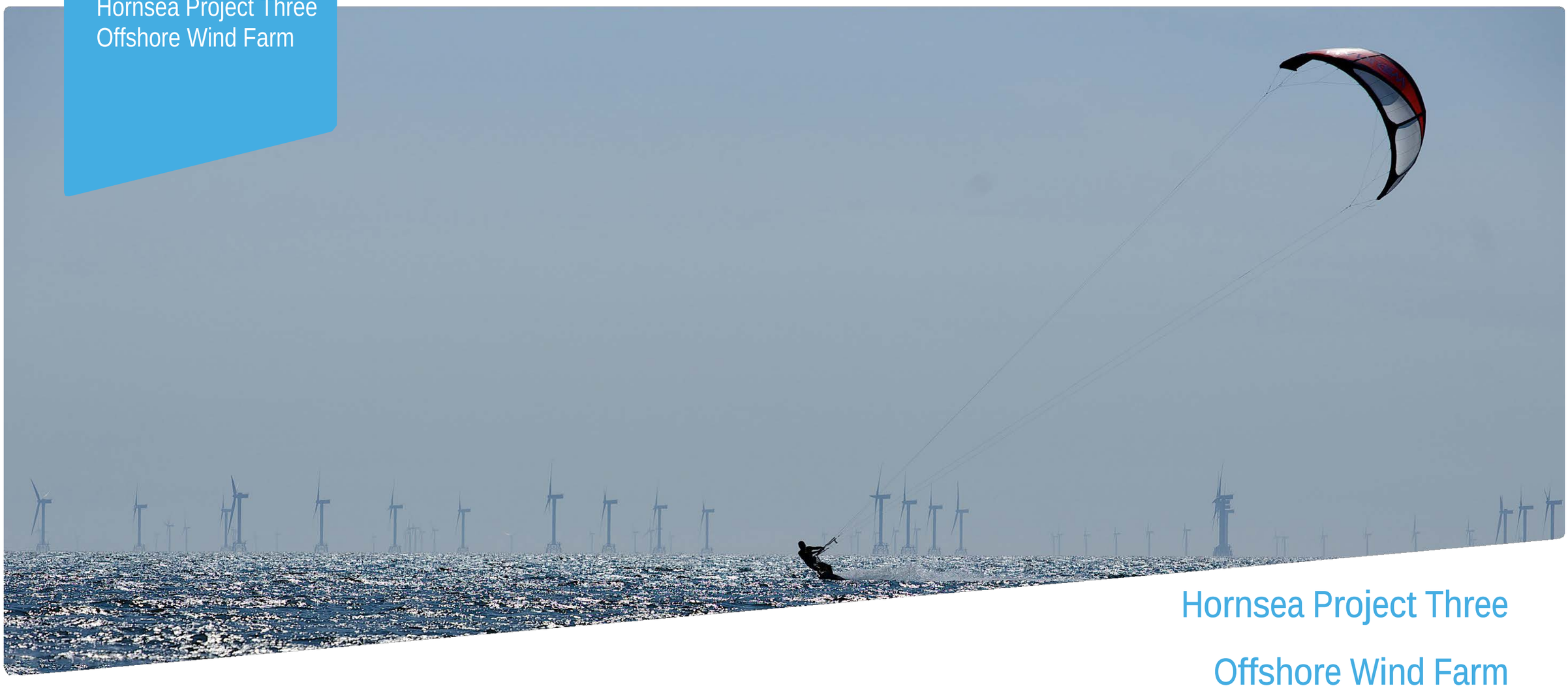
Hornsea Project Three
Offshore Wind Farm



Hornsea Project Three

Offshore Wind Farm

Preliminary Environmental Information Report:
Annex 3.2 – Dredging and Disposal: Site Characterisation

Date: July 2017

Hornsea 3
Offshore Wind Farm

DONG energy

Environmental Impact Assessment

Preliminary Environmental Information Report

Volume 4

Annex 3.2 - Dredging and Disposal: Site Characterisation

Liability

This report has been prepared by RPS, with all reasonable skill, care and diligence within the terms of their contracts with DONG Energy Power (UK) Ltd.

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This report is also downloadable from the Hornsea Project Three offshore wind farm website at:
www.dongenergy.co.uk/hornseaproject3

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Front cover picture: Kite surfer near one of DONG Energy's UK offshore wind farms © DONG Energy Hornsea Project Three (UK) Ltd., 2016.

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Glossary

Term	Definition
Astronomical tide	The tide levels and character which would result from the gravitational effects of the earth sun and moon without any atmospheric influences.
Benthic	A description for animals, plants and habitats associated with the seabed. All plants and animals that live in, on or near the seabed are benthos.
Benthic ecology	Benthic ecology encompasses the study of the organisms living in and on the sea floor, the interactions between them and impacts on the surrounding environment.
Biotope	The combination of physical environment (habitat) and its distinctive assemblage of conspicuous species.
Demersal	Living on or near the seabed.
Epibenthic	Organisms living on the surface of the seabed.
Epifauna	Animals living on the surface of the seabed.
Fishery	A group of vessel voyages which target the same species or use the same gear;
Fishing ground	An area of water or seabed targeted by fishing activity.
Fleet	A physical group of vessels sharing similar characteristics (e.g. nationality).
Habitat	The place in which a plant or animal lives. It is defined for the marine environment according to geographical location, physiographic features and the physical and chemical environment (including salinity, wave exposure, strength of tidal streams, geology, biological zone, substratum, 'features' (e.g. crevices, overhangs, rockpools) and 'modifiers' (e.g. sand-scour, wave-surge, substratum mobility).
Heritage	Historic or cultural associations.
Heritage asset	Those elements of the historic environment that hold value to this and future generations because of their historic, archaeological, architectural or artistic interest are called ”heritage assets”. A heritage asset may be any building, monument, site, place, area or landscape, or any combination of these (DECC, 2011).
ICES statistical rectangles	Defined areas, 1 degree longitude x 0.5 degree latitude equalling approximately 30 x 30 NM used for fisheries statistics.
Infauna	The animals living in the sediments of the seabed.
Intertidal	An area of a seashore that is covered at high tide and uncovered at low tide.
Landings	Quantitative description of amount of fish returned to port for sale, in terms of value or weight.
Marine Management Organisation	A UK government department that license regulate and plan commercial fisheries activities in the seas around England, with jurisdiction from 0 to 12 NM.
Otter trawl	A net with large rectangular boards (otter boards) which are used to keep the mouth of the trawl net open. Otter boards are made of timber or steel and are positioned in such a way that the hydrodynamic forces, acting on them when the net is towed along the seabed, pushes them outwards and prevents the mouth of the net from closing.
Pelagic	Of or relating to the open sea.
Prehistoric archaeology	In the British Isles the period from the earliest hominin occupation more than 780,000 years Before Present (BP) to the time of the Roman invasion of Britain in 43 AD.
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 Particulate Matter (SPM)	Close to the bed, suspended matter typically consists of re-suspended mineral matter, but higher up in the water column SPM is typically in the form of flocs – loosely bound aggregates composed of mineral matter (e.g. clay minerals) as well as organic matter.
Suspended sediment concentration	Mass of sediment in suspension per unit volume of water.
The Crown Estate	An independent commercial business, created by Act of Parliament that owns the UK seabed out to 200 NM.
Total Allowable Catches	Total Allowable Catches (TACs) are catch limits, expressed in tonnes or numbers that are set for some commercial fish stocks.
Written Scheme of Investigation (WSI)	A plan detailing the protocol for any archaeological investigation to be carried out prior to the construction of Hornsea Project Three, including procedures for field survey and watching briefs, as may be required.

Acronyms

Acronym	Description
AC	Alternating current
BAP	Biodiversity Action Plan
TEL	Threshold Effect Level
Cefas	Centre for Environment, Fisheries and Aquaculture Science
CPA	Closest Point of Approach
cSAC	Candidate Special Area of Conservation
DBT	Dibutyltin
DC	Direct current
EEZ	Exclusive economic zone
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency
EU	European Union

Acronym	Description
GBF	Gravity Base Foundations
HV	High Voltage
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
ICES	International Council Of The Exploration Of The Sea
JNCC	Joint Nature Conservation Committee
LAT	Lowest Astronomical Tide
MCZ	Marine Conservation Zone
MHWS	Mean High Water Spring
MLWS	Mean Low Water Spring
MMO	Marine Management Organisation
NE	Natural England
NRHE	National Record Of The Historic Environment
OSPAR	Oslo-Paris Commission
PAH	Polycyclic Aromatic Hydrocarbon
PEIR	Preliminary Environmental Information Report
RCD	Reverse Circulation System
REWS	Radar Early Warning Systems
rMCZ	Recommended Marine Conservation Zone
SAC	Special Area Of Conservation
SPA	Special Protection Area
SPM	Suspended Particulate Matter
SSC	Suspended Solids Concentrations
SSSI	Site Of Special Scientific Interest
TBT	Tributyltin
TPH	Total Petroleum Hydrocarbon
TPT	Triphenyltin
UK	United Kingdom
UKHO	United Kingdom Hydrographic Office
VER	Valued Ecological Receptor
WTG	Wind turbine Generator

Units

Unit	Description
%	Percent
€	Euro (EUR)
µg/kg	Micrograms per gram
km	Kilometre
km^2	Squared Kilometre
m	Metre
m^3	Cubic metre
mg/kg	Milligrams per gram
mg/l	Milligrams per litre
MW	Megawatt
nT	Nanotesla

1. Site Characterisation for Disposal Licence Application

1.1 Introduction

1.1.1.1 DONG Energy Power (UK) Ltd. (hereafter referred to as DONG Energy), on behalf of DONG Energy Hornsea Project Three (UK) Ltd. is promoting the development of the Hornsea Project Three Offshore Wind Farm (hereafter referred to as Hornsea Three). Hornsea Three is a proposed offshore wind farm array with a total generating capacity of 2,400 MW and includes the associated offshore cable corridor and onshore infrastructure. The Hornsea Three array area is located in the east of the former Hornsea Zone, in the central region of the southern North Sea, approximately 121 km from the UK coast (at Tringham, Nofolk)and 10.1 km from the median line between UK and Dutch waters (Figure 1.1). All references to Hornsea Three in this Annex shall, for the purposes of the report, refer to the offshore infrastructure and activities only.

1.1.1.2 RPS was commissioned to undertake a Site Characterisation report, drawing on the findings to date of the Environmental Impact Assessment (EIA) for Hornsea Three, to support the application for licensing of marine disposal sites in relation to the offshore elements of the proposed development.

1.1.1.3 Two marine disposal sites are being applied for:

1. Hornsea Three array; and
2. Hornsea Three Offshore cable corridor.

1.1.1.4 Site characterisation is the process whereby the proposed marine disposal sites for dredged material and drill arisings are described in terms of their existing environment, using all available data sources. A full site characterisation report must be submitted to the Marine Management Organisation (MMO) in order to inform the decision making process with regard to proposed marine disposal. Based on prior experience outlined in paragraph 1.1.1.6, such a report is required to contain the following information as a minimum:

- The need for the new disposal site(s);
- The dredged material characteristics;
- The disposal site characteristics;
- The assessment of potential effects; and
- The reasons for the site(s) selection.

1.1.1.5 This document represents the site characterisation for two proposed disposal sites associated with the construction of Hornsea Three; Hornsea Three array disposal site and the offshore cable corridor disposal site. The locations of the proposed sites are presented in Figure 1.1.

1.1.1.6 The structure of this Site Characterisation report follows a similar structure to that applied for the same exercise undertaken for previous projects within the Former Hornsea Zone (namely Hornsea Project One and Hornsea Project Two), with deemed Marine Licenses issued under the Development Consent Order (DCO) to provide for the disposal of material arising from the construction process of those projects. This structure was agreed on Hornsea Project One between the Applicant for that project and the MMO/Cefas. As part of that process, the structure was also issued to the Joint Nature Conservation Committee (JNCC) and Natural England (NE). It is considered that the structure and content of the document remains valid and has therefore been followed in this report for Hornsea Three.

1.1.1.7 It is intended that the deemed Marine Licenses for Hornsea Three would cover the deposit of all substances and articles (including spoil) and the carrying out of works involved in the construction of the generating station and associated development. This site characterisation report has therefore been provided to inform the MMO's decision making and facilitate inclusion of any relevant conditions covering the disposal activity within the deemed Marine Licences for Hornsea Three. .

1.1.1.8 Noting that all the information required for site characterisation to support a disposal application is contained within the Hornsea Three Preliminary Environment Information report (PEIR), this report takes the form of a 'framework' document that provides a summary of the key points relevant to site characterisation and directs the reader back to where the more detailed information and data presented within various sections of the PEIR can be found. As such, the information presented in the following sections should be read in conjunction with the wider PEIR.

1.1.1.9 This Disposal Site Characterisation is structured as follows:

- Section 1: Introduction and project background;
- Section 2: Assessment of the need for a new disposal site, predicted sources and amounts of spoil, consideration of alternative disposal options;
- Section 3: Characteristics of disposal sites; physical, biological and human characteristics;
- Section 4: Characteristics of material to be disposed, physical, chemical, and biological (including toxicology) properties of material to be disposed, method of dredging/drilling and disposal;
- Section 5: Assessment of potential adverse effects of *in situ* disposal of dredge/drill material; and
- Section 6: Conclusions.

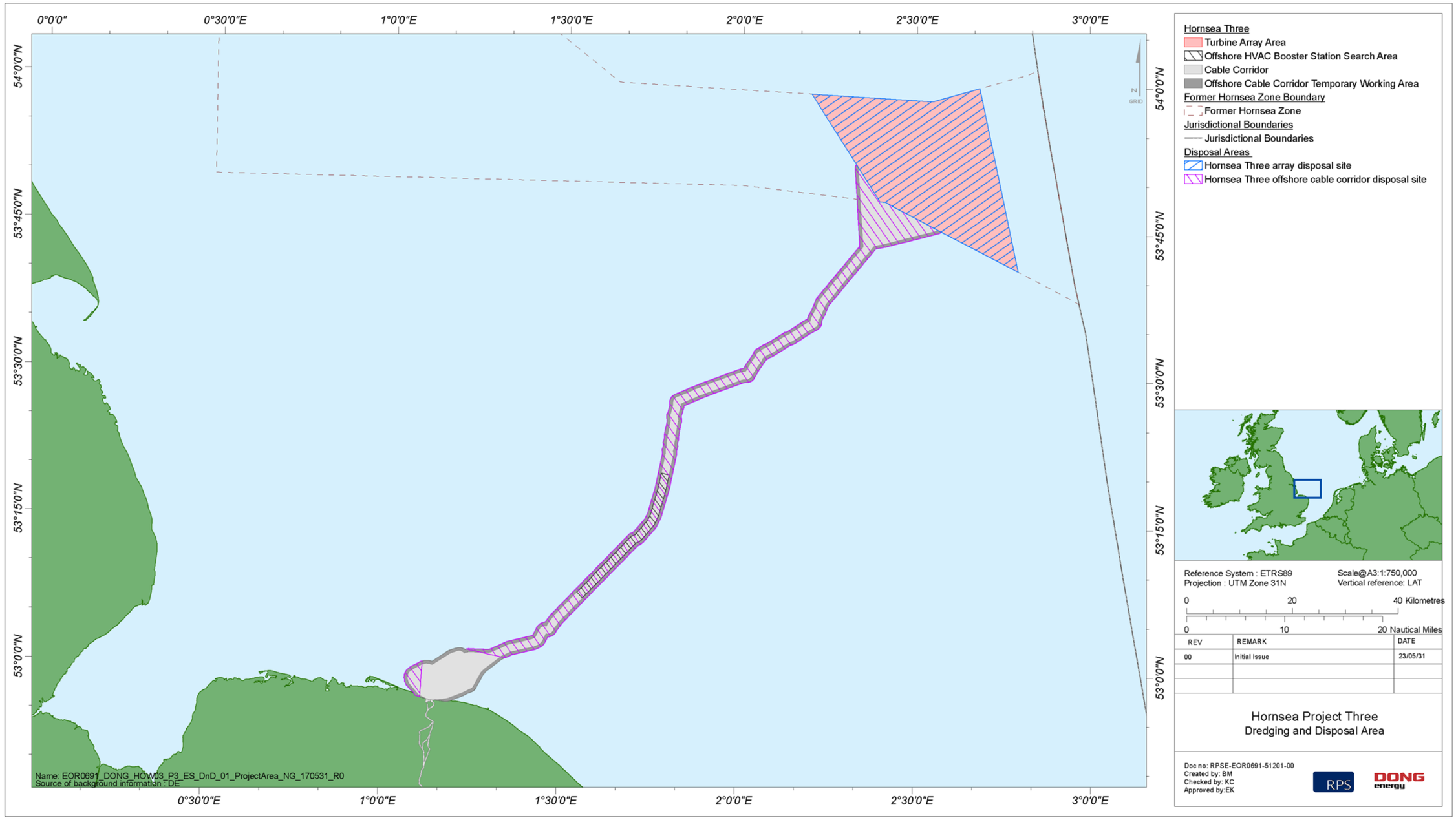

Figure 1.1: Location of the proposed Hornsea Three array disposal site and Hornsea Three offshore cable corridor disposal site (excluding the Cromer Shoal Chalk Beds MCZ site).

2. Assessment of the Need for a New Disposal Site

2.1 Hornsea Three

2.1.1 The Project

Hornsea Three array

2.1.1.1 Hornsea Three array is located in the east of the former Hornsea Zone and has a total area of 696 km^2. The western boundary of Hornsea Three array area Hornsea Three array lies 121 km to the northeast of Tringham, Norfolk, and approximately 10.1 km west of the median line between UK and Dutch waters (Figure 1.1).

2.1.1.2 The boundary of the Hornsea Three array area is illustrated in Figure 1.1, which also represents the boundary of the proposed Hornsea Three array disposal site. All materials proposed to be disposed of *in situ* arising from seabed preparation for gravity base foundations (GBFs), drill arisings from piled foundation installation and sandwave clearance prior to inter array cable installation will be disposed of within the Hornsea Three array area disposal site.

Hornsea Three offshore cable corridor

2.1.1.3 The offshore cable route corridor extends from the proposed landfall at Weybourne in north Norfolk, offshore in a north-easterly direction to the southern boundary of Hornsea Three array (See Figure 1.1). The route is approximately 145 km in length.

2.1.1.4 The boundaries of the Hornsea Three offshore cable corridor are illustrated in Figure 1.1, which also represent the boundaries of the proposed Hornsea Three offshore cable corridor disposal site. All materials proposed to be disposed of *in situ* arising from sandwave clearance prior to cable installation and foundation installation associated with the HVAC boosters stations within the Hornsea Three offshore cable corridor boundary, with the exception of Cromer Shoal Chalk Beds MCZ. This MCZ site is excluded from the disposal area to minimise effects on protected features relating to smothering, deposition and increased suspended sediment concentrations (SSC). In addition no sandwave clearance is proposed within the MCZ site.

2.1.2 Project components

2.1.2.1 The key marine components of Hornsea Three relevant to this report include:

- Turbines;
- Turbine foundations;
- Array cables;
- Offshore substation(s), and platform(s);
- Interconnector cables;
- Offshore accommodation platform/s; and
- Offshore export cable/s;
- Onshore cabling; and
- Onshore substation and onshore HVAC booster stations.

2.1.2.2 Due to the inclusion of an HVAC and HVDC transmission option, depending on the option selected prior to construction, Hornsea Three will have slightly different key components in addition to those listed above. The difference between the HVAC and HVAC transmission options are explained further in chapter 3: Project Description.

2.1.2.3 Full details of the Hornsea Three project design are provided in volume 1, chapter 3: Project Description.

2.1.3 Summary of foundation options

2.1.3.1 Five foundation types for turbines are being considered for Hornsea Three. At present, more information is required to inform the final foundation choice (i.e., which option(s) are the most economic and technically appropriate for the project). It is possible that more than one type of foundation may be used across Hornsea Three. The final selection of foundation type(s) for Hornsea Three will be dependent upon a number of parameters including; the final turbine size, seabed conditions, water depth, environmental considerations, economics and supply chain. The following foundation concepts are being considered:

- Monopiles, including braced and guyed designs;
- Steel jackets/space frame structure supported by piles (including both driven and suction piles);
- Monopods (suction piles)
- GBFs, including mono suction caissons; and
- Floating foundations.

2.1.3.2 Floating foundation anchors would be secured by means which would fall within the design envelopes of GBF, jacket pile or suction caisson jacket. Therefore the dredging and disposal of material associated with the installation of floating foundations is considered under the other foundation concepts and so is not discussed further in this document. Further details on the five foundation options assessed within the Environmental Impact Assessment (EIA) are provided in volume 1, chapter 3: Project Description.

2.1.4 Methodology for identification of sandwave clearance sites along the offshore cable corridor

2.1.4.1 In order to inform the Hornsea Three EIA, geophysical and benthic sampling site-specific surveys were undertaken as agreed with the statutory consultees. A summary of the surveys undertaken to date is outlined in Table 2.1 below. Table 2.1 also provides a summary of the information previously collected from the former Hornsea Zone, which has been used to help inform understanding of the marine processes environment across the wider regional-scale.

2.1.4.2 Analysis of geophysical and geotechnical survey data has identified the presence of bedforms along the Hornsea Three offshore cable corridor and within the array (see Figure 2.1). As such, clearing or 'pre-sweeping' to the level of the bottom of the trough of the sandwave prior to cable burial may be required.

2.1.4.3 The analysis of available geophysical data (see Table 2.1) has been used to identify locations of sandwaves within Hornsea Three (volume 2, chapter 1: Marine Processes), a proportion of which may require clearing (volume 1, chapter 3: Project Description). This in turn has been used to calculate an estimate of the volume of sediment that would require clearing within the array and along the offshore cable corridor (see volume 1, chapter 3: Project Description).

2.2 Predicted sources and amounts of spoil

2.2.1 Sources of spoil

2.2.1.1 Spoil will be generated as a consequence of the installation of all the foundation types being considered by the project (including seabed levelling); from drilling of monopiles and/or pin-piles used to support jacket foundations, from seabed preparation prior to gravity base installation or from sandwave clearance prior to the installation of array, platform inter-connector, inter-accommodation and export cables.

2.2.1.2 Depending on the local ground conditions, drilling may be required to facilitate the installation of monopiles and/or pin-piles for jacket foundations to their target depth, with the subsequent drill arisings disposed of at sea adjacent to the foundation location.

2.2.1.3 GBFs will likely require the most seabed preparation of any of the foundation types. The soft mobile surface sediment will have to be removed from the seabed to provide a firm, level surface. In the maximum design scenario, it is assumed that in some areas of Hornsea Three a 5 m thick layer of top sediment with a diameter of 61 m may have to be excavated before installation of GBFs. However, based on initial site surveys, it is expected that the average thickness of the dredged layer will be up to approximately 2 m, depending on GBF design (see the maximum design scenario table in volume 2, chapter 1: Marine Processes). For the purposes of the impact assessments presented in volume 2 of this PEIR, it has been assumed that the spoil arisings will be disposed of using 11,000 m^3 hoppers to transport and deposit them approximately 500 m away from the GBF locations.

2.2.1.4 Spoil arising from the foundation installations described above, is proposed to be disposed of within the Hornsea Three array disposal site. The exception to this is spoil arising from the installation of foundations relates to the offshore HVAC booster stations that are located within the offshore HVAC booster station Search Area along within the offshore cable corridor (see Figure 1.1). The spoil from these installations, is proposed to be disposed of within the offshore cable corridor.

2.2.1.5 Should dredging be required prior to installation of electrical cables within Hornsea Three array disposal site or along the offshore cable corridor, this spoil will require disposal. If required, material dredged from within the Hornsea Three array area will be disposed of within Hornsea Three array disposal site (as described in paragraph 2.2.1.3 for GBFs) and material dredged from sandwaves along the offshore cable corridor is proposed to be disposed of within the offshore cable corridor disposal area, with the exception of the Cromer Shoal Chalk Beds MCZ site, as noted in paragraph 2.1.1.4.

2.2.2 Volumes of spoil

2.2.2.1 The EIA process for Hornsea Three has been undertaken using the maximum design scenario approach. In order for this to be achieved, the maximum design scenario volumes of spoil generated for each of the foundation installation methods have been calculated. These figures have been used for the assessments, as presented in volume 2 of this PEIR.

2.2.2.2 The total volumes required for disposal within Hornsea Three array disposal site and offshore cable corridor disposal site are included in For foundations, Table 2.3 presents the total volume of spoil generated assuming the build out of the entire project using each foundation type (presented separately for the array area and offshore cable corridor). The total spoil volume for each disposal site is then calculated by combining the maximum design scenario for each foundation type (in terms of spoil volume) with the volume of sandwave clearance. In the case of both the array area and offshore cable corridor, the maximum design scenario is provided assuming the use of GBFs for turbines, HVAC substations and offshore HVAC booster substations and piled jacket foundations for HVDC substations and accommodations platforms (see Table 2.1).

2.2.2.3 For the purposes of assessing the impact of the seabed preparation activity on marine ecology receptors, the maximum spoil volume for an individual turbine has been used in the modelling, which was undertaken to assess the dispersion and fate of the material, as described in volume 2, chapter 1: Marine Processes.

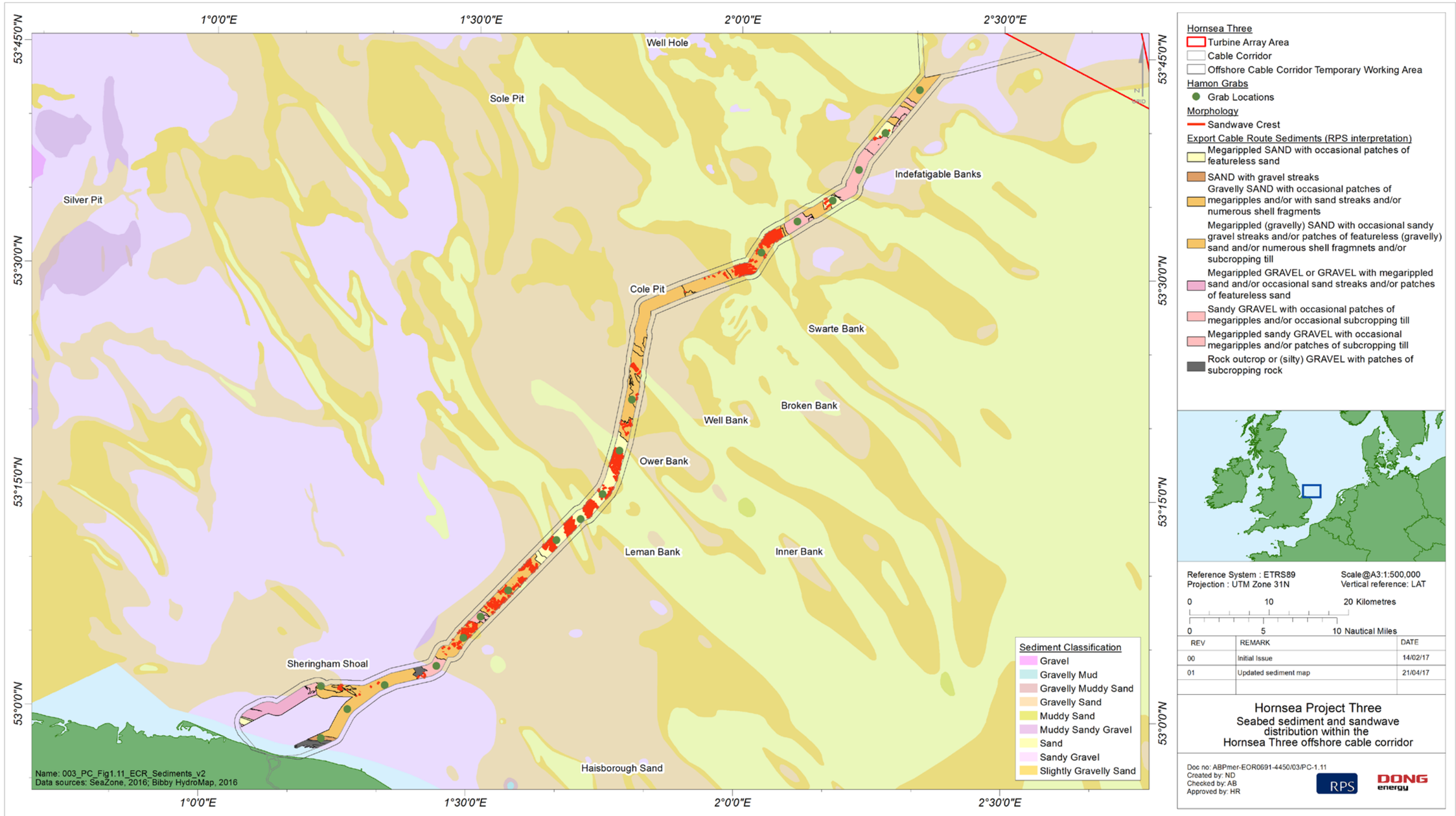

Figure 2.1: Seabed sediment and sandwave distribution within the Hornsea Three offshore cable corridor.

Table 2.1: Summary of site-specific and former Hornsea Zone geophysical, geotechnical and benthic sampling survey data.

Title	Extent of survey	Overview of survey	Survey contractor	Year	Reference to further information
Hornsea Three array area bathymetric and geophysical survey	Hornsea Three array area and cable fan area (100 m by 100 m line spacing)	Multibeam echo sounder, backscatter and sub bottom profiler and 20 ground truthing grab samples.	Clinton	2016	Clinton (2016)
	Hornsea Three array area (500 m by 500 m line spacing)	Bathymetric and geophysical survey consisting of dual frequency side scan sonar, ultra-high resolution seismic survey, magnetometer and 20 ground truthing grab samples.	EGS	2016	EGS (2016)
Hornsea Three offshore cable corridor bathymetric and geophysical survey	Hornsea Three offshore cable corridor. The survey corridor width was 1.5 km, the line spacing varied between 55 and 60 m depending on the water depth, with 55 m spacing used in the shallower areas. There were also cross-lines along the entire route spaced at a nominal 1 km.	Bathymetric and geophysical survey consisting of dual frequency side scan sonar, seismic survey and magnetometer and 20 ground truthing grab samples	Bibby HydroMap	2016	Bibby HydroMap (2016)
Former Hornsea Zone geotechnical survey	Former Hornsea Zone	Borehole (9 no.) and Cone Penetration Tests (CPTs) (27 no.) from locations across the former Hornsea Zone	Fugro GeoConsulting Limited	2011	Fugro GeoConsulting Limited (2012)
Former Hornsea Zone benthic survey	Former Hornsea Zone	Former Hornsea Zone benthic survey (27 no. grab samples within the Hornsea Three array area)	Emu	2010	Emu (2011b)

2.2.2.4 The maximum amount of spoil to be disposed of from the Hornsea Three array is 2,450,467 m^3 (Table 2.1). The source of this total volume of spoil could be (a) dredging works for seabed preparation associated with installation of GBFs, (b) drill arisings from monopile/jacket foundation installation, (c) sandwave clearance for installation of cables, or (d) a combination of all three.

2.2.2.5 The maximum volume of spoil that is anticipated to be generated within the cable route corridor through cable burial, sandwave clearance and the installation of four offshore HVAC booster stations is 427,056 m^3. This volume assumes a maximum design scenario for total spoil volume, which is calculated based on the use of a GBF for the four offshore HVAC reactive compensation substations (Table 2.2).

Table 2.2: Summary of maximum total spoil arisings.

Element	Spoil volume in the proposed Hornsea Three array (turbines, offshore substations and platforms, accommodation platforms and sandwave clearance) disposal site (m^3)[a]	Spoil volume in the proposed Hornsea Three offshore cable corridor (offshore HVAC booster stations and sandwave clearance) disposal site (m^3)
Turbine foundations (GBF)	1,289,847	-
HVAC Substations (or offshore HVAC booster stations; both Box type GBF)	735,000	245,000
HVDC Substations (Piled jackets)	193,960	-
Accommodation Platforms (Piled jackets)	63,335	-
Sandwave clearance	168,325	182,056
Total maximum design scenario volume	*2,450,467*	*427,056*

a Based on an average levelling depth of 2 m (see paragraph 2.2.1.3).

2.3 Consideration of alternative disposal options

2.3.1.1 Once dredged or drilled material has been produced, it is classed as a waste material (London Convention, 1972). Once a material has entered the waste stream it is strictly controlled; disposal of dredged 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 which sets out a sequence of waste management options: prevention; re-use; recycle; other recovery; and disposal (MMO, 2011). Where prevention or minimisation is not possible, management options for dealing with dredged material must consider the alternative options in the outlined order of priority (i.e., re-use, recycle, other recovery and then disposal). The consideration of alternatives to disposal of dredged and/or drilled material within Hornsea Three array and the offshore cable corridor is, therefore, an important part of the site characterisation process and is required in order to inform the decision-making process led by the MMO and their advisers.

2.3.1.2 The following sections of this site characterisation document present information on potential alternative options for the disposal of dredged and/or drilled material derived from Hornsea Three array and the sandwave and offshore HVAC reactive compensation substations.

2.3.2 Waste hierarchy

Prevention

2.3.2.1 The waste hierarchy places a strong emphasis on waste prevention or minimisation of waste. However, consent is being sought for the potential use of a range of foundations for Hornsea Three (see paragraph 2.1.3.1). Installation of all foundation types listed in paragraph 2.1.3.1 and seabed preparation prior to cable installation will lead to the production of spoil. Preparation for the installation of GBFs would result in the maximum spoil volume. Should GBFs be installed in Hornsea Three, then seabed preparation works and the associated dredging and disposal works will be unavoidable, as a flat and stable seabed will be required to seat the GBFs.

2.3.2.2 In some areas within the offshore array (and in the Hornsea Three offshore cable corridor for the export cables) existing sandwaves and similar bedforms may be required to be removed before cables are installed. This is done for two reasons. Firstly, many of the cable installation tools require a relatively flat seabed surface in order to work properly. It may not be possible to install the cable up or down a slope over a certain angle, or to use the installation tool on a camber. Secondly, 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 Three, sandwave clearance and the associated dredging and disposal works will in some cases be unavoidable (see volume 1, chapter 3: Project Description).

Re-use

2.3.2.3 In line with the waste hierarchy, where prevention is not possible, the first step in the process is to identify any potential re-uses of the dredged material (MMO, 2011). Potential options for the re-use of dredged and/or drilled material from Hornsea Three are listed below:

- Use in beach nourishment schemes;
- Use in land reclamation schemes; and
- Use in habitat enhancement schemes.

2.3.2.4 In theory, the material proposed to be dredged and/or drilled within Hornsea Three array and the offshore cable corridor could potentially be used for alternative uses, including beach nourishment, land reclamation and/or habitat enhancement. However, transfer of the proposed amounts of material due to be dredged from Hornsea Three array (a maximum of 2,450,467 m^3) to another location where this alternative use may be required would require approximately 223 round trips of at least 242 km per trip (the Hornsea Three array area is 121 km from the nearest shoreline) with a commercial-scale suction dredger (assuming a hopper capacity of 11,000 m^3). Similarly, the amounts of material due to be dredged from the cable route corridor (a maximum of 427,056 m^3) would require approximately 39 round trips of an approximate average of 140 km per trip (the centre of the offshore sandwave clearance area is approximately 70 km from the nearest shoreline).

2.3.2.5 Dredger movements of this scale would lead to other environmental impacts such as the release of fuel combustion emissions into the atmosphere that would be avoided if the dredged material was permitted to be disposed of *in situ* as per the methods and assessment presented in volume 2 of this PEIR.

2.3.2.6 At the time of writing, no specific projects have been identified that could accept material from Hornsea Three array and the offshore cable corridor but it is considered unlikely that any single project requiring sediments for uses such as those listed above would require as much as 2,877,523 m^3 of material. Therefore, it is expected that even if all material could be re-used, this would be via multiple projects in different locations. This would increase the number of dredger transits to and from Hornsea Three array and the offshore cable corridor and would therefore increase potential related environmental impacts such as those related to fuel emissions.

2.3.2.7 Another factor to consider, with respect to the specific disposal of drill arisings away from Hornsea Three array, is that any vessel used to transport these materials from the drilling location to either an existing licensed disposal site and/or locations where alternative uses for the material may be found, would need to deploy at least a 4-point anchor pattern next to the drilling barge prior to every loading event (anchoring would not be required for the removal of dredged material off-site as the vessel used to transport the materials off-site would be the same vessel that carried out the dredging activity).

2.3.2.8 Deployment of up to four anchors at every drilling location would represent an additional impact on the seabed over and above those already identified via other construction activities. Disposal of drill arisings *in situ* would, therefore, remove this impact.

2.3.2.9 In conclusion, the assessments undertaken to date have not identified any significant adverse (in EIA terms) impacts on receptors via this proposed disposal activity (see the summary of assessments in section 5 and the full assessments in volume 2, chapter 2: Benthic Intertidal and Subtidal Ecology; volume 2, chapter 3: Fish and Shellfish Ecology; volume 2, chapter 4: Marine Mammals; volume 2, chapter 9: Marine Archaeology; volume 2, chapter 11: Infrastructure and other Users).It is concluded that whilst potential alternative options for use of this material may exist in theory, disposal *in situ* remains the most viable and least damaging environmental option. In situ disposal also has the advantage of retaining sediment within the local sediment transport system. Further details on the rationale for disposal within Hornsea Three array disposal site and the Hornsea Three offshore cable corridor disposal site are provided below.

Recycle

2.3.2.10 When a dredged material is recycled it takes a different form from which it originated (e.g. 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 land construction projects. As such, the same issues discussed previously in paragraph 2.3.2.4 (transportation of the dredged material to land) also apply here and would be avoided if the dredged material was permitted to be disposed of *in situ*.

Other recovery

2.3.2.11 There are currently very few examples of recovery from dredged material (MMO, 2011) and no such options have been identified for the dredged and/or drilled material from Hornsea Three.

Disposal

2.3.2.12 With respect to disposal at an existing marine disposal site, the closest open marine disposal site to Hornsea Three array and the offshore cable corridor is the Hornsea disposal site Subzone 1 at a distance of 7.3 km to the west, with the nearest site to the offshore cable corridor also being the Hornsea disposal site Subzone 1, located 6.2 km from the offshore cable corridor. It is understood that Hornsea disposal site Subzone 1 is licenced to take spoil from the Hornsea Project One only. Furthermore, this site is unlikely to have the capacity to accept all of the spoil produced by Hornsea Three, as this will be utilised for the spoil material arising from the construction of Hornsea Project One. The next nearest open disposal site is the West of Inner Dowsing Bank disposal site located approximately 131 km due southwest of Hornsea Three array and 48 km northwest of the offshore cable corridor. This site is not considered to be within an operationally practicable distance from the Hornsea Three array and the offshore cable corridor and, as such, has not been considered further. Therefore, it is concluded that disposal at existing marine disposal sites does not represent the most logical or environmentally robust approach to disposal of material from Hornsea Three array and the offshore cable corridor.

Rationale for characterising the sites as disposal sites

2.3.2.13 Having taken into consideration the waste hierarchy, as outlined in the Waste Framework Directive (paragraphs 2.3.2.1 to 2.3.2.12), disposal of material derived from the construction process within the boundaries of the proposed disposal sites (i.e. Hornsea Three array disposal site and the Hornsea Three offshore cable corridor disposal site) is considered to be the optimal solution on technical, operational, cost and environmental grounds. The PEIR for Hornsea Three has presented a robust assessment of the potential environmental impacts of this activity on all receptors and has concluded that there will be no significant (in EIA terms) impacts upon any receptors as a result of disposal *in situ* (see the summary of assessments in section 5 and the full assessments in volume 2, chapter 2: Benthic Intertidal and Subtidal Ecology; volume 2, chapter 3: Fish and Shellfish Ecology; volume 2, chapter 4: Marine Mammals; volume 2, chapter 9: Marine Archaeology; volume 2, chapter 11: Infrastructure and other Users).

2.3.2.14 The material proposed to be disposed of within Hornsea Three array disposal site and the Hornsea Three offshore cable corridor disposal site, as a result of seabed preparation works for GBFs and sandwave clearance, is likely to be similar to the existing seabed material, as this will be the source of this material, albeit originating from a greater depth in some cases. Therefore, the overall sediment composition of the site is not predicted to change as a result of this activity.

2.3.2.15 The predicted increases in suspended sediment concentrations and subsequent deposition on the seabed have been assessed as not resulting in any significant adverse impacts on receptors in the area (see the summary of assessments in section 5 and the full assessments in volume 2, chapter 2: Benthic Intertidal and Subtidal Ecology; volume 2, chapter 3: Fish and Shellfish Ecology; volume 2, chapter 4: Marine Mammals; volume 2, chapter 9: Marine Archaeology; volume 2, chapter 11: Infrastructure and other Users).

2.3.2.16 Drill arisings will be different to the material currently forming the seabed sediments in Hornsea Three array as Quaternary deposits currently underlying the recent Holocene sediments will, potentially, be deposited on the seabed. The Quaternary deposits that form the majority of the seabed in Hornsea Three array and the cable route corridor (and much of the seabed in this part of the North Sea) are the Botney Cut Formation and Bolders Bank Formation. The Botney Cut Formation comprises mainly of sands, while the Bolders bank Formation consists of a stiff till of gravelly, sandy clay with erratics of chalk, sandstone and mudstone.

2.3.2.17 For Hornsea Three, an average of 5,845 m^3 of sediment (based on the largest size of GBF) will be released per foundation for each of the turbines within the Hornsea Three array. With respect to the offshore HVAC booster stations, an average of 61,250 m^3 of sediment per offshore HVAC booster station will be released as a result of foundation installation at each location.

2.3.2.18 It is unlikely that there will be any effect of disposal mounds in the array area or offshore cable corridor on the passage of waves, either locally or regionally, due to the local reduction in water depth. The maximum volumes of sediment of each mound are limited by the scale of the activity (the capacity of the dredger or the volume of the pile to be drilled), which also limits their maximum possible size. A mound of typical thickness (approximately 0.5 m) will reduce the water depth locally by the same amount, however, the difference is small relative to the regional water depth and to relative natural variation in local water depth, e.g. due to bedforms (tens of centimetres to a few metres) and tidal processes (2 to 5 m range, twice daily, on a mean spring tide). The area of effect on water depth for individual mounds of typical thickness is also relatively small (order of a few hundred metres). Thicker deposits would have a correspondingly smaller footprint and so have even less potential to affect wave conditions beyond the local area.

2.3.2.19 The future behaviour of any mounds that are formed on the seabed due to the disposal is difficult to predict, due the uncertainties regarding the nature of the material. This is especially the case with drill arisings, as the way in which the material breaks down during drilling is dependent on many different factors. Conceptually, it is possible to define the process that is likely to apply to such drill arising deposits. Mounds will typically be expected to be winnowed from the surface of the mound by the prevailing tidal regimes, removing the finer sediment fraction. Over time this will leave a coarser grained sediment lag. Depending on the exact location, it is possible that these deposits will become covered by a veneer of sediments from the surrounding sediment transport regime. Deposits resulting from seabed preparation works are more likely to be assimilated in the baseline sediment transport regime, as the particle size distribution will remain largely unchanged.

3. Characteristics of Disposal Sites

3.1 Physical characteristics

3.1.1 Bathymetry

Hornsea Three array disposal site

3.1.1.1 Within the Hornsea Three array area, water depths vary from approximately -26.6 m LAT to -72.7 m LAT (EGS, 2016), see volume 2, chapter 1: Marine Processes, for further details.

Offshore cable corridor disposal site

3.1.1.2 The Hornsea Three offshore cable corridor is fairly shallow throughout, with water depths typically less than -30 m LAT. In offshore areas, the shallowest water depths are associated with the crests of the Norfolk sandbanks which shallow to approximately -5 m LAT (Bibby HydroMap, 2016). See volume 2, chapter 1: Marine Processes, for further details.

3.1.2 Tidal and wave regime

Hornsea Three array disposal site

3.1.2.1 Tidal elevation in the Hornsea Three array ranges from +3.2 m lowest astronomical tide (LAT) for Mean High Water Springs (MHWS) to +0.5 m LAT for Mean Low Water Springs (MLWS). V), as detailed in volume 2, chapter 1: Marine Processes. A review of the metocean data collected within the former Hornsea Zone in relation to waves is also presented in volume 2, chapter 1: Marine Processes, however in summary, wave peak periods were found to vary between 2 seconds and 20 seconds, indicating that the waves recorded are both locally generated wind waves and remotely generated swell waves. The dominant wave direction was found to be northwesterly to northerly.

Offshore cable corridor disposal site

3.1.2.2 Tidal elevation in the Hornsea Three array ranges from +5.4 m lowest astronomical tide (LAT) for Mean High Water Springs (MHWS) to +0.5 m LAT for Mean Low Water Springs (MLWS). See volume 2, chapter 1: Marine Processes, for further detail. For the purpose of this assessment, due to the proximity of Hornsea Three array and the offshore part of the cable route corridor, the wave regime is considered to be as described in paragraph 3.1.2.1. The wave regime within inshore and nearshore areas will be of a generally similar or smaller wave height and period to offshore areas, but may also exhibit a degree of spatial variability owing to the sheltering effect of the banks further offshore. See volume 2, chapter 1: Marine Processes, for further details.

3.1.3 Solid geology

Hornsea Three array disposal site

3.1.3.1 Consideration of the BGS 1:250 000 Solid Geology Sheet suggests that the bedrock in this region is likely to be chalk, argillaceous (clay) rock or mudstone comprising Tertiary, Mesozoic or Paleozoic aged units (BGS, 1987; Cameron *et al*., 1992). However, the available survey data suggests that bedrock is not exposed anywhere within the Hornsea Three array area and is instead overlain by varying thicknesses of Quaternary sediments. At no location is bedrock found within 50 m of the seabed and therefore it will not be disturbed by any project construction-related activities (EGS, 2016).

Offshore cable corridor disposal site

3.1.3.2 Along almost the entire Hornsea Three offshore cable corridor, pre-Quaternary geology is generally not encountered at depths which could be impacted by cable installation activities. The only exception to this general pattern occurs within nearshore/inshore areas off Cromer where Cretaceous chalk is either found exposed or very close (<5 m) to the seabed (Bibby HydroMap, 2016; Gafeira *et al*., 2010).

3.1.4 Quaternary deposits

Hornsea Three array disposal site

3.1.4.1 Deposits belonging to the Bolders Bank formation are found very close (< ~1 m) to the seabed surface across the vast majority of the Hornsea Three array area. Deposits belonging to the Botney Cut formation are also both widespread and encountered at shallow (< ~5 m) depths below the seabed surface. Conversely, the Yarmouth Roads, Swarte and Eem Formations are far less common, with the Yarmouth Roads and Swarte formations only encountered within Outer Silver Pit and the Eem Formation only present on the margins of Outer Silver Pit and Markham's Hole. See volume 2, chapter 1: Marine Processes, for a list of succession of Quaternary deposits within the former Hornsea Zone.

Offshore cable corridor disposal site

3.1.4.2 Two glacial till units have been identified by the Hornsea Three offshore cable corridor geophysical survey and these are widely encountered at shallow (< ~5 m) depths below the seabed. The upper unit is anticipated to comprise gravelly sandy clays of the Bolders Bank Formation whilst the lower glacial till unit probably comprises sands and gravels, with interbedded silts and clays belonging to the Egmond Ground Formation. In many areas, these units have been incised by channels with the thickness of channel infill (thought to comprise laminated clays and sands) typically in the range of 0 m to 5 m, and very occasionally exceeding 10 m (Bibby HydroMap, 2016).

3.1.5 Seabed Sediments

Hornsea Three array disposal site

3.1.5.1 The Hornsea Three array area is characterised by the presence of coarse grained sediments with both sand and sandy gravel particularly prevalent (Emu, 2011b; Clinton, 2016; EGS, 2016). In many areas, these coarse grained sediment units also contain some finer muddy material, reflecting lower energy settings more conducive to sediment deposition. This is particularly the case within the areas of deep water associated with Markham's Hole and Outer Silver Pit, a finding that is consistent with regional scale seabed mapping from the BGS (BGS and Rijks Geologische Dienst, 1987). See volume 2, chapter 1: Marine Processes, for further details.

Hornsea Three offshore cable corridor disposal site

3.1.5.2 The seabed along the Hornsea Three offshore cable corridor dominantly comprises coarse grained sand and gravel sediments (Bibby HydroMap, 2016). The relative proportion of sands and gravels varies along the Hornsea Three offshore cable corridor, with more sandy sediments associated with the flanks and crests of sandbanks and more gravelly sediments encountered in the sandwave troughs and elsewhere. See volume 2, chapter 1: Marine Processes, for further details.

3.1.6 Bedforms and sediment transport

Hornsea Three array disposal site

3.1.6.1 Within the vicinity of the Hornsea Three array area, including the area of Markham's Triangle rMCZ, tidal currents are the main influence on offshore sediment transport, rather than the wave climate (see volume 2, chapter 1: Marine Processes) due to water depth. Existing regional-scale mapping suggests that bedload sediment transport is broadly to the northwest in the vicinity of the Hornsea Three array area (e.g. Kenyon and Cooper, 2005; SMart Wind, 2015), though net rates of sediment transport are considered to be limited for this region. See volume 2, chapter 1: Marine Processes, for further details.

3.1.6.2 Sandwaves (characterised by wave lengths >25 m and heights >0.3 m) are present in a small number of locations in the far western area of the site. Although the wavelengths of these features may exceed 400 m, heights do not exceed ~2 m. Megaripples (wave lengths <25 m and heights <0.3 m) are also widespread and are often found superimposed on the sandwaves. Within northeastern and central areas, sand ribbons are also encountered. These elongate low elevation (typically less than 1 m in height) longitudinal bedforms extend for a distance of several kilometres and in all areas are aligned to the tidal axis (northwest to southeast). Sand ribbons are indicative of sediment starved environments with strong (> ~0.9 m/s) tidal flows (Kenyon, 1970). See volume 2, chapter 1: Marine Processes, for further details.

Hornsea Three offshore cable corridor disposal site

3.1.6.3 Existing regional-scale mapping suggests that where the Hornsea Three offshore cable corridor meets the Hornsea Three array area, bedload sediment transport is broadly to the northwest and towards the south/southeast within inshore/nearshore areas. The two regions of sediment transport are separated by a bedload parting zone which runs in an approximately shore parallel direction, at a distance of approximately 15 km from the coast. See volume 2, chapter 1: Marine Processes, for further details.

3.1.6.4 Prominent relict features include the Indefatigable Banks located close to Hornsea Three array area. The Indefatigable Banks form part of the north Norfolk sandbank system and formed during the mid-Holocene post-glacial transgression (Kenyon *et al*., 1981; Cooper *et al*., 2008). The Indefatigable Banks contrast with other sandbanks also belonging to the north Norfolk sandbanks but which are located closer inshore and are known to be active under present day hydrodynamic conditions (Kenyon and Cooper, 2005). Together, these banks underpin the qualifying features of the North Norfolk Sandbanks and Saturn Reef SCI. See volume 2, chapter 1: Marine Processes, for further details.

3.1.7 Suspended sediment concentrations

Hornsea Three array disposal site

3.1.7.1 SSC within the Hornsea Three array area was typically found to be in the range 10 to 30 mg/l although slightly higher values were experienced during spring tides and storm conditions (EMU, 2011a). See volume 2, chapter 1: Marine Processes, for further details.

Hornsea Three offshore cable corridor disposal site

3.1.7.2 During the winter months, mean surface Suspended Particulate Matter (SPM) concentrations are typically around 5 mg/l in the vicinity of the Hornsea Three array area, increasing to around 50 mg/l within inshore areas of the Hornsea Three offshore cable corridor. During summer months, mean SPM is usually in the range 0 to 5 mg/l, with values increasing with greater proximity to the coast. However, within inshore and (especially) nearshore areas where water depths are very shallow, strong tidal currents combined with wave stirring of the bed will result in high turbidity levels. These will be greatest closer to the seabed, in nearshore areas (i.e. < -5 m LAT), in areas exposed to larger waves and may be in the order of 100's to 1,000's mg/l during storm conditions.

3.2 Biological characteristics

3.2.1 Benthic subtidal ecology

3.2.1.1 Across much of Hornsea Three epifaunal communities are sparse, and infaunal subtidal biotopes fall into three main types; sand and muddy sands (SS.SSa: Sublittoral Sands and Muddy Sands); coarse sediments (SS.SCS: Sublittoral Coarse Sediment); and mixed sediments (SS.SMx: Sublittoral Mixed Sediment). These biotopes were then grouped based on their similarities to produce valued ecological receptors (VERs) against which impact assessments have been undertaken.

Hornsea Three array disposal site

3.2.1.2 The following describes the broad habitat types, the representative VERs and the biotopes that these encompass, recorded within the Hornsea Three array:

- Sandy sediments with low infaunal diversity and sparse epibenthic communities (Habitat A and Habitat H, the latter representing the habitat within an MCZ or rMCZ) are characterised by the biotopes IMuSa[1], NcirBat[2], FfabMag[3], EpusOborApri[4], ApriBatPo[5] and ScupHyd[6]. This habitat was recorded throughout the western and central sections of the Hornsea Three array area;
- Brittlestar dominated communities in deep muddy sands communities (Habitat B) characterised by AfilMysAnit[7]. This habitat was recorded in the central and northern sections of the Hornsea Three array area; and

[1] SS.SSa.IMuSa (IMuSa) Infralittoral muddy sand.

[2] SS.SSa.IFiSa.NcirBat (NcirBat) *Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand.

[3] SS.SSa.IMuSa.FfabMag (FfabMag) *Fabulina fabula* and *Magelona mirabilis* with venerid bivalves and amphipods in infralittoral compacted fine muddy sand.

[4] SS.SSa.CFiSa.EpusOborApri (EpusOborApri) *Echinocyamus pusillus*, *Ophelia borealis* and *Abra prismatica* in circalittoral fine sand.

[5] SS.SSa.CFiSa.ApriBatPo (ApriBatPo) *Abra prismatica*, *Bathyporeia elegans* and polychaetes in circalittoral fine sand.

[6] SS.SSa.IFiSa.ScupHyd (ScupHyd) *Sertularia cupressina* and *Hydrallmania falcata* on tide-swept sublittoral sand with cobbles or pebbles.

[7] SS.SMu.CSaMu.AfilMysAnit (AfilMysAnit) *Amphiura filiformis*, *Mysella bidentata* and *Abra nitida* in circalittoral sandy mud.

- Coarse and mixed sediments with moderate to high infaunal diversity and scour-tolerant epibenthic communities (Habitat C and Habitat G, the latter representing the habitat within an MCZ or rMCZ) are characterised by MedLumVen/EpusOborApri[8], MedLumVen[9], MoeVen[10], MysThyMx[11], PoVen[12], ScupHyd and FluHyd[13]. This habitat was mostly recorded in the southern and eastern parts of the Hornsea Three array area.

3.2.1.3 One species of conservation importance, the ocean quahog *Arctica islandica* (Species L) which is listed by OSPAR as being a threatened and/or declining species (Region II - Greater North Sea), was found in small numbers in the Hornsea Three array area. Further detail on the benthic subtidal ecology of Hornsea Three array is provided in volume 2, chapter 2: Benthic Intertidal and Subtidal Ecology.

Hornsea Three offshore cable corridor disposal site

3.2.1.4 The following describes the broad habitat types, the representative VERs and the biotopes that these encompass, recorded within the Hornsea Three offshore cable corridor area:

- Sandy sediments with low infaunal diversity and sparse epibenthic communities (Habitat A and Habitat H, the latter representing the habitat within an MCZ or rMCZ) are characterised by the biotopes IMuSa, NcirBat, FfabMag, EpusOborApri, ApriBatPo and ScupHyd. This habitat was recorded in parts regularly distributed along the Hornsea Three offshore cable corridor;
- Coarse and mixed sediments with moderate to high infaunal diversity and scour-tolerant epibenthic communities (Habitat C and Habitat G, the latter representing the habitat within an MCZ or rMCZ) are characterised by MedLumVen/EpusOborApri, MedLumVen, MoeVen, MysThyMx, PoVen, ScupHyd and FluHyd. This habitat was recorded in the very offshore and inshore extents of the offshore cable corridor; and
- Mixed sediments with high infaunal and epifaunal diversity ((Habitat D and Habitat I, the latter representing the habitat within an MCZ or rMCZ) are characterised by SspiMx[14]. This habitat was recorded along much of the Hornsea Three offshore cable corridor.

3.2.1.5 Other habitats of conservation importance, with limited distributions, included:

- Annex I 'Sandbanks' within an SAC (Habitat E) occurs in the offshore cable corridor which coincides with the North Norfolk and Saturn Reef SCI;
- Annex I reefs within an SAC (Habitat F) occurs in the offshore cable corridor which coincides with the North Norfolk and Saturn Reef SCI;
- Subtidal chalk reefs (Habitat J) occurs in the inshore area of the Hornsea Three offshore cable corridor, within the Cromer Shoal Chalk beds MCZ; and
- Peat and clay exposures (Habitat K) occurs in the inshore area of the Hornsea Three offshore cable corridor, within the Cromer Shoal Chalk beds MCZ.

3.2.1.6 Further detail on the benthic subtidal ecology of Hornsea Three offshore cable corridor is provided in volume 2, chapter 2: Benthic Intertidal and Subtidal Ecology.

3.2.2 Fish and shellfish ecology

3.2.2.1 A total of 25 fish and shellfish VERs were identified as being important in the Hornsea Three fish and shellfish study area. These comprise eight demersal fish species, three pelagic fish species, sandeel, eight migratory fish species and five shellfish species (see volume 2, chapter 3: Fish and Shellfish Ecology.

Hornsea Three array disposal site

3.2.2.2 The fish communities characterising the Hornsea Three array area were found to comprise mainly demersal fish species such as whiting, dab, plaice, solenette and grey gurnard, all of which were recorded in abundance during trawl surveys. The Hornsea Three fish and shellfish study area was also found to be characterised by other demersal species such as lemon sole, common sole and cod. Small demersal species including the short spined sea scorpion, lesser weaver, dragonet and scaldfish were also recorded in surveys across the former Hornsea Zone including the Hornsea Three array area.

[8] SS.SCS.CCS.MedLumVen/ SS.SSa.CFiSa.EpusOborApri (MedLumVen/EpusOborApri) Mosaic of *Mediomastus fragilis*, *Lumbrineris* spp. and venerid bivalves in circalittoral coarse sand or gravel and *Echinocyamus pusillus*, *Ophelia borealis* and *Abra prismata* in circalittoral fine sand.

[9] SS.SCS.CCS.MedLumVen (MedLumVen) *Mediomastus fragilis*, *Lumbrineris* spp. and venerid bivalves in circalittoral coarse sand.

[10] SS.SCS.ICS.MoeVen (MoeVen) *Moerella* spp. with venerid bivalves in infralittoral gravely sand.

[11] SS.SMX.CMx.MysThyMx (MysThyMx) *Mysella bidentata* and *Thyasira* spp. in circalittoral muddy mixed sediment.

[12] SS.SMx.OMx.PoVen (PoVen) Polychaete-rich deep Venus community in offshore mixed sediments.

[13] SS.SMx.CMx.FluHyd (FluHyd) *Flustra foliacea* and *Hydrallmania falcata* on tide-swept circalittoral mixed sediment.

[14] SS.SBR.PoR.SspiMx (SspiMx) *Sabellaria spinulosa* on stable circalittoral mixed sediment.

3.2.2.3 Pelagic species recorded in the Hornsea Three fish and shellfish study area included sprat, herring and mackerel, with sprat and herring identified as being two of the key characterising species within the Hornsea Three fish and shellfish study area. Two sandeel species were recorded in trawl surveys within the Hornsea Three fish and shellfish study area: lesser sandeel and greater sandeel which are hereafter referred to collectively as sandeel. Elasmobranchs including thornback ray and spotted ray were recorded in surveys across the former Hornsea Zone but at very low abundances in the Hornsea Three array.

3.2.2.4 The shellfish ecology of the Hornsea Three fish and shellfish study area was found to be primarily characterised by four commercial species: brown crab, European lobster, Norway lobster and common whelk. Norway lobster was recorded consistently in deep water, sandy mud habitats within the Hornsea Three array area and in the deep waters to the north and northwest of it.

3.2.2.5 Further detail on the benthic subtidal ecology of Hornsea Three array is provided in volume 2, chapter 3: Fish and Shellfish Ecology.

Hornsea Three offshore cable corridor disposal site

3.2.2.6 The offshore cable corridor communities were similar to those described for the Hornsea Three array (paragraph 3.2.2.2), with a few exceptions. Inshore areas were characterised by lower abundances of species such as dab and higher abundances of crustaceans such as crabs and European lobster. Brown crab was by far the most abundant shellfish species in the offshore cable corridor, especially in the nearshore section where it is targeted by commercial fisheries along the north Norfolk coast. Ray species, particularly the thornback ray, have been recorded and tagged in proximity to the nearshore section of the Hornsea Three offshore cable corridor (McCully *et al*., 2013).

3.2.2.7 Further detail on the fish and shellfish ecology of the Hornsea Three offshore cable corridor is provided in volume 2, chapter 3: Fish and Shellfish Ecology.

3.2.3 Marine mammals

Hornsea Three array disposal site

3.2.3.1 The key species identified as marine mammal valued ecological receptors in Hornsea Three array area are the harbour porpoise, white-beaked dolphin, minke whale, grey seal and harbour seal. The identification of these species as being VERs is based on their protected status and their abundance and distribution within the Hornsea Three regional marine mammal study area, as well as their wider distribution and abundance within their natural range (volume 5 annex 4.1: Marine Mammal Technical Report).

Hornsea Three offshore cable corridor disposal site

3.2.3.2 The five species identified as marine mammal VERs in the Hornsea Three array area, as described in paragraph 3.2.3.1, are also relevant within the Hornsea Three offshore cable corridor; see volume 5 annex 4.1: Marine Mammal Technical Report.

3.2.4 Designated sites of nature conservation importance

Hornsea Three array disposal site

3.2.4.1 The northeast section Hornsea Three array area coincides with Markham's Triangle recommended Marine Conservation Zone (rMCZ) (see volume 2, chapter 2: Benthic Subtidal and Intertidal Ecology or chapter 3: Fish and Shellfish Ecology). This site is proposed for two broadscale habitats: subtidal coarse sediment and subtidal sand. Shallow sandy sediments are considered to be a suitable habitat for sandeels (species of conservation importance) which are an important food source for marine mammals (see volume 5 annex 2.1: Benthic Ecology Technical Report and volume 5 annex 3.1: Fish and Shellfish Technical Report). Sections of the Hornsea Three offshore cable corridor coincide with the Southern North Sea Candidate Special Area of Conservation (cSAC) which is designated for the harbour porpoise; see volume 5 annex 4.1: Marine Mammal Technical Report.

3.2.4.2 The Hornsea Three array area does not lie within the boundary of any international designated site of nature conservation (e.g., Special Area of Conservation (SAC), Special Protection Area (SPA), Ramsar site or Site of Special Scientific Interest (SSSI)). The closest designated site to Hornsea Three array is North Norfolk Sandbanks and Saturn Reef SCI, which is 9.4 km south of Hornsea Three array. Klaverbank SCI lies in Dutch waters 10.5 km to the east of Hornsea Three array (see volume 2, chapter 2: Benthic Ecology).

3.2.4.3 Far-field impacts (increased SSC and deposition; see volume 2, chapter 2: Benthic Ecology) via sediment plumes likely to arise from disposal activities have the potential to reach the North Norfolk Sandbanks and Saturn Reef SCI and Klaverbank SCI sites, as these lie within a tidal ellipse of the Hornsea Three array area. However, it is predicted that the effects of these impacts will be temporary and not significant (see volume 2, chapter 2: Benthic Ecology and volume 4, annex 5.3: Transboundary Screening for further detail).

Hornsea Three offshore cable corridor disposal site

3.2.4.4 The Hornsea Three offshore cable corridor coincides with the North Norfolk Sandbanks and Saturn Reef SAC. The North Norfolk Sandbanks and Saturn Reef SCI is designated for the Annex I habitats 'sandbanks which are slightly covered by sea water all the time' and 'reefs', specifically Ross worm (*S. spinulosa*) reefs, which are both primary reasons for the designation of the site. Joint Nature Conservation Committee (JNCC) and Natural England (NE) have advised that the whole site is treated as comprising Annex I habitat. . The nearshore end of the Hornsea Three offshore cable corridor disposal site for the offshore cable corridor is immediately adjacent to, but does not overlap with, Cromer Shoal Chalk Beds MCZ (Figure 1.1). The Cromer Shoal Chalk Beds MCZ is designated for several seafloor features including subtidal chalk and peat and clay exposures (note these also constitute UK BAP priority habitats). This MCZ site is excluded from the disposal area to minimise effects on protected features relating to smothering, deposition and increased suspended sediment concentrations (SSC). As noted in paragraph 3.2.4.1, sections of the Hornsea Three offshore cable corridor) coincide with the Southern North Sea Candidate Special Area of Conservation (cSAC) which is designated for the harbour porpoise; see volume 5 annex 4.1: Marine Mammal Technical Report.

3.3 Human environment characteristics

3.3.1 Commercial fisheries

Hornsea Three array disposal site

3.3.1.1 The Hornsea Three array commercial fisheries study area is dominated by landings of sole and plaice targeted by all EU member states' vessels. Peaks in sole and plaice landings are noted in 2013 and 2014, with a significant drop in 2015. This is understood to be linked to changes in Total Allowable Catches (TACs) and quotas, with an increase in plaice TAC in 2015 resulting in fishermen targeting this species with more effort in grounds north of Hornsea Three (namely the Dogger Bank).

3.3.1.2 *Nephrops* is landed by Dutch, UK, Belgian and German demersal otter trawlers, with an average annual value of €480,000 from 36F2. Landings of *Nephrops* from 36F2 have remained fairly consistent across the five-year period from 2011 to 2015.

3.3.1.3 More sporadic landings of pelagic species are noted for anchovy (by Dutch and Danish fleets), sprat (by UK and Danish fleets), mackerel (by Dutch and French fleets), herring (by Dutch fleet) and boarfish (by UK fleet). The Danish fleet has landed relatively small quantities of sandeel from 36F2 across 2011 to 2015.

3.3.1.4 Further details on commercial fishing grounds within Hornsea Three array are provided in volume 2, chapter 6: Commercial Fisheries.

Hornsea Three offshore cable corridor disposal site

3.3.1.5 The offshore cable corridor extends over an area which includes significant fishing grounds for whelk, sole, crab, lobster and plaice. The commercial fishery along the cable route corridor is dominated by landings of these species which are targeted by all EU member states, but are largely landed by UK and Dutch registered vessels.

3.3.1.6 Further details on commercial fishing grounds within the vicinity of the Hornsea Three offshore cable corridor are provided in volume 2, chapter 6: Commercial Fisheries.

3.3.2 Cables and pipelines

Hornsea Three array disposal site

3.3.2.1 There is one active telecoms cable, Norsea com 1 segment 3/Tampnet operated by Viatel UK Ltd/Tampnet, which crosses north-south across the Hornsea Three array area. There are two out of service cables crossing the Hornsea Three array area, one route with two branches (Stratos 1 and Stratos 2) and one route Weybourne to Esbjerg. There are no other cables within 1 km of the Hornsea Three array area.

3.3.2.2 There are no pipelines located within the Hornsea Three array area or within 500 m of the Hornsea Three array area, however the Topaz to Schooner gas export and methanol umbilical pipelines are located within 1 km of the Hornsea Three array area, see volume 2, chapter 11: Infrastructure and Other Users for further information.

Hornsea Three offshore cable corridor disposal site

3.3.2.3 There are two active telecoms cables (Norsea com 1 segment 3/Tampnet and North Sea Offshore operated by British Telecom), and two out of service telecoms cables (Stratos and Weybourne to Esbjerg) crossing the Hornsea Three offshore cable corridor, with North Sea Offshore, Stratos and Weybourne to Esbjerg making landfall in the area of the Hornsea Three landfall. In the landfall location, the Hornsea Three offshore cable corridor also crosses the export cables for the Dudgeon and Sheringham Shoal offshore wind farms (volume 2, chapter 11: Infrastructure and Other Users).

3.3.2.4 There are 27 active pipelines which intersect the Hornsea Three offshore cable corridor, and a further two active pipelines within 1 km of the offshore cable corridor. Pipeline crossings are listed in volume 2, chapter 11: Infrastructure and Other Users.

3.3.3 Oil and gas operators and other users

Hornsea Three array disposal site

3.3.3.1 There are currently 11 licenced blocks coincident with the Hornsea Three array area licenced by Centrica, INEOS and Shell. There are five open (unlicensed) blocks coincident with the Hornsea Three array area (49/2, 49/4, 49/7, 49/8 and 49/9). There are an additional three blocks (49/1 and 49/10 unlicensed; 49/10a operated by Centrica) within 1 km of the Hornsea Three array area. None of the unlicensed blocks have been offered in the 29th supplementary round (volume 2, chapter 11: Infrastructure and Other Users).

3.3.3.2 There are no completed or drilling wells within the Hornsea Three array area however there is one suspended well within the Hornsea Three array area (49/08c-4 operated by Wintershall) and an additional suspended well within 1 km of the Hornsea Three array area.

Hornsea Three offshore cable corridor disposal site

3.3.3.3 There are currently eight licenced blocks coincident with the Hornsea Three offshore cable corridor, operated by Shell, INEOS, Independent Oil and Gas and ConocoPhillips, with two of these blocks (48/23c and 48/24b operated by Independent Oil and Gas) coinciding with the offshore HVAC booster station search area. There are 15 unlicensed blocks within the offshore cable corridor, with six of these (48/19, 48/20, 48/24, 48/25, 48/28 and 48/29) coinciding with the offshore HVAC booster station search area. There are an additional three blocks (49/12a and 49/16a licenced to ConocoPhillips and 49/12b licenced to Alpha Petroleum) within 1 km of the offshore cable corridor. None of the unlicensed blocks have been offered in the 29th supplementary round with the exception of block 48/25a which has been offered.

3.3.3.4 There are no completed, drilling or suspended wells within the Hornsea Three offshore cable corridor however there are four completed wells within 1 km of the offshore cable corridor.

3.3.3.5 Unlicensed blocks 49/2, 49/7 and 49/8 overlap with both the Hornsea Three array area and the offshore cable corridor (volume 2, chapter 11: Infrastructure and Other Users).

3.3.4 Marine archaeology

Hornsea Three array disposal site

3.3.4.1 Although much post-Devensian and Holocene archaeological material will have been reworked and lost during the last marine transgression of the North Sea, there is a strong potential for the survival of sites and material from this period in the palaeolandscape features of the regional marine archaeology study area. A number of palaeochannels were noted in the geophysical data from the Hornsea Three array area; these areas are likely to have been foci of human activity during this period. Geotechnical surveys undertaken within and in the vicinity of the Hornsea Three array area, the results of the Humber REC palaeoenvironmental programme (Tappin *et al*., 2011) and the interpretation of geophysical survey results further demonstrate that palaeochannels from the southern North Sea can preserve highly valuable palaeoenvironmental deposits.

3.3.4.2 SeaZone data indicates that the UKHO holds data for a total of 182 live wrecks and 98 dead wrecks within the regional marine archaeology study area. Of these, a total of 12 lie within the Hornsea Three array area (two live and two dead wrecks). The SeaZone records contain no references to aircraft crash sites within Hornsea Three.

3.3.4.3 Magnetometer data indicates the presence of ferrous and thus typically anthropogenic material both on, and under the seabed. Such data is generally interpreted in conjunction with other geophysical data such as side scan sonar, sub-bottom profile data and multibeam echosounder data to identify potential contacts of interest. Magnetic anomalies of greater than 500 nT have been provisionally identified as areas of archaeological potential. A total of 123 contacts of archaeological potential have been recognised within the Hornsea Three array area. Of these 123 were identified within the Hornsea Three array area. In addition, a total of 29 magnetic anomalies with an intensity >100 nT with no strong correlating seabed contact were identified across the Hornsea Three array area. A total of four magnetic anomalies of greater than 500 nT are located within the Hornsea Three array area, which have been provisionally identified as areas of archaeological potential. See volume 2, chapter 9: marine Archaeology for further information.

Hornsea Three offshore cable corridor disposal site

3.3.4.4 As discussed in paragraph 3.3.4.1, a number of palaeochannels were noted in the geophysical data from the Hornsea Three array area. Several such features were also identified in the area traversed by the Hornsea Three offshore cable corridor. Valuable palaeoenvironmental deposits are likely to be preserved in these palaeochannels, see volume 2, chapter 9: Marine Archaeology for further information.

3.3.4.5 SeaZone data indicates that the UKHO holds data for a total of 23 wrecks lie within the Hornsea Three offshore cable corridor (14 live and four dead wrecks, and three live and two dead obstructions). The NRHE lists 118 recorded positions in the regional marine archaeology study area, of these, 36 are located in the Hornsea Three offshore cable corridor (including temporary working areas).

3.3.4.6 The centre points of 24 NRHE Named Location polygons fall within the regional marine archaeology study area, of which three are located in the Hornsea Three offshore cable corridor (including temporary working areas). Together these Named Locations in the regional marine archaeology study area, contain records of 391 maritime casualties. The bulk of these Named Locations are of 19th and 20th century date. There are a number of aircraft losses recorded, including a total of nine records of Queen Bees within the regional marine archaeology study area, a low-cost radio-controlled target aircraft used for realistic anti-aircraft gunnery training during and after the Second World War.

3.3.4.7 A total of 140 contacts of archaeological potential have been recognised within the Hornsea Three offshore cable corridor. (not including the temporary working areas). In addition, a total of 157 magnetic anomalies with an intensity >100 nT with no strong correlating seabed contact were identified across the Hornsea Three offshore cable corridor (not including the temporary working areas). A total of 13 magnetic anomalies of greater than 500 nT are located within the offshore cable corridor, which have been provisionally identified as areas of archaeological potential. See volume 2, chapter 9: Marine Archaeology for further information.

4. Characteristics of Material to be Disposed

4.1 Physical, chemical, and biological (including toxicology) properties of material to be disposed

4.1.1 Sources of information on material to be disposed

4.1.1.1 The Hornsea Three array area is located within the former Hornsea Zone, for which extensive data and knowledge is available. This data/knowledge has been acquired through prior zonal studies and from the surveys and characterisations undertaken for Hornsea Three.

4.1.1.2 The baseline characterisation of the Hornsea Three offshore cable corridor within this PEIR has primarily drawn upon the site-specific survey completed in 2016 and desktop information from third-party surveys, including surveys targeting areas within and in close proximity to areas designated for nature conservation. A further site-specific survey of the Hornsea Three offshore cable corridor is planned for 2017. This survey has been drawn up to address further data requirements identified from analysis of benthic data acquired during the sampling campaigns of the geophysical surveys; namely macrofaunal data, particle size data and chemistry data. Together with the existing data (i.e. geophysical ground-truthing samples retained for benthic analysis, habitat assessment data of offshore cable corridor and historic survey data), this survey will be used to establish a robust and up-to-date characterisation of the baseline environment in the Hornsea Three offshore cable corridor. The scope and design of the site-specific Hornsea Three offshore cable corridor survey has been discussed and agreed with relevant stakeholders via a Marine Processes, Benthic Ecology and Fish and Shellfish Expert Working Group. The results will be used to update the Hornsea Three baseline characterisation in the Environmental Statement (including relevant updates to this Site Characterisation document).

4.1.1.3 Survey data collected across Hornsea Three array area and the cable route corridor to date, together with further survey work in Quarter Two of 2017 (as described in paragraph 4.1.1.2), will ensure a comprehensive characterisation of the physical, chemical and biological characteristics of the sediments proposed to be disposed of within the site, either via dredging associated with seabed preparation or via drill arisings.

4.1.1.4 A summary of datasets relevant to seabed sediments in Hornsea Three array area and the cable route corridor is provided below in Table 4.1, along with a cross-reference to chapters and/or annexes of the PEIR where additional detail on these surveys is provided.

Table 4.1: Summary of data sources relevant to seabed sediments in Hornsea Three array and offshore cable corridor.

Survey type	Hornsea Three array/cable route corridor	Relevant data	Relevant section of Hornsea Three PEIR
Geophysical (bathymetry, side scan sonar, sparker and pinger seismic and magnetometry).	The geophysical surveys included identification of bathymetry and seabed features (using side scan sonar), shallow geophysical surveys (using hull mounted pinger and surface towed sparker) and geohazards (using side scan sonar and magnetometry) across the former Hornsea Zone and Hornsea Three array area and geophysical survey consisting of side scan sonar and multibeam echosounder data for the offshore cable corridor.	Bathymetry, interpreted seabed surface geology, sub-surface geology.	Volume 2, chapter 1: Marine Processes.
Geotechnical data (CPT's, Boreholes and Vibrocores)	27 cone penetration tests (CPTs), 9 Boreholes from locations across the former Hornsea Zone.	Data on sub-surface geology.	Volume 2, chapter 1: Marine Processes.
Benthic grab and drop-down video (DDV)	Hornsea Three array: 45 stations Offshore cable corridor: 20 stations, 18 further stations planned.	Particle Size Analysis (PSA) data, information on benthic infaunal and epifaunal communities.	Volume 2, chapter 2: Benthic Intertidal and Subtidal Ecology and volume 5, annex 2.1: Benthic Ecology Technical Report.
Sediment chemistry grab survey	Hornsea Three array: 40 stations Offshore cable corridor: 16 stations, five further stations planned for Quarter Two 2017.	Contaminant levels for heavy metals, organotins, total petroleum hydrocarbons (TPH), polyaromatic hydrocarbons (PAHs and total PAHs) and organochlorine pesticides.	Volume 2, chapter 2: Benthic Intertidal and Subtidal Ecology and volume 5, annex 2.1: Benthic Ecology Technical Report.
2 m epibenthic beam trawl surveys.	Hornsea Three array: Nine stations Offshore cable corridor: Five stations planned for Quarter Two 2017.	Information on epifaunal communities, including demersal fish.	Volume 2, chapter 2: Benthic Intertidal and Subtidal Ecology and volume 5, annex 2.1: Benthic Ecology Technical Report.
Trawl surveys	Hornsea Three array: Nine 2 m epibenthic beam trawls and 12 otter trawls. Offshore cable corridor: Five 2 m epibenthic beam trawls planned for Quarter Two 2017.	Information on fish and shellfish communities, including demersal and pelagic fish.	Volume 2, chapter 3: Fish and Shellfish Ecology and volume 5, annex 3.1: Fish and Shellfish Ecology Technical Report.

4.1.2 Key characteristics of the material to be disposed within Hornsea Three array

4.1.2.1 As outlined in paragraphs 2.2.1.1 to 2.2.1.5 the source of any sediment disposed of within Hornsea Three array disposal site will be material dredged as part of seabed preparation prior to installation of GBF structures, material from drilling activities associated with piled foundation installation and sandwave clearance prior to cable installation.

4.1.2.2 Therefore, the materials potentially disposed of *in situ* will be both shallow seabed (i.e., sediments from seabed level to 5 m beneath existing seabed level), as well as material from deeper in the soil profile from the drilling process.

4.1.2.3 The following sections provide a summary of the key characteristics of both these sources of material under discrete sub-headings. The characteristics as defined here are the same as those used within the impact assessments presented in volume 2, chapter 1: Marine Processes, chapter 2: Benthic Intertidal and Subtidal Ecology and chapter 3: Fish and Shellfish Ecology.

Physical characteristics

Dredged material

4.1.2.4 The dominant sediment types identified within the Hornsea Three array that will be dredged from seabed preparation and sandwave clearance areas and disposed of *in situ* are largely sand and gravel with varying proportions of each where these coincide. The offshore cable corridor generally comprises gravels and mixed sediments with varying proportions of mud.

4.1.2.5 The mean (± standard deviation) percentage gravel, sand and mud in each of the broad sediment types identified across the benthic ecology study area are presented below in Table 4.2.

Table 4.2: Mean (± standard deviation) percentage gravel, sand and mud in each of the broad sediment types identified across the Hornsea Three benthic ecology study area.

Broad sediment type	% gravel (± standard deviation)	% sand (± standard deviation)	% mud (± standard deviation)
Sand and muddy sand	0.71 ± 1.13	95.51 ± 7.02	3.77 ± 7.14
Coarse sediment	31.44 ± 17.54	66.59 ± 17.67	1.93 ± 1.81
Mixed sediment	36.63 ± 15.22	53.32 ± 13.59	10.06 ± 4.02

4.1.2.6 Although the actual process of disposal may result in a slight change in the existing particle size composition of seabed sediments, the material disposed of *in situ* via seabed preparation works and sandwave clearance works will be similar to the existing material as the removal and subsequent disposal of material will take place in almost the same area.

Drill arising material

4.1.2.7 The material that will potentially be disposed of following drilling activities is different in nature to that disposed of via seabed preparation as these drilled materials will include seabed sediments and also sediment from deeper in the soil profile.

4.1.2.8 Based on a review of geophysical and geotechnical data it can be noted that drilled material will comprise the following mixture of recent (Holocene) sediments and Quaternary deposits:

- Recent (Holocene) sediments (sand and sandy gravel);
- Botney Cut Formation (mainly sands);
- Bolders Bank Formation (stiff diamictons with widely ranging grain sizes);
- Eem Formation (very fine to medium-grained, slightly gravelly, shelly sands);
- Egmond Ground Formation (gravelly sands interbedded with silt and clay);
- Swarte Bank Formation (mainly glacio-fluvial sands); and
- Yarmouth Roads Formation (characterised by a range of sediment types). (BGS, 1986; 1987; 1991; Cameron *et al*., 1992).

4.1.2.9 The exact proportions of each of these deposits which will form the basis of the drill arisings deposited on the seabed will vary according to the location within the Hornsea Three array where drilling is undertaken.

4.1.2.10 Further details of the physical characteristics of the dredged and/or drilled material can be found in volume 2, chapter 1: Marine Processes.

Chemical characteristics

Dredged material

4.1.2.11 In terms of sediment chemistry, a sediment chemistry grab sample survey was undertaken at 40 stations across the central section of the former Hornsea Zone, this has been used to inform the sediment conditions at the Hornsea Three array (see Table 4.2).

Metals analysis

4.1.2.12 The results of the heavy metals analysis for the subtidal samples revealed that, except for arsenic, cadmium and nickel, concentrations of all metals within sediments were below both the Cefas AL1 and the more stringent Canadian TEL, and therefore were at levels below which biological effects in benthic organisms could be expected.

4.1.2.13 Arsenic was found to exceed the Canadian TEL at all but five sites within the Hornsea Three benthic ecology study area, and of the sites with elevated levels of arsenic, five recorded concentrations above the Canadian PEL at levels where a toxicity effect would be evident. Although levels of arsenic in sediments exceeded the Cefas AL1 of 20 mg/kg at 26 sites, concentrations at all sites were well below the Cefas AL2 of 100 mg/kg.

4.1.2.14 Historically the Humber has been subjected to a large point discharge of arsenic from industrial sources and samples collected during various North Sea surveys between 1991 and 1995 have identified numerous areas with high raw arsenic concentrations, particularly off north Yorkshire and the Humber Estuary (Whalley *et al*., 1999). However, Whalley *et al*. (1999) demonstrated that after normalisation against iron, the levels of arsenic in historical samples were much reduced in significance. Whalley *et al*. (1999) proposed that the low residual values might be explained by dilution into the Humber Estuary's high suspension load, or by particulate transport away from the region. Also, the Humber Estuary receives large amounts of iron waste (Millward and Glegg, 1997) to which arsenic may sorb (Cefas, 2000). The arsenic concentrations within sediments in the Hornsea Three benthic ecology study area are similar to those reported by Whalley *et al*. (1999); therefore, they are considered unlikely to represent excessive levels for the region. As such, only impacts by remobilisation of contaminated sediments within the Hornsea Three offshore cable corridor are assessed; this impact will not be considered within the Hornsea Three array area.

4.1.2.15 The level of cadmium marginally exceeded the Canadian TEL and Cefas AL1 at one site in the centre of the former Hornsea Zone but was well within the Cefas AL2 and the Canadian PEL. The concentration of nickel marginally exceeded the Canadian TEL (15.9 mg/kg) at one site but was below the Cefas AL1 (20 mg/kg) at all sites.

Organotins

4.1.2.16 Levels of TBT and TPT in the Hornsea Three benthic ecology study area subtidal sediments were below the limits of detection of the analysis used at all sites (i.e. <5 µg/kg for TBT and <50 µg/kg for TPT). Although for the majority of the Hornsea Three benthic ecology study area the levels of DBT were also below the limit of detection of the analysis used (i.e. <5 µg/kg), where recorded above this (locations within the Hornsea Project Two array area), the recorded concentrations were all well within the Cefas AL1 for DBT of 0.1 mg/kg.

Hydrocarbon analysis

4.1.2.17 The results for total petroleum hydrocarbons (TPH) within the Hornsea Three benthic ecology study area ranged from 0.76 mg/kg to 18.52 mg/kg. All recorded TPH values from the Hornsea Three benthic ecology study area were well below the Cefas AL1 of 100 mg/kg. The typical range for Total Hydrocarbon Content in offshore North Sea sediments is 17 to 120 mg/kg (Cefas, 2001). The values recorded in the Hornsea Three benthic ecology study area are towards the lower end of this range, supporting the conclusion that hydrocarbon concentrations within the Hornsea Three benthic ecology study area are very low.

Polycyclic aromatic hydrocarbons (PAHs)

4.1.2.18 The results for total PAH (i.e. the summed total of the EPA 16 including dibenzothiophene) ranged between <0.001 and 0.303 mg/kg, although the majority of sites were below 0.030 mg/kg and so within the range of typical sediments for the North Sea. All values of the United States Environmental Protection Agency (US EPA) 16 listed PAHs were well below the Cefas AL1 concentrations for individual PAHs and also the Canadian TEL levels throughout the Hornsea Three benthic ecology study area.

Biological characteristics

Dredged material

4.1.2.19 The biological characteristics of the seabed sediments likely to be dredged in the Hornsea Three array as part of seabed preparation prior to GBF installation and sandwave clearance prior to cable installation are described in section 3.2.

4.1.3 Key characteristics of the material to be disposed within the offshore cable corridor

4.1.3.1 As outlined in paragraphs 2.2.1.1 to 2.2.1.5, the source of any sediment disposed of within the offshore cable corridor will be material dredged as part of seabed preparation prior to installation of GBF structures and/or material from drilling activities associated with piled foundation installation of the offshore HVAC booster stations, together with sandwave clearance works associated with export cable installation within the offshore cable corridor. Therefore, the materials potentially disposed of in the offshore cable corridor will be both shallow seabed (i.e., sediments from seabed level to 5 m beneath existing seabed level), as well as material from deeper in the soil profile from the drilling process.

4.1.3.2 The following sections provide a summary of the key characteristics of both of these sources of material under discrete sub-headings. The characteristics as defined here are the same as those used within the impact assessments presented in volume 2, chapter 1: Marine Processes, chapter 2: Benthic Intertidal and Subtidal Ecology and chapter 3: Fish and Shellfish Ecology. Note that the site-specific survey planned for Quarter Two 2017 in the offshore cable corridor will contribute to the characterisation of material to be disposed, any further information extra to that already obtained will be included in the Site Characterisation submitted as part of the Environmental Statement.

Physical characteristics

Dredged material

4.1.3.3 The dominant sediment types identified from the PSA samples in the offshore cable corridor are gravelly sands and sandy gravels (i.e., coarse sediment with low (<1%) mud content). Limited areas of the offshore cable corridor comprised mixed sediments (sand, gravel and >5% mud content).

4.1.3.4 The sandwave clearance material to be disposed of will be similar to the surrounding sediments as the removal and subsequent disposal of material will, on the whole, take place in almost the exact same area, or the immediate vicinity.

Drill arising material

4.1.3.5 Drill arising material will originate only from the drilling activities associated with piled foundation installation of the up to four offshore HVAC booster stations located in the offshore cable corridor. The nature of this material will be as described in section 4.1.2.7 to 4.1.2.10.

Chemical characteristics

4.1.3.6 Site-specific subtidal sediment contamination data is currently not available for the Hornsea Three offshore cable corridor, therefore it is not possible to describe the characteristics of each parameter (i.e. metals, organotins and hydrocarbons) in the PEIR. However, as discussed in paragraph 4.1.1.2 a site-specific survey will be undertaken along the Hornsea Three offshore cable corridor and sediment contaminant data acquired in the pending survey will inform the Site Characterisation submitted as part of the Environmental Statement.

Biological characteristics

4.1.3.7 The biological characteristics of the seabed sediments likely to be dredged in the Hornsea Three array as part of seabed preparation prior to GBF installation and sandwave clearance prior to cable installation, are described in paragraph 3.2.1.4.

4.2 Method of dredging/drilling and disposal

4.2.1.1 As outlined in Paragraphs 2.2.1.1 to 2.2.1.5, material removed from within Hornsea Three and disposed of *in situ* will be derived from three potential sources; dredging as part of seabed preparation works prior to GBF installation, sandwave clearance works prior to cable installation and drilling activities associated with monopile installation.

4.2.2 Dredging

4.2.2.1 It is expected that any dredging required for seabed preparation and sandwave clearance will be undertaken via a modern, commercial scale trailer hopper suction dredger and/or static dredging, as used to extract sand and gravel for the marine aggregates industry.

4.2.2.2 For trailer hopper suction dredging this process typically results in dredge tracks of 2 to 3 m width and up to 0.3 m depth being created at each pass of the dredger head on the seabed. Successive dredging over the same area can reduce the seabed level by up to 5 m. For static dredging, a vessel anchors over a particular area and extracts material to the required depth.

4.2.2.3 Modern dredging vessels and their associated positioning systems enables seabed dredging to be very exact and to be undertaken within discrete areas. Material dredged from the seabed can then be re-deposited in another area of the site via discharge directly from the same dredger.

4.2.3 Drilling

4.2.3.1 If percussive piling installation is not possible due to the presence of rock or hard soils, the material inside the monopile may be drilled out before the monopile is driven to the required depth. This can either be done in advance of the driving or during the process if the piling rate slows significantly during piling, known as refusal, in order to complete the installation. If drilling is required, spoil arising from the drilling will be released adjacent to the foundation location above the sea surface; see volume 1, chapter 3, Project Description.

5. Assessment of Potential Adverse Effects

5.1 Evaluation of potential adverse effects of *in situ* disposal of dredge/drill material

5.1.1 Physical environment

5.1.1.1 The following section of the document provides an overview of the key findings to date of the Hornsea Three EIA, as reported in the PEIR, relevant to the disposal of dredged and/or drilled material *in situ* within the Hornsea Three array area and the offshore cable corridor. One physical receptor has been assessed in the context of dredging and disposal activities (see Table 5.1). Note that marine processes are not in themselves receptors in the majority of cases when carrying out an impact assessment, but changes to these processes may have an impact on other sensitive receptors (Lambkin *et al.,* 2009). The receptor groups for the potential impact pathways considered within volume 2, chapter 1: Marine Processes lie principally in other offshore EIA topics, namely chapter 2: Benthic Ecology, chapter 3: Fish and Shellfish Ecology, chapter 4: Marine Mammals, chapter 5: Offshore Ornithology, chapter 9: Marine Archaeology, and chapter 10: Infrastructure and Other Users. In such instances, a significance of effect has not been assigned within the marine processes assessment, see volume 2, chapter 1: Marine Processes for further information on the physical pathways and volume 5, annex 1.1: Marine Processes Technical Report for more detailed technical information which underpins the impact assessments presented in volume 2, chapter 1: Marine Processes.

5.1.2 Biological and human environment

5.1.2.1 This PEIR for Hornsea Three provides detailed preliminary impact assessments related to disposal activities on a number of sensitive biological and human environment receptors, including benthic habitats, fish and shellfish habitats, marine mammals, offshore ornithology, commercial fisheries, marine archaeology and infrastructure and other users.

5.1.2.2 For all of these assessments, the effects defined within volume 2, chapter 1: Marine Processes have been interpreted with regard to their subsequent impact on various receptors. The sensitivity of various receptors to these effects (increased suspended sediment concentrations, sediment deposition and potential loss of seabed habitats) has been determined based on relevant literature and an assessment of the significance of any impacts undertaken.

5.1.2.3 Table 5.1 below provides a summary of the key impacts on physical, biological and human receptors assessed within the PEIR. The relevant section of the PEIR, where further details of these impact assessments are presented, is also provided.

Table 5.1: Summary of impacts relevant to the disposal of spoil within Hornsea Three array disposal site and Hornsea Three offshore cable corridor disposal site.

Potential impact	Relevant section of PEIR	Magnitude of impact	Sensitivity of receptor	Significance of effect including designed in measures
Marine Processes				
Removal of sandwaves impacting sandbank systems within proximity to the Hornsea Three array area and offshore cable corridor.	Volume 2, chapter 1: Marine Processes	Minor	Medium	**Minor adverse** (not significant in EIA terms).
Subtidal Benthic Ecology				
Temporary habitat loss/disturbance due to cable laying operations (including anchor placements), spud-can leg impacts from jack-up operations and seabed preparation works for gravity base foundations (GBFs), may affect benthic ecology.	Volume 2, chapter 2: Benthic Intertidal and Subtidal Ecology	Minor (Habitats A to E, G, H and I and Species L)	Low (Habitats A, B and C) Medium (Habitats D, E, G, H and I and species L)	**Minor adverse** (Habitats A to E, G, H and I and Species L; not significant in EIA terms).[a]
Temporary increases in suspended sediment concentrations and associated sediment deposition from cable and foundation installation and seabed preparation during the construction phase may affect benthic ecology.	Volume 2, chapter 2: Benthic Intertidal and Subtidal Ecology	Minor (Habitats A to K and Species L)	Low (Habitats A to I and Species L) Medium (Habitats J and K)	**Minor adverse** (Habitats A to K and Species L; not significant in EIA terms).
Seabed disturbances within the offshore cable corridor leading to the release of sediment contaminants and resulting in potential effects on benthic ecology.	Volume 2, chapter 2: Benthic Intertidal and Subtidal Ecology	To be confirmed in the Environmental Statement.	To be confirmed in the Environmental Statement.	To be confirmed in the Environmental Statement.
Fish and Shellfish Ecology				
Temporary habitat loss/disturbance from construction operations including foundation installation (e.g. jack-up operations and seabed preparation works) and cable laying operations (including anchor placement) may affect fish ecology	Volume 2, chapter 3: Fish and Shellfish Ecology	Minor	Low to medium	**Minor adverse** (not significant in EIA terms).
Temporary increases in suspended sediment concentrations (SSC) and associated sediment deposition as a result of foundation installation, cable installation and seabed preparation resulting in potential effects on fish and shellfish receptors	Volume 2, chapter 3: Fish and Shellfish Ecology	Minor	Low to medium	**Minor adverse** (not significant in EIA terms).
Seabed disturbances within the offshore cable corridor leading to the release of sediment contaminants and resulting in potential effects on fish and shellfish ecology	Volume 2, chapter 3: Fish and Shellfish Ecology	To be confirmed in the Environmental Statement.	To be confirmed in the Environmental Statement.	To be confirmed in the Environmental Statement.
Marine Mammals				
Increased vessel traffic during construction may result in an increase in disturbance, collision risk, or injury to marine mammals	Volume 2, chapter 4: Marine Mammals	Minor	Medium	**Minor** (not significant in EIA terms).
Increased suspended sediments arising from construction activities, such as cable and foundation installation, may reduce water clarity and impair the foraging ability of marine mammals	Volume 2, chapter 4: Marine Mammals	Negligible	Low	**Negligible** (not significant in EIA terms).
Changes in the fish and shellfish community resulting from impacts during construction may lead to loss of prey resources for marine mammals	Volume 2, chapter 4: Marine Mammals	Minor	Low	**Minor** (not significant in EIA terms).

Potential impact	Relevant section of PEIR	Magnitude of impact	Sensitivity of receptor	Significance of effect including designed in measures
Birds				
Offshore undersea habitat loss due to construction of infrastructure and changes to physical processes may lead to changes in habitat available for birds and their prey species	Volume 2, chapter 5: Offshore Ornithology	Negligible	Medium (fulmar, gannet, guillemot, lesser black-backed gull, great black-backed gull). Low to medium (kittiwake, razorbill). Medium to high (puffin).	**Negligible** or **minor adverse** (fulmar, gannet, kittiwake, razorbill, guillemot, lesser black-backed gull, great black-backed gull; not significant in EIA terms). **Negligible** (puffin; not significant in EIA terms).
Marine Archaeology				
Construction activities within the Hornsea Three array area and offshore cable corridor causing the removal or disturbance of sediments resulting in a potential effect on near-surface prehistoric land surfaces.	Volume 2, chapter 9: Marine Archaeology	Negligible	High	**Minor adverse** (not significant in EIA terms).
Construction of turbines, and substations and accommodation platforms within the Hornsea Three array area with jacket foundations causing the removal or disturbance of sediments resulting in a potential effect on deeply buried prehistoric land surfaces.	Volume 2, chapter 9: Marine Archaeology	Negligible	High	**Minor adverse** (not significant in EIA terms).
Seabed preparation in connection with gravity base foundation installation and sand wave clearance causing sediment deposition on the seabed resulting in a potential effect on a variety of heritage assets.	Volume 2, chapter 9: Marine Archaeology	Negligible	Negligible	**Negligible** (not significant in EIA terms).
Infrastructure and Other Marine Users (including cables/pipelines and oil and gas operators)				
Installation of infrastructure has the potential to lead to increased suspended sediment concentrations and deposition, which could cause a change in aggregate resource in aggregate extraction areas	Volume 2, chapter 11: Infrastructure and other Users	Negligible	Medium	**Negligible**

a A moderate adverse impact is predicted for habitats J (subtidal chalk) and K (peat and clay exposures) for this impact within volume 2, chapter 2: Benthic Intertidal and Subtidal Ecology. However, this outcome has not been reported in this table as it relates specifically to the direct loss of these features as a result of cable installation and anchor placements, as opposed to any indirect impacts arising from the disposal of dredged sediments prior to cable installation.

6. Conclusions

6.1.1.1 This document represents the findings to date of the Site Characterisation for the proposed licensed Hornsea Three array disposal site and the Hornsea Three offshore cable corridor disposal site as required by the MMO. This Site Characterisation will be updated with further survey data, where relevant, and to address consultation feedback prior to the issue of the Environmental Statement. The Site Characterisation submitted as part of the Environmental Statement will support the authorisation of the disposal activities in the deemed Marine Licences and will enable the MMO to consider relevant conditions covering the disposal activity within the deemed Marine Licences for Hornsea Three.

6.1.1.2 Noting that all the information required for site characterisation to support a disposal application would be contained within the Hornsea Three PEIR, this document takes the form of a 'framework' document that provides a summary of the key points relevant to site characterisation and refers the reader back to the more detailed information and data presented within various sections of the PEIR.

6.1.1.3 The source of material proposed to be disposed of within Hornsea Three array disposal site will be sediment dredged from the existing seabed via a trailer suction hopper dredger as part of seabed preparation works prior to GBF installation and sandwave clearance prior to Hornsea Three array cable installation and/or materials from the deeper soil profile and top layers of upper sediments derived from drilling activities associated with monopile installation.

6.1.1.4 The source of material proposed to be disposed of within the Hornsea Three offshore cable corridor disposal site will be sediment dredged from sandwaves which have been identified as potentially requiring clearing prior to export cable installations. Sandwave clearance via a trailer suction hopper dredger has been considered in this Site Characterisation. Additionally material from four offshore HVAC booster station will be disposed in the offshore cable corridor as described above, in paragraph 6.1.1.3.

6.1.1.5 Within the boundaries of the Hornsea Three array disposal site, an upper estimate of 2,450,467 m^3 of material is proposed to be disposed of *in situ* in the form of shallow dredged sediments and possibly also drill arisings. For the Hornsea Three offshore cable corridor disposal site, an upper estimate of 427,056 m^3 of material is proposed to be disposed of *in situ*.

6.1.1.6 Based on PSA sampling undertaken, the sediments to be disposed from the seabed preparation works in the Hornsea Three array disposal site is predominantly sand and gravel, while sediments in the Hornsea Three offshore cable corridor disposal site comprise areas of coarse and mixed sediments.

6.1.1.7 Sediment chemistry survey data indicates that contaminant concentrations in surface sediments are below levels at which adverse biological effects on benthic organisms are likely to occur. The biological characteristics of the sediments to be disposed of (and the receiving environment) have also been assessed. Hornsea Three array is dominated by two broad habitat types; Habitat A (Sandy sediments with low infaunal diversity) and Habitat C (Coarse sediments with moderate to high infaunal diversity. The offshore cable corridor is dominated by two broad habitat types: Habitat A (Sandy sediments with low infaunal diversity) and Habitat D (Mixed sediments with high infaunal and epifaunal diversity characterised by the SspiMx biotope).

6.1.1.8 The impacts of disposal via either the return of dredged material to the water column and seabed and/or the placement of drill arisings adjacent to foundations has been fully assessed within the PEIR. No effects of moderate or major adverse significance (i.e., significant in EIA terms) have been identified in relation to sediment disposal, with only negligible to minor adverse effects predicted on relevant receptors.

6.1.1.9 In conclusion, based on the proposals for disposal within the Hornsea Three array disposal site and Hornsea Three offshore cable corridor disposal site, the nature of the material to be disposed of, the receiving environment and the predictions of the EIA work undertaken to date on the impact of these activities on physical, biological and human receptors, no significant adverse impacts are predicted.

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