Section 10

The Physical Environment - Assessment of Impacts

10 THE PHYSICAL ENVIRONMENT – ASSESSMENT OF IMPACTS

10.1 INTRODUCTION

This section describes the potential impacts, mitigation measures and subsequent residual impacts on the physical environment as a result of Humber Gateway.

The topics covered in this section include:

- water quality; and
- coastal processes

In all cases, the potential impacts as a result of construction, operation and decommissioning are considered.

A stand alone coastal processes assessment report is presented in *Appendix B2 Coastal Processes Embedded Mitigation Assessment*. This report provides detailed information concerning the assessment process and methods used in both the water quality and coastal processes assessments (note that the water quality assessment forms part of the coastal processes assessment).

10.2 WATER QUALITY ASSESSMENT

10.2.1 Scope and Methodology

Introduction and Scope of the Assessment

The water quality impact assessment investigates the potential for the physical and chemical properties of the water column to be impacted as a result of activities during the construction, operation and decommissioning phases of the Humber Gateway project.

Construction activities which have the potential to cause impacts to water quality (primarily through disturbance to the seabed and release of sediment into the water column, but also potentially by disturbing contaminated sediment) include:

- seabed preparation;
- gravity base foundation installation;
- monopile installation (drilling or piling);
- export and inter-array cable installation (trenching, jetting or ploughing); and
- substation installation (drilling or piling).

Other construction activities which have the potential to cause impacts to water quality include those which have the potential to result in the release of a substance into the aquatic environment including:

- release of grouting material during monopile installation;
- accidental release of antifouling paint during painting of monopiles; and
- accidental release of oil and grease from construction vessels.

E.ON is committed to the use of best practice techniques and due diligence throughout all construction, operation and maintenance activities. This will be in accordance with a Construction Environmental Management Plan (CEMP) which will be prepared for the project. This commitment assures the use of appropriate preventative measures at all times and serves as an embedded mitigation against this type of pollution incident. In the event of any pollution, quantities of accidentally released materials are likely to be small and regional dispersal rates are high. For these reasons, the issue of impacts resulting from accidental pollution incidents has been scoped out of this assessment.

There is little potential for water quality to be impacted during the operational phase as all likely maintenance work will be conducted above the sea surface. The only potential risk is through the accidental spillage or release of materials such as grease and oils during maintenance work. E.ON is committed to the use of best practice and pollution prevention guidelines at all times. This will be in line with the Integrated Pollution Prevention and Control (IPPC) Directive such that any potential risk is minimised. As stated above, quantities of accidentally released materials are likely to be small and regional dispersal rates are high. For these reasons, this issue is also scoped out of this assessment.

There is potential for water quality to be impacted during the decommissioning phase through the re-suspension of fine particulate matter during the removal of offshore components. This impact is likely to occur in a similar way though to a lesser degree than that described for the construction phase and the embedded mitigation will be the same as for the construction phase of the project.

Consultation

Cefas and Defra were consulted and their comments are recorded in *Appendix A Summary of Consultation Responses*. Their key concern in relation to water quality was the potential for changes to turbidity, during both construction and operation.

Realistic Worst Case

Introduction

The project description, presented in *Section 6*, describes the Rochdale envelope and the realistic worst case scenarios that have been assessed are described below.

Foundation Type

The largest monopile, or alternatively the gravity base foundation, could represent the realistic worst case in the assessment of impacts to water quality. Therefore, both scenarios have been included in the assessment (*Appendix B2 Coastal Processes Embedded Mitigation Assessment*).

These options are as follows.

- Monopile foundations, 4 to 6 m diameter. If piling is used then minimal disturbance to the seabed will result. However, in the realistic worst case scenario drilling may be required, which would result in the release of 1,321 m^3 (on average) of sediment per monopile.

- Gravity base foundations, comprising a large (between 20 and 40 m) solid concrete foundation piece onto which the main tower (diameter between 6 and 8 m) is attached. Seabed preparation is required and seabed penetration of this design is between 0.5 and 2 m. In this instance, a sediment release of 1,885 m^3 per foundation is predicted.

Spoil Disposal

Spoil excavated during seabed preparations will be disposed of either within the Humber Gateway site or at a designated site remote to the development. For the purposes of the water quality assessment, it is considered that the realistic worst case scenario is that spoil will be disposed of within the Humber Gateway site.

Export Cable Corridor

Two export cable route corridors (representing the two cable route options) have been surveyed, as shown in *Figure 5.6*. Both the northern and southern cable route options will make landfall to the south of the village of Easington on the Holderness Coast. For the purposes of this assessment the cable construction corridor is assumed to be 300 m width, the cable is expected to have a diameter of 190 mm and to be buried to the maximum depth of between 1 and 3 m.

Cable Installation Methodology

Three methods of cable installation have been identified, as follows.

- *Ploughing*. This method has been typically deployed in materials ranging from silt to structure-less chalk (weak rock) [(1)]. The cable is buried by a passive tool mounted on skids which is pulled through the seabed by a towing vessel. The plough is usually deployed in a simultaneous lay and trench mode, using cable depressors to push the cable into position at the base of the trench. Jet assist options are sometimes fitted to the plough in conditions of firmer soils and, for deeper burial, a rock penetrating tooth or a vibrating plough share is sometimes used. This method typically keeps soil disturbance to a minimum, however silt and structure-less chalk may remain in suspension for periods of time. Cables at North Hoyle and Scroby Sands offshore wind farms have been buried using this method, as have telecom and power cables.

- *Jetting*. The mechanism used for jetting is dependant upon the soil type. In non-cohesive material either liquefaction or fluidisation can be used and the tools are usually mounted on remotely operated vehicles. Water jets are used to displace the sediment and the cable generally settles under its own weight. Cables at the offshore wind farms at North Hoyle, Arklow Bank, Nysted, Horns Rev and Scroby Sands have been installed using this method.

- *Trenching*. If rock or more resistant substrate is present, methods may need to be employed that use various techniques to cut through the hard substrate.

Whilst the first two methods may release material into the water column, it is the jetting method that has the potential to result in greater volumes of suspended sediment as it directly fluidises the material. Therefore, whilst all three methods have the potential to be used within the project, it is jetting that is regarded as the realistic worst-case scenario and has therefore been assessed in this study.

Construction Schedule

With regard to water quality, the realistic worst case for the installation schedule (for each foundation type) is that which gives rise to the highest rate of sediment disturbance. This has been assumed to be:

- monopile - continual installation for eight hours out of every 24 hours; and
- gravity base - continual installation for 16 hours, followed by eight hours downtime.

It should be noted that these timings do not take into account any downtime that may be necessary due to adverse weather conditions and therefore represent a realistic worst case scenario.

It has been assumed that the cable will be laid at a rate of 150 m hr^{-1} and that this will be a continuous process.

Embedded Mitigation

All construction vessels will be well maintained and operators will comply with best practice techniques for minimising the risk of accidental spills into the marine environment. This will be in accordance with a CEMP which will be prepared for the project.

Methodology

Introduction

This section describes the guidance, prediction methods and assessment criteria that have been applied to this assessment. It should be noted that these are also adopted for the cumulative assessment (*Section 13*).

[(1)] Royal Haskoning, 2006. Review of cabling techniques and effects applicable to the offshore wind farm industry: Technical Report (Draft). Ref. 9R7535/R00002/SJV/Pbor.

Guidance Documents

Guidance on the generic requirements for coastal process studies (including water quality) is provided in three main documents:

- *Offshore Wind Farms: Guidance Note for Environmental Impact Assessment in Respect of FEPA and CPA requirements: Version 2* [(1)];
- *Guidance on Environmental Impact Assessment in Relation to Dredging Applications* [(2)]; and
- *Nature Conservation Guidance on Offshore Wind Farm Development* [(3)].

Prediction Methods

To predict the potential increases in turbidity resulting from disturbance to the seabed or release of excavated material during construction, detailed modelling studies have been carried out. (*Appendix B2 Coastal Processes Embedded Mitigation Assessment*). These modelling studies have taken into consideration the realistic worst case scenarios described above.

Assessment Criteria

Since sensitivity of the physical receptors (e.g. waves and tides) is not an appropriate factor in this instance, only the predicted magnitude of the impact (spatial and temporal) can be described. Impacts are described as being ***significant*** or ***not significant***.

This assessment is based on professional judgement founded on a thorough understanding of the baseline environment (described in *Section 7*), consideration of all appropriate standards and legislation (including the Dutch Sediment Quality Standards, which are considered to be appropriate and relevant standards in this case) and the likely effects of the Humber Gateway project. Where a predicted impact falls within the range of natural variation or appropriate standards, impacts are not considered to be significant.

(1) Defra, Cefas and DfT, 2004. Offshore wind farms: guidance note for Environmental Impact Assessment in respect of FEPA and CPA requirements: Version 2.
(2) OfDPM, 2001. Guidance on Environmental Impact Assessment in Relation to Dredging Applications.
(3) Defra, 2005. Nature Conservation Guidance on Offshore Wind Farm Development.

10.2.2 ASSESSMENT OF POTENTIAL IMPACTS

Increased Suspended Sediment Concentrations during Construction

Construction activity (seabed preparation, turbine, substation and cable installation) has the potential to disturb the seabed. In general, when an area of seabed is disturbed, fine particulate matter becomes suspended and results in localised increased turbidity levels. Extended periods of elevated turbidity can impact a number of species including filter-feeding benthic species and juvenile fish, as the suspended sediments may clog the gills and feeding mechanisms and damage respiratory organs. Furthermore, prolonged turbidity can reduce light penetration of the water column such that primary production is impeded. As suspended sediments fall out of suspension, they can smother feeding and spawning grounds, including any eggs or larvae that may dwell in the sediments.

The extent to which localised or regional turbidity is affected by the Humber Gateway development can be compared with the extent to which comparable effects are caused by natural conditions. Storm and flood events, for example, cause regional increases in suspended sediment loads and consequential fall out effects once weather conditions become more settled. There are also other anthropogenic activities that increase turbidity, such as marine aggregate dredging and trawling.

Turbidity levels are naturally high along the Holderness Coast, with the Humber Gateway site located at least partially within the Humber Estuary plume. The maximum baseline turbidity in this area is approximately 16 to 126 mg l^{-1} in winter and 4 to 256 mg l^{-1} in summer, as defined in the southern *North Sea Sediment Transport Study Phase 2* [(4)].

The potential impacts during turbine installation activities have been investigated by considering sediment spill during both monopile and gravity-base foundation installation. Three sediment sizes have been considered, from muds to medium sands, and it is shown that a plume is only created for the mud sized sediments, with the coarser material being re-deposited immediately. Typical suspended sediment concentrations for both foundation types are in the order of 20 mg l^{-1}. This is slightly greater than the average values recorded during the metocean survey (12.6 mg l^{-1}) that was commissioned by E.ON and carried out for this EIA, but below the maximum value that was recorded during this survey (20.8 mg l^{-1}). The predicted levels are therefore considered to be comparable to background concentrations. It is shown that the monopile installation creates the greatest plume, both in terms of magnitude and extent (*Figure 10.1*). As time period increases, the extent of the plume increases in a southerly direction, however it

(4) Cefas, 2002. Southern North Sea Sediment Transport Study - Sediment Transport Report. Great Yarmouth Borough Council by HR Wallingford, Cefas/UEA, Posford Haskoning and Dr. Brian D'Olier.

does not extend as far as either the Holderness or Lincolnshire coast and remains offshore. Once the installation process stops, the size and magnitude of the plume will decrease, therefore this effect is considered to be short term.

Jetting during cable installation is predicted to result in a localised sediment plume with suspended sediment concentrations in line with background concentrations (typically les than 20 mg l^{-1}). Again, the predicted levels are therefore considered to be comparable to background concentrations.

For the above reasons, ***no significant impacts*** to suspended sediment concentrations or turbidity are anticipated.

Re-Mobilisation of Sediment-Bound Contaminants during Construction

The seabed disturbance described above has the potential to release inorganic sediment-bound contaminants such as heavy metals and hydrocarbons into the water column. Releases of these substances can lead to unfavourable conditions for biota, particularly for juvenile fish and filter-feeding benthic species.

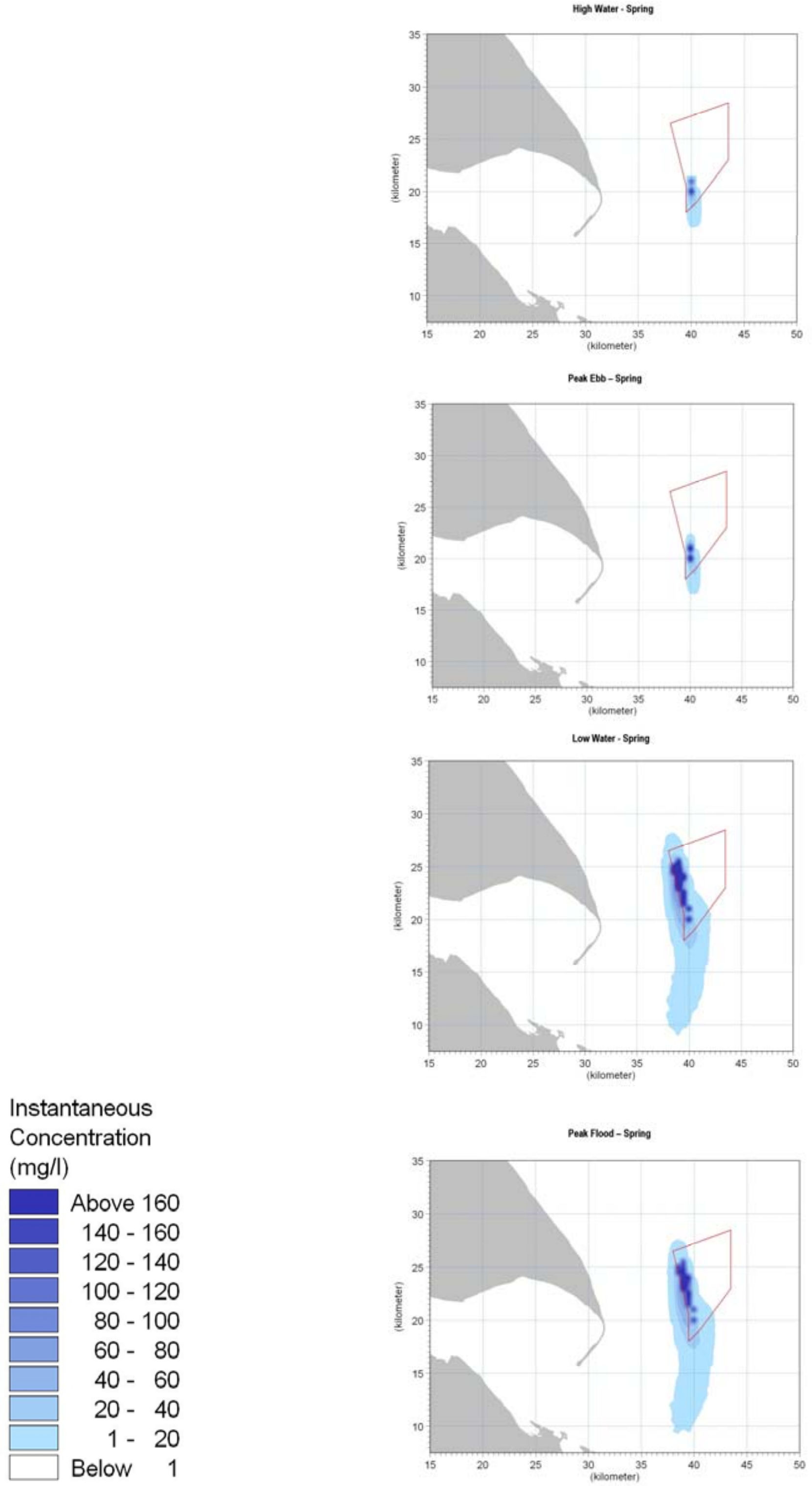
There is also the potential for layers of anoxic sediments to be disturbed, or those containing pathogens, harmful bacteria or viruses. This could pose public health risks for bathing waters and affect compliance with the *Bathing Waters Directive Environmental Quality Standards (EQS)*.

Levels of contaminated sediment are understood to be low across the Humber Gateway site and cable route areas (*Section 7.4.3*), with concentrations of polycyclic aromatic hydrocarbon (PAHs) compounds being below the detection limit (less than 0.35 mg l^{-1}) and, with the exception of nickel, all metal concentrations were low. The mean nickel concentration (16.5 mg kg^{-1}) was below the Dutch Sediment Quality standard. The scope for disturbance of sediment-bound contaminants to impact water quality significantly is therefore low. As has been described in the case of suspended sediments, the degree of disturbance of contaminated sediments would be similar to that resulting from storm or flood events. As such, ***no significant impacts*** to water quality are predicted as a result of disturbance of sediment-bound contaminants.

Increased Suspended Sediment Concentrations during Decommissioning

Any increase to turbidity caused by decommissioning activities is likely to occur to a lesser degree than that caused by construction activities as the decommissioning operations are less complex and will occur for a shorter duration. No significant impacts are predicted during the construction phase as a result of elevated turbidity, so it can be inferred that similarly, ***no significant impacts*** will occur during the decommissioning phase.

Figure 10.1 Suspended Sediment Plume (mg l^{-1}) from Sediment Spill during Monopile Installation



10.2.3 Mitigation Measures

There are no mitigation measures further to those embedded in the project design that relate to potential changes to water quality.

10.2.4 Residual Impacts

The previously described, minor changes to water quality during the construction and eventual decommissioning of the wind farm are temporary and localised in nature. As such, there will be ***no significant residual impacts*** to water quality as a result of the Humber Gateway project.

10.2.5 Monitoring

If required, post-construction monitoring of water quality will be undertaken in line with best practice guidelines. The design of this survey will be agreed at the appropriate time in line with guidance sought from the relevant regulatory authorities.

10.2.6 Enhancements

No enhancement measures are proposed.

10.2.7 Summary

The predicted effects on water quality have been assessed in relation to the sensitivity of the four designated Bathing Waters along the coast adjacent to the Humber Gateway site (in light of the necessity for continued compliance with EQS set out in the *Bathing Waters Directive* and other legislation) and on species inhabiting the sea area.

The disturbance and re-suspension of fine particulate matter and sediment-bound contaminants (as a result of construction and decommissioning activities) are considered to be the most likely areas of potential impact. Background levels and natural variability of turbidity are high in the region and are commonly caused by naturally occurring storm and flood events. Predictions show that the extent and severity of any increases in suspended solids (due to construction or decommissioning activities) will fall within the range of natural variability.

As a result, and as summarised in *Table 10.1*, ***no significant impacts*** to water quality are anticipated.

Table 10.1 Summary of Impacts to Water Quality

Potential Impact	**Potential Impact Significance**	**Additional Mitigation (in addition to embedded mitigation)**	**Residual Impact Significance**
Increased suspended sediment during construction of turbine foundations and cable routes	*No significant impact*	*None*	***No significant impact***
Re-mobilisation of sediment-bound contaminants during construction	*No significant impact*	*None*	***No significant impact***
Increased suspended sediment during decommissioning of turbines and cable routes	*No significant impact*	*None*	***No significant impact***

10.3 COASTAL PROCESSES

10.3.1 SCOPE AND METHODOLOGY

Introduction and Scope of the Assessment

The coastal environment is a dynamic regime in which sediment transport rates and / or local morphological changes are affected by:

- periodic tidal effects;
- episodic wind and wave effects; and
- the trends associated with climate change issues.

To enable an assessment to be carried out of the potential changes that may be introduced by the Humber Gateway project, the baseline environment has been described in terms of coastal processes and the potential natural changes (i.e. sea level rise) over the wind farm's operating period. The baseline is described in *Section 7* and more detail can be found in *Appendix B1 (Coastal Processes Baseline Assessment)*.

The scope of the assessment on coastal processes has been influenced by formal guidance and consultation with stakeholders. This is described in the following sections.

Consultation

A series of coastal process issues have been raised during consultation and following the issuing of the Scoping Report [(1)]. The responses received from consultation are detailed in *Appendix A* and can be grouped into the following key issues:

- the potential to affect littoral drift leading to the exposure of coastal archaeological features;
- changes to shoreline processes which may impact Spurn Head and other coastal conservation sites;
- changes to turbidity, during both construction and operation (discussed in *Section 10.2.2*);
- seabed scour, with the potential to expose remnants of ancient environmental features and displace benthic features; and
- scour during construction, potentially affecting seabed habitats.

Cefas and Defra were consulted in relation to the scope of the cumulative assessment for coastal processes. This is discussed further in *Section 13.2*.

Realistic Worst Case

Introduction

As noted in *Section 10.2.1*, the water quality and coastal processes assessments are closely related. As a result, the realistic worst case scenarios previously defined generally also apply in relation to coastal processes. Where this is not the case, this has been discussed further in the following sections.

Turbine Layout

Two of the five layout options proposed have been assessed in relation to coastal processes. These allow the evaluation of the potential effects of the largest number of smaller turbines with closer spacing (83 x 3.6 MW turbines – Layout 2) versus the smallest number of larger turbines with wider spacing (42 x 7 MW turbines – Layout 5). This conforms to the 'Rochdale envelope' approach.

Foundation Type

The realistic worst case foundation type is considered to be the concrete gravity base option, since this represents the greatest physical blockage to the physical environment. It therefore has the potential to cause the greatest changes to the wave and tidal regimes. This foundation type also involves a far greater degree of seabed preparation than the other structures and hence introduces a greater potential for seabed disturbance during the construction phase.

Scour Protection

Detailed engineering design and geotechnical investigations will determine whether scour protection is required. If scour protection is deemed necessary, gravel and possibly boulders will be used at the periphery, covering an area less than 1.5 times the diameter of the monopile. For gravity base designs, it is anticipated that this protection would consist of an approximately 1 to 1.5 m thick layer of gravel extending 10 to 15 m or more from the outer edge of the base plate perimeter. If found to be necessary, this basic method of protection may

(1) Emu Ltd, 2004. Humber Wind Ltd, Proposed HGOWF Offshore Wind Farm. EIA Scoping Report.

also be assisted by a skirt penetrating 0.5 to 2 m into the ground in the periphery of the concrete gravity base plate.

The installation and design of any scour protection will follow best practice in order to reduce the potential for secondary scour.

Cable Installation Methods and Overall Construction Schedule

The realistic worst case assumptions in relation to cable installation methods and construction schedule are described in the water quality section (*Section 10.2.1)*.

Embedded Mitigation

There are no embedded mitigation measures related to coastal processes.

Methodology

Guidance Documents

Guidance on the generic requirements for coastal process studies is provided in three main documents:

- *Offshore Wind Farms: Guidance Note for Environmental Impact Assessment in Respect of FEPA and CPA requirements: Version 2* [1];
- *Guidance on Environmental Impact Assessment in Relation to Dredging Applications* [2]; and
- *Nature Conservation Guidance on Offshore Wind Farm Development* [3].

The above guidance states that the coastal process study should assess the magnitude and significance of change to the following coastal regimes:

- the hydrodynamic regime, encompassing both the tidal and wave regimes (including, for example, tidal currents and wave heights); and
- sedimentological regime, including seabed sediment distribution and transport pathways.

These regimes were considered over a range of spatial and temporal scales. The spatial scales consisted of:

- near-field (the area within the immediate vicinity of the turbines and along the cable route); and
- far-field (the wider coastal environment over which impacts could occur).

The temporal scales consisted of:

- baseline (pre-construction phase);
- construction phase;
- post-construction phase;
- sediment recovery phase (period during which a new equilibrium position is attained with the wind farm in place); and
- lifetime of the wind farm.

Prediction Methods

To assess the potential and outcome of any localised scour around the turbine foundations and to assess the effects of the Humber Gateway development upon the existing coastal processes, a combination of site information and model outputs has been used to derive inputs to suitable empirical methods. The detailed methodology is presented in *Appendix B2 (Coastal Processes Embedded Mitigation Assessment)*.

Significance Criteria

In order to assess the potential impacts of the Humber Gateway development on the existing coastal processes, a combination of qualitative assessment of site data, empirical evaluation and detailed numerical modelling has been used to define the magnitude of any impact.

In light of the above information, the impacts are described as being ***significant*** or ***not significant***. This is determined by professional judgement taking into consideration the likely nature of the impact and the characteristics of the receiving environment. For example, in general terms, when a predicted impact falls within the range of natural variability in the baseline environment, the impact is not considered to be significant. Details of the specific criteria used for the different aspects of the coastal processes assessment are described in *Table* 10.2.

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[1] Defra, Cefas and DfT, 2004. Offshore wind farms: guidance note for Environmental Impact Assessment in respect of FEPA and CPA requirements: Version 2.
[2] OfDPM, 2001. Guidance on Environmental Impact Assessment in Relation to Dredging Applications.
[3] Defra, 2005. Nature Conservation Guidance on Offshore Wind Farm Development.

Table 10.2 Criteria Used for Assessing Significance

Regime	Issue	Criteria for Assessing Significance
		Near Field
Tidal	Changes to flows (bifurcation of flows around structures)	Predicted changes are considered in relation to their implications for sediment transport. If changes to near field flows are predicted to cause scour effects, they are considered to be significant.
Wave	Changes to wave heights or wave transmission	If changes to wave transmission translate to a significant change to the regional wave climate, impacts are considered to be significant.
Sediment	Scour around structures and creation of scour holes	If scour holes created by each individual structure interact with adjacent scour holes, impacts are considered to be significant.
		Far Field
Tidal	Changes to direction or magnitude of flows	If large scale alterations to tidal flow speeds and/or direction on a regional scale are predicted, impacts are considered to be significant.
Tidal	Changes to tidal residuals	If there is a switch in tidal dominance (i.e. flood to ebb or visa versa) or alterations to gross residual circulations around banks sufficient to affect bank maintaining processes, impacts are considered to be significant.
Wave	Changes to wave climate	If changes to the regional wave climate impinge upon other seabed uses or features or along adjacent coastline, impacts are considered to be significant.
Sediment	Increase in suspended sediment to create plume	If there are increases in background suspended sediment levels with a duration and extent that will impact upon seabed or coastal features, impacts are considered to be significant.
Sediment	Changes to fate of sediment	If deposition of sediment on the seabed is predicted to cause impacts to other seabed features or users (e.g. smothering of benthos, reduction in navigable depths), impacts are considered to be significant.
Sediment	Increase in suspended sediment from cable laying	If increases in background suspended sediment levels due to the cable burial process have a duration and extent that will impact upon other adjacent seabed or coastal features, impacts are considered to be significant.
Sediment	Changes existing bed load transport pathways	If alteration to a known bed load transport pathway is likely to impinge on features supplied with sediment by the pathway, impacts are considered to be significant.
Sediment	Changes to suspended sediment pathways	If alteration to a known suspended load transport pathway is likely to impinge on downdrift features or features affected by any newly created pathway, impacts are considered to be significant.
Sediment	Changes to existing coastal sediment transport	If alteration to longshore or cross-shore coastal sediment transport along adjacent stretches of coast are likely to have a detrimental effect on the form and function of coastal and associated features, impacts are considered to be significant.
Sediment	Scour resulting on creation of plume	If increases in background suspended sediment levels have a duration and extent that will impact upon other seabed or coastal interests, impacts are considered to be significant.
Sediment	Fate of scour material	If deposition of sediment on the seabed impacts other seabed features or users (e.g. smothering of benthos, reduction in navigable depths) impacts are considered to be significant.
Sediment	Interaction of sediment plumes from Humber Gateway and dredging	If interaction leads to a greater effect than would be reasonably expected from the two individual activities not acting ‘in combination’, impacts are considered to be significant.

10.3.2 ASSESSMENT OF POTENTIAL IMPACTS

Potential Impacts to the Hydrodynamic Regime during Operation

The potential for impacts to the hydrological regime are limited to the operational phase. During operation, the physical presence of structures in the water column (foundations, monopiles and scour protection if found to be necessary) has the potential to cause changes to the way water behaves around them. This effect can be predicted at both near and far field scales.

The assessment has shown that, for all the hydrodynamic parameters, Layout 2 has the potential to induce the greatest change to the regime (*Figure 10.2*). This is as a consequence of the smaller spaced structures within the site, and is a conclusion that has been reached in other wind farm studies.

It has been shown that directional changes are generally restricted to within the development site and are typically of the order of 1 º to 2 º. Furthermore, whilst the changes in current speed extend outside the development site, these represent at most a 4% change in magnitude. Minimal increases in flow speed, of the order of 0.02 m s^{-1}, may occur along the shoreline. However, these are not expected to affect the present sediment transport regime detrimentally, particularly as it has been shown that it is the wave climate that is the dominant process in the nearshore zone. The largest changes in current speed are predicted to occur in close proximity to the turbine structures, and represent a reduction of the order of 16%. As the change is a reduction in flow, consequential, detrimental, changes in the erosive properties of the seabed are not envisaged. ***No significant impacts*** to currents are therefore anticipated in the near-field or far-field zones.

It should be noted that, due to the scale of the modelling over the near-field and far-field, the potential impact is over-predicted. This is illustrated using structure scale modelling which has shown that flow reductions as a result of the individual structures typically remain isolated from each other and only join at certain tidal stages i.e. during peak flows.

Potential water level changes are considered to be minimal, particularly when assessed in relation to natural changes, for example sea-level rise. The maximum change due to the wind farm typically represents +0.01 m (during a spring tide) whilst the maximum change due to sea level rise is 0.34 m. For these reasons, ***no significant impacts*** to water levels are anticipated.

Potential Impacts to the Wave Regime during Operation

The potential for impacts to the wave regime are limited to the operational phase. During operation, the physical presence of structures in the water column (foundations, monopiles and scour protection if found to be necessary) has the potential to cause changes to the way water behaves around them as previously described.

The potential changes in the wave climate, which are limited to the operational phase, have been assessed for a combination of representative low frequency high energy events. These consist of four different wave return periods, each from three directions, using numerical modelling techniques. The return periods selected were the 0.1, 1, 10 and 50 year events from the most extreme directions of 330ºN, 000ºN and 030ºN. The assessment has shown that, as for the potential impacts upon the hydrodynamic regime, Layout 2 has a greater impact than that of Layout 5.

In all cases, the wave height will be reduced as a consequence of the wind farm and the greatest reduction is observed within the wind farm site itself. The changes in wave height, for all return periods, are greatest for the 030ºN direction. The changes are, however, minimal and represent a maximum 1% reduction for the 0.1 year return period and a 3% reduction for the 50 year return period (*Figure 10.3*). No resulting changes to regional wave climate are anticipated and ***no significant impacts*** to the near field wave regime are therefore anticipated.

The shoreline at Spurn is also subject to potential changes in wave height, of the order of 0.02 m for the most frequent event simulated (0.1 year return period). The consequential changes in the nearshore wave height upon littoral transport have been investigated further and are predicted to be insignificant. Thus the regional shoreline sediment transport which currently occurs in the nearshore is not expected to be affected, and therefore downdrift processes are also not expected to change. For these reasons, ***no significant impacts*** to the far field wave regime are anticipated. More details can be found in *Appendix B2.*

Figure 10.2 Current Speed Changes throughout the Tidal Cycle at Four Observation Points as a Consequence of Layouts 2 and 5

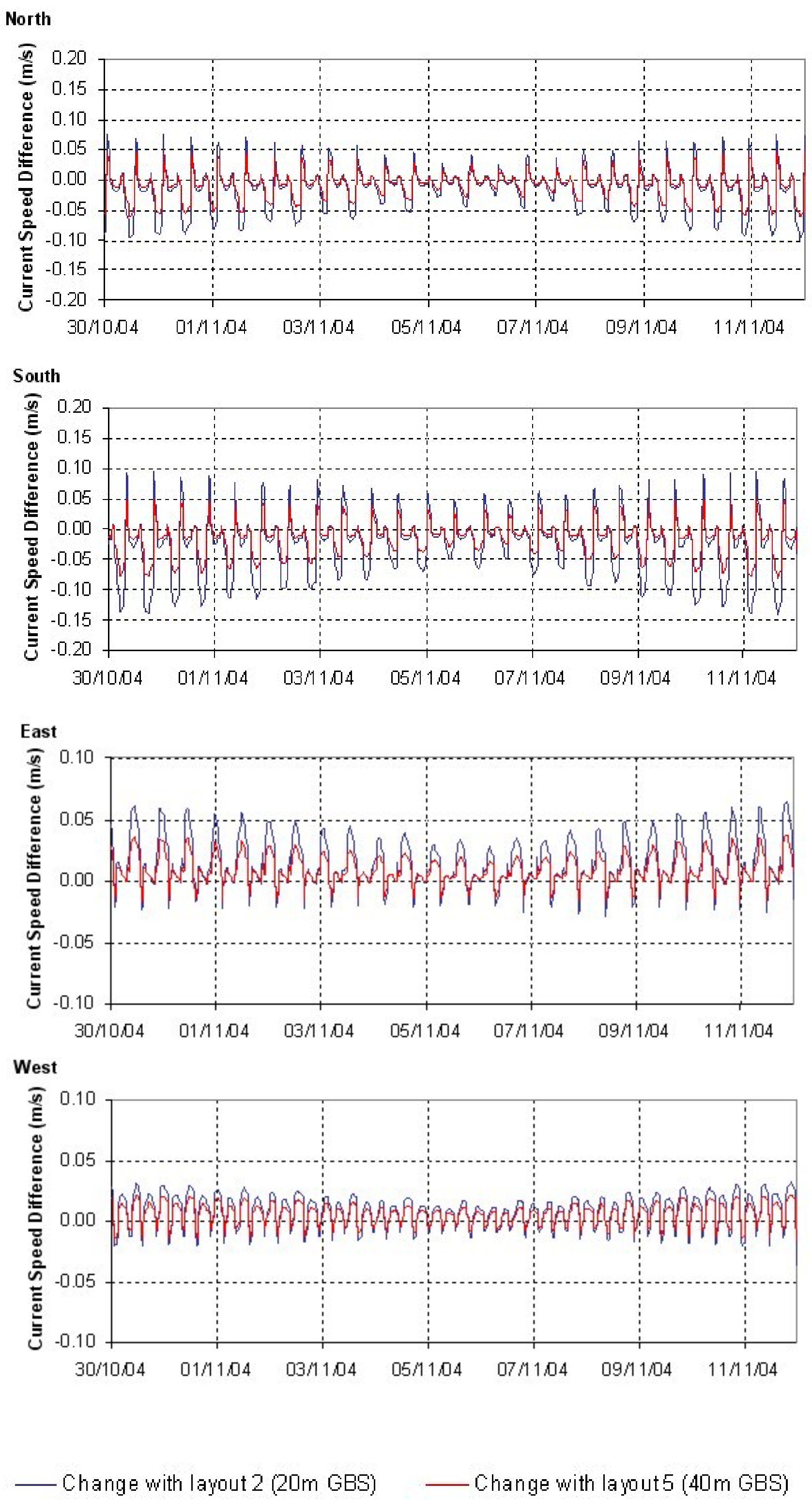
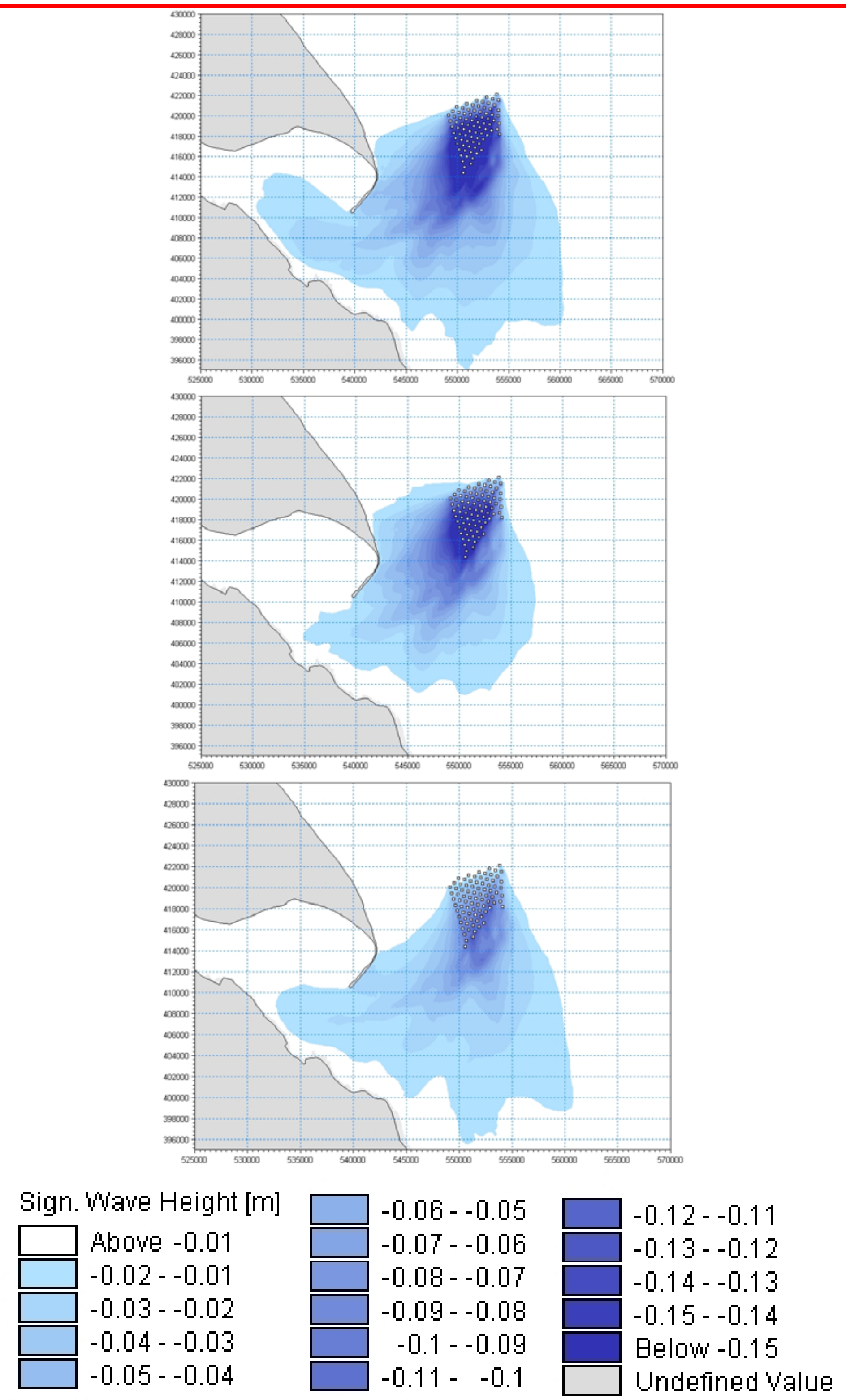


Figure 10.3 Changes in Significant Wave Height (m) at High Water (for Layout 2, 50 year return period)



Sedimentological Regime

Introduction

Both the construction and operational phases of the Humber Gateway project have the potential to cause impacts to the sedimentological regime, as follows.

- Release of sediments into the water column as a result of disturbance from construction and decommissioning activities (foundation / monopile and cable installation). This issue has been assessed in the water quality section (*Section 10.2.2)* and is not included in detail in this section.
- Deposition of sediments released as a result of construction activities (foundation / monopile and cable installation). This also applies to decommissioning, although to a lesser extent.
- Alteration to sediment transport routes as a result of the physical presence of the turbine structures in the water column during the operational phase.
- Seabed scour as a result of the physical presence of the turbines during the operational phase.
- Shoreline impacts as a result of any changes to sediment transport or littoral drift during the operational phase.

Potential Release of Suspended Sediments as a result of Construction Activities

The potential impacts during turbine installation activities have been investigated by considering sediment spill during both monopile and gravity-base foundation installation. Predicted suspended sediment concentrations for both foundation types are in the order of 20 mg l^{-1} which is slightly greater than the average values recorded during the metocean survey (12.6 mg l^{-1}) but below the maximum value recorded during the metocean survey (20.8 mg l^{-1}).

Jetting during cable installation is predicted to result in a localised sediment plume with suspended sediment concentrations typically less than 20 mg l^{-1}.

The predicted levels are therefore considered to be comparable to background concentrations and there will therefore be ***no significant impact***. Further details are provided in the water quality section (*Section 10.2.2)*.

Potential Sediment Deposition and Seabed Thickness Changes as a Result of Construction Activities

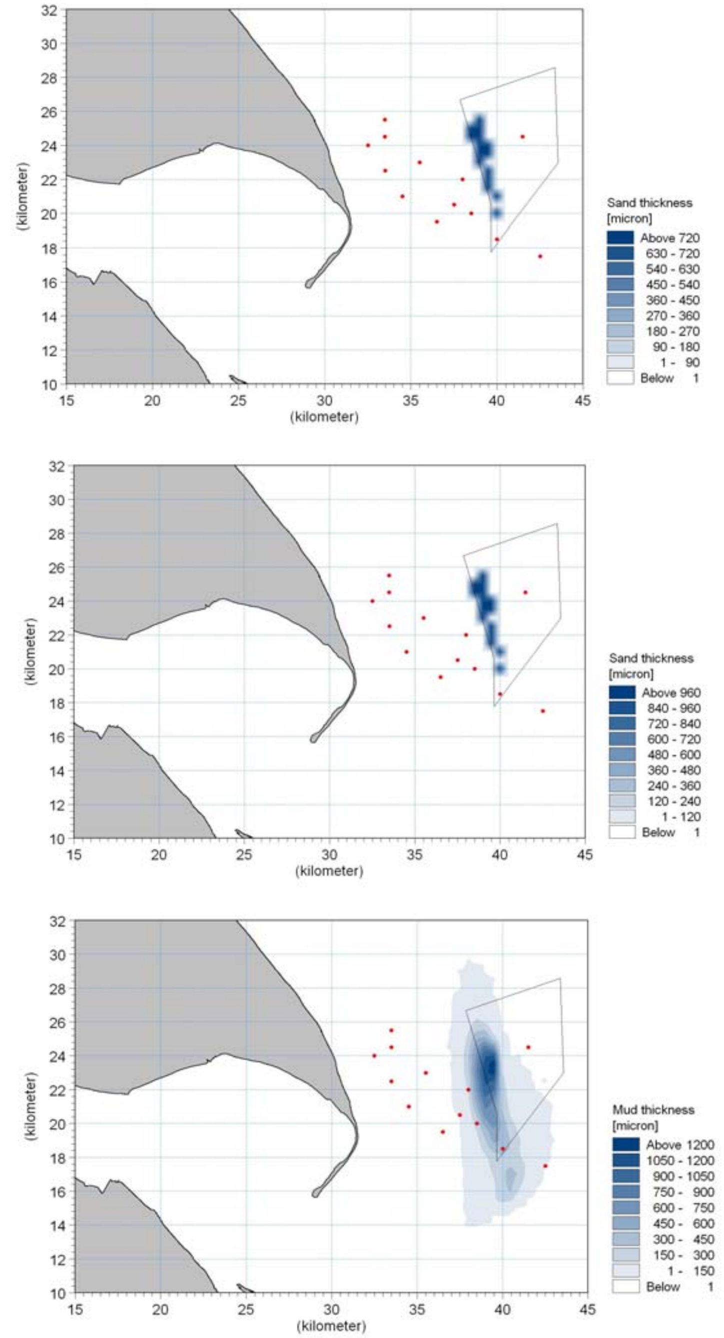
Turbine foundation and cable route installation activities have the potential to release suspended sediments which would in turn be deposited on the seabed.

In relation to turbine installation, the greatest deposition of sand is anticipated to be closest to the turbine structures (*Figure 10.4*) and is associated with the gravity base foundation. This is a direct consequence of the greater volume of sand sized sediment released during foundation installation. A maximum deposition of 3,200 µm is predicted (equivalent to approximately three grains of sand lain on top of each other). The mud sized material is anticipated over a wider area, however the greatest deposition is likely to be in the vicinity of the turbine array (1,200 µm and 160 µm for monopile and gravity base, respectively). Over a larger area, the deposition predicted is much smaller and in the order of 1 µm, however even this is not anticipated to reach the shoreline. At sites where *Sabellaria spp.* communities are located, deposition is predicted to be typically less than 300 µm. For these reasons, ***no significant impacts*** are anticipated in relation to changes to seabed thickness.

The predicted change in seabed thickness resulting from cable installation activities is shown in *Figure 10.5.* A similar sand deposition pattern is predicted for both the northern and southern cable route options. The mud fraction from the southern cable route, however, is predicted to disperse over a greater area than that of the northern cable route due to influences from the tidal regime of the Humber Estuary. Consequential increases in bed thickness are of the order of 5.6 µm (equivalent to one grain of very fine silt). Due to the very small magnitude of change, ***no significant impacts*** are predicted to seabed thickness as a result of cable installation activities.

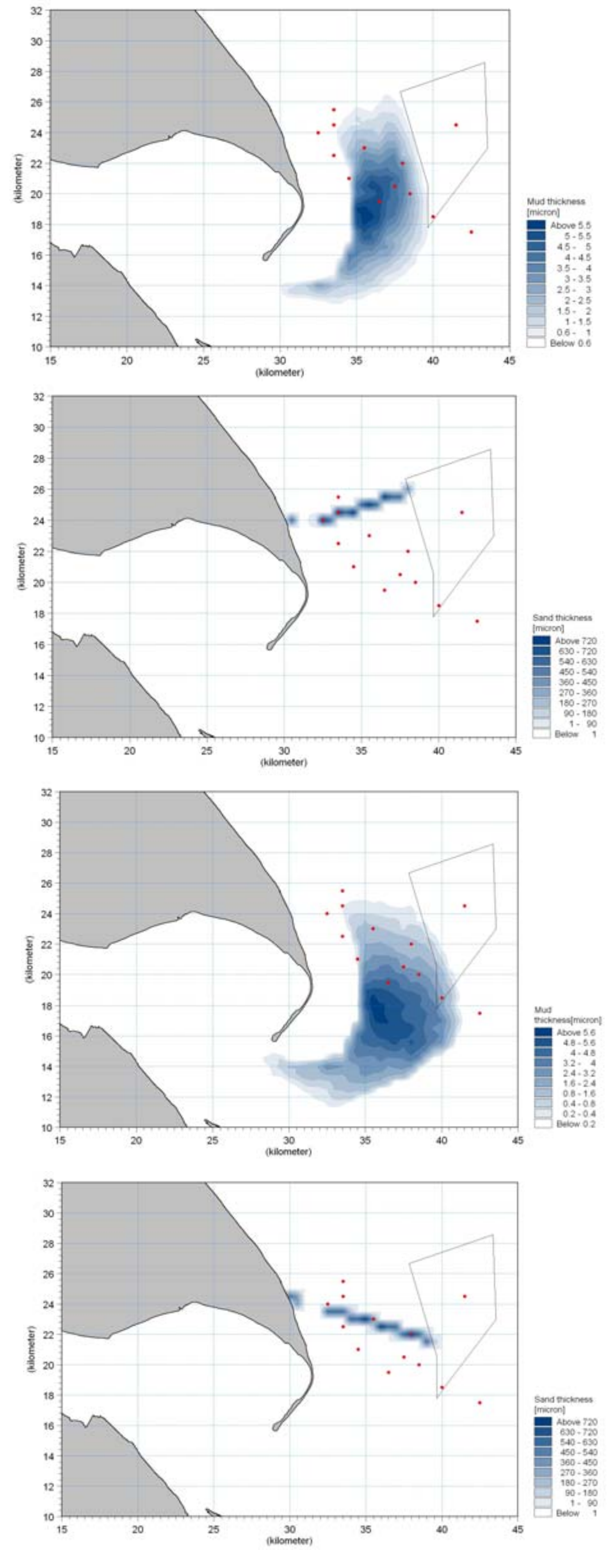
It should be noted that mud and medium sized sand values have been used for the modelling which, as shown from the geophysical survey, are in the minority with coarse sands being the smallest grain size sampled. As such, the modelling undertaken provides a realistic worst case prediction of the potential effects of the turbine installation.

Figure 10.4 Change in Bed Thickness (µm) at the End of a Spring-Neap Tidal Cycle Following Monopile Installation Sediment Releases



Sabellaria Locations

Figure 10.5 Change in Bed Thickness (µm) at the End of a Spring-Neap Tidal Cycle Following the Cable Installation Sediment Releases



Sabellaria Locations

Potential Impacts on Sediment Transport in the Vicinity of the Site during Operation

The potential for the presence of Humber Gateway (Layouts 2 and 5) to result in changes to net sediment transport rates on the site over a spring-neap cycle has been investigated. The results show that, over the far-field, whilst the potential impacts from Layout 2 are greater than those for Layout 5, the greatest effects are shown to occur within and immediately to the west of the Humber Gateway site. Only slight effects are observed in the vicinity of the coast (limited to an area immediately offshore from Spurn Head). This is dealt with in more detail below.

In the most northern part of Humber Gateway site there is a predicted change from a net northwards to net southwards direction. Slight directional deviations are also shown in the southern part of the Humber Gateway site.

An investigation of the impact of a surge event (50 year return period) on sediment transport has also been undertaken which showed that such an event has a greater impact on the net sediment transport regime than the operational impacts of Layout 2 or 5.

It can be concluded that, relative to the impacts potentially induced by a natural event such as a surge, both layouts are predicted to have little effect upon the net sediment transport potential over a spring-neap cycle and these small effects will not detrimentally affect the regional sediment transport regime.

The Humber Gateway project will therefore result in ***no significant impacts*** to sediment transport regimes during operation. It should be noted, however, that a single surge event represents a short-term 'interruption' to the system, whilst the wind farm may impact the sediment transport regime over a longer period. Notwithstanding this, the conclusion above still stands.

Potential Scour Impacts during Operation

Based on the geophysical survey information, with the exception of the southern edge the wind farm site is not covered by any extensive areas of mobile sediment. Furthermore, based on survey results from earlier wind farm developments where monopile foundations have been constructed in multi-modal sediment environments (for example, North Hoyle), there is little evidence to suggest that there is any scour taking place around the turbine foundations. The risk of scour at the Humber Gateway site is therefore considered to be low and it is unlikely that scour protection will be required. However, for completeness the assessment has considered the scheme both with and without scour protection.

A scour assessment for 6 m diameter monopiles at the Humber Gateway site (assuming no scour protection) has been carried out (*Appendix B2*). This assessment was based on the assumption that the seabed consists of a mono-modal sediment which remains uniform with depth. The assessment predicted that scour depths could range between 1.7 m and 2.6 m for monopile foundations and between 1 and 2 m for gravity base foundations, depending on grain size. The sediments at the Humber Gateway site are mixed (sandy gravel and gravely sand with numerous pebbles, cobbles and small boulders). This material typically overlies a stiff to very stiff boulder clay, and clays which scour much more slowly than sand. Evidence from post-construction surveys at North Hoyle Offshore Wind Farm, where the sediment characteristics and magnitude of physical processes are comparable, showed scour depressions of no more than 0.5 m at a few turbines.

There is however a lack of evidence of scour around gravity based turbines. The dimensions of the Winga wreck (80 m length, 20 m width and 4.3 m height) which was identified during the Humber Gateway geophysical survey are comparable to a gravity base foundation structure. Scour around the Winga was shown to be 1.5 to 1.8 m depth, providing an indication of potential scour that might be expected as a result of a gravity base foundation at the Humber Gateway site. However, of the five UKHO wrecks, none showed signs of any significant scouring.

Given the results of Humber Gateway scour predictions, evidence of scour around known wrecks in the vicinity of the Humber Gateway and post construction monitoring results at similar sites (North Hoyle), major scour is unlikely to occur. As a result ***no significant impacts*** are anticipated as a result of the presence of the turbine structures either with or without scour protection during the operational phase.

Changes to Wave Energy and Consequential Impacts on Coastal Erosion during Operation

With regard to the potential impacts of the wind farm upon the adjacent shoreline, impacts have been assessed by taking into consideration the scale of an individual turbine foundation and the total number of turbines.

Given the larger dimensions of the 40 m gravity-based foundation (based on the largest foundations necessary for a 7 MW turbine), it is likely that local effects on waves will be greater and may include more prominent diffraction effects when compared with the smaller 20 m gravity-based foundation. However, diffraction will only occur around either foundation option if the ratio of the diameter of the tower to the wavelength is greater than 0.2.

The total number of turbines and their relative separation become additional considerations to the scale of the individual turbine. *Table 10.3* identifies that the total cross-section profile in the water column (i.e. the area presented to a passing wave) is greater for Layout 2 than Layout 5, given the greater number of turbines (83 compared to 42). In addition, it is noted that Layout 5 offers greater separation between turbines, making it easier for waves to pass through the turbine site unimpeded.

Table 10.3 Summary of Array Scale Dimensions

Dimension	Layout 2	Layout 5
Number of turbines	83	42
Net section area for foundations / turbines	13,031 m^2	12,096 m^2
Separation between turbines (average distance)	588 m	862 m

The larger number of turbines associated with Layout 2 is anticipated to result in a marginally larger amount of 'blocking' effect (i.e. larger net section area) to waves passing through the Humber Gateway site. As such, the potential effects to waves in the lee of Humber Gateway and at the coast are anticipated to be slightly greater than for Layout 5.

Changes to the net sediment transport along the shoreline will result largely from alterations in the nearshore wave climate, as this is the dominant forcing mechanism in these water depths. The potential impacts of Layouts 2 and 5 have been investigated using an annual wave climate that includes for both the 'frequent, less energetic' and 'infrequent, more 'energetic' (i.e. extreme conditions) waves.

The observed erosion of the beaches along the Holderness Coast is a result of waves, wave driven currents and geological structure. The waves tend to undercut the cliffs, making them prone to failure and both waves and nearshore currents typically transport the material away from the source. It is difficult to determine the sediment supplied into the nearshore zone due to cliff erosion accurately, as rates of retreat vary considerably over short temporal and spatial scales. Annual volumes of coarse sediment range from 500,000 m^3 ± 50% and from 1 million m^3 to 3.5 million m^3 including all fractions [(1)].

The ultimate destinations of the eroded sediment are likely to be different for different size fractions. For the coarser sand and pebbles, net sediment transport is to the south, which contributes to the maintenance of the sand and shingle spit of Spurn Head, while finer fractions are carried into the Humber Estuary by the tide [(2)].

Relative changes in the net sediment transport rates have been investigated at eight profiles between Holmpton on the Holderness Coast and Donna Nook along the North Lincolnshire coast (*Figure 10.6)*.

Profile 97 (positioned furthest north of the wind farm) was chosen as it is directly exposed to the northeasterly waves and has the potential to be most affected by southerly waves passing through the Humber Gateway site.

Profiles 108 to 110 were selected to identify the effect of a greater portion of waves being blocked from easterly directions, and to accurately represent the landfall corridor for the export cables.

Two other profiles along the Holderness Coast were chosen, one directly in the lee of, and closest, to the wind farm (Profile 123) and Profile 133 at the tip of Spurn Head. These profiles were selected to determine the impact of waves from the prevailing northeasterly direction.

In addition, two sites were chosen on the North Lincolnshire coast at Donna Nook (DN A and DN B) to determine the consequence of waves being blocked from the northeast and to identify any impacts arising from changes in sediment transport.

Changes to predicted net sediment transport rates at these sites and as a result of the wind farm development are presented in *Table 10.4.*

The predicted changes in sediment transport at these locations, as shown in *Table 10.4,* will have implications for erosion and deposition along this coast. These implications are described below.

Along the Holderness Coast from Out Newton to Kilnsea (between Profiles 97 and 123), there is a general trend of increasing sediment transport rates to the south, i.e. from around 117,131 to 254,572 $m^3 yr^{-1}$. South of Profile 123 (which is located at an apex of the coast and junction with Spurn Head), the orientation of the coastline turns by around 90º, with an associated rapid reduction in sediment transport rate due to a reduced exposure to waves. Consequently, sediment transport rates at Profile 133, near the tip of Spurn Head, are relatively low and confirm that this is an area where coarse sediment accumulates.

(1) HR Wallingford, CEFAS/UEA, Posford Haskoning and D'Olier, 2002. Southern North Sea Sediment Transport Study: Phase II.

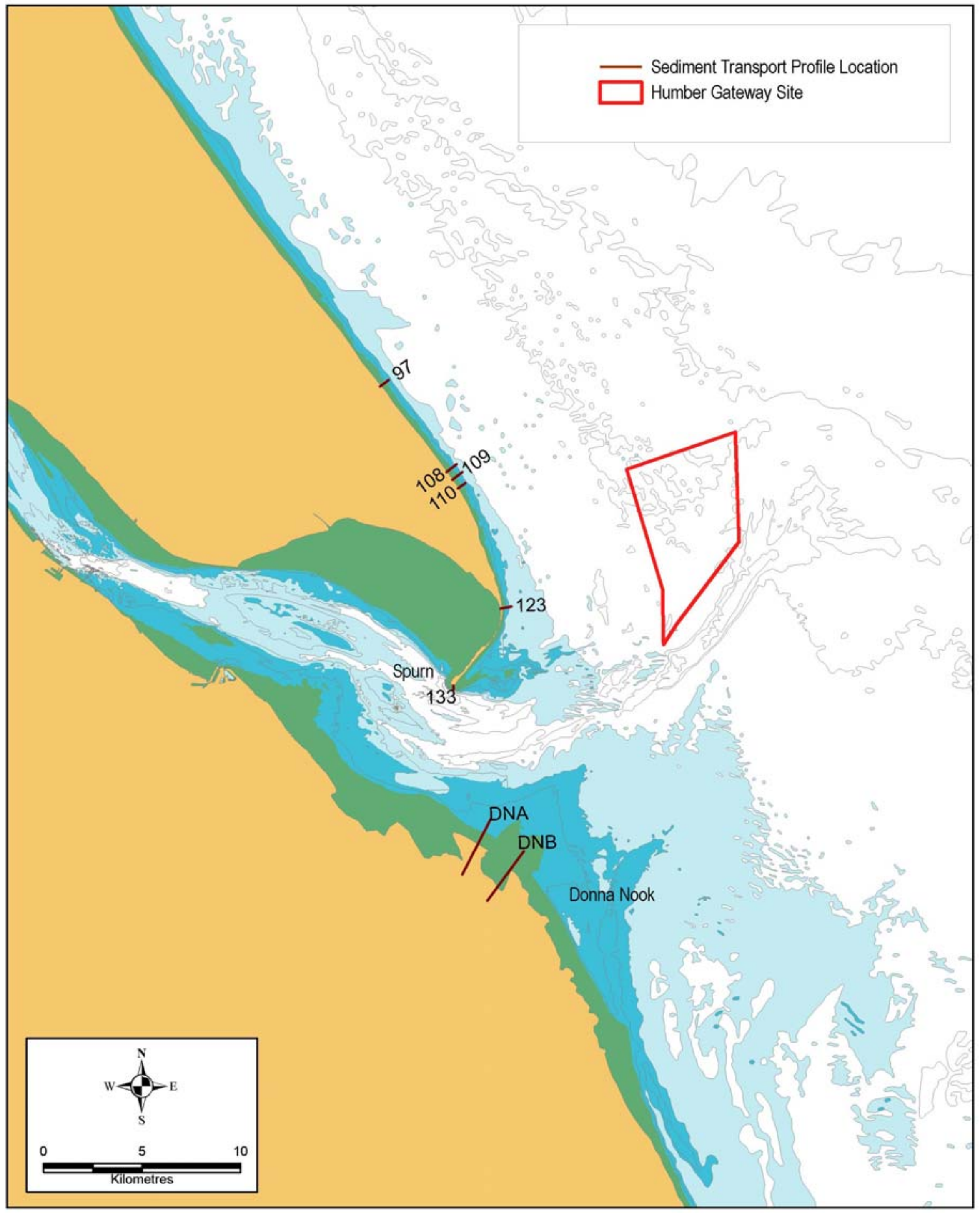
(2) Balson P S, Tragheim D, and Newsham R, 1997. Predicting sediment yield from recession of the Holderness Coast. In Land-Ocean Interaction Study, Second Annual meeting, Hull. Pp 152-154.

Table 10.4 Potential Changes in Net Sediment Transport (m^3 yr^{-1})

Profile ID	Baseline	Drift Direction	Increase over baseline with Layout 2	Increase over baseline with Layout 5	% change from baseline for Layout 2	% change from baseline for Layout 5
97	117,131	south	12.33	0.00	0.01	0.00
108	46,397	south	5.61	5.61	0.01	0.01
109	124,242	south	429.47	355.55	0.35	0.29
110	135,364	south	0.00	0.00	0.00	0.00
123	254,572	south	-2,333.05	-789.83	-0.92	-0.31
133	14,477	west	11.48	31.23	0.08	0.22
DN A	7,683	east	35.42	17.27	0.46	0.23
DN B	8,755	west	-239.19	-93.81	-2.73	-1.07

NB. Negative values represent a reduction in sediment transport rates

Figure 10.6 Location of Cross-Shore Profiles



Produced by ABPmer Ltd. © British Crown and SeaZone Solutions Limited, 2007. All rights reserved. Data License No. 122005.07. NOT TO BE USED FOR NAVIGATION. **PROJECTION**: British National Grid

On an annual basis, the impact of the wind farm on the adjacent coast will depend on the frequency of waves from different directions, as well as their magnitude. For the area of the coast between Out Newton and Easington (Profiles 97, 108, 109 and 110), the near shore wave climate will only be modified when waves pass through the Humber Gateway site from the easterly and southerly directions. Waves from the north will not be affected by the wind farm for this stretch of coast. However, there are relatively few waves from either the easterly or southerly directions, with most waves coming from the northeast. As a consequence, the existing dominant net drift of sediment to the south could be slightly enhanced (potentially resulting in more erosion at the north of this stretch of coast and more deposition to the south) by a slight reduction in any counter-drift to the north provoked by southerly waves. However, this effect will be negligible from both Layout 2 and Layout 5, being small fractions of one percent change (although Layout 2 has a slightly greater effect than Layout 5).

For Profile 123, positioned just to the south of Kilnsea, the near shore wave climate will be modified when waves pass through the wind farm from east and northeast directions. Since the northeasterly sector is also the prevailing wave direction here, more of an effect on net sediment transport rates is observed than at other sites. The tendency will be for the wind farm to create a small reduction in wave height in its lee. Locally, this will reduce the rate of sediment transport along the coast by a very small amount.

Sediment transport at Profile 133 (Spurn Point) is less than that along the main Holderness Coast. Work carried out by the Institute of Estuarine and Coastal Studies (IECS) indicates that this is due to a change in the coastal alignment at Easington, which causes sand and shingle to move offshore rather than continuing to be transported southwards along the coast [(1)].

In contrast to the other profiles along the Holderness Coast, Profile 133 is orientated north-south due to the alignment of Spurn Head and, as a result, there is a lower sediment transport rate here and it is not directly affected by waves from the north. However, when the predominant waves from the northeast pass through the wind farm they will be partially blocked, reducing wave heights by approximately 1%. This reduction will lead to a modification in the wave climate, placing a greater emphasis on waves from the east, thereby providing a slightly greater potential to increase sediment transport to the west towards the tip of Spurn Head. However, the predicted magnitude of this change is extremely small, being only 0.2% change from the existing conditions.

The salt marshes, mud flats and extensive sandbanks fronting Donna Nook mark a change in the form and physical processes which characterise this section of coastline. The low lying land is in distinct contrast to the steep chalk cliffs of Flamborough Head and the beach zone, comprising sand and shingle, which extends southwards towards Spurn Head.

[(1)] Institute of Estuarine and Coastal Studies (IECS), University of Hull, 2006. Preliminary Assessment of the Cable Landfall, Humber Gateway Wind Farm.

These changes are reiterated within the Shoreline Management Plan (SMP), which designates Donna Nook as the start of a separate management sub-cell to the Holderness Coast, defined by the formation of a drift divide. The drift divide indicates that sediment transport pathways at Donna Nook are separate from those along the Holderness Coast, where instead of predominantly being from north to south the net sediment transport is to the west along the south bank of the Humber Estuary, and to the east along the Lincolnshire coast.

Net sediment transport volumes at Donna Nook are low when compared to those along the Holderness Coast, partly due to the formation of an extensive system of sandbanks which indicate a more stable sediment regime along this section of shoreline.

The wind farm will result in an increase in net sediment transport at Profile DN A, although the change in volume is very small (17.3 to 35.4 $m^3 yr^{-1}$). At Profile DN B, the wind farm will offer a degree of protection from the larger northeasterly waves, resulting in a small reduction in sediment transport rates of between 93.8 and 239.2 $m^3 yr^{-1}$.

Although the percentage changes in net sediment transport at Donna Nook are higher than for the Holderness Coast, the second *Southern North Sea Sediment Transport Study* [(2)] indicates that there is currently little quantification of sediment transport volumes around Donna Nook, which is partly due to the complex nature of the sandbanks. The modelling results suggest that actual annual net sediment transport volumes are substantially lower at Donna Nook and, therefore, these changes are also considered to be very small.

In conclusion, the results from the littoral drift modelling establish that Layout 2 has a negligible effect on net sediment transport rates, and that these changes are well within the tolerance of natural year on year variations in sediment supply. Layout 5 is predicted to have an even lesser effect on waves and consequently a lesser effect on net sediment transport rates when compared to Layout 2. As a result, ***no significant impacts*** to net sediment transport rates are anticipated. Similarly, ***no significant impacts*** to coastal erosion rates are predicted.

10.3.3 Mitigation

There are no further mitigation measures in addition to those embedded in the project design that relate to potential changes to coastal processes.

[(2)] HR Wallingford, CEFAS/UEA, Posford Haskoning and D'Olier, 2002. Southern North Sea Sediment Transport Study: Phase II.

10.3.4 Residual Impacts

The residual impacts will remain the same as those described in the potential impacts section.

10.3.5 Monitoring

If required, post-construction monitoring of coastal processes will be undertaken in line with best practice guidelines. The design of this survey will be agreed at the appropriate time in line with guidance sought from the relevant regulatory authorities.

10.3.6 Enhancements

No enhancement measures are proposed.

10.3.7 Summary

The coastal process impacts have been assessed:

- over a range of temporal and spatial scales as detailed in guidelines for the development of offshore wind farms;
- having regard to stakeholder concerns;
- in the context of changes that will occur naturally e.g. sea level rise; and
- with consideration to existing variability in the natural system.

Table 10.5 presents a summary of the findings of the assessment. The assessment has shown that there is limited potential for any changes to the existing hydrodynamic, wave and sedimentological regimes both in the near-field and far-field (or regional) areas. The changes that are predicted are less than those that result from future natural changes to the regimes, such as sea level rise, and are comparable to those observed within the natural variability of the system.

Table 10.5 Summary of Impacts to Coastal Processes

Potential Impact	Potential Impact Significance	Additional Mitigation (in addition to embedded mitigation)	Residual Impacts
Hydro-dynamics			
Changes to current direction or speed during operation	*No significant impacts*	None	***No significant impacts***
Changes to water levels during operation	*No significant impacts*	None	***No significant impacts***
Wave regime			
Wave direction / magnitude change during operation	*No significant impacts*	None	***No significant impacts***
Sediment			
Increase in suspended sediments during construction	*No significant impacts*	None	***No significant impacts***
Changes in seabed thickness from sedimentation during foundation installation and cable laying	*No significant impacts*	None	***No significant impacts***
Impacts on sediment transport around the site during operation	*No significant impacts*	None	***No significant impacts***
Scour impacts during operation	*No significant impacts*	Possibly scour protection (depends on detailed design and geotechnical investigations)	***No significant impacts***
Changes to wave energy and impacts on coastal erosion during operation	*No significant impacts*	None	***No significant impacts***