# Hornsea Project Four: Preliminary Environmental Information Report (PEIR)

# Volume 4, Annex 4.4: Dredging and Disposal (Site Characterisation)


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# Glossary

| Term | Definition |
|---|---|
| Benthic | A description for flora and fauna associated with the seabed. Flora and fauna that lie in, on or near the seabed are termed 'benthos'. |
| Biotope | The combination of physical environment (habitat) and its distinctive assemblages of conspicuous species. |
| Demersal | Fish living on or near the seabed. |
| Epibenthic | Organisms living specifically on the seabed surface. |
| Epifauna | Animals living on the seabed surface. |
| Habitat | The place in which an animal or plant lives. In the marine environment, this is defined according to geographical location, physiographic features and the physical and chemical environment, including salinity, wave exposure, tidal currents, geology, substrate, biological zone, features and modifiers. |
| Infauna | Animals living in the seabed sediment. |
| Intertidal | Area of seashore that is covered at high tide and uncovered at low tide. |
| Landings | Quantitative description of the amount of fish returned for sale in terms of value or weight. |
| Pelagic | Relating to the open sea. |
| Scour | Local erosion of sediments caused by local flow acceleration around an obstacle and associated turbulence enhancement. |
| Subtidal | Area extending from below low tide to the edge of the continental shelf. |
| Suspended Sediment Concentration | Mass of sediment in suspension per unit volume of water. |

# Acronyms

| Acronym | Definition |
|---|---|
| DCO | Development Consent Order |
| dML | deemed Marine Licence |
| Cefas | Centre for Fisheries and Aquaculture Science |
| ECC | Export Cable Corridor |
| ES | Environmental Statement |
| HVAC | High Voltage Alternating Current |
| ICES | International Council for the Exploration of the Sea |
| JNCC | Joint Nature Conservation Committee |
| MBT | Monobutyltin |
| MCZ | Marine Conservation Zone |
| MFE | Mass-Flow Excavation |
| MMO | Marine Management Organisation |
| MU | Management Unit |
| OGA | Oil and Gas Authority |
| PEIR | Preliminary Environmental Information Report |
| SAC | Special Area of Conservation |

| Acronym | Definition |
|---|---|
| SCANS | Small Cetacean Abundance in the North Sea |
| SSC | Suspended Sediment Concentration |
| UK | United Kingdom |
| UKCS | UK Continental Shelf |
| UKHO | UK Hydrographic Office |
| WTG | Wind Turbine Generator |

# Units

| Unit | Definition |
|---|---|
| £ | Great British Pounds Sterling |
| µm | Micrometre |
| cm | Centimetre |
| g | Gram |
| Km | Kilometre |
| l | Litre |
| m | Metre |
| $m^3$ | Cubic metres |
| mg | Milligram |
| ng | Nanogram |
| nT | Nanotesla |
| s | Seconds |

# 1 Introduction

1.1.1.1 Ørsted Hornsea Project Four Limited (the Applicant) are proposing to develop Hornsea Four Offshore Wind Farm (Hornsea Four). Hornsea Four will be located approximately 65 km offshore the East Riding of Yorkshire in the Southern North Sea and will be the fourth project to be developed in the former Hornsea Zone. Hornsea Four will include both offshore and onshore infrastructure, including offshore Wind Turbine Generators (WTGs), export cables to landfall and connection to the electricity transmission network. The location of Hornsea Four is illustrated in **Figure 1**. Details of the project design can be found in **Volume 1, Chapter 4: Project Description**.

1.1.1.2 This document has been drafted by GoBe Consultants Ltd and comprises the site characterisation for Hornsea Four as required to permit disposal of seabed and sub-bottom geological material that may arise during the construction of the offshore elements of Hornsea Four.

1.1.1.3 Site characterisation is the process whereby a proposed marine disposal site for spoil material and drill arisings generated by construction activities is described in terms of the existing environment, using all available data sources. It is a requirement that a site characterisation report be submitted to the Marine Management Organisation (MMO), and their scientific advisor, Cefas (the Centre for Environment, Fisheries and Aquaculture Science), to inform the decision-making process and to allow the licensing of the disposal site as well as facilitating the consideration of the need for any relevant conditions in relation to the disposal activity within the deemed Marine Licences (dMLs) for Hornsea Four. The following information is provided:

- The need for the new disposal site;
- The dredged and/or drilled material characteristics;
- The disposal site characteristics;
- The assessment of potential effects; and
- The reasons for the site selection.

1.1.1.4 This document outlines the site characterisation for two proposed Hornsea Four disposal sites:

- Array Disposal Site: the full extent of the Hornsea Four array area (as defined in the DCO Works Plans (**Volume D1, Annex 4.1**)); and
- Offshore Export Cable Corridor (ECC) Disposal Site: the full extent of the offshore ECC including the temporary works area and HVAC booster area of search (as defined in the DCO Works Plans (**Volume D1, Annex 4.1**)).

1.1.1.5 The disposal activity will involve the deposit of sedimentary material originating from preparatory dredging and seabed clearance, foundation drilling and sandwave clearance activities associated with the construction of Hornsea Four.

1.1.1.6 This disposal site characterisation addresses the disposal within the array area and offshore ECC in **Section 4**.

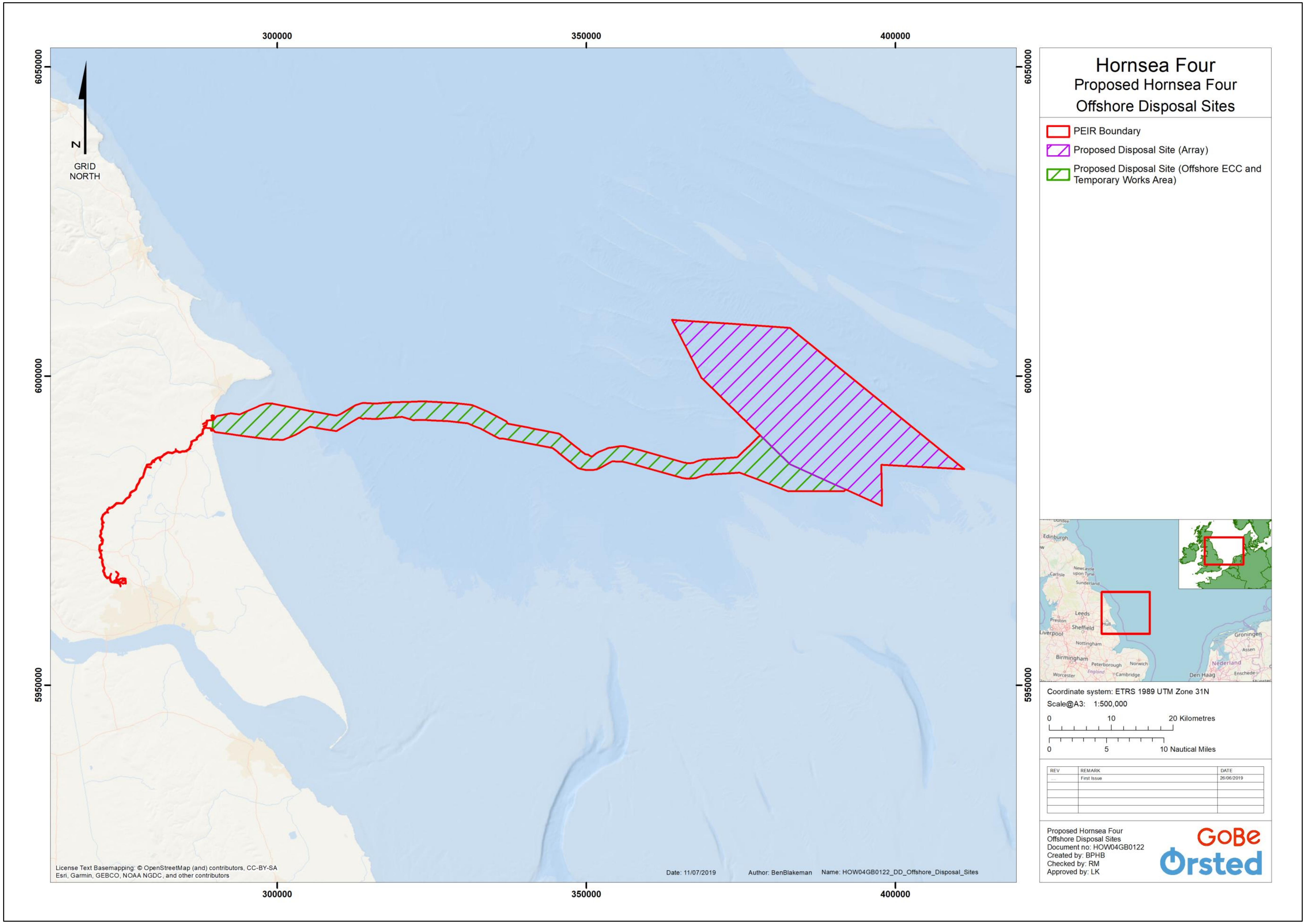


Figure 1: Location of the proposed Hornsea Four Array Disposal Site and the Hornsea Four Offshore ECC Disposal Site (not to scale).

# 2 Predicted source of spoil and estimated quantities for disposal

## 2.1 Sources of spoil

### 2.1.1 Hornsea Four array disposal site

2.1.1.1 Spoil for disposal within the array area will be generated from the installation of each of the foundation types that are included in the project design (either through seabed preparatory works and/or from drilling); during preparatory works prior to offshore ECC, array and inter-connector cable installation (i.e. sand wave clearance); and during cable trenching. Full details of the proposed project design, including spoil generating operations within the array area, are set out in **Volume 1, Chapter 4: Project Description**. The main components which may generate spoil for disposal within the array area are as follows:

- Seabed preparation for suction caisson, jacket and/or monopile foundations for WTGs, offshore substation (OSS) and the offshore accommodation platform;
- Drill arisings from the installation of monopiles and/or pin-piled jackets for WTGs, OSS and the offshore accommodation platform; and
- Sandwave clearance prior to array cable installation and export cables within the array.

2.1.1.2 The maximum design scenario (MDS) for foundation seabed preparation comprises suction caisson jackets, and the maximum design scenario for drill arisings comprises monopiles. Seabed preparation and drill arising allowances for HVAC booster stations are considered within **Section 2.1.2**.

*Seabed preparation*

2.1.1.3 For those foundation types that may require seabed preparation (i.e. suction caisson and piled jackets), surficial sediment may need to be removed to create a stable and level seabed prior to foundation installation. Typically, surface sediments (sands and gravels) will be removed by a suction hopper dredger which will subsequently release the dredged sediment from its hopper either at the water surface or via discharge pipes, within the array area. Alternatively, the seabed may be levelled by the use of a Mass Flow Excavator (MFE) which uses high pressure jetting to displace the sediment away from the target location, with disturbed sediment then settling naturally in the wider vicinity.

*Foundation drilling*

2.1.1.4 Depending on ground conditions within the Hornsea Four array area, drilling may be required to install piles to their target depth for those WTG and OSS foundation types involving piling (i.e. monopiles or pin-piled jackets). It is assumed that up to 10% of pile locations or up to 10% of pile depths across the array may require drilling.

2.1.1.5 Spoil created by drilling will normally be disposed of adjacent to the foundation location (i.e. the drilling location) and will be discharged at the sea surface settling rapidly to the seabed. Drill arisings typically comprise inert sub-bottom geological material; as a result, it will not result in the introduction of contaminants of anthropogenic origin to the marine environment.

*Sandwave clearance*

2.1.1.6 Prior to the installation of array cables (and the offshore ECC within the array), sandwave clearance/levelling (30 m wide cable corridor) may be required to facilitate the use of cable installation equipment within its operational tolerances and to reduce stress on the cable by maximising the bending radius. Sandwave clearance also reduces the chance of unsuccessful cable installation and increases the likelihood of installation to the maximum target burial depth.

2.1.1.7 As with seabed preparation described above, sandwave clearance may be undertaken by suction hopper dredger, which will subsequently release material at the sea surface or via discharge pipes and will be composed of surficial sediments. Alternatively, the seabed may be levelled by the use of MFE.

### 2.1.2 Hornsea Four offshore ECC disposal site

2.1.2.1 Spoil for disposal within the offshore ECC will be generated from the installation of each of the HVAC booster station foundation types included in the project design (either through seabed preparatory works and/or from drilling); the preparatory works prior to export cable installation (i.e. sand wave clearance); and during export cable trenching. Full details of the proposed project design, including spoil generating operations within the offshore ECC, are set out in **Volume 1, Chapter 4: Project Description**. The main components which may generate spoil for disposal within the offshore ECC are as follows:

- Seabed preparation for suction caisson, jacket and/or monopile foundations for HVAC booster stations;
- Drill arisings from the installation of monopiles and/or pin-piled jackets for HVAC booster stations; and
- Sandwave clearance prior to export cable installation.

*Seabed preparation*

2.1.2.2 For those foundation types that may require seabed preparation (i.e. suction caisson and piled jacket foundations), surficial sediment may need to be removed to create a stable and level seabed prior to foundation installation. Typically, surface sediments (sands and gravels) will be removed by a suction hopper dredger which will subsequently release the dredged sediment from its hopper either at the water surface or via discharge pipes, within the offshore ECC. Alternatively, the seabed may be levelled by the use of MFE.

*Foundation drilling*

2.1.2.3 Depending on ground conditions within the Hornsea Four offshore ECC, drilling may be required to install HVAC booster station foundation piles to their target depth. It is assumed that up to 10% of locations or depth may require drilling.

2.1.2.4 Spoil created by drilling will normally be disposed of adjacent to the foundation location (i.e. the drilling location) and will be discharged at the sea surface settling rapidly to the seabed.

Drill arisings typically comprise inert sub-bottom geological material; as a result, it will not result in the introduction of contaminants of anthropogenic origin to the marine environment.

*Sandwave clearance*

2.1.2.5 Prior to the installation of export cables, sandwave clearance/levelling may be required (30 m wider cable corridor) to facilitate the use of cable installation equipment within its operational tolerances and to reduce stress on the cable by maximising the bending radius. Sandwave clearance also reduces the chance of unsuccessful cable installation and increases the likelihood of installation to the maximum target burial depth.

2.1.2.6 As with seabed preparation described above, sandwave clearance may be undertaken by suction hopper dredger, which will subsequently release material at the sea surface or via discharge chutes and will be composed of surficial sediments. Alternatively, the seabed may be levelled by the use of MFE.

## 2.2 Volumes of spoil for disposal

### 2.2.1 Hornsea Four array disposal site

2.2.1.1 The MDS volumes of material to be disposed in the array area from seabed preparation, pile drilling and cable installation are summarised in **Table 1**. It is possible that piled jacket foundations may require seabed preparation as well as drilling. In this case, the total volume for this foundation type will not exceed the total volume for suction caisson jacket foundations.

**Table 1: Summary of maximum design scenario spoil volumes associated with seabed preparation, pile drilling and cable installation in the Hornsea Four array area.**

| Source | Volume ($m^3$) | |
|---|---|---|
| | Drilling for piled foundations | Seabed preparation for suction caisson foundations (as maximum design scenario volumes) |
| ***Foundations*** | | |
| WTG Foundations (180) | 127,235 $m^3$ (assuming 10% of sites require drilling to full pile depth) | 2,134,440 $m^3$ |
| OSS Foundations (6 small or 3 large) | 13,854 $m^3$ (assuming drilling of all piles to 10% of pile depth) | 737,130 $m^3$ |
| Offshore Accommodation Platform (1) | 1,540 $m^3$ (assuming drilling of all piles to 10% of pile depth) | 57,245 $m^3$ |
| *Foundation sub-total* | *142,629 $m^3$* | *2,928,815 $m^3$* |
| ***Cables (Sandwave Clearance)*** | | |
| Array cables | 769,000 $m^3$ | |
| Interconnector cables | 115,000 $m^3$ | |
| Export cable (part within array) | 77,000 $m^3$ | |
| *Cables sub-total* | *961,000 $m^3$* | |
| **Total** | **1,103,629 $m^3$** (in the case of piled foundations) | **3,889,815 $m^3$** (in the case of suction caisson foundations) |

### 2.2.2 Hornsea Four Offshore ECC disposal site

2.2.2.1 The MDS for the offshore ECC includes export cable installation, as well as seabed preparation and drilling for HVAC booster station foundations. These are described in Table 2. It is noted that piled jacket foundations may require seabed preparation as well as drilling. In this case, the total volume will not exceed that for seabed preparation for suction caisson jackets.

**Table 2: Summary of maximum design scenario spoil volumes associated with seabed preparation, pile drilling and cable installation in the Hornsea Four offshore ECC.**

| Source | Volume ($m^3$) | |
|---|---|---|
| | Drilling for piled foundations | Seabed preparation for suction caisson foundations |
| ***Foundations*** | | |
| HVAC Booster Stations (3) | 4,618 $m^3$ (assuming drilling of all piles to 10% of pile depth) | 171,735 $m^3$ |
| ***Cables (Sandwave Clearance)*** | | |
| Export cable (ECC only) | 757,000 $m^3$ | |
| **Total** | **761,618 $m^3$** (in the case of piled foundations) | **928,735 $m^3$** (in the case of suction caisson foundations) |

### 2.2.3 Total

2.2.3.1 As a worst-case, the total volume of material that may require disposal would be up to 4,818,650 $m^3$ (if suction caissons were used across all foundations), of which up to 3,889,815 $m^3$ may be disposed of in the array area and up to 928,735 $m^3$ in the offshore ECC.

2.2.3.2 If piled foundations were used and required drilling (without the need for seabed preparation) the worst-case total would be up to 1,865,247 $m^3$, with up to 1,103,629 $m^3$ in the array area and up to 761,618 $m^3$ in the offshore ECC.

## 3 Alternative options for disposal

3.1.1.1 Once drilled or dredged material has been produced, it is classified as a waste material. Once a material has entered the waste stream it is strictly controlled.

3.1.1.2 Disposal of dredged and drilled material is controlled under the London Convention 1972, the Oslo-Paris Commission (OSPAR) Convention 1992, and the EU Waste Framework Directive 2008/98/EC. At the core of the Waste Framework Directive is the Waste Hierarchy (DEFRA, 2011) which comprises:

- Prevention;
- Re-use;
- Recycle;
- Other recovery; and
- Disposal.

3.1.1.3 Where prevention or minimisation is not possible, management options for dealing with waste material must consider the alternative options in the order of priority indicated above (i.e. re-use, recycle, other recovery and then disposal).

3.1.1.4 The consideration of alternative solutions to the disposal of drilled and/or dredged material within the array and offshore ECC is therefore an important part of the site characterisation process and is required in order to inform the decision-making process required of the MMO and their advisors. The following sections of this document present information on potential alternative to the disposal of drilled and dredged material produced during the construction of Hornsea Four.

## 3.2 Prevention

3.2.1.1 The Waste Hierarchy places a strong emphasis on waste prevention or the minimisation of waste. However, consent is being sought for Hornsea Four for the use of a range of foundation options and foundation and cable installation methodologies; further information is required before the design of Hornsea Four can be finalised and it is possible, for example, that more than one foundation type may be used across the project.

3.2.1.2 For piled foundations, if percussive piling alone does not achieve full pile penetration due to the presence of hard ground conditions, the material inside the monopile/pin piles may need to be drilled out before the pile can be driven to the required depth. If drilling is required, the generation of spoil arising from the drilling will be unavoidable. For monopile foundations, the MDS of up to 10% of the foundations may require drilling.

3.2.1.3 If suction caisson foundations are chosen, seabed preparation works including dredging and disposal will be unavoidable in order to achieve the flat and stable seabed that is required to seat these particular foundation types, although the volumes of spoil generated will depend on the size of foundations needed and the amount of seabed preparation required at each location.

3.2.1.4 Sandwave clearance is expected to be required in areas where sandwave gradients are in excess of the working limits for standard cable installation equipment, to avoid unnecessary strain on the cables through bending, and to maximise ploughing efficiency and reduce the chances of burial failure. Additionally, the cable must be buried to a depth where it may be expected to stay buried for the duration of the project lifetime. Sandwaves are generally mobile in nature therefore the cable must be buried beneath the level where natural sandwave movement would uncover it. Sometimes this can only be done by removing the mobile sediments before installation takes place. Therefore, to install the cables for

Hornsea Four, sandwave clearance and the associated dredging and disposal works will in some cases be unavoidable.

3.2.1.5 As a result, the safe and effective installation of the Hornsea Four infrastructure may involve installation techniques that give rise to spoil; whilst volumes of spoil will be minimised to that necessary for safe and effective installation it is not possible to prevent spoil generation.

### 3.3 Re-use

3.3.1.1 Where prevention is not possible, re-use of dredged and drilled material is the preferred option. Potential options for the re-use of dredged and drilled material can include:

- Beach nourishment/replenishment schemes;
- Land reclamation schemes; and
- Habitat enhancement schemes.

3.3.1.2 The material for disposal within the array and offshore ECC could potentially have alternative uses. Transfer of the volume of spoil material to another location where material could be re-used would consist of the movement of up to 3,889,815 $m^3$ from the array area and up to 928,735 $m^3$ from the offshore ECC. Alternative uses are most likely to be based on land, which would require a total of up to approximately 439 dredging cycles (assuming a hopper capacity of 11,000 $m^3$). Each cycle would form a round trip from the closest port (for example, in the Humber).

3.3.1.3 Collection of drill arisings would be costly due to the need for suction dredging vessels in addition to drilling vessels and the limited material produced at each foundation site means collection would not be viable.

3.3.1.4 Dredger movements would lead to additional environmental impacts due to increased vessel emissions that could be avoided if dredged material were disposed of *in situ* (i.e. close to the source of production). Barges for transporting material away from Hornsea Four may also require four-point anchoring systems at each loading point, which would also result in an additional environmental impact which the disposal of material *in situ* would preclude.

3.3.1.5 At the time of writing, no projects have been identified that could accept the type and volume of spoil material that might be generated during the construction of Hornsea Four. Therefore, even if it were technically and economically feasible to re-sue the spoil material, at present there are no known projects to facilitate its re-use.

3.3.1.6 In conclusion, the assessments undertaken have not identified any significant adverse (in EIA terms) impacts on receptors as a result of the proposed disposal activity. It is concluded that whilst potential alternative options for use of this material may exist in theory and at some point in the future, disposal in situ remains the most viable option. *In situ* disposal also has the advantage of retaining sediment within the local sedimentary system.

### 3.4 Recycle

3.4.1.1 Recycling of drilled and dredged material would involve transforming the material into a different form, for example to produce bricks or aggregate material. As outlined in the MMO guidance (MMO, 2011), these are generally land-based solutions with any material produced used in onshore construction projects. As such, the same issues with respect to vessel movements to transport the dredged material to land, as discussed above, would apply. The disposal of drilled and dredged spoil material *in situ* would preclude the additional environmental impacts that would arise.

### 3.5 Other recovery

3.5.1.1 There are currently very few examples of recovery from dredged and drilled material (MMO, 2011) and no such options have been identified for the spoil material that may be generated during the construction of Hornsea Four.

### 3.6 Disposal

3.6.1.1 With regards to the potential to dispose of the produced spoil at an existing marine disposal site, the closest open marine disposal site is for Hornsea Project One, located immediately to the east of Hornsea Four.

3.6.1.2 Disposal sites are generally licensed to enable the disposal of material from specific locations and activities. It is not considered desirable to use an existing disposal site since they are not generally designated for additional volumes beyond those necessary for the specific purpose for which they were licensed.

3.6.1.3 In addition, the use of another site, such as the Hornsea Project One licensed disposal site, would require the transport of the Hornsea Four spoil material away from Hornsea Four to another disposal site, resulting in additional vessel movements. The receiving seabed environment at an alternative location may also be characterised by a somewhat different sediment composition. Disposal of the spoil material *in situ* within the Hornsea Four project boundary, and close to the point of production, ensures that the spoil will be returned into a broadly similar sedimentary environment (and in the case of drill arisings, ensures that the spread of material away from the point of production is minimised). Disposal of material at another disposal site may also require hydrodynamic and sediment transport modelling studies to determine the capacity of the site to accommodate the additional spoil type and volumes.

3.6.1.4 Therefore, it is concluded that disposal at an existing marine disposal sites does not represent the most efficient or environmentally robust approach to disposal of material from Hornsea Four array area and the offshore ECC.

## 4 Characteristics of the Hornsea Four disposal sites

### 4.1 Physical characteristics

4.1.1.1 This section provides a summary of the physical characteristics of the Hornsea Four array area and offshore ECC. Further details on the physical environment are set out (**Volume 5, Annex 1.1: Marine Processes Technical Report** and **Volume 2, Chapter 1: Marine Geology, Oceanography and Physical Processes**.

### 4.1.2 Array area

Tide and wave regime

4.1.2.1 Tidal flows across the array area occur at velocities of 0.5 – 0.6 m/s, though this is limited to peak flows during spring tides. Tidal ellipses are generally aligned north-west to south-east.

4.1.2.2 Waves across the array have periods in the range of 3 – 6 s, typically around 4 s. Significant wave heights are typically less than 1 m but reach up to 4.5 m during storm events. Wave directions are predominantly from the south-west. Due to local water depths of more than 32 m, even the largest waves are not capable of inducing currents at the seabed that would disturb sediments.

Seabed geology

4.1.2.3 Holocene deposits are generally less than 2 m thick across the array, varying with the presence of thick sandwave features to greater than 18 m towards the western boundary. Beneath the surface layer there is a firm to stiff clay till of the Bolders Bank Formation. There may be areas of exposed chalk bedrock, or areas close to the seabed surface, in the north-west corner of the array.

4.1.2.4 Medium-sized sand is the dominant sediment type across the offshore array, with patches containing a small gravel content and others with a small percentage of fines. Mean particle diameters across the array vary between 245 μm and 648 μm with an overall mean diameter of 414 μm. According to the Wentworth classification, this is generally presented as medium to coarse sand.

Bedforms and sediment transport

4.1.2.5 The general seabed profile across the array area shelves into deeper water in a northerly direction from around 40 m to 55 m depth. There is a small area along the eastern boundary which reaches around 60 m coinciding with the Outer Silver Pit. The shallowest parts of the array are associated with large bedform structures, including sandwaves with wavelengths greater than 25 m in the northern part of the western boundary. The shallowest depth is approximately 32 m, associated with the ridge of a sandbank feature in the north-west of the array.

4.1.2.6 Sandwave crests are evident across much of the array, except in the southern extents, and are generally aligned perpendicular to the axis of tidal flows. Bedform features and megaripples indicate a net direction of bedform migration towards an area known as 'The Hills'.

Suspended sediments

4.1.2.7 Surface turbidity is relatively low across the offshore array area, with monthly averaged concentrations typically less than 5 mg/l across the whole year, with minimal seasonal variation. The relatively low concentrations are due to a low content of fine material in the seabed sediments and the area being distant from any terrestrial sources such as the Humber.

### 4.1.3 Offshore ECC

Tide and wave regime

4.1.3.1 In open water, tidal flows are generally to the south-east on the flood tide and north-west on the ebb. Closer inshore flows become more aligned with the orientation of the coastline, especially around Flamborough Head where flows are also strongest (1.2 m/s). regional mapping shows tidal flows tend to reduce from west to east along the offshore ECC, but the most sheltered conditions are in the lee of the headland. Peak flows on a mean spring tide in the HVAC booster station search area are approximately 0.84 m/s.

4.1.3.2 The general pattern across the offshore ECC is for lower wave heights and wave periods closer to shore, increasing in the offshore, and this also varies seasonally. Average wave heights in the inshore section of the ECC are 1.2 m in winter and 0.79 m in summer. In the HVAC booster station search area, this increases to 1.84 m in winter and 1.06 m in summer. This increases towards the array area.

Seabed geology

4.1.3.3 Surficial sediment cover along the offshore ECC indicates an increasing sand content from inshore to offshore. From the landfall, the surficial sediments comprise sands with patches of gravelly sand across Smithic Sands, then sandy gravels onto gravelly sands, slightly gravelly sands and finally sands once into the array area.

4.1.3.4 Particle size information from grab samples suggests that the mud fraction is relatively low in surficial sediments (typically less than 1%). The highest mud content is approximately 6% in an area classed as 'muddy sandy gravel' 9 km to the west of the HVAC booster station search area.

Bedforms and sediment transport

4.1.3.5 The offshore ECC commences from the seaward extent of the landfall area with depths approximately 7 m onto a relatively flat seabed profile. This flat area is the seaward end of an ebb tidal channel that extends to Flamborough Head and defines the inshore flank of Smithic Sands. From this location, the offshore ECC gently shallows onto the southern part of Smithic Sands where depths reduce to around 5 m. Approximately 9 km from the coastline, the offshore ECC reaches the eastern edge of the bank, which also aligns with the seaward limit of Flamborough Head. Further to the east, the headland no longer provides direct sheltering from north and north-easterly waves, or strong tidal flows, and the seabed drops to around 20 m. The profile of the seabed continues to deepen in an easterly direction and reaches around 50 m at the HVAC booster station search area (approximately 34 km offshore), which is also the deepest section of the export cable route.

4.1.3.6 East from the HVAC booster station search area the offshore ECC passes just to the south of The Hills, a series of sinuous inter-related sandbank features with near symmetrical sandwaves. There are various undulations in depth along the route but also a generally shallowing profile to around 45 m at the seaward end of the offshore ECC.

4.1.3.7 Waves in deeper sections of the offshore ECC have too short a wave period to influence the seabed, however in shallower areas, waves begin to exert a stirring effect on the seabed which can increase sediment mobility rates and associated transport.

Suspended sediments

4.1.3.8 Surface turbidity in the nearshore section of the offshore ECC exhibits a high level of seasonal variation. Surface concentrations are highest in the first 10 km and are highest in winter. July is typically the month with the lowest concentrations. Concentrations range from 2 – 14 mg/l close to shore, reducing to 2 or 3 mg/l further offshore. This is mainly due to sediments from coastal erosion in winter, shallower water and stronger local flows maintaining the material in suspension.

## 4.2 Biological characteristics

4.2.1.1 This section provides a summary of the biological characteristics of the disposal sites. Full details are provided in **Volume 2, Chapter 2: Benthic and Intertidal Ecology, Volume 2, Chapter 3: Fish and Shellfish Ecology, Volume 2, Chapter 4: Marine Mammals** and **Volume 2, Chapter 5: Offshore and Intertidal Ornithology** and their associated Technical Annexes.

### 4.2.2 Benthic and intertidal ecology

4.2.2.1 Across the Hornsea Four array area, a total of 2,678 individuals representing 163 taxa were recorded from the 21 macrofaunal samples acquired. The macrofaunal community was found to be relatively sparse with 54 taxa appearing at a single station and 34 of those taxa represented by a single individual.

4.2.2.2 Analysis of benthic grab samples obtained across the Hornsea Four array area identified eight EUNIS categories and ranged between level 4 and level 5 depending on the level of confidence to which the data could be classified.

4.2.2.3 Results of seabed imagery collected across the array correlated with those geophysical and benthic grab findings, with footage revealing predominantly sandy sediments (from gravelly sand to muddy sand). Visible fauna were generally sparse, although at one station (located at the most southerly station, outside of the array) the habitat 'seapen and burrowing megafauna community' was identified.

4.2.2.4 Predictive habitat modelling revealed that the biotope *Mysella bidentata* and *Thyasira spp*. in circalittoral muddy mixed sediment (SS.SMx.CMx.MysThyMx) were predominantly concentrated over the mixed sediments and coarse sediments that characterised the benthic ecology study area and were more likely to be found in the discreet mixed and coarse sediments located offshore.

4.2.2.5 The biotopes *Abra prismatica*, *Bathyporeia elegans* and polychaetes in circalittoral fine sand (SS.SSa.CFiSa.ApriBatPo) and *Echinocyamus pusillus*, *Ophelia borealis* and *Abra prismatica* in circalittoral fine sand (SS.SSa.CFiSa.EpusOborApri) were predicted to be more likely to occur across the sand and muddy sand sediment habitats with S.SSa.CFiSa.ApriBatPo more likely to characterise these sediments in the offshore portion of the benthic ecology study area and (SS.SSa.CFiSa.EpusOborApri throughout the entire subtidal benthic ecology study area.

4.2.2.6 *Abra alba* and *Nucula nitidosa* in circalittoral muddy sand or slightly mixed sediment (SS.SSa.CMuSa.AalbNuc) and *Nephtys cirrosa* and *Bathyporeia spp*. in infralittoral sand (SS.SSa.IFiSa.NcirBat) were predicted to be more likely to occur across the sand and muddy sand sediment habitats with SS.SSa.CMuSa.AalbNuc located in the southern offshore area and SS.SSa.IFiSa.NcirBat in the southern nearshore and offshore areas.

4.2.2.7 In the intertidal, the biotope that characterised area during the Phase I walkover survey along the Holderness Coast between Bridlington and Skipsea was coarse littoral sand (LS.LSa.MoSa.Bar.Sa), which is typical of clean sands in areas of high hydrodynamic energy, as seen along this portion of coastline.

### 4.2.3 Fish and shellfish ecology

4.2.3.1 The fish communities within the study area broadly comprised of demersal species, with high abundances of whiting (*Merlangius merlangus*), dab (*Limanda limanda*), plaice (*Pleuronectes platessa*), solenette (*Buglossidium luteum*) and grey gurnard (*Eutrigula gurnardus*) present. Spatial variability was found to influence species composition across the study area, with deeper offshore areas, including the proposed Hornsea Four array area having increased abundances of whiting, and shallower inshore areas, proximal to the nearshore Section of the ECC having higher occurrences of dab and crustaceans.

4.2.3.2 Pelagic species recorded within the study area included sprat (*Sprattus sprattus*), herring (*Clupea harengus*) and mackerel (*Scomber scombrus*), with sprat and herring being a key characterising species of the otter and beam trawl surveys. All three species showed seasonal variability in abundance, with sprat and herring having higher abundances in spring, and mackerel being more abundant in autumn within the proposed array area.

4.2.3.3 Sandeel were generally recorded at low abundances during otter and bream trawl surveys proximal to the array area, compared to many of the other characterising species. It should be noted, however, that these survey methods are not specifically designed to sample sandeel. Sandeel abundances as recorded during trawl surveys across the study area were generally found to be highest to the west of the Hornsea Four array area.

4.2.3.4 Nursery and spawning habitats within the Hornsea Four study area were categorised by Ellis *et al*. (2012) as either high or low intensity, dependant on the level of spawning activity or abundance of juveniles recorded within these habitats. Coull *et al*. (1998) does not provide this level of detail but has been used for species where spawning activity data is scarce). Herring and sandeel are of particular relevance when considering impacts to spawning areas as they are demersal spawners, laying their eggs in the sediment.

4.2.3.5 A number of migratory fish species have the potential to occur in the southern North Sea fish and shellfish study area, migrating to and from rivers and other freshwater bodies in the area which these species use either for spawning habitat (e.g. sea lamprey Petromyzon marinus, river lamprey (*Lampetra fluviatilis*), twaite shad (*Alosa fallax*), allis shad (*Alosa alosa*), Atlantic salmon (*Salmo salar*) and sea trout (*Salmo trutta*), or growth and development to the adult phase with spawning occurring at sea (i.e. European eel (*Anguilla Anguilla*)).

4.2.3.6 The shellfish ecology of the Hornsea Four fish and shellfish study area was found to be primarily characterised by four commercial species: brown crab (*Cancer pagurus*), European lobster (*Homarus gammarus*), Nephrops and common whelk (*Buccinum undatum*).

### 4.2.4 Marine mammals

4.2.4.1 The Hornsea Four site specific surveys suggested that the area may be important for harbour porpoise (*Phocoena phocoena*), with higher average densities here than in the rest of the reference population MU (North Sea). This is reflected by a number of other data sets describing harbour porpoise abundance and distribution of harbour porpoise in the North Sea. The Hornsea Four array area is located within the Southern North Sea SAC designated for harbour porpoise.

4.2.4.2 The densities used in the impact assessment are based on the best available data, with consideration given to the most up to date information together with the necessary precaution applied where there is uncertainty (i.e. where density estimates vary considerably between data sources, a range of estimates will be presented in the impact assessment, with the focus being on more recently collected data sets). None of the site-specific surveys extend far enough from the Hornsea Four array to provide reliable density estimates for the entire potential behavioural impact zones for the noise impact assessment, and as such, broader scale density estimates from SCANS III were incorporated into the assessment for cetacean species comparison).

4.2.4.3 The marine mammal species which are most likely to occur in the Hornsea Four marine mammal study area are: harbour porpoise, minke whale (*Balaenoptera acutorostrata*), white-beaked dolphin (*Lagenorhynchus albirostris*), harbour seal (*Phoca vitulina*) and grey seal (*Halichoerus grypus*).

### 4.2.5 Offshore Ornithology

4.2.5.1 Twenty-four offshore aerial digital surveys have been conducted across Hornsea Four between April 2016 and March 2018. A total of 22 bird species were recorded, with the key species recorded in the greatest abundance/density within the array area (and 4 km buffer) being fulmar (*Fulmarus glacialis*), gannet (*Morus bassanus*), kittiwake (*Rissa tridactyla*), great black-backed gull (*Larus marinus*), guillemot (*Uria aalge*), razorbill (*Alca torda*) and puffin (*Fratercula arctica*).

4.2.5.2 In the intertidal, a desktop study was undertaken to derive the baseline of intertidal birds, which includes several species such as common scoter, red-throated diver, cormorant, shag, curlew, turnstone and numerous gull species. In general, the landfall area is not considered to be of particular importance for intertidal birds.

4.2.5.3 A number of Special Protection Areas (SPAs) were identified as having potential connectivity to Hornsea Four, the closest being the Greater Wash SPA and the Flamborough and Filey

Coast SPA. Potential effects on these sites are considered separately within the Report to Inform Appropriate Assessment (RIAA).

### 4.2.6 Designated sites

4.2.6.1 The Hornsea Four PEIR boundary is in close proximity to, a number of sites designated for nature conservation and water quality, including the Flamborough Head SAC, the Flamborough and Filey Coast SPA, the Greater Wash SPA, the Holderness Inshore Marine Conservation Zone (MCZ) and the Holderness Offshore MCZ. The only site designated for nature conservation that the Hornsea Four boundary overlaps with is the Southern North Sea SAC. The inshore section of the offshore ECC runs through the Yorkshire South waterbody and is in close proximity to two designated Bathing Waters (BWs) at Wilsthorpe and Fraisthorpe.

4.2.6.2 Further information and assessment of impacts to designated sites can be found in the RIAA which considers effects on Natura 200 sites (SACs, SPAs and Ramsar sites), the MCZ Assessment (**Volume 5, Annex 2.3**) and the Water framework Directive (WFD) Assessment (**Volume 5, Annex 2.2**).

## 4.3 Human environment characteristics

4.3.1.1 This section summarises the human environment of the Hornsea Four array area and offshore ECC. Further detail can be found in the Commercial Fisheries, Shipping and Navigation, Marine Archaeology and Infrastructure and Other Users PEIR chapters (**Volume 2**, **Chapter 7**; **Chapter 8**; **Chapter 10;** and **Chapter 12**, respectively) and their associated Technical Annexes.

### 4.3.2 Commercial fisheries

4.3.2.1 The Hornsea Four array area and offshore ECC overlaps ICES rectangles 37E9, 37F0, 37F1, 36E9, 36F0 and 36F1, which have an annual average value of £19.51 million for all UK vessels for the years 2013 to 2017 (MMO, 2017).

4.3.2.2 For non-UK vessels, the commercial fisheries study area is dominated by landings of herring by Dutch and German vessels in particular, and of sandeels, predominantly by Danish vessels. The significant landings are reflective of the industrial scale of these fisheries. The average annual value of herring landings between 2012 and 2016 was in excess of approximately £5.67 million, and for sandeel landings the equivalent value was approximately £1.75 million. Data shows notable fluctuations in annual landings for both species, indicative of the opportunistic nature of the fisheries. Herring, caught mainly by pelagic trawl, are primarily landed from ICES rectangle 37F0, which overlaps with the offshore ECC and a small portion of the array area. Highly mobile pelagic species, that move in shoals and are not associated with specific seabed habitats, are assumed to be available to catch across large areas i.e., if a shoal of herring cannot be caught within Hornsea Four array area or offshore ECC, this shoal is expected to move to an area where they can be caught.

4.3.2.3 Sandeels, caught mainly by otter trawl, are primarily landed from ICES rectangle 37FI, which overlaps with a large portion of the array area and the offshore ECC to a lesser extent. North Sea sandeel grounds are well-mapped, and data indicates that whilst the array area does partially overlap with some grounds, the majority of grounds within ICES rectangle 37F1 are to the north of the array area.

4.3.2.4 Excluding herring and sandeel fisheries, the key species are brown crab and King scallop, targeted primarily by UK potters and dredgers respectively. Brown crab represent the most significant landings by weight across the inshore and southern portion of the study area in ICES rectangles 37E9, 36E9, 36F0 and 36F1. Landings have steadily increased over the five-year study period, peaking at over 5,500 tonnes in 2016. Scallop landings originate primarily from inshore ICES rectangle 37E9, and annual landings fluctuate markedly over the five-year study period, peaking in 2015 at over 2,800 tonnes. Other species of importance based on landings weight include whiting, lobsters, whelks, plaice and mackerel.

#### 4.3.3 Shipping and navigation

4.3.3.1 Hornsea Four array area is positioned in the North Sea, approximately 65 km from shore and is near to a number of major shipping routes. A number of shipping routes pass through the Hornsea Four array area. These are principally vessels transiting northeast/southwest between the Humber Estuary and the entrance to the Baltic Sea. Other routes passing through the site run between northeast England and Scottish / European ports in the southern North Sea. A greater amount of traffic passes across the offshore ECC. Commercial shipping is also recorded at anchor near to the offshore ECC landfall.

4.3.3.2 The key passenger route identified is the Newcastle to Amsterdam DFDS ferry. This ferry service operates daily, seven days a week. In addition to this route, some cruise ship activity was recorded in the data passing through, or near to, the Hornsea Four array area.

4.3.3.3 AIS is not mandated aboard recreational vessels. However, given the distance of Hornsea Four offshore, it is unlikely that any significant recreational activity takes place in the study area.

4.3.3.4 Some fishing activity is recorded near to the Hornsea Four array area, however, full marine traffic surveys (including the use of radar) will be undertaken to more effectively map their intensity. Most of the activity recorded is along the offshore ECC, near to where it makes landfall.

4.3.3.5 The principal activity near to Hornsea Four are those vessels engaged in the oil and gas industry. In particular, offshore supply vessels are active at the fields located near to the study area and pass through the Hornsea Four array area. The Babbage and Ravenspurn gas fields are located adjacent to the southwestern corner of the Hornsea Four array area. The Hyde and West Sole gas fields are located to the south and the Garrow and Kilmar gas fields to the north. Significant activity by these vessels has also been recorded across the offshore limits of the offshore ECC.

#### 4.3.4 Marine archaeology

4.3.4.1 The geoarchaeological potential within the deposits present is high and it is likely that the general area contains important prehistoric archaeological material and paleoenvironmental evidence. Specifically, there is likelihood of surviving remains of

Mesolithic activity and settlement on the Mesolithic shoreline identified in the northern part of the array area.

4.3.4.2 The sedimentary sequence assessment identified deposits of archaeological potential within the Hornsea Four marine archaeology study area, including: Holocene deposits, Boteny cut, Eem Formation and Yarmouth roads.

4.3.4.3 Within the PEIR boundary there are 18 known wrecks with 13 classified as LIVE. In addition, there are seven fouls and seabed obstructions. The majority of the known wrecks are dated to the 20$^{th}$ century.

4.3.4.4 In terms of geophysical data, the following contacts of archaeological potential have been identified: 129 features of low potential, 24 magnetic anomalies over 100 nT but with no seabed contact, two features of medium potential, and three features of high potential.

#### 4.3.5 Oil and Gas activity

4.3.5.1 There are currently seven licenced blocks for oil and gas exploration coincident with the Hornsea Four array area (and a 1 km buffer); licences are held by Bridge Petroleum, Premier Oil, and Spirit Energy. There are eight unlicensed blocks coincident with the Hornsea Four array.

4.3.5.2 There are currently nine licenced blocks coincident with the Hornsea Four ECC (and associated 1 km buffer); licences are held by Perenco, Premier Oil and Spirit Energy. There are currently 10 unlicensed blocks within the Hornsea Four ECC.

4.3.5.3 There are 29 wells located within 1 km of the Hornsea Four array area and 40 wells within 1 km of the offshore ECC. There is a total of 10 permanent surface platforms within 9 nautical miles of the Hornsea Four array are, with none within 1 km. there are three platforms within 1 km of the offshore ECC.

# 5 Characteristics of the material for disposal

## 5.1 Physical characteristics

#### 5.1.1 Array area

Drilled material

5.1.1.1 The spoil material derived from drilling activities will be different in nature to that disposed of via seabed preparation/dredging as these drilled materials will include predominantly sediment/rock from deeper in the soil profile.

5.1.1.2 Beneath the veneer of surficial sediments (sands), sub surface geology consists of a firm to stiff clay till (the Bolders Bank formation) and below that, chalk bedrock. In some areas, there may be exposed chalk bedrock, or chalk bedrock close to the surface below surficial sediments.

5.1.1.3 The exact proportions of these deposits that will form the basis of the drill arisings deposited on the seabed will vary according to the drilling locations and the depth to which drilling occurs.

Dredged material

5.1.1.4 The dominant sediment types identified in the array area that will be dredged are sands, with some pockets of slightly gravelly sands and some patches containing a small proportion of fines. **Figure 2** shows the sediment distribution across the array area.

5.1.1.5 Although the actual process of disposal may result in a slight change to the existing particle size composition of seabed sediments, the material disposed *in situ* via seabed preparation and cable trenching would be similar to the existing material as the spoil disposal will occur close to the site of production.

### 5.1.2 Offshore ECC

Drilled material

5.1.2.1 As with the array area, sub-surface geology in the HVAC booster station search area beneath the veneer of surficial sediments (sands), consists of a firm to stiff clay till (the Bolders Bank formation) and below that, chalk bedrock. In some areas, there may be exposed chalk bedrock, or chalk bedrock close to the surface below surficial sediments.

5.1.2.2 As with the array, the exact proportions of these deposits that will form the basis of the drill arisings deposited on the seabed will vary according to the location of drilling and the depth to which drilling occurs.

Dredged material

5.1.2.3 Surficial sediment cover along the offshore ECC indicates an increasing sand content from inshore to offshore. From the landfall, the surficial sediments comprise sands with patches of gravelly sand across Smithic Sands, then sandy gravels onto gravelly sands, slightly gravelly sands and finally sands once into the array area. **Figure 3** shows the sediment distribution across the offshore ECC.

5.1.2.4 As with the array, although the actual process of disposal may result in a slight change to the existing particle size composition of seabed sediments, the material disposed in situ via seabed preparation and cable trenching would be similar to the existing material as the spoil disposal will occur close to the site of production.

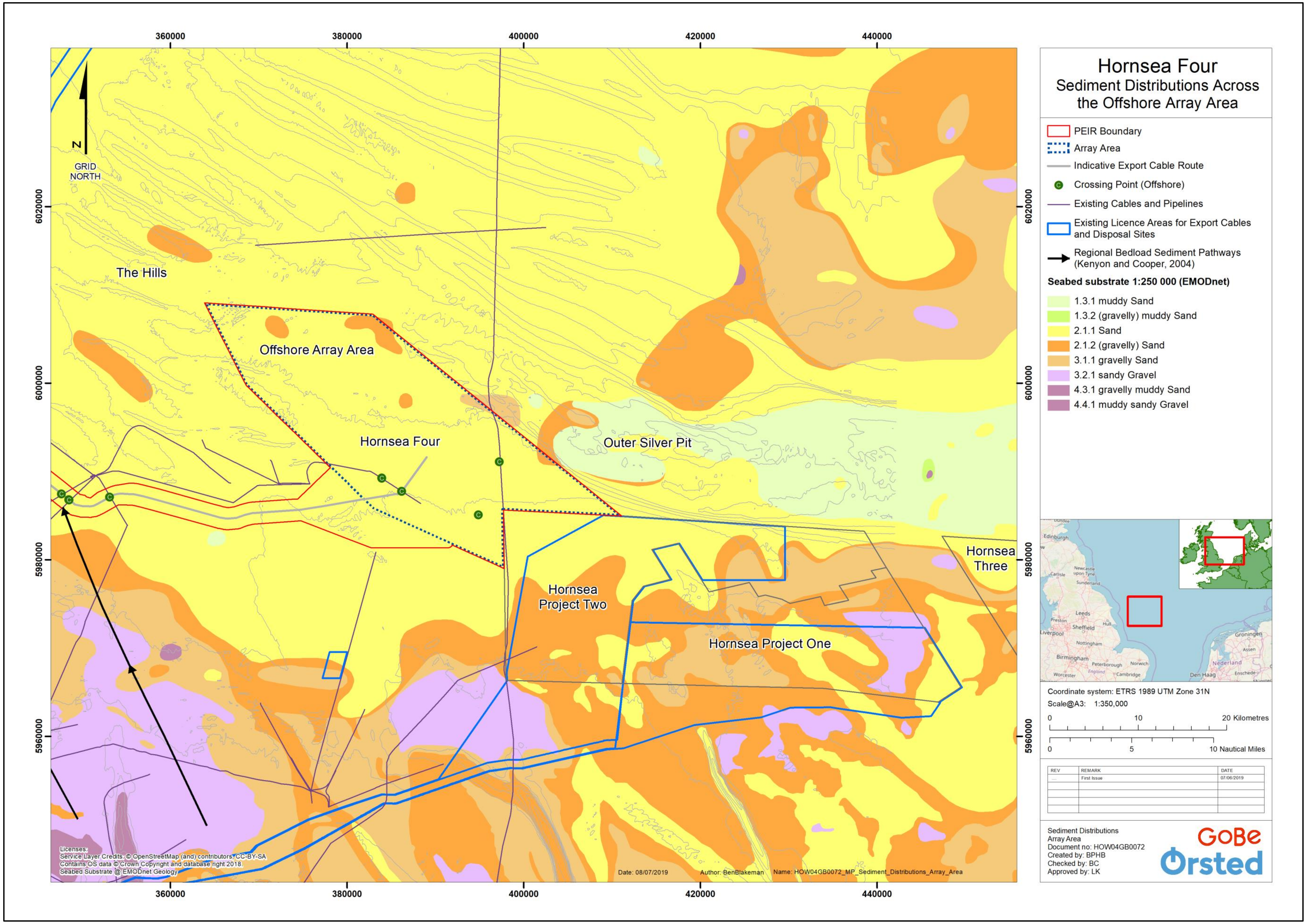


Figure 2: Sediment distributions across the array area based on descriptive classifications by Folk (1954) (not to scale).

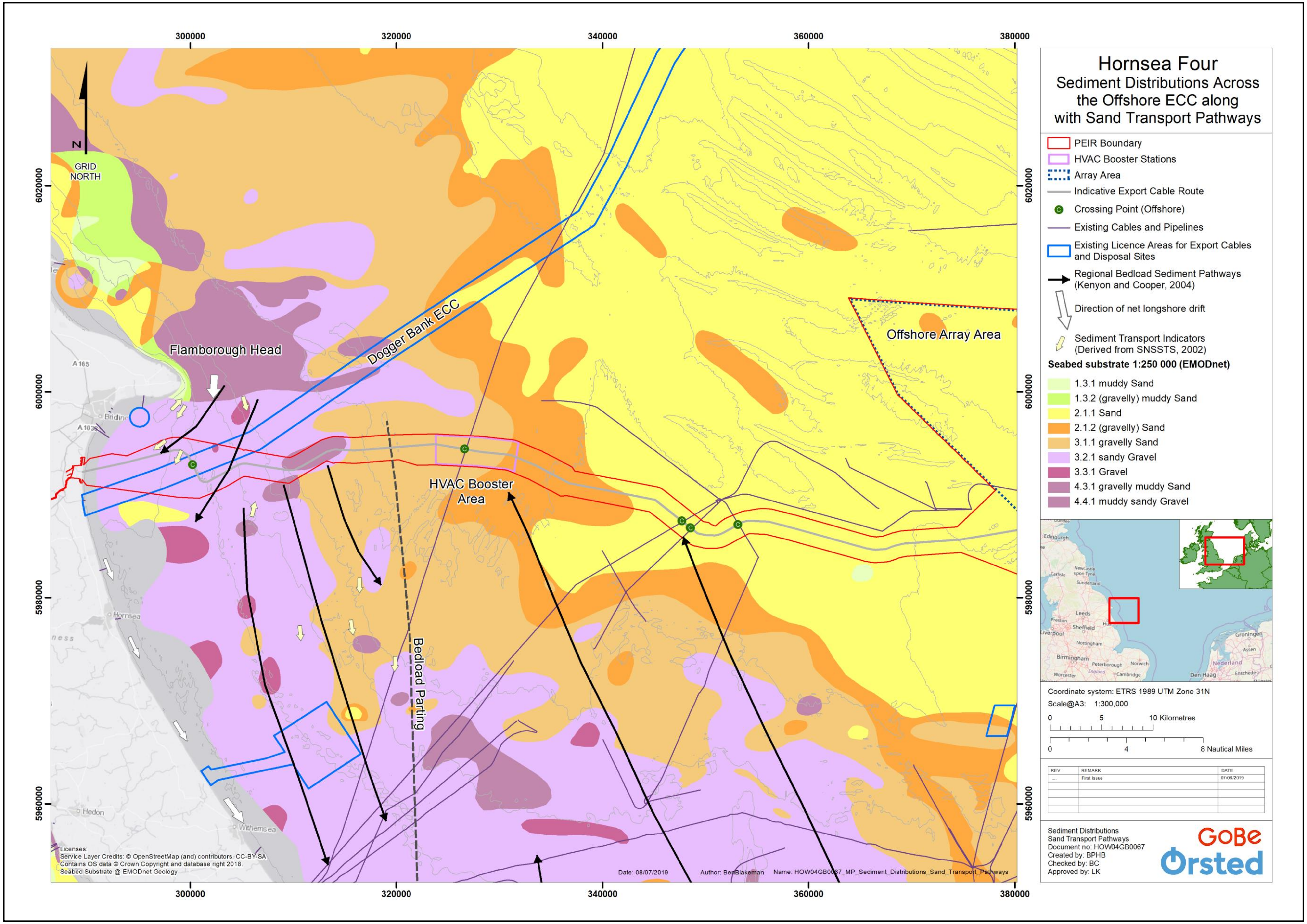


Figure 3: Sediment distributions across the offshore ECC based on descriptive classifications by Folk (1954) (not to scale).

## 5.2 Chemical characteristics

5.2.1.1 This section summarises the chemical characteristics of sediments in the array and offshore ECC. Further detail can be found in **Volume 2, Chapter 2: Benthic and Intertidal Ecology** and **Volume 5, Annex 2.1: Benthic and Intertidal Ecology Technical Report**.

### 5.2.2 Array area

5.2.2.1 The results of the sediment contamination analyses revealed that the majority of the hydrocarbons recorded from the sediments within the Hornsea Four array occurred at expected background concentrations with some elevation in concentrations present close to existing oil and gas infrastructure. All hydrocarbons were below the threshold levels considered likely to exert an effect on the faunal community.

5.2.2.2 All metal concentrations were below their respective apparent effect thresholds. Values for monobutyltin (MBT) were below the limit of detection at all but seven stations where a value of 1 ng/g was recorded. Values were below the limit of detection for dibutyltin and tributyltin.

### 5.2.3 Offshore ECC

5.2.3.1 A full suite of contaminant analyses will be undertaken across the offshore ECC during the further sampling planned to occur in 2019 and will be reported in the ES to accompany the DCO application. This section will be updated to summarise the results of the further sampling and analysis.

## 5.3 Biological characteristics

5.3.1.1 Biological characteristics were similar in both the array and the offshore ECC. Further detail can be found above in **Section 4.2** and in the sources described in **Table 3** below.

**Table 3: Locations of more detailed information for specific data categories.**

| Data | Relevant PEIR Document |
|---|---|
| Contaminant analysis | **Volume 2, Chapter 2: Benthic and Intertidal Ecology**<br>**Volume 5, Annex 2.1: Benthic and Intertidal Ecology Technical Report** |
| Seabed geology | **Volume 2, Chapter 1: Marine Geology, Oceanography and Physical Processes**<br>**Volume 5, Annex 1.1: Marine Processes Technical Report** |
| Biotopes and benthic fauna | **Volume 2, Chapter 2: Benthic and Intertidal Ecology**<br>**Volume 5, Annex 2.1: Benthic and Intertidal Ecology Technical Report** |
| Fish and shellfish spawning and nursery areas | **Volume 2, Chapter 3: Fish and Shellfish Ecology**<br>**Volume 5, Annex 3.1: Fish and Shellfish Ecology Technical Report** |

# 6 Assessment of the potential adverse effects of *in situ* spoil disposal

## 6.1 Physical environment

6.1.1.1 Marine processes are not themselves receptors in the majority of cases. However, changes to these processes may have an impact on other sensitive receptors. This section summarises the findings of the impact assessment of these physical changes on sensitive biological and human receptors.

### 6.1.2 Drilled material

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

6.1.2.2 Monopile foundations and pin-piled jacket foundations would be installed using standard drilling techniques. In some locations, the particular geology may present some obstacle to piling, in which case some or all of the seabed material might be drilled within the pile footprint to assist pile installation. It is assumed that drilling of the full pile depth may be required at up to 10% of pile locations. However, it should be noted that drilling (though consented) was not required at Hornsea Project One, which represents broadly similarly regional seabed characteristics to those at Hornsea Four.

6.1.2.3 Sediment deposition as a result of drilling for a single pile location could deposit coarse-grained and clastic sediment within an area in the order of approximately 10 – 100 m downstream and a few tens of metres wide from individual foundation locations, with an average thickness in the order of 1 – 10 m.

6.1.2.4 Deposits of mainly sandy sediment will concentrate within an area in the order of approximately 100 – 500 m downstream of foundation locations and in the order of approximately 10 – 100 cm to 1 m wide.

6.1.2.5 Fine-grained material will be dispersed widely within the surrounding area and is not expected to settle to a measurable thickness.

6.1.2.6 Suspended Sediment Concentration (SSC) will be increased by tens to hundreds of thousands of mg/l at the point of sediment release at the sea surface. However, the majority of sediment is expected to settle quickly to the seabed and SSCs outside of one tidal excursion (approximately 16 km) are expected to increase by less than 10 mg/l due to ongoing dispersion of material.

6.1.2.7 It is noted that, whilst the absolute width, length, shape and thickness of local sediment deposition as a result of drilling is estimated, it cannot be predicted with certainty and is likely to vary due to the nature of the drill spoil, the local water depth, and the ambient environmental conditions during the drilling activity. If the total volume of drill arisings were distributed equally across the relevant disposal site (array or offshore ECC), the increase in bed elevation would be almost immeasurable. However, in reality, the change will consist of a series of smaller, discrete, overlapping and non-overlapping deposits distributed throughout parts of the array area and offshore ECC where foundations are located. Monitoring of drill arising mounds on the Lynn and Inner Dowsing Offshore Wind Farm found that after four months, mounds had been reduced from 3 m to 1.2 m, however this figure is only presented as a guide as sediment and oceanographic conditions may be slightly different at Hornsea Four.

#### 6.1.3 Dredged material

6.1.3.1 No significant adverse effects are predicted on marine geology, oceanography and physical processes from the disposal of dredged material from seabed preparation, sandwave clearance and cable trenching within the array or the offshore ECC. The maximum design scenario involves seabed preparation by suction hopper dredger with release of dredged material at the sea surface, as well as sandwave clearance and cable installation by MFE.

6.1.3.2 Dredging of coarse sediment would not create persistent plumes as the coarse material would quickly settle to the seabed. However, the disturbance of finer sediment has the potential to give rise to more persistent plumes that settle out over a wider area. It should be noted that sediments within the Hornsea Four array are predominantly sands containing a low portion of fines.

6.1.3.3 In the case of dredging, when dredged material is released, approximately 90% will fall directly to the seabed (termed the dynamic plume phase). The remaining 10% will become more dispersed and stay in suspension (termed the passive plume phase). Sand-sized material could remain in suspension for a short time and be transported downstream (depending on the flood/ebb tides at the time of release). Finer sediment could remain suspended for longer, in the order of hours to days. Localised increases in SSC of up to several hundred mg/l in the immediate vicinity of the release location will be considerably higher than background levels, although highly localised and lasting for a very short period (in the order of hours).

6.1.3.4 For sandwave clearance and cable trenching using MFE, the height of release is at or near the seabed, and there is far less potential for persistent plumes or significant deposition away from the location of the activity.

6.1.3.5 In terms of bed-level changes associated with dredging for installation of all foundations using suction caissons, if the total volume of dredged material were deposited evenly across the relevant disposal site (array or offshore ECC), the increase in bed elevation would me almost immeasurable. In reality, as with drill arisings, the change will comprise a series of smaller, discrete, overlapping and non-overlapping deposits, potentially from multiple dredging cycles around each dredged area, distributed throughout the parts of the array area of offshore ECC where foundations, sandwaves and cables are located.

### 6.2 Biological and Human Environment

6.2.1.1 The PEIR for Hornsea Four provides a detailed impact assessment relating to disposal activities on a number of sensitive physical, biological and human environment receptors, including (amongst others) benthic habitats, fish and shellfish spawning and nursery habitats, marine mammals, birds, commercial fisheries and shipping and navigation.

6.2.1.2 **Table 4** provides a summary of the key impacts relating to the activities described in this document on physical, biological and human receptors assessed within the PEIR. The relevant chapters/documents of the PEIR are also referenced where further detail of those impact assessments can be found.

**Table 4: Summary of impacts from disposal of material from seabed preparation, sandwave clearance, pile drilling and cable trenching within the Hornsea Four PEIR boundary.**

| Potential Impact | Relevant Section of PEIR | Magnitude of Impact | Sensitivity of Receptor | Significance of Effect |
|---|---|---|---|---|
| *Marine Geology, Oceanography and Physical Processes* | | | | |
| Seabed levelling – HVAC booster station search area | **Volume 2, Chapter 1: Marine Geology, Oceanography and Physical Processes** | N/A | Pathway | N/A |
| Seabed levelling – offshore array area | | N/A | Pathway | N/A |
| Cable trenching – offshore ECC | | N/A | Pathway | N/A |
| Cable trenching – offshore array area | | N/A | Pathway | N/A |
| Foundation installation – drilling at HVAC booster station search area | | N/A | Pathway | N/A |
| Foundation installation – drilling at the offshore array area | | N/A | Pathway | N/A |
| *Benthic and Intertidal Ecology* | | | | |
| Temporary increases in SSC and sediment deposition in the Hornsea Four array area and offshore ECC | **Volume 2, Chapter 2: Benthic and Intertidal Ecology** | Minor | Sensitivity to heavy smothering (5 – 30 cm)<br>*A. islandica*, SS.SMu.CFiMu.SpnMeg: Not sensitive<br>SS.SSa.IFiSa.NcirBat, SS.SMx.CMx.MysThyMx: Low<br>SS.SSa.CMuSa.AalbNuc, SS.SSa.CFiSa.ApriBatPo, SS.SSa.CFiSa.EpusOborApri: Medium<br>Sensitivity to light smothering (<5 cm)<br>Chalk reef habitat of Flamborough Head SAC: Medium<br>Submerged or partially submerged sea caves of Flamborough Head SAC: Negligible | Minor adverse |

| Potential Impact | Relevant Section of PEIR | Magnitude of Impact | Sensitivity of Receptor | Significance of Effect |
|---|---|---|---|---|
| | | | Broadscale habitat features of the Holderness Offshore and Inshore MCZ: Low | |
| Temporary increases in SSC and sediment deposition in the intertidal area | | Minor | LS.LSa.MoSa.Bar.Sa: Negligible<br>Submerged or partially submerged sea caves: Low | Negligible adverse |
| *Fish and Shellfish Ecology* | | | | |
| Temporary localised increases in SSC and smothering | **Volume 2, Chapter 3: Fish and Shellfish Ecology** | Minor | Medium | Minor adverse |
| Direct and indirect seabed disturbances leading to the release of sediment contaminants | | Negligible | Medium | N/A (magnitude assessed as negligible) |
| *Marine Mammals* | | | | |
| Vessel collision risk | **Volume 2, Chapter 4: Marine Mammals** | Minor | Medium | Minor adverse |
| Non-piling noise (e.g. cable laying, dredging) | | Negligible | Negligible to Low | Negligible adverse |
| Reduction in prey availability | | Negligible | Low | N/A (magnitude assessed as negligible) |
| Reduction in foraging ability | | Negligible | Low | N/A (magnitude assessed as negligible) |
| *Ornithology* | | | | |
| Potential displacement of seabirds from the ECC during export cable laying | **Volume 2, Chapter 5: Offshore and Intertidal Ornithology** | Negligible to minor | Medium to high | Negligible adverse |
| Potential displacement of seabirds from the array area during the construction of foundations, WTGs and associated vessel activity | | Negligible to minor | Medium to high | Negligible adverse |
| Indirect impacts through effects on habitats and prey | | No significant impacts predicted. | | |

# 7 Monitoring

7.1.1.1 Based on the findings of the impact assessments presented in the PEIR, and summarised within this document, long-term impacts of disposal of spoil and dredged material within the Hornsea Four array and offshore ECC are not anticipated. This is due to the limited increase in seabed level and the temporary nature of any sediment plumes generated.

7.1.1.2 The deposition of sediment from disposal activities is also predicted to only result in short-term, spatially discrete impacts, and the fact that the seabed material to be disposed of *in situ* is not heavily contaminated has shown that contamination will not occur.

7.1.1.3 The only potential longer-term impact of disposal that may arise will be the deposition of drill arisings on the seabed which may consist of large, granular materials that are too large to be moved by tidal currents and may remain *in situ* for long periods of time. The exact scope for this potential impact will rely on the nature of the materials drilled out during pile drilling. Post-construction bathymetric monitoring will be required; however, no other monitoring is proposed.

# 8 Conclusions

8.1.1.1 This document represents the site characterisation for the Hornsea Four array area and offshore ECC. It forms the proposal for licensed disposal sites within the array area and the offshore ECC for drill arisings, and material from seabed preparation, sandwave clearance and cable trenching. This is required by the MMO to allow them to consider the potential impacts of disposal within these sites.

8.1.1.2 Noting that all the information required for a site characterisation to support a disposal licence application will be contained within the Environmental Statement (ES) submitted at DCO Application, this document takes the form of a 'framework' document that provides a summary of the key points of relevance to site characterisation and refers to more detailed information and data presented within the relevant sections of the PEIR at this stage.

8.1.1.3 The source of material proposed to be disposed of within the array and ECC will be sediment dredged from the upper 3 m of the existing seabed via suction hopper dredger as part of seabed preparation works for suction caisson turbine, OSS and accommodation platform foundations, sandwave clearance and cable trenching via MFE, and/or materials from the deeper soil profile and upper sediments derived from drilling activities for piled turbine, offshore substation and accommodation platform foundations.

8.1.1.4 Within the Hornsea Four Array Disposal Site, an upper estimate of 3,889,815 $m^3$ of material will be disposed of *in situ* in the form of shallow dredged sediments or an upper estimate of 1,103,629 $m^3$ of material from drill arisings which would also be disposed of *in situ*.

8.1.1.5 Within the Hornsea Four Offshore ECC Disposal Site, an upper estimate of 928,735 $m^3$ of material will be disposed of in situ in the form of shallow dredged sediments or an upper estimate of 761,618 $m^3$ of material from drill arisings which will also be disposed of in situ.

8.1.1.6 Where drilling is required to facilitate the installation of piles to target depth, the drill arisings will be disposed of at sea, adjacent to the foundation location.

8.1.1.7 The impacts of disposal via the return of dredged material to the water column and/or the placement of drill arisings adjacent to foundations has been fully assessed. No moderate or major (significant) adverse effects have been identified, with only negligible and minor (non-significant) effects predicted on certain receptors.

8.1.1.8 As the assessment has not identified any significant adverse effects on receptors via this proposed disposal activity, it is concluded that, whilst potential alternative options for the use of this material may exist, disposal *in situ* remains the most viable option.

## 9 References

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