depth, soil type and soil strength), to enable first order estimates of scour hole formation to be made for a range of different foundation types and sizes within the envelope of that which could ultimately be considered within the East Anglia THREE site. The scour assessment methods are described in detail in *Appendix 7.3* (with appropriate references made to the full evidence base that has underpinned the methods used).

38. These assessments identified that the greatest potential for scour hole formation is associated with the conical gravity base structures. It also showed that, for a given water depth, the scour volume released is greater for a larger diameter of gravity base structure. Furthermore, the scour volume was greater under the 1 in 50 year return period condition that was considered when compared against a 1 in 1 year condition. All of the results from the scour assessments are in accord with intuitive expectations. The assessments identified that, for a given diameter of gravity base structure, the scour volumes were greatest in the shallowest water conditions considered and reduced with increasing water depth, despite the modest increases in wave conditions associated with the deeper water areas. This was primarily because of a reduction in wave-induced stirring at the sea bed in the areas of greater water depth.

39. A sample of results from the scour assessments is presented in *Table 7.6* and this shows that the worst case scenario would be if the largest diameter gravity base structure for a particular wind turbine rating (i.e. 40m for a 7MW turbine and 60m for a 12MW turbine) was installed in relatively shallow water depths (30.8m). However, only 15.6% of the East Anglia THREE site is in water depths less than 35m. Despite this, and in order to ensure a highly conservative assessment, the scour volume released under this scenario has been assumed to apply across the whole

East Anglia THREE site. In reality, the scour volume released, even from the largest diameter gravity base structure for a particular wind turbine rating, would decrease in deeper water as there would be a reduction in wave-induced stirring at the sea bed due to the increased water depth.

Table 7.6 Comparative Test of Scour Hole Development

Water Depth (m)	Basal Diameter (m)	Return Period (years)	Wave Height H_s (m)	Wave Period T_p (m)	Current U_c (m)	Scour Area (m^2)	Scour Volume V (m^3)
30.8	40	1	6.1	11.1	1.30	2,001	786
		50	7.3	12.3	1.40	2,990	3,646
30.8	50	1	6.1	11.1	1.30	2,890	1,003
		50	7.3	12.3	1.40	4,078	4,580
30.8	60	1	6.1	11.1	1.30	3,952	1,256
		50	7.3	12.3	1.40	5,336	5,573

40. It should be noted that the volumes of sediment released from sea bed preparation activities are considerably greater than the volumes released by scour even under the conservative worst case assessments, based on a 60m diameter gravity based structure in 30.8m water depth under a 1 in 50 year return period storm.

41. In keeping with the assessments of scour hole formation, it has been estimated that the footprint of scour protection material that may be required associated with the different foundation types being considered is also greatest for the conical gravity base structures (*Table 7.7*).

Table 7.7 Worst Case Assumptions for Scour Protection Footprints

Foundation Type	Turbine rating (MW)	Foundation Dimensions (m)	Scour Protection Footprint (m^2)*
Gravity base structures	7	40 (basal diameter)	10,053
	12	60 (basal diameter)	22,620
Jackets (pin piles)	7	33.5 x 33.5	1,893
	12	43.5 x 43.5	1,893
Jackets (suction buckets)	7	38 x 38	1,810
	12	50 x 50	2,827
Suction caisson	7	25 (diameter)	4,418
	12	30 (diameter)	6,362
Monopiles	7	10 (diameter)	1,964
	12	12 (diameter)	2,828

* Assumptions behind these calculations are provided in section 5.5.4.2.5 of Chapter 5 Description of the Development

42. During the decommissioning phase, worst case assumptions involve activities that are similar to those that would be encountered during the construction phase.

43. Due to the above considerations, conical gravity base structures of the upper bound diameter for each of the wind turbine ratings are considered to be the worst case for near-surface sediment disturbance effects during construction or decommissioning, blockage effects during operation and scour hole formation or, as a corollary, scour protection footprints during operation.

44. Drilling of 12m diameter monopiles to depths of 40m is considered to be the worst case for sub-surface sediment disturbance during construction.

45. A summary of the worst case assumptions for foundation types is presented in *Table 7.8*.

Table 7.8 Worst Case assumptions for foundations

Impact	Parameter	Notes
Construction		
Near-surface sediment disturbance	Conical gravity base structure	40m basal diameter for 7MW wind turbines 60m basal diameter for 12MW wind turbines
Sub-surface sediment disturbance	Monopiles	Drilled piles of up to 12m diameter to a depth of 40m below the sea bed
Operation		
Blockage of wave propagation	Conical gravity base structure	40m basal diameter for 7MW wind turbines 60m basal diameter for 12MW wind turbines
Blockage of tidal currents		
Blockage of sea bed sediment transport		
Scour hole formation		
Scour protection material footprint and volumes		

7.3.2.4 Meteorological Masts, Monitoring Buoys and Guard Buoys

46. Operational meteorological masts and LiDAR and wave monitoring and guard buoys may be installed within the proposed East Anglia THREE site.

47. There could be a minimum of zero and a maximum of two meteorological masts installed on monopiles, jackets with pin piles, jackets with suction caissons, gravity base structures or suction caisson foundations.

48. There could be a minimum of zero and a maximum of two LiDAR monitoring buoys installed, anchored to the sea bed.

49. There could be a minimum of zero and a maximum of two wave monitoring buoys installed, anchored to the sea bed.

50. There could be a minimum of zero and a maximum of 8 guard buoys

51. Anchors for all buoys listed above would be attached to the sea bed by anchors with a seabed footprint no more than 2m by 2m which would penetrate the sea bed by a depth of up to 1m.

7.3.2.5 Offshore Platforms

52. Between one and six offshore electrical platforms would be used within the East Anglia THREE site. The offshore platforms would be installed on jacket foundations with pin piles or on gravity base structures.

53. There could also be a minimum of zero and a maximum of one accommodation platform installed on a monopile, a jacket with pin piles, a jacket with suction caissons, a gravity base structure or a suction caisson foundation.

7.3.2.6 Cables

54. There would be slight differences in the cable requirements dependent on the Single Phase or Two Phased approach as shown in *Table 7.9*.

Table 7.9 Worst Case Assumptions for Cables

Cable Type	Single Phase maximum length (km)	Two Phased maximum length (km)
Inter-array	550	550
Platform links	195 (13 x 15km)	240 (15 x 15km)
Interconnection (to East Anglia ONE)	380 (4 x 95km)	380 (4 x 95km)
Export cable	664 (4 x 166km)	664 (4 x 166km)

55. For the purposes of this assessment therefore the worst case in terms of area of sea bed affected is with the Two Phased approach, where the maximum possible number of platform link cables required is greater.

56. Up to 4 export cables would each be located within the export cable corridor for the proposed East Anglia THREE project. The total length of the export cable corridor is 166km, with a total of up to 664km of export cables installed.

57. There would also be up to 4 interconnector cables located within an interconnector cable corridor extending between the East Anglia THREE site and the East Anglia ONE site. This interconnector corridor occupies some overlap with the export cable corridor. The total length of the interconnector cable corridor is 95km, with a total of up to 380km of interconnector cables installed.

58. Up to two export cables and up to two interconnector cables could be installed in each phase of the Two Phased approach should that approach be taken.

59. The total area of sea bed within the export cable corridor (alone) is 454km^2, and the total area of sea bed within the interconnector cable corridor (alone) is 238km^2. Due

to the overlap between these corridors, the total sea bed area within the export cable corridor and the interconnector cable corridor combined is 571km^2.

60. In addition, there would be up to 240km of platform link cables (under the worst case) and up to 550km of inter-array cables installed.

7.3.2.7 Cable Laying

61. It is intended that the cables of the proposed East Anglia THREE project would be buried below the surface of the sea bed to depths of 0.5 to 5.0m. The actual depths would be determined following detailed investigations and design. In some areas, where large sand waves or megaripples are present, sea bed levelling may first be required before the cable can be installed. Such levelling would only be intended to prevent exposure of the cables and the formation of free-spans. The majority of any required sand wave levelling would be in offshore areas of the export cable corridor and parts of the interconnector cable (i.e. also offshore), with only a small proportion required in the inshore section of the export cable corridor (see *Figure 7.6*).

62. Indicative installation methods and rates presently being considered are described in *Table 7.10*.

Table 7.10 Cable Installation Methods and Rates

Technique	Description	Installation Rate (m/hour)
Ploughing	Cutting through the sea bed with a blade, behind which the cable is laid	150-300
Trenching or cutting	Excavating a trench whilst temporarily placing the excavated sediment adjacent to the trench and back-filling the trench once the cable has been laid	30-80
Jetting	Fluidising the sea bed using a combination of high-flow low pressure and low-flow high pressure water jets, enabling the cable to sink beneath the sediment surface	150-450
Vertical injector	Using a large jetting or cutting share strapped to the side of a barge for cable laying at the foot of a trench in shallow waters	30-80

63. Of the above cable installation techniques, jetting is considered the worst case in terms of this assessment since it the fluidising of the sediment results in greatest suspension of sediment off the sea bed and into the water column.

64. For purposes of the EIA, a worst case assumption has been made that some form of cable protection measures would be required in areas where cable cannot be buried (e.g. areas of exposed bedrock) and at cable crossings.

65. The preferred method for cable protection would be concrete mattresses; however other methods may be used.

66. The total length of inter-array cables, platform link cables and interconnector cables being considered under a worst case (Two Phased approach) is 1,170km. In total, up to 10% of these cables would be unburied and require protection, amounting to a combined length of 117km. If it is assumed, for purposes of calculation, that the width of cable protection works is 3m (see Chapter 5 Description of the Development section 5.5.14.2), then the worst case cable protection for the inter-array cables, platform link cables and interconnector cables would have a sea bed footprint of 351,000m^2.

67. The total length of export cables being considered under a worst case (identical for Single Phase or Two Phased approach) is 664km. In total, up to 10% of these cables would be unburied and require protection, amounting to a combined length of 66.4km. If, as above, it is assumed that the width of cable protection works is 3m then the worst case cable protection for the export cables would have a sea bed footprint of 199,200m^2. This calculation represents a precautionary worst case for the assessment of footprint because in the nearshore, between the coast and the Greater Gabbard Offshore Wind Farm and Galloper Offshore Wind Farm cable crossings, 2.5% would be set as an upper limit of the length of export cable where cable protection is employed.

68. The maximum height of cable protection measures from the sea bed would range from 1 to 3m. Under a precautionary worst case, the total area of all cable protection works would be 550,200m^2 (section 5.5.14.4 Chapter 5 Description of the Development). This represents 0.06% of the total sea bed area within the East Anglia THREE site (304.8km^2) and the export cable corridor and the interconnector cable corridor combined, accounting for overlap (571km^2).

69. There would be additional cable protection requirements where either export cables, interconnector cables or platform link cables cross existing cables or pipelines. The maximum height of cable crossing protection measures from the sea bed would range from 0.9m (typically for cable crossings) to 4m (typically for pipeline crossings) (Section 5.5.14.5 Description of the Development).

70. For the export cables, crossings would be required at up to 25 locations for each of the 4 cables (a maximum of 100 crossings in total). These would particularly be in the area where the East Anglia THREE export cable corridor crosses the export cables of the Greater Gabbard Offshore Wind Farm and Galloper Offshore Wind Farm. The footprint area of cable crossings would be up to 336m^2 per crossing, or up to 33,600m^2 for the proposed East Anglia THREE project as a whole. This represents 0.007% of the total sea bed area within the export cable corridor (454km^2).

71. For the interconnection cables, cable crossings would be required at up to 16 locations (a maximum of 64 crossings in total). The footprint area of cable crossings would be up to 336m^2 per crossing, or up to 21,504m^2 for the proposed East Anglia THREE project as a whole. For the platform link cables, the worst case is that there would be up to 32 crossings required (for the Two Phased approach). The footprint area of cable crossings would be up to 336m^2 per crossing, or up to 10,752m^2 for the East Anglia THREE project as a whole. Under a worst case, the total area of interconnector and platform link cable crossings would be 32,256m^2. This represents 0.01% of the total sea bed area within the East Anglia THREE site (304.8km^2).

72. As previously discussed, for the purposes of a worst case assessment, the present assumption is that up to 10% of all inter-array cables, platform link cables, interconnector cables and export cables in locations that are to the east of the cable crossings would be unburied and require protection and that up to 2.5% of the export cables in locations to the west of the Greater Gabbard cable crossings would also require protection. Detailed pre-construction design work would be required to refine these figures and to determine locations at which burial would not be possible. The worst case values used in the assessment are intended to allow for flexibility within the DCO and are based on recent practical experience of cable installation which demonstrates that achieving 100% burial is not always possible.

73. During the construction phase, cables would be installed using a best practice approach with the objective of minimising, as far as practicable, possible effects on key receptors (e.g. marine water and sediment quality, fish and shellfish ecology, commercial fisheries, benthic ecology, etc.). A detailed cable laying plan would be developed pre-construction which incorporates a cable burial risk assessment to ascertain burial depths and cable laying techniques in accordance with the draft DCO and with the objective of achieving optimum cable burial and thereby minimising the lengths of remaining unburied cable that would require protection.

74. It is agreed that EATL would adopt a hierarchical approach to cable protection options. Cable would be buried where this can be practicably achieved. In the event

that full burial of lengths of inter-array, platform links, interconnection and export cable cannot be achieved, protection options would be assessed using a number of criteria, including the aim of selecting protection methods which would cause least disturbance to sensitive receptors. The preference for these areas would be to use mattresses unless this is not practicably achievable, in which case other alternatives would be considered.

7.3.2.8 Cable Landfall

75. The offshore export cables would make landfall at Bawdsey in Suffolk. They would then be pulled through ducts which would be installed by East Anglia One Limited (EAOL) as part of the East Anglia ONE project, through a process of horizontal directional drilling under the cliffs at Bawdsey. These ducts would be installed to depths of 3 to 10m below the sea bed and would either be by a long duct (approximately 1,100m in length) method or by a shorter duct method.

76. EATL anticipates that the cable ducts would be installed from shore with a setback distance of up to 180m from the cliff top to allow for the effects of natural coastal erosion, with duct ends buried in the sea bed up to 1,100m from the base of the cliff for the long duct, and closer inshore for the short duct. Ducts would be left within the sea bed and the cables would be installed within them and connected to offshore export cables.

77. For long duct method, a trench would be excavated using a barge based excavator or suction dredger from the duct end towards deeper water and softer sediments whereby a plough or jetting tool could be used to install the export cable further offshore.

78. For the short duct method the duct exit point would require temporary access from the cliff top to the beach area so that the end of the pre-installed duct could be excavated. This would be located in order to minimise disturbance to the Site of Special Scientific Interest (SSSI) at Bawdsey Cliffs and to avoid vegetated shingle at landfall. Access would most likely comprise a temporary ramp constructed to enable safe vehicular access down the cliff. The temporary access would be required for a tracked excavator, which would be used to prepare the exit point and make the connection with the duct.

79. Due to the approach described above, the inshore section (including the landfall) of the export cable corridor for the proposed East Anglia THREE project is common to that for the East Anglia ONE project. Suitable allowance would be made in the design of the pre-installed ducts to accommodate the predicted future rates of cliff recession and foreshore lowering throughout the operational phase. Specific

assessment of the baseline coastal characteristics and the predicted future coastal change at the landfall has been made (ABPmer 2012c; 2013) and is summarised in *Appendix 7.4*.

80. The impacts associated with the installation of the East Anglia ONE cables and the pre-installation of the ducts that would be subsequently used by the proposed East Anglia THREE project have been assessed as part of the East Anglia ONE ES. Under a worst case, the further impacts associated with the proposed East Anglia THREE project solely arise from the installation of the export cables within the pre-installed ducts. This would involve lifting the marker buoy and excavating the ends of the ducts so that the export cables can be installed. The worst case in terms of sediment disturbance would be if this was undertaken at ducts which were pre-installed using the short duct method, since the excavations for the proposed East Anglia THREE project would be required closer to shore, in shallower water.

7.3.3 Embedded Mitigation Specific to Marine Geology, Oceanography and Physical Processes

81. The proposed East Anglia THREE project would have a total capacity of 1,200MW, with between 100 (12MW) and 172 (7MW) wind turbines being present. In order to mitigate the effects on the marine geology, oceanography and physical processes, a minimum separation of 675m has been defined between adjacent wind turbines within each row and a minimum spacing of 900m has been defined between rows in order that the potential for interaction of effect between adjacent wind turbines is minimised.

82. The selection of appropriate foundation designs and sizes at each wind turbine location would be made following interpretation of geophysical and geotechnical data from within the proposed windfarm site. This would ensure that the worst case foundation types and sizes are not applied universally across the whole site, but are tailored to those areas where the physical conditions dictate their need.

83. For the foundation types that would experience the potential for greatest scour, namely gravity base structures, scour protection material is likely to be installed during the construction process in order to mitigate the effects of scour on the suspended sediment and bed level changes in the vicinity of each wind turbine location.

84. For other foundation types, where the scour potential involves lower quantities of sediment release due to scour processes, the design would, where feasible to do so, allow for local scour around the piles to minimise the footprint of ‘foreign’(scour protection) material that is introduced on the sea bed.

85. For piled foundation types, such as monopiles and jackets with pin piles, pile-driving would be used in preference to drilling where it is practicable to do so, i.e. where ground conditions allow. This would ensure that only the minimum quantity of sub-surface sediment is released into the water column from the installation process.

86. Micro-siting would be used to minimise the requirements for sea bed preparation prior to foundation installation. Gravity base structures would not be used in areas characterised by sandbanks or sand waves with heights greater than 5m in further pursuance of this aim.

87. Cables would be buried where possible, to within target depths of 0.5 to 5.0 m. The optimum depths would be determined during pre-construction engineering studies and would be detailed in Cable Specification and Installation Plan (see below). Cable burial to appropriate depths would reduce the risk of exposure of buried cable due to bed level changes, reducing the need for subsequent re-burial which would cause further disturbance to the sea bed. In addition, ensuring cable burial in areas where it is practicable to do so would minimise the requirement for cable protection measures and thus effects on sediment transport.

88. In the near shore, between the coastline and the Greater Gabbard Offshore Wind Farm and Galloper Wind Farms cable routes, where larger amounts of cable protection could adversely affect the physical processes, a limit of 2.5% would be set as an upper limit of the length of cable where cable protection is employed.

89. A Cable Specification and Installation Plan, would be agreed with the relevant authorities post application. This plan would include a detailed cable laying plan for the Order limits, incorporating a burial risk assessment to ascertain suitable burial depths and cable laying techniques, including cable protection.

7.4 Assessment Methodology

7.4.1 Legislation, Policy and Guidance

90. The NPS of direct relevance to this chapter are:

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

91. With regard to the physical environment, EN-3 states that *geotechnical investigations should form part of the assessment as this will enable design of appropriate construction techniques to minimise and adverse effects* (Paragraph 2.6.193). *The assessment should include predictions of 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 (Paragraph 2.6.194).

92. With regards to coastal change, EN-1 states that *where relevant, applicants should undertake coastal geomorphological and sediment transfer modelling to predict and understand impacts and help identify relevant mitigating or compensatory measures* (Paragraph 5.5.6). EN-1 sets out (Paragraph 5.5.7) that *the ES 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) … and any relevant Marine Plans*[1] *… and capital programmes for maintaining flood and coastal defences.*
- *The effects of the proposed project on marine ecology, biodiversity and protected sites.*
- *The effects of the proposed project on maintaining coastal recreation sites and features.*
- *The vulnerability of the proposed development to coastal change, taking account of climate change, during the project's operational life and any decommissioning period.*

93. EN-1 (Paragraph 5.5.9) states that *the applicant should be particularly careful to identify any effects of physical changes on the integrity and special features of Marine Conservation Zones, candidate marine Special Areas of Conservation (SACs), coastal SACs and candidate coastal SACs, coastal Special Protection Areas (SPAs) and potential SCIs and Sites of Special Scientific Interest (SSSI).*

94. With regard to the sub-tidal environment, EN-3 (Paragraph 2.6.113) states that *where necessary, assessment of the effects on the sub-tidal environment should include:*

[1] Objective 10 of the East Inshore and East Offshore Marine Plans is "*To ensure integration with other plans, and in the regulation and management of key activities and issues, in the East Marine Plans, and adjacent areas*" this therefore refers back to the objectives of the SMPs

- *Loss of habitat due to foundation type including associated sea bed preparation, predicted scour, scour protection and altered sedimentary processes.*
- *Environmental appraisal of inter-array and cable routes and installation methods.*
- *Habitat disturbance from construction vessels extendible legs and anchors.*
- *Increased suspended sediment loads during construction.*
- *Predicted rates at which the sub-tidal zone might recover from temporary effects.*

95. With regards the inter-tidal environment, EN-3 (Paragraph 2.6.81) states that *an assessment of the effects of installing cable across the inter-tidal 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 of the final choice.*
- *Any alternative cable installation methods that have been considered by the applicant during the design phase and an explanation of the final choice.*
- *Potential loss of habitat.*
- *Disturbance during cable installation and removal (decommissioning).*
- *Increased suspended sediment loads in the inter-tidal zone during installation.*
- *Predicted rates at which the inter-tidal zone might recover from temporary effects.*

96. EN-1 (Section 4.8) advises that *the resilience of the project to climate change should be assessed in the ES accompanying an application*.

97. The Marine Policy Statement (MPS, HM Government 2011) provides the high-level approach to marine planning and general principles for decision making that contribute to achieving this vision. It also sets out the framework for environmental, social and economic considerations that need to be taken into account in marine planning. With regard to the topics covered by this chapter the key reference is in section 2.6.8.6 which states:

"…Marine plan authorities should not consider development which may affect areas at high risk and probability of coastal change unless the impacts upon it can be managed. Marine plan authorities should seek to minimise and mitigate any geomorphological changes that an activity or development will have on coastal processes, including sediment movement."

98. With regard to the East Inshore and East Offshore Marine Plans (HM Government 2014) Objective 6 "*To have a healthy, resilient and adaptable marine ecosystem in the East Marine Plan areas*" is of relevance to this Chapter as this covers policies and commitments on the wider ecosystem, set out in the MPS including those to do with the Marine Strategy Framework Directive and the Water Framework Directive (see Chapter 3 Policy and Legislative Context, as well as other environmental, social and economic considerations. Elements of the ecosystem considered by this objective include "*coastal processes and the hydrological and geomorphological processes in water bodies and how these support ecological features".*

99. In addition to NPS, MPS and East Inshore and East Offshore Marine Plans, guidance on the generic requirements, including spatial and temporal scales, for physical process studies associated with offshore windfarm developments is provided in seven main documents:

- 'Offshore windfarms: guidance note for Environmental Impact Assessment in respect of Food and Environmental Protection Act (FEPA) and Coast Protection Act (CPA) requirements: Version 2' (Cefas 2004).
- 'Guidance on Environmental Impact Assessment in Relation to Dredging Applications' (Office of the Deputy Prime Minister 2001).
- 'Coastal Process Modelling for Offshore Windfarm Environmental Impact Assessment' (COWRIE 2009).
- 'Review of Cabling Techniques and Environmental Effects applicable to the Offshore Windfarm Industry' (BERR 2008).
- 'General advice on assessing potential impacts of and mitigation for human activities on Marine Conservation Zone (MCZ) features, using existing regulation and legislation' (Joint Nature Conservation Committee (JNCC) & Natural England 2011).
- 'Guidelines for data acquisition to support marine environmental assessments of offshore renewable energy projects' (Cefas 2011).

- 'East Inshore and East Offshore Marine Plan Areas: Evidence and Issues' (MMO 2012).

7.4.2 Data Sources

100. The baseline understanding presented in *Appendix 7.2* and summarised in section 7.5 and the assessment of effects presented in section 7.6 have been informed by a number of useful data and information sources.

101. These include a series of previous surveys and studies, including numerical modelling studies, which were undertaken to inform the ZEA (GL Noble Denton 2011; ABPmer 2012a; Deltares 2012) and the ES for the East Anglia ONE project (ABPmer 2012b). Specific assessments have also previously been undertaken at the location of the landfall of the export cable corridor to characterise the shoreline (ABPmer 2012c) and assess coastal changes over time (ABPmer 2013).

102. Further project-specific surveys have been undertaken to inform the proposed East Anglia THREE project. Details are provided in *Table 7.11*.

Table 7.11 Data Sources

Data	Year	Coverage	Confidence	Notes
Geophysical Survey	Oct 2010	East Anglia Zone (partial)	High	High-resolution swath bathymetric survey.
Geophysical Survey	June – Sept 2012	East Anglia THREE site	High	High-resolution sea bed bathymetry, sea bed texture and morphological features, and shallow geology using multi-beam echo sounder, side-scan sonar and sparker and pingers.
Geophysical Survey	July - Oct 2012 Aug – Sept 2014	East Anglia THREE / FOUR cable corridor (additional survey in 2014 to widen the cable corridor at a known pinch point)	High	High-resolution sea bed bathymetry, sea bed texture and morphological features, and shallow geology using multi-beam echo sounder, side-scan sonar and sparker and pingers.
Geophysical Survey	Oct 2011 - Feb 2012	East Anglia ONE cable corridor (including shared inshore section with East Anglia THREE / FOUR)	High	High-resolution sea bed bathymetry, sea bed texture and morphological features, and shallow geology using multi-beam echo sounder, side-scan sonar and sparker and pingers.
Metocean Survey	Dec 2012 – Dec 2013	East Anglia THREE site	High	Acoustic Wave and Current (AWAC) meter and Directional Wave Rider (DWR) buoy

Data	Year	Coverage	Confidence	Notes
				deployed. Sediment grab samples, Water samples and Turbidity measurements.
Metocean Survey	Jan 2011 – Jan 2012	East Anglia ONE site (for wider context)	High	Directional Wave Rider (DWR) buoy deployed
ADCP Spring tidal data	September 2013	East Anglia THREE site	High	Tidal velocity and direction through the water column
ADCP Neap tidal data	July 2013	East Anglia THREE site	High	Tidal velocity and direction through the water column
Grab Sample Survey	September 2010 to January 2011	East Anglia Zone	High	Grab samples at selected sites (48 no. within the proposed East Anglia THREE site)
Grab Sample Survey	April – May 2013	East Anglia THREE site and offshore cable corridor	High	Grab samples (5 no. within the windfarm site and 47 no. within offshore cable corridor)
Geotechnical Survey	August 2010	East Anglia Zone	High	Boreholes at selected sites across the zone

7.4.3 Impact Assessment Methodology

103. In order to meet the requirements of the guidance documents stated in section 7.4.1, the assessment approach has adopted the following stages, as described further in *Appendix 7.1*:

- Review of existing relevant data;
- Acquisition of additional project-specific data to fill any gaps;
- Formulation of a conceptual understanding of baseline conditions;
- Consultation and agreement with the regulators regarding proposed assessment approaches;
- Determination of the worst case assumptions;
- Consideration of embedded mitigation measures; and
- Assessment of effects using analytical tools, empirical methods, results from previous numerical modelling and expert based judgements.

104. The assessment of effects on the marine geology, oceanography and physical processes is predicated on a source-pathway-receptor (S-P-R) conceptual model, whereby:

- The source is the initiator event;
- The pathway is the link between the source and the receptor impacted by the effect; and
- The receptor is the receiving entity.

105. An example of the S-P-R conceptual model is provided by cable installation which disturbs sediment from the sea bed (source). This sediment is then transported by tidal currents until it settles back to the sea bed (pathway). The deposited sediment could change the composition and topography of the sea bed (receptor).

106. Consideration of the potential effects of the proposed East Anglia THREE project on the marine geology, oceanography and physical processes receptors is required over the following spatial scales:

- Near-field (i.e. the area within the immediate vicinity (tens or hundreds of meters) of the windfarm site and along the offshore cable corridor); and
- Far-field (i.e. the wider area that might also be affected indirectly by the project, e.g. due to disruption of waves, tides or sediment pathways passing through the site).

107. There are three main phases of development that have been considered, in conjunction with the present-day baseline, over the life-cycle of the proposed East Anglia THREE project, namely:

- Construction phase (up to 41 months duration);
- Operation phase (up to 25 years duration and including all operation and maintenance activities); and
- Decommissioning phase (up to 2 years duration).

108. A brief description of each phase is summarised in the following sub-sections.

7.4.3.1 Baseline (Pre-existing Conditions)

109. The baseline conditions represent the ranges and interactions of naturally occurring physical processes and morphological responses, both prior to the installation of any windfarm infrastructure and over the lifetime of the windfarm, in the absence of the

proposed infrastructure. The baseline also reflects an on-going history of human use of the area for a range of activities principally fishing. Accordingly, the potential effects of natural dynamism and climate change are also considered as part of the baseline conditions. For instance, it is generally anticipated that climate change will result in global scale effects which will be represented at regional scales by rising mean sea level.

7.4.3.2 Construction Phase

110. Impacts upon the hydrodynamic regime, as a consequence of the construction phase, are typically only likely to be associated with the presence of engineering equipment, for example, jack-up barges placed temporarily on site to install the wind turbine structures. As such, equipment is only likely to be positioned at one site at a time for a relatively short duration (of the order of days), the consequential effects upon the hydrodynamic regime are deemed to be small in magnitude and localised in both temporal and spatial extent.

111. The greatest potential impacts during the construction phase are likely to be upon suspended sediment concentrations and consequential sediment deposition arising from sea bed disturbance during installation activities or cable laying processes. However, impacts are mainly expected to arise only locally around the source of the effect and persist for short time scales (order of hours to days) during the construction period.

112. As EATL is currently considering constructing the project in either a Single Phase or in a Two Phased approach, both scenarios have been considered during the Construction Phase. Under the Single Phased approach the project would be constructed in one single build period and under a Two Phased approach the project would be constructed in two phases each consisting of up to 600MW. Indicative programmes for both Single Phase and Two Phased approaches are shown in *Tables 5.34* and *5.37* of Chapter 5 Description of the Development. In summary, the offshore components of the Single Phase construction would last for 41 months, with the offshore components of the Two Phased construction lasting for 42 months (due to an overlap between the two construction phases under this approach).

7.4.3.3 Operation Phase

113. Impacts upon the hydrodynamic and sediment regimes as a consequence of maintenance activities during the operation phase are typically only likely to be associated with the presence of engineering equipment, for example, jack-up barges or anchored vessels placed temporarily on site to maintain the wind turbine structures. As such, equipment is only likely to be positioned at one site at a time for a relatively short duration (of the order of hours to days), the consequential effects

upon the hydrodynamic regime are deemed to be low in magnitude being localised in both temporal and spatial extent.

114. The greatest potential impacts during the operation phase are likely to be associated with the physical presence of the wind turbine foundation structures throughout its operational life-cycle. The East Anglia THREE site covers approximately 305km^2 of sea bed within which the wind turbines would be installed. During the operational phase, effects due to the presence of the foundation structures have the potential to be larger in magnitude and in temporal and spatial extents than during other phases of the proposed East Anglia THREE project life-cycle.

115. Potential effects on the tidal regime associated with the presence of the foundations may include changes to the naturally occurring patterns of tidal water levels, current speeds and directions.

116. Potential effects on the wave regime associated with the presence of the foundations may include changes to the naturally occurring wave heights, periods and directions.

117. Potential effects on the sediment regime associated with the presence of the foundations may occur as a result of the changes to the tidal and wave climate, as described above, potentially manifesting as:

- The alteration of suspended and / or bed load sediment transport pathways within both the near- and far-fields;
- Scour around the wind turbine foundations and / or the cables, with the potential for the eroded material to be transported away from the East Anglia THREE site; and
- Changes to the sediment transport processes along adjacent coastlines due to landfall of the offshore cable.

7.4.3.4 Decommissioning Phase

118. On expiry of the lease, there is a statutory requirement for EATL to decommission the proposed East Anglia THREE project. Should EATL wish to consider re-powering the windfarm at this time, this would be subject to a new consent.

119. The scope of the decommissioning works would be determined by the relevant legislation and guidance at the time of decommissioning and would most likely involve removal of the accessible installed components including scour and cable protection. Offshore, this is likely to include all of the wind turbine components,

part of the foundations (those above sea bed level) and the sections of the inter-array cables close to the offshore structures.

120. With regards to offshore cables, general UK practice would be followed, i.e. buried cables would simply be cut at the ends and left *in situ*, with the exception of the inter-tidal zone across the beach where the cables would otherwise be at risk of becoming exposed over time.

121. After decommissioning, the East Anglia THREE site is expected to return to its baseline condition, allowing for some measure of climate change and within the range of natural variability.

7.4.3.5 Impact Assessment Methodology

122. In Chapter 6 EIA Methodology, a method is presented for enabling assessments of the potential impacts arising from the proposed East Anglia THREE project on the receptors under consideration. Such assessments incorporate a combination of the sensitivity of the receptor, its value (if applicable) and the magnitude of the change to determine a significance of impact.

123. For the effects on marine geology, oceanography and physical processes a number of discrete receptors can be identified. These include certain morphological features with ascribed inherent values, such as:

- Offshore sandbanks – these morphological features play an important role in influencing the baseline tidal, wave and sediment transport regimes; and
- Beaches and sea cliffs - these morphological features play an important natural coastal defence role at the shoreline.

124. However, in addition to identifiable receptors, there are other changes to the marine geology, oceanography and physical processes which may potentially be caused by the proposed East Anglia THREE project which in themselves are not necessarily impacts to which significance can be ascribed. Rather, these changes (such as a change in the wave climate, a change in the tidal regime or a change in the suspended sediment concentrations in the water column) represents an 'effect' which may manifest itself as an impact upon other receptors, most notably water quality, benthic ecology, fisheries or navigation (e.g. in terms of increased suspended sediment concentrations or erosion or smothering of habitats on the sea bed).

125. To this end, the assessment presented in this chapter follows two approaches. The first assessment approach is designed for situations where potential impacts can be defined as directly affecting receptors which possess their own intrinsic

morphological value. In this case, the determination of significance of the impact is based on an assessment of sensitivity of the receptor (see section 7.4.4.1) and magnitude of effect (see section 7.4.4.2) by means of an impact significance matrix (see section 7.4.4.3).

126. The second assessment approach is designed for situations where effects (or changes) in the baseline marine geology, oceanography or physical processes conditions may occur which could potentially manifest as impacts upon receptors other than marine geology, oceanography and physical processes. In this case, the magnitude of effect is determined in a similar manner to the first assessment method (see section 7.4.4.2) but the assessment of sensitivity of the other receptors and the significance of impacts on those other receptors is made within the relevant chapters of this ES pertaining to those receptors.

7.4.3.6 Sensitivity and Value

127. The sensitivity of a receptor is dependent upon its:

- *Tolerance* to an effect (i.e. the extent to which the receptor is adversely affected by a particular effect);
- *Adaptability* (i.e. the ability of the receptor to avoid adverse impacts that would otherwise arise from a particular effect); and
- *Recoverability* (i.e. a measure of a receptor's ability to return to a state at, or close to, that which existed before the effect caused a change).

128. In addition, a *value* component may also be considered when assessing a receptor. This ascribes whether the receptor is rare, protected or threatened.

129. The sensitivity and value of discrete morphological receptors have been assessed using expert judgement and described with a standard semantic scale. Definitions for each term are provided in *Table 7.12* and *Table 7.13*. These expert judgements regarding receptor sensitivity are closely guided by the conceptual understanding of baseline conditions presented in detail in *Appendix 7.2*, which is also summarised in section 7.5.

Table 7.12 Definitions of the Different Sensitivity Levels for a Morphological Receptor

Sensitivity	Definition
High	Tolerance: Receptor has very limited tolerance of effect. Adaptability: Receptor unable to adapt to effect. Recoverability: Receptor unable to recover resulting in permanent or long-term (>10 years) change.
Medium	Tolerance: Receptor has limited tolerance of effect Adaptability: Receptor has limited ability to adapt to effect. Recoverability: Receptor able to recover to an acceptable status over the medium term (5-10 years).
Low	Tolerance: Receptor has some tolerance of effect. Adaptability: Receptor has some ability to adapt to effect. Recoverability: Receptor able to recover to an acceptable status over the short term (1-5 years).
Negligible	Tolerance: Receptor generally tolerant of effect. Adaptability: Receptor can completely adapt to effect with no detectable changes. Recoverability: Receptor able to recover to an acceptable status near instantaneously (<1 year).

Table 7.13 Definitions of the Different Value Levels for a Morphological Receptor

Value	Definition
High	Value: Receptor is designated and/or of national or international importance for marine geology, oceanography or physical processes. Likely to be rare with minimal potential for substitution. May also be of significant wider-scale, functional or strategic importance.
Medium	Value: Receptor is not designated but is of local to regional importance for marine geology, oceanography or physical processes.
Low	Value: Receptor is not designated but is of local importance for marine geology, oceanography or physical processes.
Negligible	Value: Receptor is not designated and is not deemed of importance for marine geology, oceanography or physical processes.

7.4.3.7 Magnitude

130. The magnitude of an effect is dependent upon its:

- *Scale (i.e. size, extent or intensity);*
- *Duration;*
- *Frequency of occurrence; and*
- *Reversibility (i.e. the capability of the environment to return to a condition equivalent to the baseline after the effect ceases).*

131. The magnitude of effect has been assessed using expert judgement and described with a standard semantic scale. Definitions for each term are provided in *Table 7.14*. These expert judgements regarding magnitude of effect are closely guided by the conceptual understanding of baseline conditions presented in detail in *Appendix 7.2*, which is also summarised in section 7.5.

Table 7.14 Example Definitions of the Magnitude Levels for Physical Processes Effects

Magnitude	Definition
High	Scale: A change which would extend beyond the natural variations in background conditions. Duration: Change persists for more than 10 years. Frequency: The effect would always occur. Reversibility: The effect is irreversible.
Medium	Scale: A change which would be noticeable from monitoring but remains within the range of natural variations in background conditions. Duration: Change persists for 5-10 years. Frequency: The effect would occur regularly but not all the time. Reversibility: The effect is very slowly reversible (5-10 years).
Low	Scale: A change which would barely be noticeable from monitoring and is small compared to natural variations in background conditions. Duration: Change persists for 1- 5 years. Frequency: The effect would occur occasionally but not all the time. Reversibility: The effect is slowly reversible (1- 5 years).

Magnitude	Definition
Negligible	Scale: A change which would not be noticeable from monitoring and is extremely small compared to natural variations in background conditions. Duration: Change persists for <1 year. Frequency: The effect would occur highly infrequently. Reversibility: The effect is quickly reversible (<1 year).

7.4.3.8 Impact Significance

132. Following the identification of receptor sensitivity and value, and magnitude of the effect, it is possible to determine the significance of the impact. A matrix is presented in *Table 7.15* as a framework to show how a judgement of the significance of an impact has been reached.

Table 7.15 Impact Significance Matrix

	Magnitude				
Sensitivity & Value	**High**	**Medium**	**Low**	**Negligible**	**No change**
High	**Major**	**Major**	**Moderate**	**Minor**	**No Impact**
Medium	**Major**	**Moderate**	**Minor**	**Negligible**	**No Impact**
Low	**Moderate**	**Minor**	**Minor**	**Negligible**	**No Impact**
Negligible	**Minor**	**Negligible**	**Negligible**	**Negligible**	**No Impact**

133. Through use of this matrix, an assessment of the significance of an impact can be made in accordance with the definitions in *Table 7.16*.

Table 7.16 Impact Significance Definitions

Impact Significance	Definition
Major	Very large or large change in receptor condition which is likely to be an important consideration at a national or regional level.
Moderate	Intermediate change in receptor condition, which is likely to be an important consideration at a local level.
Minor	Small change in receptor condition, which may be raised as a local issue but is unlikely to be important in the decision making process.
Negligible	No discernible change in receptor condition.
No Impact	No change in receptor condition.

134. It should be noted that impacts may be deemed as being either positive (beneficial) or negative (adverse).

135. For the purposes of the EIA, 'major' and 'moderate' impacts are deemed to be significant. In addition, whilst 'minor' impacts are not significant in their own right, they may contribute to significant impacts cumulatively or through interactions.

136. Embedded mitigation (as previously described in section 7.3.3) has been referred to and included in the initial assessment of significance of an impact. If an identified impact requires further mitigation then the residual impact is evaluated. If no further mitigation is required, or is unlikely to have a positive ameliorating effect or if no further mitigation is practicably achievable, then the assessment of significance of an impact would remain as the initial assessment.

7.4.4 Cumulative Impact Assessment

137. Cumulative impacts have been assessed through consideration of the extent of influence of changes or effects upon marine geology, oceanography and physical processes arising from the proposed East Anglia THREE project alone and those arising from the proposed East Anglia THREE project cumulatively or in combination with other offshore windfarm developments (particularly the East Anglia ONE project but also giving consideration to the offshore cables crossing those for Greater Gabbard Offshore Wind Farm and Galloper Offshore Wind Farm) and other nearby sea bed activities, including marine aggregate extraction and marine disposal.

138. The cumulative impact assessment draws from findings of earlier studies undertaken to inform the East Anglia ZEA (ABPmer 2012a) which considered cumulative effects arising from development of the whole zone and the ES for the East Anglia ONE

project (ABPmer 2012b) which considered cumulative effects from that project and marine aggregate extraction activities in close proximity to the export cable corridor.

7.4.5 Transboundary Impact Assessment

139. Transboundary impacts have been assessed through consideration of the extent of influence of changes or effects and their potential to impact upon marine geology, oceanography and physical processes receptor groups that are located within other European Union (EU) member states.

140. Transboundary impacts were considered in the Scoping Report and it was concluded that "transboundary impacts are unlikely to occur or are unlikely to be significant." (EAOL 2012a). This statement is supported by the assessments that have been made in the East Anglia Zonal Environmental Appraisal (ABPmer 2012a), the Environmental Statement of the East Anglia ONE project (ABPmer 2012b) as well as this document.

7.5 Existing Environment

141. The baseline physical environment of the sea bed within and adjacent to the proposed East Anglia THREE project, covering both the East Anglia THREE site and the offshore cable corridor, has been characterised in detail in *Appendix 7.2*.

142. The baseline physical environment of the shoreline in the vicinity of the landfall of the offshore cable corridor has been characterised in detail in *Appendix 7.4*.

143. This section provides an overview of the key information from the assessment of the existing physical environment.

144. Given the extensive work that has previously been undertaken to characterise the baseline physical environment across the East Anglia Zone, the approach taken in the proposed East Anglia THREE project has been to:

- Review existing relevant data and reports from across the East Anglia Zone;
- Acquire additional data to fill any gaps, specific to the proposed East Anglia THREE project; and
- Formulate a conceptual understanding of the baseline physical environment, specific to the proposed East Anglia THREE project.

145. It is important to recognise from the outset that the baseline physical environment is not static, but instead will exhibit considerable variability due to cycles or trends of natural change. These can include the short-term effects of storms and surges, the well-observed patterns in the movement of tides during spring and neap cycles and

the longer term effects of sea-level rise associated with global climate change, for example.

7.5.1 Data and Information Sources

146. Considerable existing data and information has previously been collated, analysed and interpreted to inform the East Anglia ZEA (ABPmer 2012a) and the EIA of the East Anglia ONE project (ABPmer 2012b).

147. Numerical modelling of waves, tidal currents and sediment plumes was also undertaken to inform the earlier ZEA and EIA studies (GL Noble Denton 2011; ABPmer 2012a; 2012b; Deltares 2012) and this information has provided useful input to characterisation of the existing environment.

148. Specific investigations have also been made at the landfall of the offshore cable corridor for East Anglia THREE to characterise the shoreline (ABPmer 2012c) and the changes in sea bed and shoreline over time (ABPmer 2013).

149. To inform the proposed East Anglia THREE project, further metocean, geophysical and grab sample surveys have been undertaken. These surveys are summarised in the earlier *Table 7.11*.

7.5.2 Bathymetry and Morphology

150. Water depths within the East Anglia THREE site vary from a maximum depth of 49m below LAT across the western part of the project site to a minimum depth of 25m below LAT on the crest of a sand ridge in the centre of the project site (*Figure 7.2*).

151. The bathymetry is dominated by a series of three north-south oriented sand ridges with widths of 2 to 3km and heights of up to 17m above the surrounding sea bed. Smaller bedforms, including sand waves (greater than 2m high), megaripples (less than 2m high) and sand ribbons, are present throughout the East Anglia THREE site.

152. Asymmetric sand waves occur across approximately 50% of the sea bed of the East Anglia THREE site. Where they are present along the tops of the sand ridges, their crests are oriented predominantly northwest to southeast. In deeper locations, the crests are oriented more west to east. The sand waves have wavelengths of 200 to 300m and heights of 2 to 7m and their flanks are generally covered by megaripples.

153. Megaripples are common throughout the site. They have typical wavelengths of 5 to 20m and heights of 0.3 to 2m and their crests are oriented west to east.

154. Sand ribbons are occasional bedforms aligned south-southwest to north-northeast. They have widths of 20 to 100m and heights of about 0.5 to 1.5m and may be covered in megaripples or occasional sand waves. Sand ribbons form in areas where

tidal currents are strong. They are located across the deeper parts of the East Anglia THREE site where sand is less abundant.

155. Example images from the geophysical survey of the sand ridges, sand waves, megaripples and sand ribbons can be seen in *Appendix 7.2 Diagram 7.2.1.*

156. Areas where steep sand waves (with slopes greater than 10°) occur have also been identified and are displayed in *Figure 7.6*. The majority of these occur in the offshore sections of the offshore cable corridor and within the southern and Eastern parts of the East Anglia THREE site.

7.5.3 Geology

157. The geology of the East Anglia THREE site comprises three geological formations; in ascending order (older to younger) these are the Pleistocene Yarmouth Roads Formation comprising 0 to 100m thick riverine sands and channel infills, overlain by the 5 to 10m thick mud of the Pleistocene Brown Bank Formation, topped by 0 to 20m of Holocene sand.

158. The Holocene sands vary in thickness from several tens of metres beneath tidal sand ridges and sand waves to a thinner veneer in deeper areas. The sand is marine and predominantly fine to medium grained with local laminae of mud.

7.5.4 Water Levels

159. Marine water levels are predominantly governed by astronomical effects but can also be significantly influenced (elevated or depressed) by meteorological influences and surge effects.

7.5.4.1 Astronomical Tidal Levels

160. The East Anglia THREE site is located only 10km (at its closest point) to the northwest of an amphidromic point[2] that is positioned just outside the central, eastern boundary of the East Anglia Zone (*Figure 7.3*).

161. Due to this, the tidal range across the windfarm area is relatively low. At the amphidromic point, the tidal range is near zero. Tidal range then increases with radial distance from this point.

162. The tidal range increases towards shore along the export cable corridor. At the shore it reaches a value of 3.6m on mean spring tides at Harwich (located approximately 7km to the southwest of the cable landfall).

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[2] Amphidromic points are locations at which the tidal rise and fall is zero; patterns of high and low tides rotate around these points.

7.5.4.2 Non-tidal Water Levels

163. The North Sea is particularly susceptible to storm surges and water levels can become elevated between 1.5 and 1.7m above astronomical tidal levels during a 1 in 1 year return period surge event, and between 2.3 and 2.5m during a 1 in 100 year return period surge event (GL Noble Denton 2011).

7.5.4.3 Climate Change

164. Due to global climate change and local land level changes, mean sea level at the shore is expected to be between 19 and 27cm higher by 2050 than 1990 values (Lowe et al. 2009).

165. Climate change is projected to have an insignificant effect on the height of storm surges over the lifetime of the proposed project (Lowe et al. 2009), although there is generally expected to be an increase in their frequency of occurrence.

7.5.5 Currents

166. Current speeds and directions are largely dictated by an astronomically-driven tidal signal, but can also be affected (strengthened, weakened or realigned) by meteorological influences or surge effects.

7.5.5.1 Tidal Currents

167. *Figure 7.4* depicts the tidal ellipses across the East Anglia Zone.

168. Current data measured within the East Anglia THREE site (described in *Appendix 7.*2) show that the majority of the currents flow along a north of northeast to south of southwest aligned axis.

169. The near-surface current speeds are generally below 1m/s, except at the peak of spring tides or during surges when they can exceed this value. During neap tides, peak currents range between 0.5 - 0.6m/s.

7.5.5.2 Non-tidal Currents

170. In addition to astronomical tidal influences, current patterns can become modified for short durations due to other processes, such as meteorological conditions and stratification in the water column.

171. Storm surges can elevate currents by up to 0.4m/s during a 1 in 50 year return period event, typically orientated in a south of south-westerly direction (GL Noble Denton 2011).

7.5.6 Wind and Wave Regimes

172. The wind regime is important in generating local wind waves. The dominant wind direction is from the southwest.

173. Wave data measured within the East Anglia THREE site (described in *Appendix 7.2*) show that a high percentage of the waves arrive from the southwest, in keeping with the predominant wind direction. A significant grouping of waves also arrive from the northeast, as a result of swell waves generated further afield in the North Sea. Waves can, however, approach from all directions.

174. During the East Anglia THREE metocean survey, the minimum significant wave height recorded was 0.18m, with a maximum significant wave height of 6.03m. The mean significant wave height was 1.27m.

175. Extreme return period wave data within the East Anglia THREE site show a 1 in 1 year return period significant wave height of 6.0m with an associated peak wave period of 11.1s. Under a 1 in 50 year return period, the corresponding values increase to 7.5m and 12.5s, respectively.

176. Closer to shore, along the export cable corridor, water depths reduce and wave effects become more important in governing sediment transport. At shallow water locations off the East Anglian coast, waves are a combination of short period wind-generated waves, which generally reveal a predominant wave direction from the east, and longer-period swell waves. Both wave types can be influential in mobilising sediment. Along the East Anglian shore itself the wave energy varies significantly and in places is heavily influenced by the sheltering effect of nearshore sandbanks.

7.5.6.1 Climate Change

177. Climate projections indicate that wave heights in the southern North Sea will increase by up to 0.05m by 2100.

7.5.7 Sediment Regime

7.5.7.1 Surface Sediments

178. The sea bed across the East Anglia THREE site is characterised predominantly by sand, with some muddy sand. This is supported by the types of bedforms (sand waves, megaripples, sand ridges) that are present. The areas of muddy sand are in deeper areas and correlate with locations where the surficial sediments are a thin veneer and the underlying muddy Brown Bank Formation is close to sea bed. At these locations bedforms are absent.

179. The median sediment grain size (d_{50}) of a series of grab samples ranges from 0.21 to 0.36mm (medium sand) with a single sample containing a d_{50} of 0.07mm (very fine sand).

180. The sea bed in the area around the offshore cable corridor (export cable and interconnector cable corridor) is predominantly sand. The median sediment grain size (d_{50}) of a series of grab samples mostly ranges from 0.23 to 0.50mm (medium sand) with a small number of samples with a d_{50} in the coarse sand or very fine sand classes.

7.5.7.2 Bedload Transport Pathways

181. Sediment transport pathways across the East Anglia Zone have been extensively investigated in previous studies (e.g. HR Wallingford et al. 2002) and through analysis of the orientation of bedforms.

182. Within the East Anglia THREE site, the steeper slopes of the sand waves face to the north or northeast indicating a migration direction, and hence sediment transport, to the north or northeast.

7.5.7.3 Suspended Sediments

183. Measurements of suspended particulate matter (SPM) within the proposed East Anglia THREE site showed concentrations of 3 - 13.5mg/l throughout the winter of 2012/13.

184. The pattern of SPM in the water column within the East Anglia THREE site mirrors the governing wave climate, with only a modest modulation due to tidal current speeds alone.

185. Suspended sediment concentrations nearer the coast can be greater and values up to 170mg/l have been recorded in the vicinity of the coast at Great Yarmouth (ABPmer 2012a). This provides a natural background context for the assessment of effects of any temporary increases in suspended sediment concentrations that may arise due to the proposed development.

7.5.7.4 Littoral (Shoreline) Transport Pathways and Coastal Erosion

186. The northern extent of the export cable corridor for the proposed East Anglia THREE project is coincident with a promontory in the shoreline at East Lane, Bawdsey. This forms a partial barrier to sediment moving south within the littoral zone from Hollesley Bay further north. The defended promontory at East Lane also exerts an artificial control on the planform evolution of the shore further south.

187. The Bawdsey foreshore consists of London Clay overlain by marine gravel and sand beaches (ABPmer 2012c). The low cliffs are pre-glacial Crag deposits, mainly composed of sand and gravel, and represent a small source of sediment to the coast to the south (ABPmer 2012c). There is a net southerly transport of sediment along

the shore, but cross-shore transport from the shore to the nearshore zone is also important (Royal Haskoning 2010).

188. There is a large, nearshore, shingle bank system which forms the ebb-tide delta at the mouth of the River Deben estuary. This system is called The Knolls and is a function of the longshore sediment supply from the north which interacts with the flow in and out of the estuary. Periodically, there are changes in the position and form of the banks, driven by storm waves (Burningham and French 2006).

189. The Knolls are important features in forming a large, temporary, sink for sediment (which at other times can also be a source of sediment to frontages south of the estuary, depending on the prevailing conditions). The banks also act to modify wave action (reduce wave heights and alter wave transformation processes to shore) and in doing so influence sediment transport at the mouth of the estuary (HR Wallingford et al. 2002).

190. Along the East Anglian coastline, longshore transport is generally to the south, although localised departures from this trend are apparent at the mouths of estuaries (Royal Haskoning 2010). Seaward of approximately the 20m isobath, even large wave heights or long wave periods have a very limited influence on the sea bed processes.

191. The coasts to the north and south of the landfall location for the proposed East Anglia THREE project are generally eroding and this erosion is likely to increase in the future with sea-level rise.

192. The shoreline management policy over the lifetime of the proposed East Anglia THREE project at East Lane, Bawdsey and to the south of the Deben Estuary is to “Hold the line of existing defences” (Royal Haskoning 2010). This is likely to lead to erosion of the foreshore seaward of the defence structures, with foreshore steepening and a loss of beach material.

193. At Bawdsey cliffs, where the export cable corridor landfall is located, the shoreline management policy is “No Active Intervention” (Royal Haskoning, 2010). As the shingle beach becomes depleted, it is likely to lead to erosion of the backing cliffs. These cliffs are currently relatively stable with only occasional slumping, which can occur during notable storm events.

194. A highly conservative upper bound of retreat of the Bawdsey cliffs over the 25 year operational lifetime of the proposed East Anglia THREE project is 100m, at an average rate of 4m per year (ABPmer 2013). A similarly conservative estimate of the changes in the intertidal and sub-tidal exposures of London Clay at Bawdsey is

lowering of the shore platform by up to 0.75m during the 25 year operational lifetime of the proposed East Anglia THREE project (ABPmer 2013). It is recognised that measureable change in the cliff position and foreshore level occurred during the winter storms of December 2013, but these events were exceptional in their magnitude and frequency of occurrence. The values presented as the conservative upper bound of cliff retreat and shore platform lowering are based on longer term average rates of change that take into consideration periods of relative stability and more notable changes associated with individual storm events. Therefore, these values remain representative of the longer term rates of change at the landfall over the operational lifetime of the proposed East Anglia THREE project.

7.6 Potential Impacts

195. The principal receptors with respect to the topic of marine geology, oceanography and physical processes are those features with an inherent geological or geomorphological value or function which may potentially be affected by the proposed East Anglia THREE project, namely:

- Offshore sandbanks and reefs – these morphological features play an important role in influencing the baseline tidal, wave and sediment transport regimes and, potentially, in sheltering the shoreline; and
- Beaches, dunes and sea cliffs - these morphological features play an important natural coastal defence role at the shoreline and often have geo-science value.

196. In respect of the above considerations, the East Anglia ZEA identified seventeen receptor groups in total. The location of these is shown in *Figure 7.5*.

197. Seven receptor groups covered sensitive coastlines in both eastern England (two receptor groups, namely 'East Anglia' and 'Essex & Kent') and across northern mainland Europe (five receptor groups, including 'France', 'Belgium', 'Southern Netherlands', 'Western Netherlands' and 'Northern Netherlands').

198. Nine further receptor groups were identified to cover the designated Natura 2000 sites in eastern England (five receptor groups, namely 'The Wash', 'Central North Sea', 'Norfolk', 'Kent & Essex' and 'Suffolk') and wider Europe (four receptor groups, namely 'France', 'Belgium', 'Southern Netherlands' and 'Northern Netherlands'). It should be noted that the Natura 2000 sites often comprise groupings of multiple distinct (and designated) features, such as sandbanks, sand dunes, and sand and shingle beaches.

199. One further receptor group covered nearby 'non-designated sandbanks' in the Outer Thames Estuary, including Inner Gabbard, Outer Gabbard, The Galloper, North Falls and one un-named bank.

200. The East Anglia ZEA assessed the potential cumulative impacts arising from development of the whole East Anglia Zone in relation to marine geology, oceanography and physical processes (ABPmer 2012a). It concluded there would be:

- No significant impacts on all seventeen receptor types in relation to changes in the wave regime. However, it was recommended that the potential impact should be considered further to confirm this at EIA stage for individual projects for four receptor groupings (namely sensitive 'East Anglia' coastline, 'Norfolk' Natura 2000 site, 'Suffolk' Natura 2000 site and 'non-designated sandbanks') due to some uncertainty regarding the magnitude of changes to the wave regime outside of the East Anglia Zone.

- No significant impacts on all seventeen receptor types in relation to changes in the current regime. However, it was recommended that the potential impact should be considered further to confirm this at EIA stage for individual projects for three receptor groupings (namely 'Norfolk' Natura 2000 site, 'Suffolk' Natura 2000 site and 'non-designated sandbanks') due to some uncertainty regarding the magnitude of changes to the flow speed outside of the East Anglia Zone.

- Impacts of moderate significance on the sensitive 'East Anglia' coastline, with no significant impacts on the other sixteen receptor types in relation to changes in the sediment transport regime. However, it was recommended that the potential impact should be considered further to confirm this at EIA stage for individual projects for one receptor grouping (namely 'Norfolk' Natura 2000 site) due to some uncertainty regarding the importance of different sediment transport pathways to morphological features within this receptor group.

201. The specific features defined within the four receptor groupings mentioned above as requiring further assessment at the EIA stage for individual projects are listed in *Table 7.17*.

202. This section directly assesses the significance of potential impacts on the wave and/or current and/or sediment transport regimes on the receptor groups of the sensitive 'East Anglia' coastline, the 'Norfolk' Natura 2000 site, the 'Suffolk' Natura 2000 site and the 'non-designated sandbanks'.

203. It should be noted that the recommendation to include the effects of changes in the wave and current regime on the ‘Norfolk’ and ‘Suffolk’ Natura 2000 sites and the ‘non-designated sandbanks’ was because of their proximity to the western margins of the East Anglia Zone (and, in some instances, their locations within the western-most areas of the East Anglia Zone). The East Anglia THREE site is located further east of these receptor groups at the eastern margin of the East Anglia Zone and this has been taken into consideration in the assessments.

Table 7.17 Marine Geology, Oceanography and Physical Processes Receptors

Receptor group (see Figure 7.5)	Extent of coverage	Description of features
East Anglian coastline (waves and sediment transport)	Felixstowe to King's Lynn	Shingle and sand beaches, dunes and cliffs.
Norfolk Natura 2000 Site (waves, currents and sediment transport)	Haisborough, Hammond and Winterton cSAC	Offshore sandbanks
	North Norfolk Sandbanks and Saturn Reef cSAC	Offshore sandbanks and reef
	Great Yarmouth and North Denes SPA	Shingle beach and sand dunes
Suffolk Natura 2000 Site (waves and currents)	Outer Thames Estuary SPA	Sandbanks and associated channels
	Minsmere to Walberswick Heaths and Marshes SAC and SPA	SAC: sand dunes, sand and shingle beaches SPA: beach, spit and bars
	Alde, Ore and Butley Estuaries SAC	Mudflats, saltmarsh and embayments
	Alde-Ore Estuary SPA	Mudflats, saltmarsh and shingle beach
	Orfordness – Shingle Street SAC/ Geological Conservation Review (GCR)	Shingle beach, spits and bars
	Benacre to Easton Bavents SPA	Estuary, mud and sandflats, sand dunes and shingle beach
Nearby non-designated sandbanks (waves and currents)	Inner Gabbard Outer Gabbard The Galloper North Falls un-named bank	Offshore sandbanks

204. In addition to the receptor groups listed in *Table 7.17*, there are other potential changes to the baseline marine geology, oceanography and physical processes associated with the proposed East Anglia THREE project which may manifest themselves as impacts upon a wider grouping of receptors. These include water quality, benthic ecology, fisheries and navigation.

205. In respect of these effects on the baseline marine geology, oceanography and physical processes, this section assesses the magnitude of change only. The assessments of the significance of impacts arising from these effects or changes on

other receptors are made within the relevant chapters of this ES pertaining directly to those receptor types.

7.6.1 Potential Impacts during Construction

206. During the construction phase of the proposed East Anglia THREE project, there would be potential for wind turbine, foundation and cable installation activities to cause sediment disturbance effects, potentially resulting in changes in suspended sediment concentrations and / or sea bed or, in the case of nearshore cable installation, shoreline levels due to deposition or erosion.

207. For each potential impact during construction, the assessment commences with a description of the Single Phase approach and then highlights any pertinent differences associated with the Two Phased approach.

7.6.1.1 Impact 1: Changes in Suspended Sediment Concentrations due to Foundation Installation

208. The installation of wind turbine foundations has the potential to disturb sediments from: (i) the sea bed (surface or shallow near-surface sediments); and (ii) from several tens of metres below the sea bed (sub-surface sediments), depending on foundation type and installation method. The worst case assumes that the disposal of any sediment that would be disturbed or removed during foundation installation would occur within the East Anglia THREE site.

7.6.1.1.1 Sea Bed and Shallow Near-bed Sediments

209. Sea bed sediments and shallow near-bed sediments within the East Anglia THREE site would become disturbed during any levelling or dredging activities that may be needed at each foundation location to create a suitable base prior installation. The worst case scenario for disturbance of these sediments is for gravity base structure installation and assumes that sediment would be removed by means of dredging and returned to the water column at its surface layer as overflow from a dredger vessel.

210. This process would cause localised and short term increases in suspended sediment concentrations both at the point of dredging at the sea bed and, more importantly, at the point of its discharge back into the water column which, in the worst case scenario, would be at the water surface.

211. Mobilised sediment from these activities may be transported by wave and tidal action in suspension in the water column, ultimately resulting in its deposition elsewhere on the sea bed.

212. The disturbance effects at each wind turbine location are likely to last for no more than a few days of construction activity, with the overall foundation installation programme lasting up to 12 months for gravity base structures (Single Phase).

213. Baseline suspended sediment concentrations within the East Anglia THREE site are typically between 5 and 10mg/l in winter and below 5mg/l in summer, with a clear pattern of wave-stirring of sediment from the sea bed during storm conditions and relatively benign concentrations during 'typical' conditions (*Appendix 7.5*).

214. The mean grain size of sea bed sediments from samples taken across the East Anglia THREE site is in the range 0.21 to 0.36mm (medium sand). Most grab samples contained only very small percentages of gravels and muds; with most being sands (see *Appendix 7.2* for further details of the grab samples).

215. The worst case scenario involves the maximum quantity of sediment released through sea bed preparation activities for the maximum gravity base structure size being considered.

216. For a release from an individual foundation, the worst case is associated with the conservative average dredging volume for each individual 12MW wind turbine (with a maximum foundation diameter of 60m). This yields a conservative average dredging volume of 26,000m^3 (see section 5.5.4.2.2 in Chapter 5 Description of the Development) per wind turbine foundation (compared with a conservative average dredging volume of 17,500m^3 for each individual 7MW wind turbine foundation with a maximum diameter of 40m).

217. For the total volume released during the construction phase, the worst case is associated with the maximum number (172) of 7MW gravity base structures of the maximum foundation diameter (40m) for that wind turbine type. This yields a conservative total dredging volume of 3,010,000m^3 for the wind turbine foundations (compared with 2,600,000m^3 for the 12MW wind turbines because there be would be fewer of these wind turbines (100 in total) across the windfarm site). Also using a worst case approach, up to two meteorological masts would be installed on gravity base foundations yielding a dredging volume of up to 20,750m^3 and jacket foundations for up to six offshore platforms (five electrical and one accommodation) would yield up to 439,350m^3.

218. Therefore, the total volume under the Single Phase approach would yield up to 3,470,100m^3 of excavated sediment.

219. To ensure a conservative approach to the assessment of effects, it has been assumed that the conservative average dredging volumes apply everywhere across the

windfarm site and therefore this assessment is a deliberate over-estimate of potential effects.

220. Expert-based assessment suggests that, due to the sediment grain sizes present across the windfarm site, the sediment disturbed from the sea bed by the drag head of the dredger would remain close to the bed and rapidly settle, whilst the majority of material released at the water surface from the dredger vessel would rapidly (order of minutes or tens of minutes) fall to the sea bed as a highly turbid dynamic plume immediately upon its discharge.

221. Some of the finer sand fraction from this release and the very small proportion of muds that are present are likely to stay in suspension for longer and form a passive plume which would become advected by tidal currents. Due to the sediment sizes present, this is likely to exist as a measureable but modest concentration (tens of mg/l) plume for around half a tidal cycle and sediment would fall to the sea bed in relatively close proximity to its release (within a few hundred metres up to around a kilometre, along the axis of the tidal flow) within a short period of time (order of hours).

222. This assessment is supported by findings from a review of the evidence-base obtained from research into the physical impacts of marine aggregate dredging on sediment plumes and sea bed deposits (Whiteside et al. 1995; John et al. 2000; Hiscock and Bell 2004; Newell et al. 2004; Tillin et al. 2011; Cooper and Brew 2013). This review identified that the highest suspended sediment concentrations associated with dredging occur for only a short duration and remain fairly local to the point of sediment release into the water column, while within the wider licensed dredge area concentrations typically remain modest (i.e. of the order of tens of mg/l). Whilst lower concentrations can be found to extend further beyond licensed dredge areas, along the axis of predominant tidal flows, the magnitudes are typically barely distinguishable from background levels.

223. Modelling simulations undertaken for the East Anglia ONE site using the Delft3D plume model (ABPmer 2012b) confirm the above expert-based assessments of suspended sediment concentrations arising from disturbance of surface and shallow near-surface sediments. There are good similarities in sediment types and distributions between the East Anglia ONE (5% gravel, 93% sand and 2% mud) and East Anglia THREE (1.5% gravel, 94.5% sand and 4% mud) sites. The water depths for each site are also within a similar range. Whilst the East Anglia THREE site is located closer to the amphidromic point than the East Anglia ONE site, and therefore the tidal currents are slightly lower, it is located further offshore and therefore the wave conditions are higher. Overall, therefore, the earlier modelling studies for the East

Anglia ONE site represent a sufficiently suitable analogue for broadly verifying the conclusions of the more qualitative expert-based assessment described above.

224. In modelling studies (ABPmer 2012b), consecutive daily releases of 22,500m^3 of sediment (mostly medium sand, but also with small proportions of gravel, other sand fractions and muds) were made at the water surface at fifteen wind turbine locations across the East Anglia ONE site. This sediment release is greater than the conservative average release volume from each of the 7MW wind turbines, but slightly lower (85% of the value) than the conservative average release volume from each of the 12MW wind turbines. Nonetheless it does represent a suitable analogue for the type and broad magnitude of effect.

225. Modelling (ABPmer 2012b) showed that away from the immediate release locations, where suspended sediment concentrations were very high (orders of magnitude in excess of natural background levels) for a very short duration (seconds to minutes) as the dynamic plume falls to the sea bed, elevations in suspended sediment concentration above background levels within the passive plume were low (<10mg/l) and within the range of natural variability. Net movement of fine grained material retained within the passive plume was to the north, in accordance with the direction of residual tidal flow. Sediment concentrations returned to background levels rapidly after cessation of the release into the water column.

226. Given this finding from the consecutive installation of fifteen wind turbine foundations, it is expected that effects from installation across the whole East Anglia THREE site would be similar, although with the point of release moving across the site with progression of the construction sequence.

7.6.1.1.2 Sub-surface Sediments

227. Deeper sub-surface sediments within the East Anglia THREE site would become disturbed during any drilling activities that may be needed at the location of each monopile or 3 or 4 legged jacket (with pin piles) in order to install piles into the sea bed. The worst case scenario for a release from an individual wind turbine assumes that a 12m diameter monopile foundation would be drilled from the sea bed surface to a depth of 40m below the sea bed surface, releasing 4,524m^3 of sediment into the water column per monopile (*Table 7.5*). (This compares with a volume of 3,142m^3 for each individual 7MW wind turbine with a maximum diameter of 10m drilled to the same 40m maximum depth).

228. For the total volume released during the construction phase, the worst case is associated with the maximum number (172) of 7MW monopiles of the maximum diameter (10m) for that wind turbine type. This yields a total volume of 540,353m^3

for the wind turbine foundations (compared with 452,389m^3 for the 12MW turbines because there be would be fewer of these wind turbines (100 in total) across the windfarm site). 8m diameter monopile foundations would represent the worst case for the two meteorological masts (Chapter 5 Description of the Development *Table 5.17*) yielding up to 4,021m^3, and jacket foundations with pin piles used for the six offshore platforms would each yield up to 11,545m^3. Therefore, the total volume increases to 555,921m^3 (Single Phase).

229. To ensure a conservative approach to the assessment of effects, it has been assumed that the conservative average release volumes apply everywhere across the windfarm site, but in reality this assessment is a deliberate over-estimate of potential effects.

230. This process would cause localised and short term increases in suspended sediment concentrations at the point of discharge of the drill arisings. Released sediment may then be transported by wave and tidal action in suspension in the water column, ultimately resulting in its deposition elsewhere on the sea bed.

231. The disturbance effects at each wind turbine location are likely to last for no more than a few days of construction activity, with the overall construction programme lasting up to 7 months for monopiles (Single Phase).

232. Although the sub-surface sediment release quantities involved under a worst case scenario are considerably lower than those involved in the worst case scenario for the surface and near-bed sediments, the sediment types would differ, with a larger proportion of finer materials.

233. The sediment types likely to be encountered have been estimated from the two available borehole logs that are located directly within the East Anglia THREE site.

234. Expert-based assessment suggests that the coarser sediment fractions (medium and coarse sands and gravels) and aggregated ‘clasts’ of finer sediment would settle out of suspension in relatively close proximity to the foundation location, whilst disaggregated finer sediments (fine sands and muds) would be more prone to dispersion across a wider area. Due to the small quantities of sediment release involved, however, these disaggregated finer sediments are likely to be widely and rapidly dispersed, resulting in only low elevations in suspended sediment concentration and low changes in bed level when they ultimately come to rest on the sea bed.

235. Modelling simulations undertaken for the East Anglia ONE project using the Delft3D plume model (ABPmer 2012b) confirm the above expert-based assessments of

suspended sediment concentrations arising from disturbance of deeper sub-surface sediments. As agreed with Natural England and Cefas through the Evidence Plan, the earlier modelling studies make a suitable analogue for the present assessments, with any key differences between the two sites being explicitly noted.

236. In the earlier modelling studies, 982m^3 of variably graded fine sediment (sand, clay and silt) was released into the water column once every two days to simulate the construction of 8 consecutively drilled (jacket) foundations over a 15 day simulation period. This value is similar to the worst case volume that would be released from the jacket foundations that are being considered for the East Anglia THREE site (831m^3), with a similar distribution of envisaged sediment types at depth, but is acknowledged to be less than the worst case scenario for the monopile foundations being considered for East Anglia THREE (4,524m^3).

237. Nonetheless, the previous modelling results support the general principles of the expert-based assessments in that, away from the immediate release locations, elevations in suspended sediment concentration above background levels were low (<10mg/l) and within the range of natural variability. Indeed, concentrations were generally no greater than 5mg/l at a distance of 5km from the release location, indicating wide dispersion in low concentrations. Net movement of fine grained material retained within a plume was to the north, in accordance with the direction of residual tidal flow, although gross movement to both the north and south was possible depending on timing of release. Sediment concentrations arising from one foundation installation were deemed unlikely to persist for sufficiently long that they significantly interact with subsequent operations and therefore no cumulative effect was anticipated.

238. The larger release volumes associated with the worst case for the East Anglia THREE site and the slightly lower tidal currents compared with the East Anglia ONE site may combine to result in larger concentrations above background levels than previously modelled (but likely to still be modest; of the order of tens of mg/l) but the principle of wide dispersion in relatively low concentrations remains valid. Furthermore, a conservative assumption was made in the modelling that all drilled sediment would fully disaggregate into component particle sizes but in reality some would arrive at the surface as larger aggregated clasts which would settle more rapidly.

239. The changes in suspended sediment concentrations (magnitudes, geographical extents and durations of effect) that are anticipated above would move across the site with progression of the construction sequence as the point of sediment release (and hence geographic location of the zone of effect) changes with the installation of foundations at different wind turbine locations.

7.6.1.1.3 Assessment of Effect Magnitude and/or Impact Significance

Single Phase

240. Given that the expert-based assessments of the dynamic and passive plume effects on suspended sediment concentrations for the proposed East Anglia THREE project are consistent with the findings of the earlier modelling studies for the East Anglia ONE project, there is high confidence in the assessment of effects.

241. The worst case changes in suspended sediment concentrations due to foundation installation are likely to have the following magnitudes of effect (*Table 7.18*):

Table 7.18 Magnitude of effect on suspended sediment concentrations due to foundation installation under worst case scenario

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field*	High	Negligible	Negligible	Negligible	Medium
Far-field	Low	Negligible	Negligible	Negligible	Low

* The near-field effects are confined to a small area (likely to be of the order of several hundred metres up to a kilometre from each foundation location), and would not cover the East Anglia THREE site.

242. The effects on suspended sediment concentrations due to foundation installation for the proposed project do not directly impact upon the identified receptor groups for marine geology, oceanography and physical processes, so there is **no impact** associated with the proposed project.

243. The effects do, however, have the potential to impact upon other receptors and therefore the assessment of impact significance is addressed within relevant chapters of the ES, taking into consideration the tidal ellipses presented in *Figure 7.4*, which represent the potential pathways between the source and receptor.

Two Phased

244. Under a Two Phased approach there would be two principal differences to the Single Phase assessment described above.

245. Firstly, under a worst case, there would be an additional offshore platform. If this is founded on the maximum diameter gravity base structure, then the total volume of sea bed sediments and shallow near-bed sediments that would be released could increase by a further 73,225m^3 (*Table 7.4)* to a total of 3,543,325m^3. Alternatively, if it is founded on a jacket structure which uses pin piles, then the total volume of sub-surface sediments that would be released could increase by a further 1,924m^3 to a total of 557,845m^3. These increases are very small in comparison to the total

volume assessed under the Single Phase approach and do not materially change the assessment of significance.

246. Secondly, the worst case release of sea bed sediments or shallow near-surface sediments would occur over two distinct phases, each lasting up to 7 months (rather than a single 12 month period), for the installation of gravity base structures. Alternatively, the worst case release of sub-surface sediments would occur over two distinct phases, each lasting up to 5 months (rather than a single 7 month period), for the installation of gravity base structures (See Chapter 5 Description of the development, *Table 5.36*). Whilst the above would mean that the effects are caused in two separate periods, with a longer additive duration of disturbance, this too would not materially change the assessment of significance compared with a Single Phase approach.

7.6.1.2 Impact 2: Changes in Sea bed Levels due to Foundation Installation

247. The increases in suspended sediment concentrations associated with Impact 1 (section 7.6.1.1) have the potential to result in changes in sea bed levels with the suspended sediment deposits on the surrounding sea bed potentially raising the seabed level slightly. There would be different settling rates for the sediment types associated with the sea bed and shallow near-bed sediment disturbance and the deeper sub-surface sediment disturbance, so each is discussed in turn.

7.6.1.2.1 Sea bed and Shallow Near-bed Sediments

248. Expert-based assessment suggests that the coarser sediment would rapidly (within the order of minutes or tens of minutes) fall to the bed as a highly turbid dynamic plume immediately upon its discharge, forming a deposit ('mound') local to the point of release. Due to the sediment grain sizes observed across the site (predominantly medium sand or coarser, with very little fine sand or muds), a large proportion of the disturbed sediment would behave in this manner.

249. The resulting mound would be a measureable protrusion from the sea bed (likely order of tens of centimetres to a few metres in height) but would remain highly localised to the release point. The precise configuration of height and spreading distance of each mound would vary across the windfarm site, depending on the prevailing conditions, but in all cases the material within the mound would be similar to that on the existing sea bed and therefore there would be no significant change in sediment type.

250. In addition to the localised mounds, some of the sediment from this release (mainly the fine sand fraction and the very small proportion of muds) is likely to form a passive plume and become more widely dispersed before settling on the sea bed.

Expert-based assessment suggests that due to the dispersion by tidal currents, the thickness of deposits across the wider sea bed area would be very small (within the order of millimetres).

251. This assessment is supported by an evidence-base obtained from research into the physical impacts of marine aggregate dredging on sediment plumes and sea bed deposits (Whiteside et al*.* 1995; John et al. 2000; Hiscock and Bell 2004; Newell et al*.* 2004; Tillin et al. 2011; Cooper and Brew 2013) which also indicates the propensity for wide dispersion and only small thicknesses of deposits on the sea bed from the release of similar sediments in similar physical environments.

252. The Delft3D plume modelling studies (ABPmer 2012b) considered the bed level changes resulting from deposition of sediments from the passive plume due to sea bed preparation for 15 foundations. This involved a worst case sediment release of 22,500m^3 per foundation (i.e. around 85% of the value of the average conservative volume considered as the worst case for an individual wind turbine in East Anglia THREE). For the most part, the deposited sediment layer across the wider sea bed was found to be less than 0.2mm thick and did not exceed 2mm anywhere. The area of sea bed upon which deposition occurred (at these low values) extended a considerable distance from the site boundary (around 50km), but in doing so only covered a very narrow width of sea bed (a few hundred metres). This is because the dispersion of the plume followed the axis of tidal flow. The previous assessment also concluded that this deposited sediment also has the potential to become re-mobilised and therefore would rapidly become incorporated into the mobile sea bed sediment layer, thus further reducing any potential effect.

7.6.1.2.2 Sub-surface Sediments

253. Expert-based assessment suggests that due to the finer-grained nature of any sub-surface sediment released into the water column from drilling, there would be greater dispersion across a wider area, in keeping with the pattern of the tidal ellipses.

254. The Delft3D plume modelling studies (ABPmer 2012b) considered the sea bed level changes resulting from deposition of sediments from drilling for 8 piled (jacket) foundations. The coarser sediment become deposited near to the point of release to thicknesses of up to a few centimetres, but over a sea bed area local to each foundation (within a few hundred metres). For the most part, the deposited sediment layer across the wider sea bed area was found to be less than 0.025mm thick.

255. Although the modelling used a smaller volume of material (982m^3 associated with jackets) than the worst case for the proposed East Anglia THREE windfarm (4,524m^3 associated with monopiles) it does support the principles of the expert-based assessment that the envisaged scale of sea bed level change would be small.

256. The sea bed level changes that are anticipated above would move across the site with progression of the construction sequence as the point of sediment release (and hence geographic location of the zone of effect) changes with the installation of foundations at different wind turbine locations.

257. In direct response to an issue raised by Natural England (see point NE-25, *Table 7.1*) a very conservative worst case scenario has also been considered whereby the sediment released from the drilling is assumed to be wholly in the form of aggregated 'clasts' of finer sediment that remain on the sea bed (at least initially), rather than being disaggregated into individual fine-grained sediment components immediately upon release. Under this scenario, the worst case assumes that a 'mound' would reside on the sea bed near the site of its release. For an individual wind turbine, the worst case is associated with a 12MW monopile (12m diameter) and assumes that each mound would contain a volume of 4,524m^3 of sediment. For the East Anglia THREE site as a whole, the worst case is for 172 of the 7MW monopiles (10m diameter), each with a volume of 3,142m^3 and hence a cumulative total volume of 540,424m^3 of sediment. These mounds would be composed of sediment with a different grain-size and behaviour character (cohesive) to the surrounding sandy sea bed and therefore represent the worst case for mound formation during construction.

258. The method for calculating the footprint of each mound follows that which was applied to the consented Dogger Bank Creyke Beck Offshore Wind Farm, and which was developed to the satisfaction of Natural England for that project (Royal Haskoning 2013). It involves the following stages:

- Calculating the maximum potential width of a mound (for the given volume) on the basis of the diameter of an assumed idealised cone on the sea bed. This is based on simple geometric relationships between volume, height, radius and side-slope angle of a cone. The latter parameter was taken as 30°, which is a suitable representation for an angle of friction of clasts of material. The maximum potential width would be 39m for the 12MW monopile (12m diameter) and 35m for the 12MW monopile (12m diameter) , with each value rounded to the nearest metre.

- Calculating the maximum potential length of the mound (for the given volume and maximum potential width). The assumed height of the mound was 'fixed' in the calculation as being equivalent to the average height of the naturally occurring sandwaves on the sea bed within the East Anglia THREE site (i.e. 4.5m). This calculation is based on simple geometric relationships between volume, height, width and length and assuming that, when viewed in side elevation, the mound would be triangular in profile but that its length is greater than its width, thus forming a 'ramp' shape. The maximum potential length would be 51m for the 12MW monopile (12m diameter) and 40m for the 12MW monopile (12m diameter), with each value rounded to the nearest metre.

- Based on the newly-calculated width and length of the mound, a footprint area on the sea bed can then be calculated.

259. Based on this approach, the footprint of an individual mound arising from the 10m diameter monopiles used for 7MW turbines would be 1,396m^2 (or 240,188m^2 for the whole East Anglia THREE site) and the footprint of an individual mound arising from the 12m diameter monopiles used for 12MW turbines would be 2,011m^2 (or 201,067m^2 for the whole East Anglia THREE site). When compared against the East Anglia THREE site as a whole (304.8km^2), the worst case area affected is only 0.08% of the sea bed.

7.6.1.2.3 Assessment of Effect Magnitude and/or impact Significance

Single Phase

260. Given that the expert-based assessments of the sea bed level changes associated with foundation installation for the proposed East Anglia THREE project are consistent with the findings of the earlier modelling studies for the East Anglia ONE project, there is high confidence in the assessment of effects, including their scaling up from modelling results of a sub-set of wind turbines to the whole project area.

261. The changes in sea bed levels due to foundation installation under: (1) the worst case sediment dispersal scenario (i.e. disaggregated sediment particles arising from surface or near-surface and sub-surface sediments) ; and (2) the worst case sediment mound scenario (i.e. aggregated 'clasts' of released sub-surface sediments) are likely to have the following magnitudes of effect (*Table 7.19*):

Table 7.19 Magnitude of effects on sea bed level changes due sediment deposition following foundation installation under (1) the worst case sediment dispersal scenario and (2) the worst case sediment mound scenario.

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
(1) Sea bed level changes due sediment deposition under the worst case sediment dispersal scenario					
Near-field*	Medium	Negligible	Negligible	Negligible	Low
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible
(2) Sea bed level changes due sediment deposition under the worst case sediment mound scenario					
Near-field+	Medium	Medium - High	High	Medium	Medium-High
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

* The near-field effects are confined to a small area of sea bed (likely to be of the order of several hundred metres up to a kilometre from each foundation location), and would not cover the whole East Anglia THREE site.

+ The near-field effects are confined to a small area of sea bed (likely to be immediately adjacent to each turbine location), and would not cover the whole East Anglia THREE site.

262. These effects on sea bed level have the potential to impact directly upon the identified receptor groups for marine geology, oceanography and physical processes. However, as there is a large separation distance (well beyond one tidal ellipse) there is no evidence to support the existence of a pathway between the source and receptor.

263. The overall impact of foundation installation activities for the proposed project under a worst case scenario on sea bed level changes for identified morphological receptor groups is considered to be **no impact**.

264. The worst case assumes that piled foundations would be drilled to their full depth and that sea bed preparation activities would be at the maximum values for the given water depth. In practice, the volumes of sediment released would be lower than the worst case at many wind turbine locations because the detailed design process would optimise the foundation type and installation method to the site conditions.

265. The effects on sea bed level have the potential to impact upon other receptors and therefore the assessment of impact significance is addressed within relevant chapters of this ES, taking into consideration the tidal ellipses presented in *Figure 7.4*, which represent the potential pathways between the source and receptor.

Two Phased

266. Under a Two Phased approach the two principal differences to the Single Phase assessment are those described previously for Impact 1 (i.e. one additional platform and the effect of distinct construction periods) and consequently there would be no material change to the assessment of significance for Impact 2 compared with that above for a Single Phase approach.

7.6.1.3 Impact 3: Changes in Suspended Sediment Concentrations During Inter-array, Platform link and Interconnector Cable Installation

267. The detail of the inter-array, platform link and interconnector cabling is dependent upon the final project design, but present estimates for the Single Phase approach are that the total length of inter-array cables for the project may be up to 550km, the total length of platform link cable may be up to 195km and total length of interconnector cable may be up to 380km (installed within 190km of trench), and the worst case cable laying technique is considered to be jetting.

268. The installation of the cabling has the potential to disturb the sea bed down to a sediment thickness of up to 5m, either directly through the installation method chosen, or through sea bed levelling of any steep sand waves that may be present along the route of any cables prior to cable installation.

269. Under a Single Phase approach the installation of inter-array, platform link and interconnector cables are likely to have some overlaps and take up to 21 months to complete. There could also be a one month overlap with the installation of the export cables (Chapter 5 Description of the Development*, Table 5.34*). However, it should be noted that this is based on an indicative programme of works which may vary considerably.

270. To investigate the likely order of magnitude of sand wave levelling that may be required for inter-array and platform link cable installation for the proposed East Anglia THREE project, comparison has been made with the work undertaken for the East Anglia ONE site. The area of the two sites is very similar (300km^2 for East Anglia ONE and 305km^2 for East Anglia THREE) and therefore a direct comparison can be made. It has been assumed that any sand wave with a slope greater than 10° would require sand wave levelling. This assumption is based on the fact that cable installation equipment generally becomes ineffective where slope angle becomes greater than 10 – 15°. *Figure 7.6* illustrates locations of where sand waves have slopes that are greater than 10° within the East Anglia THREE and ONE sites and *Table 7.20* provides total areas that are occupied by steep sloped sand waves.

271. Although the area occupied by steep sloped (greater the 10˚) sand waves is approximately 2.7 times greater in the East Anglia ONE site than the East Anglia THREE site (*Table 7.20*) a precautionary approach has been taken to estimating the amount of excavated material required. This is to assume that approximately the same amount of excavation would be required as that for East Anglia ONE which was calculated to be 136,000km^3 (EAOL 2012b).

272. To investigate the likely magnitude of sand wave levelling that would be required for interconnector cable laying during the construction of the proposed East Anglia THREE project, comparison has been made with the work undertaken for the East Anglia ONE export cables. The East Anglia ONE export cable corridor covered a total sea bed area of 283km^2, sand waves with side slopes greater than 10° occupied 3.4km^2 (around 1%) of the total area within the East Anglia ONE export cable corridor. Levelling activities within the sea bed areas characterised by these sand waves were estimated to require up to 200,000m^3 (see EAOL 2012b for further detail) of sediment excavation. This equates to a volume of 58,997m^3 per square kilometre of sea bed.

273. *Table 7.20* shows the total sea bed areas within each cable corridor considered and it can be seen that consistently these sand wave areas occupy around only 1% of the total sea bed area within each cable corridor.

Table 7.20 – Sand wave presence within the East Anglia ONE and proposed East Anglia THREE project

Description	Sea bed area (km²)		Percentage of sea bed with sand waves > 10° side slopes	Estimated volume of sediment released (m³)	
	Sand waves > 10° side slopes	Total corridor		Per square km	Total
East Anglia ONE export cable corridor (as calculated in EAOL 2012b)	3.39	282.61	1.2%	58,997	200,000
East Anglia THREE export cable corridor	5.50	453.61	1.2%	58,997	324,484
East Anglia THREE interconnector cable corridor (including area of overlap with East Anglia THREE export cable corridor)	2.50	238.14	0.9%	58,997	147,493
East Anglia THREE interconnector cable corridor (excluding area of overlap with East Anglia THREE export cable corridor)	1.04	117.49	1.0%	58,997	61,357
East Anglia ONE site	5.448	300.088	0.02	1.82%	136,000
East Anglia THREE site	1.987	304.943	0.01	0.65%	136,000*

* Although there are far less sandwaves with angles greater than 10° in the East Anglia THREE site than within the East Anglia ONE site, a precautionary approach has been taken whereby it has been assumed that approximately the same maximum amount of sea bed levelling would be required.

274. This provides a meaningful basis for the assessment of the sand wave clearance for the proposed East Anglia THREE project by means of cross-comparison with the rates of clearance assumed for the East Anglia ONE project. On this basis, the estimated volume of material excavated by sand wave clearance would be a maximum of 147,493m^3 from the interconnector cable corridor (it should be noted that some of the interconnector cable corridor overlaps with the export cable corridor as illustrated in *Figure 7.1* and *Table 7.20*) and 136,000m^3 from the East Anglia THREE site. This sediment would be released within a designated disposal area which is likely to consist of the East Anglia THREE site and offshore cable corridor which sits within the East Anglia Zone (see the Site Characterisation report for further detail).

275. The types and magnitudes of effects that could be caused have previously been assessed within an industry best practice document on cabling techniques (BERR 2008). This document has been used alongside expert-based judgement and analysis of site conditions to inform the assessments presented below.

7.6.1.3.1 Assessment of Effect Magnitude and/or Impact Significance Single Phase

276. It is anticipated using expert-based assessment that the changes in suspended sediment concentration due to inter-array, platform link and interconnector cable installation (including any necessary sand wave levelling) would be lower than those arising from the disturbance of sea bed surface and near-bed sediments during foundation installation activities including sea bed preparation.

277. This is because the majority of sediment release (apart from that released as a result of sand wave levelling) would be low and confined to near the sea bed (rather than higher in the water column) along the alignment of the cables, and the rate at which the sediment is released into the water column from the jetting process (during installation) would be relatively slow (approximately 150 – 450 m/hr, Chapter 5 Description of the Development, *Table 5.22*). The additional volume of sediment that may be released due to sand wave levelling prior to cable installation works is very low (136,000m^3 from the East Anglia THREE site and 147,493m^3 from the interconnector cable corridor) within the context of both the sediment spill during foundation installation and the changes that occur naturally in the sea bed.

278. Using this basis, the worst case changes in suspended sediment concentrations due to inter-array cable, platform link cable and interconnector cable installation (including any necessary sand wave levelling) are likely to have the following magnitudes of effect (*Table 7.21*):

Table 7.21 Magnitude of effect on suspended sediment concentrations due to inter-array cable, platform link cable and interconnector cable installation (including sand wave levelling) under worst case scenario

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field*	Low	Negligible	Negligible	Negligible	Low
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

* The near-field effects are confined to a small area (likely to be of the order of several hundred metres up to a kilometre from the cable), and would not cover the entirety of the sea bed area within the East Anglia THREE site or the entirety of the interconnector cable corridor.

279. These effects on suspended sediment concentrations do not directly impact upon the identified receptor groups for marine geology, oceanography and physical processes, so there is **no impact** associated with the proposed project.

280. The effects do, however, have the potential to impact upon other receptors and therefore the assessment of impact significance is addressed within relevant chapters of the PEIR, taking into consideration the tidal ellipses presented in *Figure 7.4*, which represent the potential pathways between the source and receptor.

Two Phased

281. Under a Two Phased approach there are two principal differences to the Single Phase assessment.

282. Firstly, the length of platform link cables may increase by up to 45km to 240km. This increase is very small (2.52%) of the total length of cabling assessed under the Single Phase approach and does not materially change the assessment of significance.

283. Secondly, the worst case installation period would be for one 18 month phase followed concurrently by one 17 month phase (with no overlap in installation of cable types between phases). However, in contrast to the Single Phase approach, there could be up to 6 months overlap in construction of these cable types with the export cables installed during each phase (Chapter 5 Description of the Development, *Table 5.37*). Due to the remaining low near-field and negligible far-field magnitude of effect, however, the overall assessment of significance remains in keeping with that above for a Single Phase approach.

7.6.1.4 Impact 4: Changes in sea bed levels due to inter-array, platform link and interconnector cable installation

284. The increases in suspended sediment concentrations associated with Impact 3 (section 7.6.1.3) have the potential to result in changes in sea bed levels as the suspended sediment deposits on the sea bed.

7.6.1.4.1 Assessment of Effect Magnitude and/or impact Significance

Single Phase

285. Given that the changes in suspended sediment concentration due to inter-array cable, platform link cable and interconnector cable installation (including any deposition arising from spilled sediment from sand wave levelling) would be less than those arising from the disturbance of sea bed and near-bed sediments during foundation installation activities, so the sea bed level changes would also be lower. The direct changes to the sea bed associated with sand wave levelling would be small and localised and are likely to recover over time due to natural sand transport pathways.

286. Using this as a basis, the worst case changes in sea bed levels due to inter-array cable, platform link cable and interconnector cable installation are likely to have the following magnitudes of effect (*Table 7.22*):

Table 7.22 Magnitude of effect on sea bed level changes due to inter-array cable, platform link cable and interconnector cable installation (including sand wave levelling) under worst case scenario

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field*	Low	Negligible	Negligible	Negligible	Low
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

* The near-field effects are confined to a small area of sea bed (likely to be of the order of several hundred metres up to a kilometre from the inter-array cable), and would not cover the whole East Anglia THREE site.

287. These effects on sea bed level are considered highly unlikely to have the potential to impact directly upon the identified receptor groups for marine geology, oceanography and physical processes. This is because the magnitude of effects is lower than those associated with foundation installation and there is a large separation distance (well beyond one tidal ellipse) which does not support the existence of a pathway between the source and receptor.

288. The overall impact of inter-array cable, platform link cable and interconnector cable installation activities under a worst case scenario on sea bed level changes for identified morphological receptor groups is regarded as **no impact**.

289. In many parts of the East Anglia THREE site there would not be the need for release of such volumes of sediment as considered under this worst case scenario and optimisation of inter-array cable, platform link cable and interconnector cable alignment, depth and installation methods during detailed design would ensure that impacts are minimised.

290. The effects on sea bed level also have the potential to impact upon other receptors and therefore the assessment of impact significance is addressed within relevant chapters of this ES, taking into consideration the tidal ellipses presented in *Figure 7.4*, which represent the potential pathways between the source and receptor.

Two Phased

291. Under a Two Phased approach the two principal differences to the Single Phase assessment are those described previously for Impact 3 and consequently there would be no material change to the assessment of significance for Impact 4 compared with that above for a Single Phase approach.

7.6.1.5 Impact 5: Changes in Suspended Sediment Concentrations during Offshore Export Cable Installation

292. The detail of the offshore export cabling is dependent upon the final project design, but present estimates are that the maximum total length of each export cable could be up to 166km in length with up to four cables being installed providing a total maximum length of 664km of export cable. The worst case cable laying technique is considered to be jetting. The furthest inshore section of the export cable corridor and the landfall is coincident with that previously assessed for the East Anglia ONE project.

293. The installation of the offshore cabling has the potential to disturb the sea bed down to a sediment thickness of up to 5m, either directly through the installation method chosen, or through sea bed levelling of any large sand waves that may be present along the export cable corridor prior to cable installation. The release of sediment from both of these construction phase activities, with the release points being along the export cable corridor, has been considered here.

294. To investigate the likely magnitude of sand wave levelling needed for cable laying during construction of the proposed East Anglia THREE project, comparison has been made with the work undertaken for the East Anglia ONE project.

295. Within the East Anglia ONE export cable corridor, which covered a total sea bed area of 283km^2, sand waves with side slopes greater than 10° occupied 3.4km^2 (around 1%) of the total area within the East Anglia ONE export cable corridor. Levelling activities within the sea bed areas characterised by these sand waves were estimated to require the excavation of 200,000m^3 of sediment (see EAOL 2012b for further detail). This equates to a volume of 58,997m^3 per square kilometre of sea bed.

296. *Figure 7.6* shows the sea bed areas within the East Anglia ONE and proposed East Anglia THREE projects where sand waves with side slopes greater than 10° are present. It also shows the total sea bed areas within each offshore cable corridor considered and it can be seen that consistently these sand wave areas occupy around only 1% of the total sea bed area within each cable corridor.

297. This provides a meaningful basis for the assessment of the sand wave clearance for the proposed East Anglia THREE project by means of cross-comparison with the rates of clearance assumed for the East Anglia ONE project. On this basis, the estimated volumes of excavated material due to sand wave clearance within the East Anglia THREE export cable corridor (including the area of overlap with the East Anglia THREE interconnector cable) would be 324,484m^3. This sediment would be released

within a designated disposal area which is likely to consist of the East Anglia THREE site and part of the offshore cable corridor which sits within the East Anglia Zone (see the Site Characterisation Report, submitted as part of this application for further detail).

298. A further consideration is the location of sand wave levelling, since there is greatest potential concern regarding sand wave levelling in areas closer to shore, where there could be interruptions to sediment transport pathways feeding the nearshore sandbank system or a reduction in the natural protection afforded by the sandbanks to the shore against wave-induced erosion. *Figure 7.6* shows the location of the sand waves with side slopes greater than 10°. It can be seen that the majority of locations are in the most seaward sections of the shared East Anglia ONE and East Anglia THREE offshore cable corridor and in parts of the East Anglia THREE interconnector corridor (including those areas that overlap with part of the seaward section of the East Anglia THREE export cable corridor).

299. Few locations are in the inshore sections and in fact of the total 5.5km^2 of steep sand wave area within the East Anglia THREE offshore cable corridor only 0.38km^2 is within the vicinity of the nearshore banks. Using the rates of clearance previously assumed, this would equate to a volume of around 22,360m^3 in the inshore area, which is very small when compared to the natural changes that occur in the sea bed in the baseline environment.

300. Any excavated material due to sand wave levelling within the export cable corridor (up to 324,484m^3 see *Table 7.20*) would be disposed of within the designated disposal site (an area which includes the East Anglia THREE site and the part of the export cable corridor which is within the East Anglia Zone; further information is provided in the Site Characterisation document which forms part of this submission).

301. The 324,484m^3 of sediment that could be disposed of within the designated disposal area is very small in relation to the sediment released as a result of sea bed preparation for foundations (see Impact 2) and therefore would have a comparatively minimal effect.

302. The installation of export cables would take up to 22 months, but there would be no overlap with the installation of inter-array cables, platform link cables or interconnector cables (Single Phase approach).

303. The assessment of changes in suspended sediment concentrations during offshore export cable installation (including any associated sand wave levelling) has been considered separately from those for the inter-array, platform link cables or

interconnector cables because parts of the export cable corridor are in considerably shallower water and in closer proximity to the identified morphological receptor groups.

304. The types and magnitudes of effects that could be caused have previously been assessed within an industry best practice document on cabling techniques (BERR 2008). This document has been used alongside expert-based judgement and analysis of site conditions to inform the assessments presented below.

7.6.1.5.1 Assessment of Effect Magnitude and/or Impact Significance

Single Phase

305. It is anticipated using expert-based assessment that the changes in suspended sediment concentration due to offshore export cable installation (including any sand wave levelling) would be less than those arising from the disturbance of sea bed and near-bed sediments during foundation installation activities, although the location of effect would differ as it would be focused along the export cable corridor.

306. This assessment is based on the overall sediment release volumes being low and confined to near the sea bed (rather than higher in the water column) along the alignment of the export cable corridor, and the rate at which the sediment is released into the water column from the jetting process would be relatively slow.

307. It is likely that the concentrations would be enhanced by the greatest amount in the shallowest sections of the export cable corridor, but in these locations the background concentrations are also greater than in deeper waters, typically up to 170mg/l (ABPmer 2012a). Furthermore, there would be relatively little sand wave levelling prior to cable laying in these inshore areas, with most occurring further offshore.

308. Modelling simulations undertaken for the East Anglia ONE project using the Delft3D plume model (ABPmer 2012b) confirm the above expert-based assessments and provided the following quantification of magnitude of change:

- Sand-sized material (which represents most of the disturbed sediment) would settle out of suspension within less than 1km from the point if installation within the export cable corridor and persist in the water column for less than a few tens of minutes.

- Mud-sized material (which represents only a very small proportion of the disturbed sediment) would be advected a greater distance and persist in the water column for hours to days.

- In water depths greater than 20m LAT, peak suspended sediment concentrations would be typically less than 100mg/l, except in the immediate vicinity (a few tens of metres) of the release location.
- In shallow water depths nearer to shore (less than 5m LAT) the potential for dispersion is more limited and therefore the concentrations are likely to be greater, approaching 400mg/l at their peak. However, these plumes would be localised to within less than 1km of the location of installation and would persist for no longer than a few hours.
- After 180 hours following cessation of installation activities any plume would have been fully dispersed.

309. There are similarities in water depth, sediment types and metocean conditions between the export cable corridor for the East Anglia ONE project and for the proposed East Anglia THREE project (indeed the inshore section is common to both proposed projects), making the earlier modelling studies a suitable analogue for the present assessments.

310. Furthermore, direct changes to the sea bed associated with sand wave levelling would be small and localised and are likely to recover over time due to natural sand transport pathways which prevail in this dynamic area of the sea bed.

311. Using this as a basis, the worst case changes in suspended sediment concentrations due to offshore cable installation are likely to have the following magnitudes of effect (*Table 7.23*):

Table 7.23 Magnitude of effect on suspended sediment concentrations due to offshore cable installation (including any sand wave levelling) under worst case scenario

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field* (nearshore)	High	Negligible	Negligible	Negligible	Medium
Near-field* (offshore)	Low	Negligible	Negligible	Negligible	Low
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

* The near-field effects are confined to a small area (likely to be of the order of several hundred metres up to a kilometre from the export cable corridor), and would not cover the whole export cable corridor.

312. These effects on suspended sediment concentrations due to offshore cable installation (including any sand wave levelling) do not directly impact upon the identified receptors groups for marine geology, oceanography and physical

processes, so there is **no impact** associated with the proposed project. The impacts arising from subsequent deposition of the suspended sediments on the sea bed are discussed under Impact 6 (section 7.6.1.6).

313. The effects do, however, have the potential to impact upon other receptors and therefore the assessment of impact significance is addressed within relevant chapters of this ES, taking into consideration the tidal ellipses presented in *Figure 7.4*, which represent the potential pathways between the source and receptor.

Two Phased

314. Under a Two Phased approach the principal difference to the Single Phase assessment is associated with the installation programme. There is no difference in the worst case length of cable to be installed.

315. The worst case installation period for the Two Phased approach would be for two separate 11 month phases. However, in contrast to the Single Phase approach, there could be up to 6 months overlap in construction of the export cables within each phase with the other cable types installed during that phase. Due to the remaining low near-field and negligible far-field magnitude of effect, however, the overall assessment of significance remains in keeping with that above for a Single Phase approach.

7.6.1.6 Impact 6: Changes in Sea bed Levels due to Offshore Export Cable Installation

316. The increases in suspended sediment concentrations associated with Impact 5 have the potential to result in changes in sea bed levels as the suspended sediment deposits on the sea bed.

7.6.1.6.1 Assessment of Effect Magnitude and/or Impact Significance

Single Phase

317. Given that the changes in suspended sediment concentration due to offshore export cable installation would be lower than those arising from the disturbance of sea bed and near-bed sediments during foundation installation activities, so the magnitude of bed level changes would also be lower, although the location of effect would differ as the majority would be focused along the export cable corridor.

318. Any excavated material due to sand wave levelling within the export cable corridor (up to 324,484m^3 see *Table 7.20*) would be disposed of within the designated disposal site (an area which includes the East Anglia THREE site and the part of the export cable corridor which is within the East Anglia Zone; further information is provided in the Site Characterisation document which forms part of this submission).

319. Modelling simulations undertaken for the East Anglia ONE project using the Delft3D plume model (ABPmer 2012b) confirm that sea bed level changes of up to 2mm would be observed within a few hundred metres of the inshore sections of the export cable corridor and further afield the sea bed level changes are not expected to be measureable.

320. The up to 324,484m^3 of sediment that could be disposed of within the designated disposal area is very small in relation to the sediment released as a result of sea bed preparation for foundations (see Impact 2) and therefore would have a comparatively minimal effect.

321. Using this as a basis, the worst case changes in sea bed levels due to offshore cable installation are likely to have the following magnitudes of effect (*Table 7.24*):

Table 7.24 Magnitude of Effect on sea bed level changes due to offshore cable installation under the worst case scenario

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field*	Low	Negligible	Negligible	Negligible	Low
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

* The near-field effects are confined to a small area of sea bed (likely to be of the order of several hundred metres up to a kilometre from the export cable corridor), and would not cover the whole export cable corridor.

322. These effects on sea bed level are considered highly unlikely to have the potential to impact directly upon the identified receptor groups for marine geology, oceanography and physical processes due to separation distances, except for parts of the Suffolk Natura 2000 site across which part of the export cable corridor crosses or comes within close proximity.

323. For most receptor groups the magnitude of effect is lower than that associated with foundation installation and there is a large separation distance (well beyond one tidal ellipse) which does not support the existence of a pathway between the source and receptor.

324. Specifically for the ‘Suffolk Natura 2000’ site, however, parts of the Outer Thames Estuary SPA would be affected, especially within the two separate areas of the SPA that extend offshore from the coasts of Suffolk and east Norfolk (rather than the large area of the SPA which extends offshore into the Outer Thames Estuary from between the counties of Kent and Essex and actually falls within the ‘Kent and Essex Natura 2000’ site).

325. Within these areas of the SPA, either parts of the sea bed are directly crossed by the export cable corridor or the boundary of the SPA is immediately adjacent to, or within one tidal excursion distance of, the export cable corridor. These situations arise within the most landward 65km of the length of the export cable corridor, with no potential for interactions with this SPA (or any other of the identified receptor groups) from the lengths of the export cable corridor that are further offshore.

326. Given these aspects, the sensitivity and value of the 'Suffolk Natura 2000' site (specifically the Outer Thames Estuary SPA located within) are presented in *Table 7.25*).

Table 7.25 Sensitivity and Value Assessment for the 'Suffolk Natura 2000' Site

Receptor	Tolerance	Adaptability	Recoverability	Value	Sensitivity
'Suffolk Natura 2000' site	Negligible	Negligible	Negligible	High	Negligible

327. The most inshore (15km) section of the export cable corridor is directly coincident with that for the East Anglia ONE project and the section between this limit and the boundary of the East Anglia Zone fully encompasses that for the East Anglia ONE project. The construction impacts associated with offshore export cable installation for the East Anglia ONE project were previously assessed within the EIA using the Delft 3D plume dispersion model, which also considered locations and rates of change in sea bed level as a result of deposition of material from the sediment plume. Given the small magnitude and relatively localised changes in sea bed level arising from modelling of the offshore export cable installation effects (up to 2mm bed level changes observed within a few hundred metres of the inshore sections of the export cable corridor), the EIA concluded that effects on identified receptors would be not significant (comparable to effects of negligible significance using the nomenclature for the proposed East Anglia THREE project).

328. The overall impact of offshore cable installation activities under a worst case scenario on bed level changes for the identified morphological receptor groups is considered to be **no impact**, except for the 'Suffolk Natura 2000' site (in particular parts of the Outer Thames Estuary SPA located within it) which is assessed to experience an impact of **negligible** significance.

329. In many parts of the export cable corridor there would not be the need for release of such volumes of sediment as considered under this worst case scenario, and optimisation of the offshore cable route selection within the corridor, depth and

installation methods during detailed design would ensure that impacts are minimised.

330. The effects on sea bed level also have the potential to impact upon other receptors and therefore the assessment of impact significance is addressed within relevant chapters of this ES, taking into consideration the tidal ellipses presented in *Figure 7.4*, which represent the potential pathways between the source and receptor.

Two Phased

331. Under a Two Phased approach the principal difference to the Single Phase assessment is that described previously for Impact 5 and consequently there would be no material change to the assessment of significance for Impact 6 compared with that above for a Single Phase approach.

7.6.1.7 Impact 7: Indentations on the Sea Bed due to Installation Vessels

332. There is potential for certain vessels used during the installation of the windfarm and offshore cable infrastructure to directly impact the sea bed. This applies for those vessels that utilise jack-up legs or a number of anchors to hold station and to provide stability for a working platform. Where legs or anchors (and associated chains) have been inserted into the sea bed and then removed, there is potential for an indentation proportional to the dimensions of the object to remain. The worst case is considered to correspond to the use of jack-up vessels since the depressions would be greater than the anchor scars.

333. A single jack-up barge leg would have a footprint of 50 to 300m^2 and a jack-up vessel would have up to 6 legs. Each leg could penetrate 0.5 to 20m into the sea bed and may be cylindrical, triangular, truss leg or lattice.

334. As the leg is inserted, the sea bed sediments would primarily be compressed vertically downwards and displaced laterally. This may cause the sea bed around the inserted leg to be raised in a series of concentric pressure ridges.

335. As the leg is retracted, some of the material would return to the hole via mass slumping under gravity until a stable slope angle is achieved. Over the longer term, the pit would become shallower and less distinct due to infilling with mobile sediments.

336. The worst case assumes that legs could be deployed on up to three different occasions around a single foundation as the jack-up barge manoeuvres into different positions.

7.6.1.7.1 Assessment of Effect Magnitude and/or Impact Significance

Single Phase

337. The worst case changes in terms of indentations on the sea bed due to installation vessels are likely to have the following magnitudes of effect (*Table 7.26*):

Table 7.26 Magnitude of Effect on Sea bed due to Installation Vessels Under Worst Case Scenario

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field (immediate vicinity of leg)	High	Negligible	Negligible	Medium	Medium
Near-field (beyond immediate vicinity of leg)	No change	-	-	-	No change
Far-field	No change	-	-	-	No change

338. There is **no impact** under a worst case scenario on the identified morphological receptor groups since they are remote from the immediate vicinity of each leg.

339. The significance of these effects on other receptors is addressed within relevant chapters of this ES.

Two Phased

340. Under a Two Phased approach there are two principal differences to the Single Phase assessment.

341. Firstly, there could potentially be one additional offshore platform that would require installation. This is such a small difference in comparison to the Single Phase approach that it does not materially change the assessment of significance.

342. Secondly, the construction phase would occur over two distinct periods, totalling a longer overall duration. In the context of this Impact, the phasing and duration of construction does not materially change the assessment of significance previously made for the Single Phase approach.

7.6.1.8 Impact 8: Changes to Suspended Sediment Concentrations and Coastal Morphology at the Offshore Cable Landfall

343. At the landfall location at Bawdsey the worst case scenario includes installation of four cables into ducts that have been pre-installed by the consented East Anglia ONE

project. Therefore, for the proposed East Anglia THREE project, the ends of the ducts would need to be excavated, cables installed and sediment backfilled.

344. Depending on the pre-installation option chosen for the ducts (i.e. long or short) during the consented East Anglia ONE project, the end of the ducts would occur either within the sub-tidal zone or intertidal zone.

345. The short duct method for pre-installing the ducts may be required in areas where there is only a thin veneer of surface sediment overlying the London Clay geology. It would involve a shorter Duct and then an offshore trench, excavated to deeper water. This enables the cable to remain buried even if the surface sediment veneer is reduced or removed by natural sediment transport processes.

346. Consequently, if the short duct method is used to pre-install the ducts, there may be some disturbance in the areas of London Clay when trenching and backfilling is needed to install the cables into the ducts for the proposed East Anglia THREE project. However, these effects would be highly localised and temporary in duration. The trenching into London Clay would likely result in clumps of mud to be displaced and back-filled, rather than the material breaking down into its constituent silt and clay particles. It is therefore unlikely that significant changes in suspended sediment concentration would be noted during these works. The back-filling of the trench would result in no noticeable change in coastal morphology after completion of the offshore cable installation into the ducts.

347. If, alternatively, the long duct method is used to pre-install the ducts, cable installation into the ducts would occur at a distance of 1,100m from the base of the cliff and therefore would cause minimal direct or indirect disturbance to the shoreline or nearshore.

348. The baseline characteristics within the export cable corridor at the landfall and across relevant adjacent lengths of shore are provided in *Appendix 7.4*. Consideration of final duct burial depths and shoreline set-back distances would be made during detailed design, based upon observations of past coastal change and projections of future coastal change, taking into consideration climate change effects (especially sea-level rise) during the operational lifetime of 25 years.

7.6.1.8.1 Assessment of Effect Magnitude and/or Impact Significance

Single Phase

349. The worst case changes to suspended sediment concentrations and coastal morphology at the cable landfall are likely to have the following magnitudes of effect (*Table 7.27*):

Table 7.27 Magnitude of Effects on Suspended Sediment Concentrations and Coastal Morphology at the Cable Landfall Under Worst Case Scenario

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field	Low	Negligible	Negligible	Negligible	Low
Far-field	No change	-	-	-	No change

350. These effects on suspended sediment concentrations and coastal morphology at the cable landfall have the potential to impact directly upon the identified receptor group for marine geology, oceanography and physical processes of the 'East Anglia' coast. In terms of its sensitivity and value of this receptor group, the following assessments apply to the magnitude of potential effects that have been identified in *Table 7.28*.

Table 7.28 Sensitivity and Value Assessment for the 'East Anglia' coast

Receptor	Tolerance	Adaptability	Recoverability	Value	Sensitivity
East Anglia coast	Negligible	Negligible	Negligible	Medium	Negligible

351. The significance of impact on the 'East Anglia' coast from installation of the offshore cables at the landfall is **negligible** under a worst case scenario.

352. The significance of impacts arising from these effects on other receptors is addressed within relevant chapters of this ES.

Two Phased

353. There would be no significant differences to the above assessment arising from a Two Phased approach. The only difference would be that the landfall operations would be undertaken as two discrete events rather than a single event. Whilst this increases the occurrences of disturbance events in excavating the ends of the pre-installed ducts, there would be less volume disturbed during each event compared to the Single Phased approach.

7.6.2 Potential Impacts during Operation

354. During the operational phase of the proposed East Anglia THREE project, there is potential for the presence of the foundations to cause changes to the tidal and wave regimes due to physical blockage effects, in turn potentially affecting the sediment regime and / or the sea bed morphology. These potential effects are considered as Operation Impacts 1 to 8. In addition, there is potential for the temporary presence

of engineering equipment, for example, jack-up barges or anchored vessels to have local effects on the hydrodynamic and sediment regimes during maintenance activities. These potential effects are considered as Operation Impact 9.

355. Note that whether the proposed East Anglia THREE project is constructed in a Single Phase or Two Phased approach does not affect the qualitative consideration of impacts, however, given that there is potential for extra infrastructure with the Two Phased approach the project design parameters covered in this section below represent that case.

7.6.2.1 Impact 1: Changes to the Tidal Regime due to the Presence of Foundation Structures

356. The presence of foundation structures within the East Anglia THREE site has the potential to alter the baseline tidal regime, particularly in respect of tidal currents and water levels. Any changes in the tidal regime may have the potential to contribute to changes in the sea bed morphology due to alteration of sediment transport patterns (see operation impact 3, section 7.6.2.3) or due to initiation of sea bed scour (see Impact 4, section 7.6.2.4).

357. Expert-based assessment suggests that each foundation would present an obstacle to the passage of currents locally, causing a small modification to the height and/or phase of the water levels and a wake in the current flow. This latter process involves a deceleration of flow immediately upstream and downstream of each foundation and an acceleration of flow around the sides of each foundation. Current speeds return to baseline conditions with progression downstream of each foundation and generally do not interact with wakes from adjacent foundations due to the separation distances.

358. There is a strong pre-existing scientific evidence base which demonstrates that the changes in the tidal regime due to the presence of foundation structures are both small in magnitude and localised in spatial extent. This is confirmed by existing guidance documents (ETSU 2000; ETSU 2002; COWRIE 2009) and numerous Environmental Statements for offshore windfarms.

359. This is further supported by Delft3D numerical modelling of changes in hydrodynamics associated with the East Anglia ONE project (ABPmer 2012b). This modelling was based on a worst case of 240 gravity base structures (50m base diameter and height up to 10m off the sea bed) and showed changes in water level of less than ±0.007m across a small geographical area.

360. In respect of changes in tidal currents, the previous modelling predicted maximum reductions in peak flow speeds of 0.05 to 0.1m/s and maximum increases in peak flow speeds of 0.05m/s, from peak baseline values for the East Anglia ONE project of around 1m/s. The geographical extent of these maximum changes was largely confined to the near-field environment (a wake zone local to each wind turbine foundation).

7.6.2.1.1 Assessment of Effect Magnitude and/or Impact Significance

361. Given that the expert-based assessments of the changes in the tidal regime associated with the presence of foundation structures for the proposed East Anglia THREE project are consistent with the findings of the earlier modelling studies for the East Anglia ONE project, there is high confidence in the assessment of effects.

362. The worst case changes in terms of the tidal regime due to the presence of largest gravity base foundations (*Table 7.3* and *Table 7.8*) are likely to have the following magnitudes of effect (*Table 7.29*):

Table 7.29 Magnitude of Effects on the Tidal Regime due to the Presence of Foundations Under Worst Case Scenario.

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field	Low	High	Medium	Negligible	Low
Far-field	No change	-	-	-	No change

363. These effects on the tidal regime have been translated into a 'zone of potential influence' based on an understanding of the tidal ellipses. It is expected that changes to the tidal regime would have returned to background levels well within the excursion of one tidal ellipse, and this threshold has been used to produce the maximum 'zone of potential influence' on the tidal regime, as presented in *Figure 7.7*.

364. The identified receptor groups for marine geology, oceanography and physical processes are remote from the 'zone of potential influence' on the tidal regime. Due to this, no pathway exists between the source and the receptor, so in terms of impacts on these receptor groups there is **no impact** associated with the proposed project.

7.6.2.2 Impact 2: Changes to the Wave Regime due to the Presence of Foundation Structures

365. The presence of foundation structures within the East Anglia THREE site has the potential to alter the baseline wave regime, particularly in respect of wave heights and directions. Any changes in the wave regime may have the potential to contribute to changes in the sea bed morphology due to alteration of sediment transport patterns (see Impact 3, section 7.6.2.3) or due to initiation of sea bed scour (see Impact 4, section 7.6.2.4).

366. Expert-based assessment suggests that each foundation would present an obstacle to the passage of waves locally, causing a small modification to the height and / or direction of the waves as they pass. Generally, this causes a small wave shadow effect to be created by each foundation. Wave heights return to baseline conditions with progression downstream of each foundation and generally do not interact with effects from adjacent foundations due to the separation distances.

367. There is a strong evidence base which demonstrates that the changes in the wave regime due to the presence of foundation structures, even under a worst case of the largest diameter gravity base structures (*Table 7.3*), are both relatively small in magnitude (typically <10% of baseline wave heights in close proximity to each wind turbine, reducing with greater distance from each wind turbine) and *relatively* localised in spatial extent (extending as a shadow zone typically up to several tens of kilometres from the site along the axis of wave approach, but with low magnitudes (only a few %) of change across this wider area). This is confirmed by a review of modelling studies from around 30 wind farms in the UK and European waters (Seagreen 2012), existing guidance documents (ETSU 2000; ETSU 2002; COWRIE 2009), published research (Ohl et al. 2001) and post-installation monitoring (Cefas 2005).

368. This is further supported by previous numerical modelling of changes in the wave regime under return period events of 1 in 0.1 year, 1 in 1 year and 1 in 10 years, associated with the East Anglia ONE project (ABPmer 2012b). This wave modelling incorporated a worst case of 240 gravity base structures with a basal diameter of 50m and up to 10m in height off the sea bed. The results were:

- Maximum percentage reductions in baseline wave height occur within or along the boundary of the East Anglia ONE site.
- During 1 in 10 year storm events, the percentage reductions in wave heights may be up to approximately 20% within the East Anglia ONE site.

- At a distance of approximately 40km from the East Anglia ONE site, maximum percentage reductions in wave height are typically less than about 2%.

- Regardless of return period or direction of the incoming wave conditions, the presence of an array of foundations within the East Anglia ONE site does not cause a measureable change in wave characteristics at the coast.

- Due to proximity of the East Anglia ONE site to the 'non designated sandbanks' receptor group and also the Galloper Offshore Wind Farm site, wave height reductions of up to about 5% were observed under the largest storm events considered at these locations. These were not considered to be significant impacts by the East Anglia ONE assessment (either alone of cumulatively with the Galloper Offshore Wind Farm). Changes under lesser magnitude events were not noticeable at the 'non designated sandbanks' receptor group or the Galloper Offshore Wind Farm site.

369. The worst case included in the wave modelling for the East Anglia ONE project considered 240 gravity base structures with a basal diameter of 50m and up to 10m in height off the sea bed. The likely envelope of wind turbine numbers and gravity base foundation sizes for the East Anglia THREE site is presented in *Table 7.30*.

Table 7.30 Likely wind turbine arrangements for worst case scenario

Turbine rating (MW)	No. wind turbines	Maximum basal diameter of gravity base structure (m)
7	172	40
12	100	60

370. The modelling for the East Anglia ONE project is considerably more conservative in terms of the number of foundations being considered for the proposed East Anglia THREE project. Also, the gravity base structure diameter modelled is larger than the maximum diameter that could be used for the 7MW turbine. Although it is smaller (at 50m) than the maximum diameter that could be used for the 12MW turbine, the largest gravity base structures are likely to be used in the deeper areas of water, furthest offshore. Also, the wave climate at the East Anglia THREE site is characterised by a far greater proportion of waves approaching from the southwest, due to the prevailing wind climate and greater distance from shore, than compared to East Anglia ONE. Therefore, there is less likelihood of any change affecting an identified receptor group.

371. Expert-based assessment suggests, therefore, that both the magnitude and spatial extent of effects on the wave climate at the East Anglia THREE site would be less than those previously assessed for the East Anglia ONE project.

7.6.2.2.1 Assessment of Effect Magnitude and/or Impact Significance

372. Taking the aforementioned considerations into account, the worst case changes in terms of the wave regime due to the presence of largest foundations (*Table 7.3* and *Table* 7.8) are likely to have the following magnitudes of effect (*Table 7.31*):

Table 7.31 Magnitude of effect on the wave regime due to the presence of foundations under worst case scenario

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field	Low	High	Medium	Negligible	Low
Far-field	Negligible	High	Medium	Negligible	Negligible

373. These effects on the wave regime have been translated into a ‘zone of potential influence’ based on an understanding of the wave roses, previous numerical modelling of effects, and using expert-based assessment.

374. *Figure 7.8* shows the wave rose from within the East Anglia THREE site. Waves are predominantly aligned north-northwest to south-southwest and this would be the axis of greatest potential influence.

375. In addition, previous wave modelling of the effect of the East Anglia ONE project on the wave regime has been used as an analogue for delineating the ‘zone of potential influence’. In that previous modelling assessment, the greatest change along the above-defined axis of greatest potential influence arose under a 1 in 10 year wave condition. The spatial extent of measureable changes (≥ ±5% of the baseline conditions) under such an event was mapped and superimposed over the East Anglia THREE site. The resulting ‘zone of influence’ on the wave regime is presented in *Figure 7.8*. Whilst it is recognised that there are differences in metocean conditions, water depths and likely gravity base sizes between the two project sites, it is believed that the highly conservative nature of the previous numerical modelling (including considerably greater number of foundations) more than covers any differences in effect that may arise due to these factors.

376. The identified receptor groups for marine geology, oceanography and physical processes are remote from the zone of influence. Due to this, no pathway exists between the source and the receptor, so in terms of impacts on these receptor groups there is **no impact** associated with the proposed project.

7.6.2.3 Impact 3: Changes to the Sediment Transport Regime due to the Presence of Foundation Structures

377. Modifications to the tidal regime and/or the wave regime due to the presence of the foundation structures during the operational phase may affect the sediment regime.

378. The issue of local scour around the foundations is considered separately (see operation impact 4, section 7.6.2.4) whilst this section addresses broader patterns of suspended and bedload sediment transport across, and beyond, the East Anglia THREE site and littoral sediment transport at the shoreline.

7.6.2.3.1 Assessment of Effect Magnitude and/or Impact Significance

379. The reductions in tidal flow (operation impact 1) and wave height (operation impact 2) that are anticipated to be associated with the presence of the largest foundation structures (*Table 7.3* and *Table 7.8*) during the operational phase would result in a reduction in the sediment transport potential across the areas where such changes are observed. Conversely, the areas of increased tidal flow around each wind turbine would result in increased sediment transport potential (and in doing so generate local scour, see Impact 4).

380. These changes to the physical processes would, however, be both low in magnitude and largely confined to local wake or wave shadow effects attributable to individual wind turbine foundations and, therefore, would be small in geographical extent. In the case of wave effects, there would also be reductions due to a shadow effect across a greater sea bed area, but the changes in wave heights across this wider area would be notably lower (a few %) than the changes local to each wind turbine foundation (tens of %). Since it is expected that the changes in tidal flow and wave heights during the operation phase would have no significant far-field effects, then so the changes in sediment transport would be similar, with the likely following magnitudes of effects (*Table 7.32*):

Table 7.32 Magnitude of effects on the sediment transport regime due to the presence of foundations under worst case scenario

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field	Low	High	Medium	Negligible	Low
Far-field	Negligible	High	Medium	Negligible	Negligible

381. The impacts on the sediment transport regime would not extend beyond the zones of influence previously illustrated for the changes to the tidal and wave regimes and

therefore, there is **no impact** associated with the proposed project on the marine geology, oceanography and physical processes receptor groups.

382. The effects of the changes in tidal regime and wave heights on the local sediment transport regime are manifest in terms of scour hole generation (see Impact 4 below).

7.6.2.4 Impact 4: Changes in Suspended Sediment Concentrations due to Scour around Foundation Structures

383. The localised changes in the tidal and wave regimes around each foundation structure are likely to result in localised scour of the sea bed, under a worst case that involves no scour protection being provided.

384. Scour assessments using empirical methods presented by Bos (2002a; 2002b), Harris et al.(2010), Khalfin (1983; 2007a, b), Sumer and Fredsoe (2002) and Whitehouse et al.(2011a, b) have been performed to determine scour depths, plan areas and associated sediment volumes for the worst case foundation type of gravity base structures (See *Table 7.6*). These methods have been further informed by the theories of Soulsby and Clarke (2005) in relation to combined waves and currents and Annandale (1995; 2006) and Annandale and Smith (2001) in relation to the strength properties of the sea bed sediments. Findings from the approaches have been verified against field measurements and laboratory scale physical model tests (Bolle et al. 2009; 2010; Khalfin 2007b; Larsen and Frigaard 2005; Margheritini 2012; Raaijmakers and Rudolph 2008; Stahlmann and Schlurmann 2010; Whitehouse et al. 2010; Yeow and Cheng 2003; Yang et al. 2010). Further information is presented in *Appendix 7.3*.

385. Using these approaches, the (overly-conservative) worst case scour volumes under a 1 in 50 year return period event for an individual foundation are associated with a 12MW wind turbine (5,573m^3 per turbine) and for the East Anglia THREE site as a whole are associated with 172 of the 7MW wind turbines (627,112m^3). These values are considerably less than the worst case volumes of sediment potentially released following sea bed preparation activities (>3 million m^3) and therefore the magnitude of effect would be much lower than previously assessed for that impact.

386. It has been assumed that the offshore substation foundations would yield the equivalent scour volumes to that of the wind turbine foundations (5,573m^3 per foundation). Under the worst case, a Two Phased approach, there would be up to 7 offshore platforms yielding a combined volume of 39,011m^3. Taking a conservative approach it has been assumed that the two meteorological mast foundations would

yield the equivalent to a 40m gravity base foundation (*Table 7.6*) therefore yielding up to 7,292m^2.

387. Therefore the total scour volume yielded by the East Anglia THREE site could be up to 673,415m^3.

388. In addition, given the sediment types prevalent across the East Anglia THREE site, most of the relatively small quantities of sediment released at each wind turbine foundation due to scour processes would rapidly settle within a few hundred metres of each wind turbine.

7.6.2.4.1 Assessment of Effect Magnitude and/or Impact Significance

389. Taking the aforementioned considerations into account, the worst case changes in suspended sediment concentrations due to scour around foundation structures are likely to have the following magnitudes of effect (*Table 7.33*):

Table 7.33 Magnitude of effects on the suspended sediment regime due to scour around foundations under worst case scenario

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field*	Low	High	Medium	Negligible	Low
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

* The near-field effects are confined to a small area (likely to be of the order of several hundred metres up to a kilometre from the foundation), and would not cover the whole East Anglia THREE site.

390. The effects on suspended sediment transport arising from scour processes would not extend more than a few hundred metres away from each wind turbine location before the sediment settles on the sea bed. Therefore, there is **no impact** associated with the proposed project on the marine geology, oceanography and physical processes receptor groups since these are located remotely from this zone of potential effect.

391. The effects do, however, have the potential to impact upon other receptors and therefore the assessment of impact significance is addressed within relevant chapters of this ES, taking into consideration the tidal ellipses presented in *Figure 7.4*, which represent the potential pathways between the source and receptor.

7.6.2.5 Impact 5: Changes to the Sea bed Morphology due to the Presence of Foundation Structures

392. The sea bed morphology would directly be impacted by the footprint of each foundation structure on the sea bed within the East Anglia THREE site. This would

constitute a 'loss' in natural sea bed area during the operational life of the proposed project.

393. This direct footprint could be further enhanced due to the presence of foundation structures in one of two ways.

394. Under a scenario of no scour protection being provided, a scour hole would be likely to develop around each foundation. This would have two implications for sea bed morphology, in addition to the direct foundation footprint. The scour hole would directly affect an area of the sea bed, lowering sea bed levels locally around each foundation and mobile sediments would be caused to become suspended into the water column. These sediments would ultimately settle back to the sea bed potentially causing bed level changes due to deposition.

395. Under an alternative scenario of scour protection being provided, the sea bed would be further occupied by material that is 'alien' to the baseline environment, such as concrete mattresses, fronded concrete mattresses, rock dumping, bridging or positioning of gravel bags.

396. The worst case direct sea bed footprint for a foundation structure is associated with the upper diameter of the gravity base structures. These maximum foundation sizes would be associated with the highest-rated wind turbines (12MW) and therefore there would be up to 100 foundations, each with a footprint of 2,828m^2 (*Table 7.3*). There would also be up to two meteorological masts, each with a footprint of 315m^2, and up to seven offshore platforms (four collector stations, two converter stations and one accommodation platform) each with a footprint of 8,011m^2 (*Table 5.16* in Chapter 5 Description of the Development), thus taking the total worst case for foundation numbers to 109. This arrangement would result in a total worst case direct foundation footprint area across the project of 339,507m^2. This represents 0.11% of the total sea bed area within the East Anglia THREE site (304.8km^2).

397. Using assessments of scour hole areas under a 1 in 50 year return period event, the worst case for an individual foundation is associated with gravity base structures for a 12MW wind turbine (5,336m^2 per turbine) and for the East Anglia THREE site as a whole is associated with 172 of the gravity base structures for 7MW wind turbines plus 9 further foundations (assumed to cause scour equivalent to that created up to seven of the 60m diameter gravity base structures for offshore platforms and that up to two 40m gravity base structures for meteorological masts) resulting in a total of 551,632m^2. This represents 0.18% of the total sea bed area within the East Anglia THREE site. The changes in sea bed levels due to settling of the scoured sea bed

sediments would be lower than those previously assessed during the construction phase for sea bed preparation activities.

398. The precise need (or otherwise) for scour protection would be defined during the detailed engineering stages and the intention is to minimise the amount of scour protection as long as it is practicable to do so. If, under a worst case, scour protection is used at all gravity base structures, the area of sea bed affected by the direct foundation footprint and scour protection footprint combined for 109 foundations increases to a maximum of 2,673,260m^2. This represents 0.88% of the total sea bed area within the East Anglia THREE site.

7.6.2.5.1 Assessment of effect Magnitude and/or Impact Significance

399. Taking the aforementioned considerations into account, the worst case changes to the sea bed morphology due to the presence of foundation structures are likely to have the following magnitudes of effect (*Table 7.34*):

Table 7.34 Magnitude of effects on sea bed morphology due to the presence of foundations under worst case scenario

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field*	High	High	High	Negligible	High
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

* The near-field effects are confined to a small area (likely to be of the order of several hundred metres up to a kilometre from the foundation (in the absence of scour protection) or within the footprint of scour protection, should it be provided), and would not cover the whole East Anglia THREE site.

400. The effects on sea bed morphology arising from the presence of foundation structures would not extend more than a few hundred metres away from each wind turbine location before any scoured sediment would settle on the bed (should no scour protection be provided)

401. As the assessment of scour around foundations concludes that the effects would extend only a few hundred meters it is likely that any scour effects associated scour protection would be confined to within a few meters of the direct footprint of that scour protection material.

402. In the case of no scour protection being provided, the scour hole would respond dynamically to the prevailing tidal current and wave conditions, alternately partially infilling and re-scouring. However, these dynamic responses would be within the bounds of natural change in sea bed levels due to prevailing tidal and wave processes. Therefore, there is **no impact** associated with the proposed project on

the identified marine geology, oceanography and physical processes receptor groups since these are located remotely from this zone of potential effect.

403. The significance of these effects on other receptors is addressed within relevant chapters of this ES.

7.6.2.6 Impact 6: Morphological and Sediment Transport Effects due to Cable Protection Measures for Inter-array Cables, Platform link Cables and Interconnector Cables

404. As a worst case scenario it has been assumed that up to 10% of the inter-array cables, platform link cables and interconnector cables cannot be buried and must instead be surface-laid and protected in some manner.

405. The preferred method for cable protection would be concrete mattresses, however other methods may be used.

406. The effects that such works may have on marine geology, oceanography and physical processes primarily relate to the potential for interruption of sediment transport processes and the footprint they present on the sea bed.

407. In areas of active sediment transport, any linear protrusion on the sea bed may interrupt bedload sediment transport processes during the operational phase of the proposed project. There is unlikely to be any significant effect on suspended sediment processes since armoured cables or cable protection works would only extend a relatively short distance (up to a maximum of 1m) above the sea bed, except for in areas where the cable crosses other sub-marine infrastructure (e.g. pipelines and cables) where it may extend to a height of up to 4m.

408. The presence and asymmetry of sand waves across around 50% of the sea bed within the East Anglia THREE site indicates that some bedload sediment transport exists, with a net direction towards the north or northeast. There are also sand ridges, megaripples and sand ribbons present.

409. Protrusions from the sea bed are unlikely to significantly affect the migration of sand waves, since sand wave heights in most areas would exceed the height of cable protection works. At cable crossings the height of cable protection would reach up to 0.9m above seabed apart from at one location where the cable would cross a pipeline. At this single location the protection could reach up to 4m in height. Where sand waves exceed the height of the protrusions they would simply pass over them.

410. If there are obstructions present to bedload transport then sand would accumulate one side or both sides of the obstacle (depending on the gross and net transport at

that particular location) to the height of the protrusion (up to 0.9m in most cases) and then form a 'ramp' over which sand transport would occur by bedload processes, thereby bypassing the obstruction.

411. There may be localised interruptions to bedload transport in other areas, but the gross patterns of bedload transport across the East Anglia THREE site would not be affected significantly.

412. The presence of cable protection works on the sea bed would represent the worst case in terms of a direct 'loss' of sea bed area, but this footprint is likely to be lower than that of the foundations (and associated scour hole or scour protection works) within the East Anglia THREE site.

7.6.2.6.1 Assessment of Effect Magnitude and/or Impact Significance

413. Taking the aforementioned considerations into account, the worst case changes to the sea bed morphology and sediment transport due to cable protection measures for inter-array cables, platform link cables and interconnector cables are likely to have the following magnitudes of effect (*Table 7.35*):

Table 7.35 Magnitude of effects on sea bed morphology and sediment transport due to cable protection measures for inter-array cables, platform link cables and interconnector cables under worst case scenario

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field*	High	High	High	Negligible	High
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

* The near-field effects are confined to a small area (likely to be within the footprint of cable protection works), and would not cover the whole East Anglia THREE site.

414. The effects on sea bed morphology and sediment transport arising from the presence of inter-array cables, platform link cables and interconnector cables protection measures would not extend far beyond the direct footprint. Therefore, there is **no impact** associated with the proposed project on the identified marine geology, oceanography and physical processes receptor groups since these are located remotely from this zone of potential effect.

415. The significance of these effects on other receptors is addressed within relevant chapters of this ES.

7.6.2.7 Impact 7: Morphological and sediment transport effects due to cable protection measures for offshore export cables

416. As a worst case scenario it has been assumed that burial of the export cables would not practicably be achievable within some areas of the export cable corridor and, instead, cable protection measures would need to be provided to surface-laid cables in these areas.

417. The locations where cable protection measures are most likely to be required are primarily in areas of cable crossings with the Galloper and Greater Gabbard Offshore Wind Farms and in areas of sea bed characterised by exposed bedrock.

418. The preferred method for cable protection would be concrete mattresses, however other methods may be used.

419. The effects that such works may have on marine geology, oceanography and physical processes primarily relate to the potential for interruption of sediment transport processes and the footprint they present on the sea bed.

420. In areas of active sediment transport, any linear protrusion on the sea bed may interrupt bedload sediment transport processes during the operational phase of the proposed project.

421. There is likely to be a difference in effect depending on whether the cable protection works are in 'nearshore' or 'offshore' areas within the export cable corridor, with any works in those areas closest to shore potentially affecting sediment transport processes along the shoreline and those areas further offshore potentially affecting sediment transport processes across the sea bed.

422. The seaward limit which marks the effective boundary between these different sediment transport pathway mechanisms is called the 'closure depth' of the shore profile and be can be calculated using the methods of Hallermeier, (1978). Along the export cable corridor, the closure depth is located in around 6m depth of water (below LAT), i.e. it is located well to the west of the area of cable crossings with the Greater Gabbard Offshore Wind Farm and Galloper Offshore Wind Farm, which occupy water depths ranging from 15 to 34m below LAT.

423. Any protrusions from the sea bed associated with cable protection measures (up to a maximum of 1m) inshore of the closure depth could potentially have an effect on sediment transport in the nearshore and along the shore because the water depths become shallower with progression from this point to the shore. Any interruptions to sediment transport locally within this zone could, in turn, affect the morphological

response of wider areas (e.g. downdrift adjacent shore frontages) due to reductions in sediment supply to those areas.

424. In the sections of the export cable corridor that are located seaward of the closure depth (including at the cable crossings and areas further to the east), any protrusions from the sea bed associated with cable protection measures (up to a maximum of 1m, except for in areas where the cable crosses other sub-marine infrastructure (e.g. pipelines and cables) where it may extend to a height of up to 4m) are unlikely to significantly affect the migration of sand waves, since their heights would in most areas where they are present exceed the likely height of cable protection works. There may be localised interruptions to bedload transport in some areas, especially at cable crossings, but the gross patterns of bedload transport would not be affected significantly.

425. As has been previously described in Section 7.5 (Baseline Environment), sediment transport processes in areas offshore of the closure depth exhibit a net northerly direction (and hence do not affect the shore or nearshore banks), whilst sediment transport processes closer to shore (within the limit of the closure depth) are net directed to the south.

426. In recognition of these sediment transport processes, especially those inshore of the closure depth, EATL has placed considerable effort in reducing the worst case requirements for cable protection measures along the offshore export cables. This has been achieved through a series of iterations between the ongoing design activities and the impact assessment process to establish the following worst case basis:

- Up to 10% of the length of the export cables at, or east of, the cable crossings with the Greater Gabbard Offshore Wind Farms and Galloper Offshore Wind Farm Export cables.
- Up to 2.5% of the length of the export cables to the west of these cable crossings.

427. This approach ensures that the requirement for cable protection along the sections of export cable that are located inshore of the closure depth are reduced to the minimum practicable values as a form of mitigation that has been embedded into the design.

428. The effects of offshore cable protection works directly at the cable landfall (on the 'East Anglia' coast) are assessed under Impact 8 (section 7.6.2.8).

7.6.2.7.1 Assessment of Effect Magnitude and/or Impact Significance

429. Taking the aforementioned considerations into account, the worst case changes to the sea bed morphology and sediment transport due to cable protection measures for offshore cables are likely to have the following magnitudes of effect (*Table 7.36*):

Table 7.36 Magnitude of effect on sea bed morphology and sediment transport due to cable protection measures for offshore cables under worst case scenario

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Inshore of cable crossings	Low (up to 2.5% cable burial)	High	High	Negligible	Low
Offshore of cable crossings	Low (up to 10% cable burial)	High	High	Negligible	Low

430. At the location of the potential cable crossings with the Galloper Offshore Wind Farm and Greater Gabbard Offshore Wind Farms, and for around 20km further east, these effects could potentially affect parts of the 'Suffolk Natura 2000' site (specifically parts of the Outer Thames Estuary SPA located within).

431. Similarly, these effects inshore of the cable crossings could also directly affect parts of the 'Suffolk Natura 2000' site (specifically parts of the Outer Thames Estuary SPA located within) and indirectly affect parts of the 'East Anglia' coast.

432. Given these aspects, the sensitivity and value of the 'Suffolk Natura 2000' site (specifically parts of the Outer Thames Estuary SPA located within) and 'East Anglia' coast are presented in *Table 7.37*.

Table 7.37 Sensitivity and Value assessment for the 'Suffolk Natura 2000' site and 'East Anglia' coast

Receptor	Tolerance	Adaptability	Recoverability	Value	Sensitivity
'Suffolk Natura 2000' site	Low	Low	Negligible	High	Medium
'East Anglia' coast	Low	Low	Negligible	Medium	Low

433. The significance of impacts relating to sea bed morphology and sediment transport arising from the presence of cable protection measures for offshore export cables would differ depending on the location of the works and the identified receptor groups under consideration.

434. In areas offshore of the cable crossings there would be direct impacts of **minor significance** on the 'Suffolk Natura 2000' site.

435. In areas inshore of the cable crossings there would be direct impacts of **minor significance** on the 'Suffolk Natura 2000' site and these, in turn, would cause indirect impacts of **minor significance** on the East Anglia coast due to interruptions to sediment transport processes.

436. There would be **no impact** on the other identified marine geology, oceanography and physical processes receptor groups since these are located remotely from the locations of potential effect.

437. The significance of these effects on other receptors is addressed within relevant chapters of this ES.

7.6.2.8 Impact 8: Morphological effects due to cable protection measures at the offshore cable landfall

438. As the offshore export cable would remain buried at the landfall throughout the operational life of 25 years, no cable protection would be required and as such no morphological effects would take place.

439. Analysis of past coastal change and future coastal projections would inform detailed engineering decisions about cable burial depths.

7.6.2.8.1 Assessment of Effect Magnitude and/or Impact Significance

440. Taking the above considerations into account, the worst case effects on the coastline morphology at the cable landfall during the operational phase of the proposed East Anglia THREE project are **no impact**.

7.6.2.9 Impact 9: Indentations on the Sea bed due to Maintenance Vessels

441. There is potential for certain vessels used during the maintenance of the windfarm and offshore cable infrastructure to directly impact the sea bed during the operation phase. This applies for those vessels that utilise jack-up legs or a number of anchors to hold station and to provide stability for a working platform. Where legs or anchors (and associated chains) have been inserted into the sea bed and then removed, there is potential for an indentation proportional to the dimensions of the object to remain. There is also potential for local effects on waves, tides and sediment transport and also for local scour hole formation around the legs or anchors while they remain in place for the duration of the maintenance works. The worst case is considered to correspond to the use of jack-up vessels (up to 2 vessels per wind turbine for a duration of 1 day to undertake maintenance) since the

depressions and potential for effects on physical processes and scour hole formation would be greater than the anchor scars.

442. As the leg is inserted, the sea bed sediments would primarily be compressed vertically downwards and displaced laterally. This may cause the sea bed around the inserted leg to be raised in a series of concentric pressure ridges.

443. As the leg is retracted, some of the material would return to the hole via mass slumping under gravity until a stable slope angle is achieved. Over the longer term, the pit would become shallower and less distinct due to infilling with mobile sediments.

444. For purposes of a worst case, it has been assumed that the total area of sea bed that may be affected by these activities is 1.31km^2 per year (based on up to 730 visits by jack-up vessels with a footprint of 1,800m^2). It is possible that different areas would be affected in each year of the operational phase.

445. The effects of the jack-up legs on waves, tides and sediment transport would be extremely localised since the legs are of small dimensions and would be temporary in nature. Once the maintenance activities are complete the jack-up barges would be moved on and no permanent effects on physical processes would remain.

446. Concerning the potential for scour, the legs of the jack-up barge would be small in diameter and this would place a physical limit on the depth and plan area of any scour hole formation (and hence the volume of scour material that would be released into the water column). This process would be further influenced by the physical conditions at each site (e.g. waves, currents, sea bed sediments, strength of underlying geology, etc.). The scour volumes arising would therefore be small in magnitude and cause an insignificant effect in terms of enhanced suspended sediment concentrations and deposition of sediments elsewhere.

7.6.2.9.1 Assessment of Effect Magnitude and/or Impact Significance

447. The worst case changes in terms of indentations on the sea bed due to maintenance vessels are likely to have the following magnitudes of effect (*Table 7.38*):

Table 7.38 Magnitude of effect on sea bed due to installation vessels under worst case scenario

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field (immediate vicinity of leg)	High	Negligible	Negligible	Medium	Medium
Near-field (beyond immediate vicinity of leg)	No change	-	-	-	No change
Far-field	No change	-	-	-	No change

448. There is **no impact** under a worst case scenario on the identified morphological receptor groups since they are remote from the immediate vicinity of each leg.

449. The significance of these effects on other receptors is addressed within relevant chapters of this ES.

7.6.3 Potential Impacts during Decommissioning

450. The scope of the decommissioning works would most likely involve removal of the accessible installed components. This is outlined in section 5.5.18 of Chapter 5 Description of the Development and the detail would be agreed with the relevant authorities at that the time of decommissioning. Offshore, this is likely to include removal of all of the wind turbine components, part of the foundations (those above sea bed level), removal of scour and cable protection (if best practice at that time dictates) removal of the sections of the inter-array cables, platform link cables and interconnector cables close to the offshore structures and parts of the export cables.

451. With regards to offshore cables, general UK practice would be followed, i.e. buried cables would simply be cut at the ends and left *in situ*, with the exception of the inter-tidal zone across the beach where the cables would otherwise be at risk of becoming exposed over time.

452. During the decommissioning phase, there is potential for wind turbine, foundation and, where undertaken, cable removal activities to cause changes in suspended sediment concentrations and / or sea bed or shoreline levels as a result of sediment disturbance effects.

453. The types of effect would be comparable to those identified for the construction phase, namely:

- Impact 1: Changes in suspended sediment concentrations due to foundation removal;
- Impact 2: Changes in sea bed levels due to foundation removal;
- Impact 3: Changes in suspended sediment concentrations due to removal of parts of the inter-array, platform link and interconnector cables;
- Impact 4: Changes in sea bed levels due to removal of parts of the inter-array, platform link and interconnector cables;
- Impact 5: Changes in suspended sediment concentrations due to removal of parts of the offshore export cable;
- Impact 6: Changes in sea bed levels due to removal of parts of the offshore export cable;
- Impact 7: Indentations on the sea bed due to decommissioning vessels; and
- Impact 8: Changes to suspended sediment concentrations and coastal morphology at the offshore cable landfall due to removal of the offshore export cable.

454. The magnitude of effects would be comparable to those identified for the construction phase. Accordingly, given that **no impact** was assessed for the identified marine geology, oceanography and physical processes receptors during the construction phase, it is anticipated that the same would be valid for the decommissioning phase.

455. The significance of effects on other receptors is addressed within relevant chapters of this ES.

7.7 Cumulative Impacts

456. The construction, operation and decommissioning phases of the proposed East Anglia THREE project would cause a range of *effects* on the marine geology, oceanography and physical processes.

457. The receptors that have been specifically identified in relation to marine geology, oceanography and physical processes are the sensitive 'East Anglia' coastline, the 'Norfolk' Natura 2000 site, the 'Suffolk' Natura 2000 site, and nearby 'non-designated sandbanks'. Impacts to the relevant designated features of these sites are assessed in Chapters: 10 Benthic Ecology, 13 Offshore Ornithology and 23 Terrestrial Ecology, and an assessment of the potential for likely significant effects on

Natura 2000 sites is assessed in the Information for the Habitats Regulations Assessment Report.

458. The effects that have been assessed for the proposed East Anglia THREE project alone are mostly anticipated to result in **no impact** in terms of *impacts* to the above-mentioned receptors (although there are some exceptions). This is primarily because these receptors are located remotely from the zones of influence arising from most of the effects and no pathway has been identified that can link the source to the receptor in most cases. This assessment remains valid for both the Single Phase and Two Phased construction approaches considered.

459. *Figure 7.9* and *Figure 7.10* show the overlap of 'zones of influence' arising cumulatively from the East Anglia ONE and proposed East Anglia THREE projects in relation to changes on the tidal and wave regimes, respectively. There is no interaction between the proposed East Anglia THREE project with the East Anglia ONE project. Due to this, there is no potential for associated cumulative impacts on the identified receptors due to changes in these processes.

460. There may, however, potentially be cumulative effects on some of the identified receptor groups arising due to:

- Installation or decommissioning of the offshore export cable (including works at the landfall of the offshore cable) associated with the East Anglia ONE, proposed East Anglia THREE and future East Anglia projects; and / or
- Installation or decommissioning of the offshore export cable (including works at the landfall of the offshore cable) for the proposed East Anglia THREE project and marine aggregate dredging activities in adjacent areas of sea bed.

461. The impacts of the offshore cable installation and decommissioning activities (including works at the landfall) on the identified receptor of the 'East Anglia' coast were identified to be of negligible significance for the proposed East Anglia THREE project alone. However, the export cable corridor at the landfall is common to the East Anglia ONE project and a future East Anglia project in addition to the proposed East Anglia THREE project and therefore there is potential for cumulative impacts to arise during the construction and decommissioning stages. Given the phased construction of the offshore cable installation (including landfall works) for each of these projects, it is unlikely that there would be overlap in export cable installation between the proposed East Anglia THREE and the consented East Anglia ONE project. Given the significance of impact assessed in construction impacts 5 and 6

(sections 7.6.1.5 and 7.6.1.6) it is not considered that cumulative impact of two projects constructing in this area at the same time would be greater than **negligible**.

462. In order to assess the potential for effects arising cumulatively between the installation of the offshore export cable for the proposed East Anglia THREE project and marine aggregate dredging activities in adjacent areas of sea bed, reference has been made to the EIA for the East Anglia ONE project. This EIA was supported by numerical modelling, using Delft3D plume modelling software, of the potential for interactions of sediment plumes arising from offshore cable installation with those arising from marine aggregate dredging sites (and indeed other sea bed activities) located within one spring tidal excursion distance from the East Anglia ONE offshore cable corridor. The modelling showed that some interaction could potentially occur between dredging plumes and plumes from cable installation and that the spatial extent of the combined plume is slightly greater than for the plumes originating from the offshore export cable installation only. Whilst maximum plume concentrations would be no greater under the cumulative scenario, a larger geographical area might experience increases in suspended sediment concentrations of more than 40mg/l than for the offshore export cable installation only scenario. Following cessation of cable burial and aggregate dredging activities, a few hundred metres away from the immediate release locations maximum theoretical bed level changes of up to 2mm were observed, with maximum levels of around 0.8mm at greater distances.

463. Given that the landfall and inshore sections of the East Anglia THREE export cable corridor are exactly coincident with those assessed for the East Anglia ONE offshore cable corridor, it is also considered the potential *cumulative impacts* between offshore cable installation and nearby marine aggregate dredging activities would be **negligible**.

464. The cumulative impact assessment findings presented above are consistent with the findings of the earlier ZEA in relation to marine geology, oceanography and physical processes (ABPmer 2012a). This concluded that whilst there would be changes (or effects) in baseline marine geology, oceanography and physical processes, the only receptor grouping to which possible significant impacts and possible significant cumulative impacts could occur was the 'East Anglia' coast.

465. In addition to the above considerations, the present assessment for the proposed East Anglia THREE project has assumed a worst case that up to 10% of the offshore cables cannot be buried at the cable crossings or locations further east and would require some form of cable protection works. Inshore of the cable crossings, these works are assumed to be required along up to 2.5% of the offshore cables as a worst case. This is based on recent practical experience of cable installation which

demonstrates that achieving 100% burial is not always possible, and therefore warrants bespoke consideration here.

466. In locations west of the cable crossings, there is potential for **minor cumulative impact** on the 'Suffolk Natura 2000' site (particularly parts of the Outer Thames Estuary SPA due to the proximity to the offshore export corridor) and the 'East Anglia' coast, should the offshore cables of each of the East Anglia ONE, proposed East Anglia THREE and future East Anglia projects require cable protection works in line with the worst case assumptions.

467. There is also potential at the cable crossings or in locations within the export cable corridor that are around 20km further east for **minor cumulative impact** on the 'Suffolk Natura 2000' site should the offshore cables of each of the proposed East Anglia THREE and future East Anglia projects require cable protection works in line with the worst case assumptions.

468. Consequently, export cables would be installed using a best practice approach with the objective of minimising, as far as practicable, possible effects on key receptors. A detailed cable laying plan would be developed in the pre-construction stage of the project which would incorporate a cable burial risk assessment to ascertain burial depths and cable laying techniques and with the objective of achieving optimum cable burial and thereby minimising the lengths of remaining unburied cable that would require protection.

469. It is agreed that EATL would adopt a hierarchical approach to cable protection options in the event that full burial of the entire lengths of the export cables cannot be achieved. Under this approach, protection options would be assessed using a number of criteria, including the aim of selecting protection methods which would cause least disturbance to sensitive receptors.

470. If 100% burial is achieved, for example, then there would be **no impact** in bedload sediment transport anywhere within the export cable corridor and hence no cumulative impact arising from the proposed projects.

471. The above cumulative impact assessment remains valid for both the Single Phase and Two Phased construction approaches considered.

7.8 Transboundary Impacts

472. The predicted changes to the baseline physical environment are not anticipated to be of sufficient magnitude or cover a sufficient geographical extent to impact upon

the identified marine geology, oceanography and physical processes receptor groups located within other EU member states.

473. This finding is supported by the assessments that have been made in the East Anglia ZEA (ABPmer 2012a) and the ES of the East Anglia ONE project (ABPmer 2012b).

7.9 Inter-relationships

474. The construction, operation and decommissioning phases of the proposed East Anglia THREE project would cause a range of effects on the marine geology, oceanography and physical processes. The magnitude of these effects has been assessed using expert assessment, drawing from a wide science base that includes project-specific surveys and previous numerical modelling activities.

475. These effects not only have the potential to directly affect the identified marine geology, oceanography and physical processes receptors but may also manifest as impacts upon receptors other than those considered within the context of marine geology, oceanography and physical processes. The assessments of significance of these impacts on other receptors are provided in the chapters listed in *Table 7.39*.

Table 7.39 Chapter topic Inter-relationships

Topic and description	Affected Chapter	Where addressed in this Chapter
Effects on water column (suspended sediment concentrations)	8 – Marine water and sediment quality 11- Fish and shellfish ecology 14 – Commercial fisheries	7.6.1.1 (foundation installation) 7.6.1.3 (inter-array cables installation) 7.6.1.5 (offshore cables installation) 7.6.2.4 (foundation scour)
Effects on sea bed (morphology / sediment transport / sediment composition)	10 – Benthic ecology 11- Fish and shellfish ecology 14 – Commercial fisheries 15 – Shipping and navigation 17 – Offshore archaeology and cultural heritage 18 – Infrastructure and other users	7.6.1.2 (foundation installation) 7.6.1.4 (inter-array cables installation) 7.6.1.6 (offshore cables) 7.6.1.7 (installation vessels) 7.6.2.3 (sediment transport regime) 7.6.2.5 (foundation scour/scour protection) 7.6.2.6 (inter-array cable protection) 7.6.2.7 (offshore cable protection in offshore zone)
Effects on physical processes (waves, tides)	9 – Underwater noise and vibration and magnetic fields	7.6.2.1 (tidal regime) 7.6.2.2 (wave regime)

Topic and description	Affected Chapter	Where addressed in this Chapter
Effects on shoreline (morphology / sediment transport / sediment composition)	10 – Benthic ecology 21 – Water resources and flood risk 29 – Seascape, landscape and visual amenity	7.6.1.8 (cable landfall) 7.6.2.7 (offshore cable protection in nearshore and inter-tidal zone)

7.10 Summary

476. The construction, operation and decommissioning phases of the proposed East Anglia THREE project would cause a range of effects on the marine geology, oceanography and physical processes. The magnitude of these effects has been assessed using expert assessment, drawing from a wide science base that includes project-specific surveys and previous numerical modelling activities.

477. The receptors that have been specifically identified in relation to marine geology, oceanography and physical processes are the sensitive 'East Anglia' coastline, the 'Norfolk' Natura 2000 site, the 'Suffolk' Natura 2000 site, and nearby 'non-designated sandbanks'.

478. The effects that have been assessed are mostly anticipated to result in **no impact** to the above-mentioned receptors because they are located remotely from the zones of influence and no pathway has been identified that can link the source to the receptor. The only exceptions to this which could potentially result in impacts to these receptors are listed in *Table 7.40*.

Table 7.40 Potential Impacts Identified for Marine Geology, Oceanography and Physical Processes Receptor Groups

Potential Impact	Receptor	Value/ Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Construction						
Changes in sea bed levels due to offshore cable installation	'Suffolk Natura 2000' site	Negligible	Low (near field only)	**Negligible**	Optimisation of offshore cable route alignment, depth and installation methods	**Negligible**
Changes to coastal	'East Anglia'	Negligible	Low (near	**Negligible**		**Negligible**

Potential Impact	Receptor	Value/ Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
morphology at the offshore cable landfall	coast		field only)			
Operation						
Morphol-ogical and sediment transport effects due to cable protection measures for offshore cables	'Suffolk Natura 2000' site (at or offshore of cable crossings)	Medium	Medium	**Minor**	Optimisation of offshore cable route alignment to minimise requirement for cable protection works	**Minor** to **no impact** (depend-ing on % burial of cable length)
	'Suffolk Natura 2000' site (inshore of cable crossings)	Medium	Low	**Minor**		**Minor** to **no impact** (depend-ing on % burial of cable length)
	'East Anglia' coast	Low	Low	**Minor**		**Minor** to **no impact** (depend-ing on % burial of cable length)
Decommissioning						
Removal of offshore cable at landfall	'East Anglia' coast	Negligible	Low (near field only)	**Negligible**	Leave cable buried *in situ* if practicable	**No impact**

479. This impact assessment remains valid for both the Single Phase and Two Phased construction approaches considered.

480. No significant cumulative impacts have been identified on the marine geology, oceanography and physical processes receptor groups between the proposed East Anglia THREE project and other nearby marine developments and activities (including other windfarm developments, marine aggregate dredging and marine disposal) with the exception of potential cumulative effects associated with the worst case assumptions of cable protection works along the offshore cables.

481. Under this scenario, there is potential for **minor cumulative impact** on the 'Suffolk Natura 2000' site (particularly parts of the Outer Thames Estuary SPA due to the proximity to the export cable corridor) and the 'East Anglia' coast should the offshore cables of each of the East Anglia ONE, proposed East Anglia THREE and future East Anglia projects require cable protection works in line with the worst case assumptions.

482. Similarly, there is potential at the cable crossings or in locations within the export cable corridor that are around 20km further east for **minor cumulative impact** on the 'Suffolk Natura 2000' site should the offshore cables of each of the proposed East Anglia THREE and future East Anglia projects require cable protection works in line with the worst case assumptions.

483. Efforts would therefore be made during detailed design to optimise the achievement of target burial depth and hence minimise the requirement for cable protection works. If, for example, 100% burial is achieved then there would be **no impact** in bedload sediment transport and hence no cumulative impact arising from the proposed projects.

484. This cumulative impact assessment remains valid for both the Single Phase and Two Phased construction approaches considered.

485. No transboundary impacts have been identified on the marine geology, oceanography and physical processes receptor groups located within other EU member states.

7.11 References

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Chapter 7 Ends Here