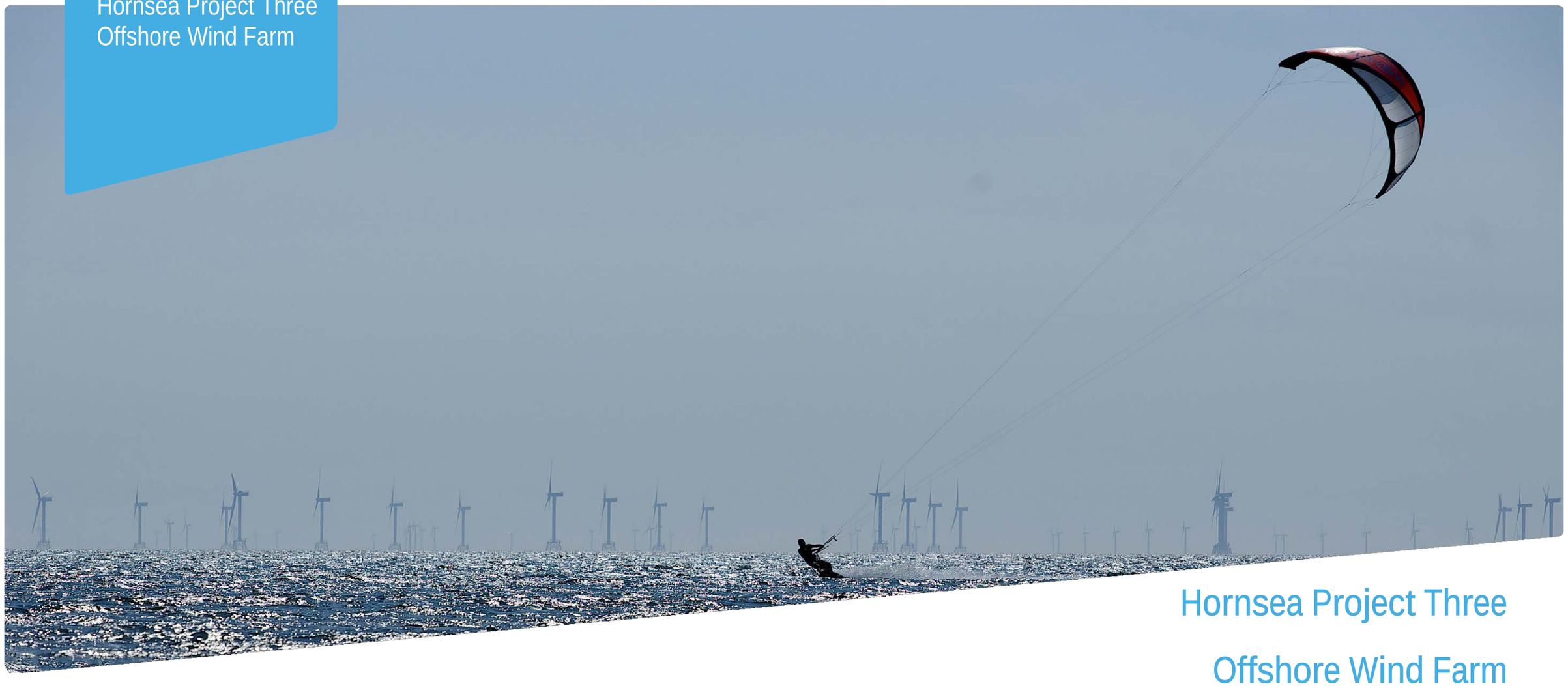
Hornsea Project Three
Offshore Wind Farm



Hornsea Project Three

Offshore Wind Farm

Environmental Statement:
Volume 4, Annex 3.2 - Dredging and Disposal: Site Characterisation

PINS Document Reference: A6.4.3.2
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Date: May 2018

Hornsea 3
Offshore Wind Farm

Ørsted

Environmental Impact Assessment

Environmental Statement

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 Orsted Power (UK) Ltd.

Report Number: A6.4.3.2

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This report is also downloadable from the Hornsea Project Three offshore wind farm website at:

www.hornseaproject3.co.uk

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Front cover picture: Kite surfer near a UK offshore wind farm © Orsted Hornsea Project Three (UK) Ltd., 2018.

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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 by 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.

Term	Definition
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
BGS	British Geological Survey
TEL	Threshold Effect Level
Cefas	Centre for Environment, Fisheries and Aquaculture Science
CPA	Closest Point of Approach
CPT	Cone Penetration Test
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
EWG	Expert Working Group
GBF	Gravity Base Foundations
HV	High Voltage
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
ICES	International Council of the Explorationof the Sea
JNCC	Joint Nature Conservation Committee
KP	Kilometer Point
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

Acronym	Description
NRHE	National Record of The Historic Environment
OSPAR	Oslo-Paris Commission
PAH	Polycyclic Aromatic Hydrocarbon
PEIR	Preliminary Environmental Information Report
PSA	Particle Size Analysis
RCD	Reverse Circulation System
REWS	Radar Early Warning Systems
rMCZ	Recommended Marine Conservation Zone
SAC	Special Area of Conservation
SoCG	Statement of Common Ground
SPA	Special Protection Area
SPM	Suspended Particulate Matter
SSC	Suspended Solids Concentrations
SSSI	Site of Special Scientific Interest
TAC	Total Allowable Catch
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. Introduction

1.1.1.1 Orsted Hornsea Project Three (UK) Ltd., on behalf of Orsted Power (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 with a capacity of up to 2,400 MW and includes the associated offshore and onshore infrastructure. The Hornsea Three array area is located in the east of the former Hornsea Zone, in the central region of the North Sea, approximately 121 km to the northeast of Tringham, Norfolk, approximately 140 km to the east of the East Riding of Yorkshire coast and approximately 10.1 km west of the median line between UK and Netherlands 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, drawing on the findings 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 This document represents the site characterisation for two proposed disposal sites associated with the construction of Hornsea Three; the Hornsea Three Array Disposal Site and the Hornsea Three Offshore Cable Corridor Disposal Site, as follows:

- Hornsea Three Array Disposal Site. This covers the extent of the Hornsea Three array area; and
- Hornsea Three Offshore Cable Corridor Disposal Site: This covers the extent of the Hornsea Three offshore cable corridor (including the temporary working areas).

1.1.1.4 The locations of the proposed disposal sites are presented in Figure 1.1.

1.1.1.5 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 for the Deemed Marine Licenses issued under the Development Consent Order (DCO). Such a report is required to contain the following information as a minimum:

- Discussion of 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.

1.1.1.6 The applications for deemed Marine Licenses for Hornsea Three covers the deposit of all substances and articles produced by dredging and drilling activities during seabed preparation works and sandwave clearance for the construction of the Hornsea Three. This Site Characterisation annex has therefore been provided to inform the MMO's decision making and facilitate determination of any relevant conditions covering the disposal activity within the deemed Marine Licences for Hornsea Three.

1.1.1.7 Noting that all the information required for site characterisation to support a disposal application is contained within the Hornsea Three Environmental Statement, 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 Environmental Statement can be found. As such, the information presented in the following sections should be read in conjunction with the wider Environmental Statement.

1.1.1.8 This Site Characterisation annex 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.

1.2 Consultation

1.2.1.1 This Site Characterisation annex was included in the Preliminary Environmental Information report (PEIR). The comments received from the MMO and Natural England are outlined in Table 1.1 and in the Consultation Report (document reference number A5.1). This annex has been updated to reflect those comments.

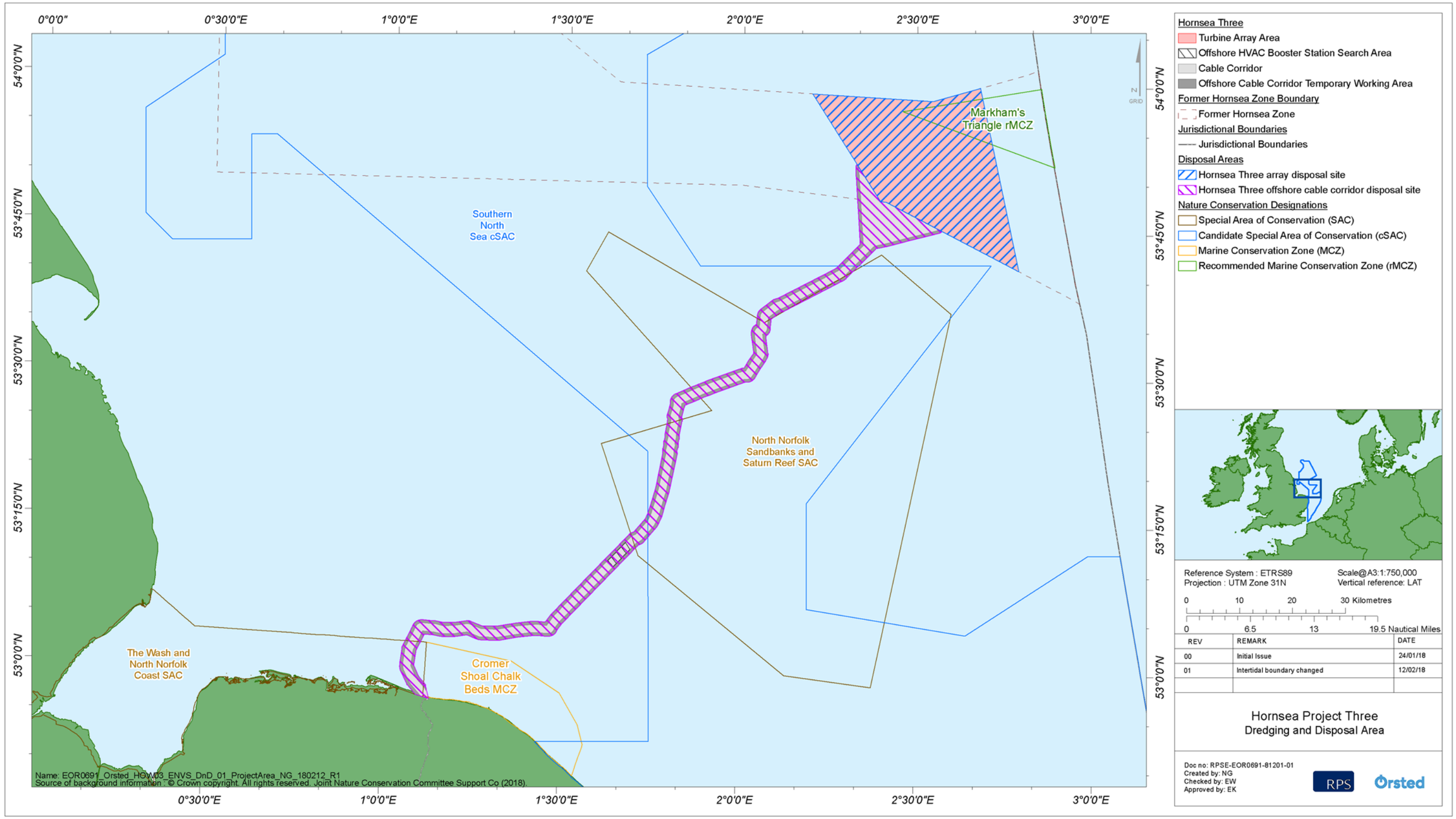

Figure 1.1: Location of the proposed Hornsea Three Array Disposal Site and Hornsea Three Offshore Cable Corridor Disposal Site.

Table 1.1: Summary of key consultation issues raised during consultation activities undertaken for Hornsea Three relevant to Site Characterisation.

Date	Consultee and type of response	Issues raised	Response to issue raised and/or where considered in this annex
20 September 2017	MMO - Section 42 consultation response	A disposal site characterisation report will be required to enable the disposal of dredging and drilling spoil adjacent to foundation locations. The MMO notes that site characterisation data has been provided as a technical annex to the PEIR (volume 4, annex 3.2: Dredging and Disposal (Site Characterisation)).	The Site Characterisation has been updated since PEIR to reflect consultee comments and changes made to the project description (see volume 1, chapter 3: Project Description).
20 September 2017	Natural England - Section 42 consultation response	The Cromer Shoal Chalk Beds MCZ is excluded from the proposed disposal site area, however, HDD pit excavation will involve placement of material on the seabed. Although this is described as a temporary measure, this could be in place for several years and as such should potentially be considered as disposal site. To minimise the loss of sediment from the offshore sandbank system it is important that disposal of dredged material occurs in the vicinity allowing it to be re-distributed throughout the local environment. Currently the proposed disposal site boundary follows that of the offshore cable corridor. Disposal of material restricted to that area may result in the net loss of material from the NNSSR cSAC/SCI as the sediment is brought outside site boundary by prevailing north-easterly sediment transport. The application should consider disposal of material further south outside the present cable corridor boundary to ensure the loss of sediment from the sandbank system is minimised.	The proposed Hornsea Three Offshore Cable Corridor Disposal Site covers the entire extent of the Hornsea Three offshore cable corridor (including the temporary working areas) and therefore includes the Cromer Shoal Chalk Beds Marine Conservation Zone (MCZ). All spoil arising from sandwave clearance activities within designated sites along the Hornsea Three offshore cable corridor will be deposited within the boundary of those site and for the North Norfolk Sandbanks and Saturn Reef SAC will be deposited within the same sandwave system within the boundary of the site. The precise disposal location selected will consider the net direction of sediment transport in the region to ensure that sediment will not be lost from the sandbank system (see section 1.11 in volume 2, chapter 1: Marine Processes and section 2.11 in volume 2, chapter 2: Benthic Ecology.
20 September 2017	Natural England - Section 42 consultation response	Concerns that the worst case scenario of removal of 5 m of sediment as seabed preparation has not been assessed. We would like to see additional evidence to support the choice of 2 m as a realistic worst case scenario and the provision of examples of GBFs already installed elsewhere (i.e. Blyth Offshore Demonstrator Project).	The 2 m value refers to the average dredging required for GBS foundations across the Hornsea Three array area. It has been estimated by considering the average seabed slope across the Hornsea Three array area, the construction methods anticipated and the dimensions of the GBS foundation structures. On this basis, the removal of up to 5 m of sediment will only be required at a limited number of turbine locations and, for the majority of turbine locations across the Hornsea Three array area, less than 2 m depth of material will require dredging prior to GBS foundation installation. Therefore when considering the Hornsea Three array area as a whole, 2 m for all turbine locations is considered a realistic MDS.
20 September 2017	Natural England - Section 42 consultation response	It is unclear why The Wash and North Norfolk SAC has not been included.	Section 3.2.4 of relevant designated sites of conservation importance has been updated to include consideration of The Wash and North Norfolk SAC.
20 September 2017	Natural England - Section 42 consultation response	The EIA should also consider a scenario whereby an MMO licence for a new dredge disposal site is not granted and an existing site needs to be used. This may not necessarily be close to the area of dredging, resulting in the material loss from the environment.	Disposal of material at Hornsea Three is considered to be the most appropriate option for preserving the integrity of the local sediment transport system (including sandwave or sandbank systems within either the Hornsea Three array area or offshore cable corridor). The full justification for this, including other environmental and technical considerations is presented in section 2.2.2. The MMO has not raised any concerns regarding granting a licence for on-site disposal and, therefore, Hornsea Three will seek to include this within the Statement of Common Ground (SoCG) with the MMO.

2. Assessment of the Need for a New Disposal Site

2.1 Hornsea Three

2.1.1 The Project

Hornsea Three array area

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 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 array, interconnector and export (located within the Hornsea Three array area) cable installation will be disposed of within the Hornsea Three Array Disposal Site.

Hornsea Three offshore cable corridor

2.1.1.3 The Hornsea Three offshore cable corridor initially extends northwest from the proposed Hornsea Three intertidal area at Weybourne in north Norfolk, passing through the southwestern corner of the Cromer Shoal Chalk Beds Marine Conservation Zone (MCZ) before turning north through the eastern section of The Wash and North Norfolk Coast Special Area of Conservation (SAC). The Hornsea Three offshore cable corridor turns east, running parallel to the coast for approximately 25 km, before progressing offshore in a north-easterly direction to the southern boundary of Hornsea Three array area (see Figure 1.1). The Hornsea Three offshore cable corridor is approximately 163 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 arising from sandwave clearance prior to cable installation and foundation installation associated with the offshore HVAC boosters stations within the Hornsea Three offshore cable corridor boundary are proposed to be disposed of approximately 500 m from the seabed preparation site. Where possible, sandwave clearance material from sandwaves cleared within designated sites will be deposited within the same sandwave system within the boundary of that site. The precise disposal location selected within the Hornsea Three offshore cable corridor disposal site will consider the net direction of sediment transport in the region to ensure that sediment will not be lost from the sandbank system.

2.1.2 Project components

2.1.2.1 The electricity generated from Hornsea Three will be transmitted via buried High Voltage (HV) cables using either Direct Current (DC) or Alternating Current (AC), or a combination of the two. Depending on the transmission option, HVAC, HVDC or a combination of both, Hornsea Three will have slightly different key components. The key marine components of Hornsea Three, including for an HVAC or HVDC transmission option, relevant to the site characterisation include:

- Turbines;
- Turbine foundations;
- Array cables;
- Offshore accommodation platform/s;
- HVAC or/and HVDC transmission system including either:
  - HVAC:
    - Offshore transformer substation(s);
    - Offshore interconnector cables(s);
    - Offshore export cable(s), including export cables and, if required, Horizontal Directional Drilling (HDD) ducts, at the Hornsea Three intertidal area; and
    - Offshore HVAC booster station(s) (unless specified otherwise this refers to both surface and subsea designs).
  - HVDC:
    - Offshore transformer substation(s);
    - Offshore interconnector cables(s);
    - Offshore HVDC converter substation(s); and
    - Offshore export cable(s), including export cables and, if required, HDD ducts, at the Hornsea Three intertidal area.

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

2.1.3 Predicted sources and amounts of spoil

Sources of spoil

2.1.3.1 In the context of this Site Characterisation, the term 'spoil' covers all material (i.e. sediment) which is extracted from (e.g. by dredging or drilling), and subsequently deposited on, the seabed during the construction of Hornsea Three.

2.1.3.2 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, and from seabed preparation prior to gravity base installation. Spoil will also arise from sandwave clearance prior to the installation of array, interconnector and export cables and from the excavation of HDD exits pits in the nearshore.

2.1.3.3 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.

2.1.3.4 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 thick layer of up to 5 m of top sediment with a diameter of 61 m may have to be excavated before installation of GBFs for the largest turbines and the seabed preparation associated with the largest foundations for offshore transformer substations may be up to 175 m in diameter. However, in most cases the layer of sediment will be considerably less than this maximum 5 m depth. Based on initial site surveys, it is expected that the average thickness of the dredged layer across the Hornsea Three Array Disposal Site will be approximately 2 m, depending on GBF design (see the maximum design scenario table in volume 2, chapter 1: Marine Processes), and thus for the purposes of site characterisation to support a disposal application the average 2 m sediment layer across the Hornsea Three Array Disposal Site is considered to be a realistic maximum design scenario.

2.1.3.5 For the purposes of the impact assessments presented in volume 2 of this Environmental Statement, 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.

2.1.3.6 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 within the Hornsea Three Offshore Cable Corridor Disposal Site (see Figure 1.1). The spoil from these installations is proposed to be disposed of within the Hornsea Three Offshore Cable Corridor Disposal Site.

2.1.3.7 Should dredging be required prior to installation of electrical cables within the Hornsea Three array area or along the Hornsea Three offshore cable corridor, this spoil will require disposal. Material dredged from within the Hornsea Three array area will be disposed of within the Hornsea Three Array Disposal Site (as described in paragraph 2.1.3.4 for GBFs) and material dredged from sandwaves along the Hornsea Three offshore cable corridor will be disposed of within the Hornsea Three Offshore Cable Corridor Disposal Site.

Volumes of spoil

Methodology for identification of foundation spoil volume

2.1.3.8 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 offshore assessments presented in volume 2, chapter 1: Marine Processes, volume 2, chapter 2: Benthic Ecology, volume 2, chapter 3: Fish and Shellfish Ecology, volume 2, chapter 4: Marine Mammals and volume 2, chapter 9: Marine Archaeology.

Methodology for identification of sandwave clearance sites

2.1.3.9 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 is outlined in Table 2.1 below.

2.1.3.10 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 baseline environment across the wider regional-scale.

2.1.3.11 Analysis of geophysical and geotechnical survey data has identified the presence of bedforms along the Hornsea Three Offshore Cable Corridor Disposal Site and at a number of locations within the Hornsea Three Array Disposal Site (see Figure 2.1 and Figure 2.2). 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. This in turn has been used to calculate an estimate of the volume of sediment that would require clearing within the Hornsea Three array area and along the offshore cable corridor (see volume 1, chapter 3: Project Description).

Total spoil volume

2.1.3.12 The total spoil volume for each disposal site is calculated by combining the maximum design scenario for each foundation type (in terms of spoil volume) with the volume of sandwave clearance. For both the Hornsea Three Array Disposal Site and Hornsea Three Offshore Cable Corridor Disposal Site, the maximum design scenario assumes the use of GBFs for turbines, offshore transformer substations and offshore HVAC booster substations and piled jacket foundations for offshore HVDC convertor substations and accommodations platforms (see Table 2.2).

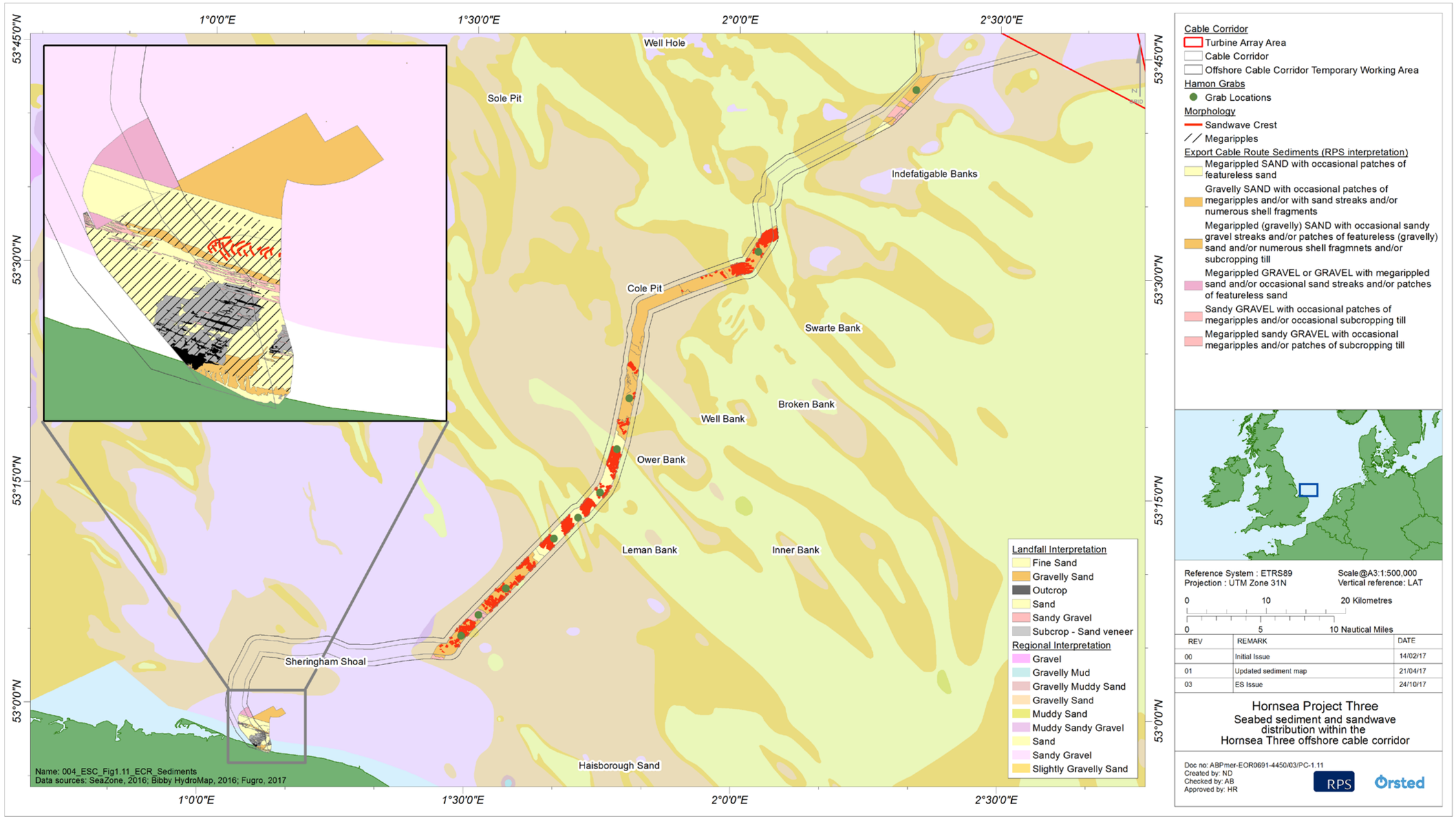

Figure 2.1: Seabed sediment and sandwave distribution within the Hornsea Three Offshore Cable Corridor Disposal Site.

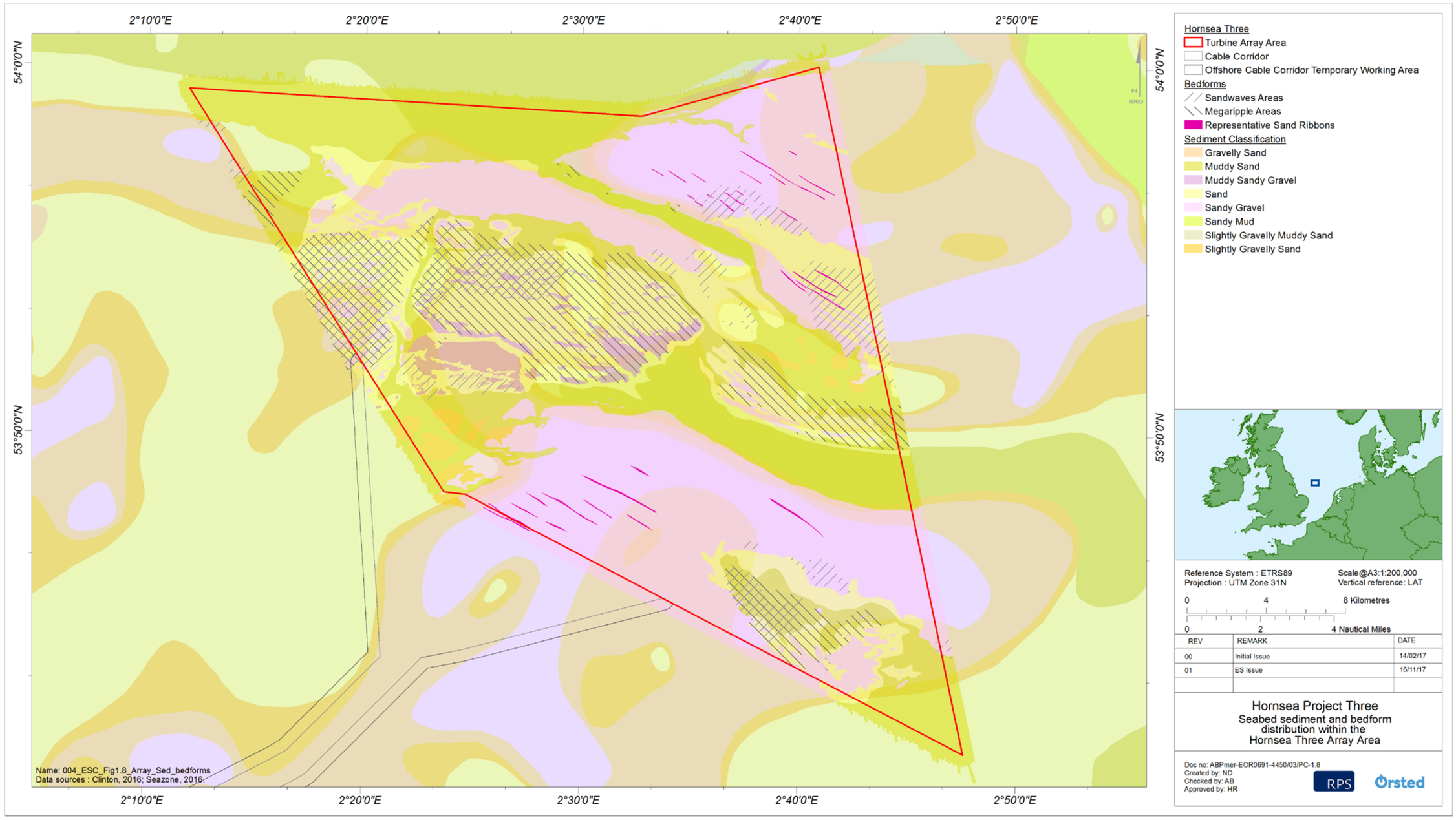

Figure 2.2: Seabed sediment and sandwave distribution within the Hornsea Three Array Disposal Site.

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	Relevant Data	Survey contractor	Year	Reference to further information
Inshore geophysical and DDV survey	Hornsea Three offshore cable corridor coinciding with the Wash and North Norfolk Coast SAC and Cromer Shoal Chalk Beds MCZ	9 DDV transects targeting potential outcropping rock; geophysical data (side scan sonar and bathymetry).	Bathymetry, interpreted seabed surface geology.	Fugro GB Marine	2017	Volume 5, annex 2.1: Benthic Ecology Technical Report
Hornsea Three benthic sampling survey - within 60 nm	Hornsea Three offshore cable corridor out to 60 nm	14 combined Hamon grab sampling and DDV stations, 15 stations for DDV only, 5 stations for sediment chemistry only, 5 beam trawls.	Particle Size Analysis (PSA) data, information on benthic infaunal and epifaunal communities. Contaminant levels for heavy metals, organotins, total petroleum hydrocarbons (TPH), polyaromatic hydrocarbons (PAHs and total PAHs) and organochlorine pesticides.	Ocean Ecology	2017	Volume 5, annex 2.1: Benthic Ecology Technical Report
Hornsea Three benthic sampling survey - beyond 60 nm	Cable fan section of the Hornsea Three offshore cable corridor and three sampling stations in Markham's Hole within the Hornsea Three array area	6 stations, 3 of which were also sampled for sediment chemistry, and 10 stations for DDV only	Information on benthic infaunal and epifaunal communities. Contaminant levels for heavy metals, organotins, total petroleum hydrocarbons (TPH), polyaromatic hydrocarbons (PAHs and total PAHs) and organochlorine pesticides.	Gardline	2017	Volume 5, annex 2.1: Benthic Ecology Technical Report
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.	Bathymetry, interpreted seabed surface geology, sub-surface geology.	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.	Bathymetry, interpreted seabed surface geology.	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	Bathymetry, interpreted seabed surface geology, sub-surface geology. Information on benthic infaunal and epifaunal communities.	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	Sub-surface geology.	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)	PSA data, information on benthic infaunal and epifaunal communities.	Emu	2010	Emu (2011b)

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

2.1.3.14 The maximum amount of spoil that is anticipated to arise within the Hornsea Three array area, which would require disposal within the Hornsea Three Array Disposal Site is 2,289,137 m^3 (Table 2.2). 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.

2.1.3.15 The maximum volume of spoil that is anticipated to be generated within the Hornsea Three offshore cable corridor through cable burial, sandwave clearance, HDD exit pit excavation and the installation of up to four offshore HVAC booster stations, which would require disposal within the Hornsea Three Offshore Cable Corridor Disposal Site, is 1,467,956 m^3. This volume assumes a maximum design scenario for total spoil volume, which is calculated based on the use of a GBFs for the four offshore HVAC booster stations (Table 2.2).

Table 2.2: Summary of maximum total spoil arisings.

Element	Spoil volume in the proposed Hornsea Three Array Disposal Site (m^3) [a]	Spoil volume in the proposed Hornsea Three Offshore Cable Corridor Disposal Site (m^3)
Seabed preparation for turbine GBFs	1,225,692	N/A
Seabed preparation for offshore transformer substation foundations (box type GBF)	735,000	245,000
Drill arisings for HVDC converter substations (piled jackets)	193,960	N/A
Drill arisings for accommodation platforms (piled jackets)	63,335	N/A
Sandwave clearance for cable installation	71,150	1,202,956
HDD exit pits	N/A	20,000
Total maximum design scenario volume	*2,289,137*	*1,467,956*

a Based on an average levelling depth of 2 m (see paragraph 2.1.3.4)

2.2 Consideration of alternative disposal options

2.2.1.1 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 European Union (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 area and the offshore cable corridor is, therefore, an important part of the site characterisation process and is required to inform the decision-making process led by the MMO and their advisers.

2.2.1.2 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 the Hornsea Three array area and the Hornsea Three offshore cable corridor.

2.2.2 Waste hierarchy

Prevention

2.2.2.1 The waste hierarchy places a strong emphasis on waste prevention or minimisation of waste. However, consent is being sought for the potential installation of a range of foundations for Hornsea Three whereby the potential generation of spoil is unavoidable due to the inherent nature of the industry standard installation techniques (see paragraph 2.1.3.2).

2.2.2.2 The installation of all foundation types listed in paragraph 2.1.3.2 and described in volume 1, chapter 3: Project Description (i.e. GBFs requiring seabed preparation and monopiles and/or pin-piles requiring drilling) as well as sandwave clearance prior to cable installation will lead to the production of spoil. 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. Similarly, in the case of the installation of monopiles and/or pin piles in Hornsea Three, if percussive piling is not possible due to the presence of rock or hard soils, the material inside the monopile/pin piles may be drilled out before the pile is driven to the required depth. If drilling is required, the generation of spoil arising from the drilling will be unavoidable.

2.2.2.3 In some areas within the Hornsea Three array area (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

2.2.2.4 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.

2.2.2.5 In theory, the material proposed to be dredged and/or drilled within Hornsea Three array area 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 area (a maximum of 2,289,137 m^3) to another location where this alternative use may be required would require approximately 208 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 Hornsea Three offshore cable corridor (a maximum of 1,467,956 m^3, including exit pit spoil) would require approximately 134 round trips of an approximate average of 140 km per trip (the centre of the Hornsea Three offshore cable corridor is approximately 70 km from the nearest shoreline).

2.2.2.6 Dredger movements of this scale would lead to other environmental impacts such as the release of fuel combustion emissions into the atmosphere and potential collision risks to marine mammals 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 Environmental Statement.

2.2.2.7 No specific projects have been identified that could accept material from Hornsea Three array area and the offshore cable corridor, and it is considered unlikely that any single project requiring sediments for uses such as those listed above would require as much as 3,757,093 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 area and the offshore cable corridor and would therefore increase potential related environmental impacts such as those related to fuel emissions.

2.2.2.8 Another factor to consider, with respect to the specific disposal of drill arisings away from Hornsea Three array area, 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). Deployment of up to four anchors at every drilling location would represent an additional impact on the seabed and associated receptors including benthic species/communities, fish and shellfish receptors (e.g. impacts to spawning and nursery grounds) and marine archaeological features over and above those already identified via other construction activities. Disposal of drill arisings *in situ* would, therefore, remove this impact.

2.2.2.9 In conclusion, the assessments undertaken 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 1: Marine Processes; volume 2, chapter 2: Benthic 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

2.2.2.10 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 2.2.2.5 (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

2.2.2.11 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

2.2.2.12 With respect to disposal at an existing marine disposal site, the closest open marine disposal site to the Hornsea Three array area and the offshore cable corridor is the Hornsea Project One array area disposal site, at a distance of 7 km to the west of the Hornsea Three array area, with the nearest site to the Hornsea Three offshore cable corridor also being the Hornsea Project One array area disposal site, located 7 km from the Hornsea Three offshore cable corridor. The next nearest open disposal site is the Hornsea Project Two disposal site located approximately 7 km due west of Hornsea Three array area and 18 km northwest of the Hornsea Three offshore cable corridor. The Hornsea Project One array area and Hornsea Project Two array area disposal sites are licenced to take spoil from the Hornsea Project One and Hornsea Project Two areas only, respectively. Furthermore, these sites are unlikely to have the capacity to accept all of the spoil produced by Hornsea Three, as they will be utilised for the spoil material arising from the construction of Hornsea Project One and Hornsea Project Two, respectively.

2.2.2.13 All other open disposal sites are at least approximately 50 km from Hornsea Three and they are unlikely to be viable options for disposal of Hornsea Three. The closest open marine disposal site to the Hornsea Three array area is the Babbage disposal site located 69 km to the west of the Hornsea Three array area. This site was opened to receive material produced from the installation of a pipeline in 2009. A total of 130,859 tonnes of material was deposited in this area in 2009, with no additional material deposited since 2009. Consultation with Cefas in 2013 has identified that this site is not currently licensed to receive additional material from other projects (S. Pacitto, Cefas, pers. comm., 2013).

2.2.2.14 To enable further disposal of material at the Babbage disposal site, further site characterisation of the area around the existing disposal site would be required along with hydrodynamic modelling studies to determine the capacity of this site in terms of additional disposal material. Noting that this document represents the site characterisation for the Hornsea Three Array Disposal Site and the Hornsea Three Offshore Cable Corridor Disposal Site, there is no strong argument for undertaking another site characterisation in the area around the existing Babbage site if one has already been carried out for the Hornsea Three sites, especially when the conclusions of this characterisation have demonstrated no significant adverse impacts of disposal activities on any receptors.

2.2.2.15 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 area and the offshore cable corridor.

Rationale for characterising the sites as disposal sites

2.2.2.16 The waste hierarchy, as outlined in the Waste Framework Directive, and potential alternative options for the disposal of dredged and/or drilled material derived from the Hornsea Three array area and the Hornsea Three offshore cable corridor, have been considered in detail in paragraphs 2.2.2.1 to 2.2.2.15. The generation of spoil has been demonstrated to be unavoidable for the range of project parameters for which consent is sought for Hornsea Three and therefore, prevention, as a waste-management measure is not deemed feasible (see paragraphs 2.2.2.1 to 2.2.2.3). The waste-management measures to re-use or recycle the spoil has been considered and discounted on the basis that the increase in vessel movements that would be generated, above those already considered within the maximum design scenario for Hornsea Three (see volume 1, chapter 3: Project Description), would incur unnecessary potential environmental impacts such as increased emissions, collision risk to marine mammals and additional habitat disturbance to benthic habitats from anchor placements (paragraphs 2.2.2.4 to 2.2.2.10). With regards to disposal of the material at an existing open disposal site, the nearest sites (i.e. the Hornsea Project One array area Hornsea Project Two array area disposal sites and the Babbage disposal site) are licenced to only accept spoil from those projects. Therefore, further site characterisation of the area around these existing disposal sites would be required to determine if the material from Hornsea Three would be suitable for disposal in these sites. The Environmental Statement 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 1: Marine Processes; volume 2, volume 2, chapter 2: Benthic 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). Therefore, there is no environmental reason to undertake further site characterisations for any other site.

2.2.2.17 Disposal of material derived from the Hornsea Three construction process within the boundaries of the proposed new 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 and environmental grounds. Further environmental justifications are presented below in paragraphs 2.2.2.18 *et seq*.

2.2.2.18 Disposal of material at Hornsea Three is considered to be the most appropriate option for preserving the integrity of the local sediment transport system (including sandwave or sandbank systems within either the Hornsea Three array area or offshore cable corridor). Assuming that any material excavated via the use of a dredger is disposed of in close proximity to the dredge location, no sediment volume will be removed from the local sediment transport systems overall. The displaced material will be of the same or similar sediment type (mineralogy and grain size distribution) as the surrounding seabed (see section 4) and, following re-settlement, will be immediately available again for transport at the naturally occurring rate and direction, controlled entirely by natural processes. As such, the sediment will have immediately re-joined the natural sedimentary environment within the local area and so by definition is not 'lost from the system' due to the dredging/spoil disposal process. See volume 2, chapter 1: Marine Processes for further information.

2.2.2.19 The potential increases in suspended sediment concentrations and subsequent deposition on the seabed are not predicted to result 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 1: Marine Processes; volume 2, chapter 2: Benthic 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).

2.2.2.20 Drill arisings will be different to the material currently forming the seabed sediments in Hornsea Three Array Disposal Site 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 area and offshore cable 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.

2.2.2.21 The area affected by the disposed of spoil arising from seabed preparation and sandwave clearance has been calculated based on the maximum volume of sediment placed across the entire Hornsea Three array, assuming all this sediment is coarse material and therefore is placed on the seabed (i.e. is not dispersed through tidal currents; see volume 2, chapter 2: Benthic Ecology). The total area of seabed affected was calculated assuming a mound of uniform thickness of 0.5 m height. As detailed in volume 5, annex 1.1: Marine Processes Technical Report, the area of seabed affected by this scenario broadly aligns with the scenario of a cone shaped mound of 1.7 m maximum height.

2.2.2.22 It is unlikely that there will be any effect from the disposal mounds in the Hornsea Three Array Disposal Site or Hornsea Three Offshore Cable Corridor Disposal Site 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.

2.2.2.23 The future behaviour of any mounds that are formed on the seabed due to the disposal is difficult to predict, due to 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 Disposal Site, water depths vary from approximately -26.6 m lowest astronomical tide (LAT) to -72.7 mLAT (EGS, 2016), see volume 2, chapter 1: Marine Processes, for further details.

Hornsea Three Offshore Cable Corridor Disposal Site

3.1.1.2 The Hornsea Three Offshore Cable Corridor Disposal Site is fairly shallow throughout, with water depths typically less than -30 mLAT. In offshore areas, the shallowest water depths are associated with the crests of the Norfolk sandbanks which shallow to approximately -5 mLAT (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 Disposal Site ranges from +2.7 mLAT for Mean High Water Springs (MHWS) to +0.5 mLAT for Mean Low Water Springs (MLWS), 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 with a large contribution of waves from the south.

Hornsea Three Offshore Cable Corridor Disposal Site

3.1.2.2 Tidal elevation in the Hornsea Three array ranges from +5.4 mLAT for MHWS to +0.5 mLAT for 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 Disposal Site and the offshore part of the Hornsea Three Offshore Cable Corridor Disposal Site, 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 British Geological Survey (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 Disposal Site 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). See volume 2, chapter 1: Marine Processes, for further details.

Hornsea Three Offshore Cable Corridor Disposal Site

3.1.3.2 Along almost the entire Hornsea Three Offshore Cable Corridor Disposal Site, 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). See volume 2, chapter 1: Marine Processes, for further details.

3.1.4 Quaternary deposits

Hornsea Three Array Disposal Site

3.1.4.1 Glacial till deposits of the Bolders Bank Formation are present in the majority of the Hornsea Three array area. The Bolders Bank Formation is also characterised by a number of Botney Cut Channels that have eroded through the unit in the array area and more widely. Markham's Hole, located in the centre and east of the Hornsea Three array area, is a valley, partly infilled with up to around 60 m of Holocene sediments. On the southwest side of Markham's Hole, a subglacial tunnel valley of the Swarte Bank Formation is present. The Eem is present Above the Swarte Bank Formation. The Swarte Bank, Eem, Bolders Bank and Botney Cut Formations were also recorded in the northern section of Hornsea Three Array Disposal Site, towards the Outer Silver Pit. See volume 2, chapter 1: Marine Processes, for further details.

Hornsea Three Offshore Cable Corridor Disposal Site

3.1.4.2 The site specific data indicates that the shallow soils sequence of the Hornsea Three offshore cable corridor from the offshore terminus to the intertidal area is comprised of the following (see volume 5, annex 9.1: Marine Archaeological Technical Report for Kilometre Point (KP) locations):

- Holocene sediments overlying Bolders Bank Formation from the northeastern end of the Hornsea Three offshore cable corridor, with a short section of Holocene sediments overlying Botney Cut Formation to KP110, in areas which were surveyed;
- Holocene sediments overlying Bolders Bank Formation from KP110 to KP82.5;
- Holocene sediments overlying Swarte Bank Formation from KP 82.5 to KP61.75;

- Holocene sediments overlying Egmond Ground Formation from KP61.75 to KP57;
- Holocene sediments overlying Bolders Bank Formation from KP57 to KP45;
- Holocene sediments overlying Swarte Bank Formation from KP 45 to KP39; and
- Shallow Chalk with isolated patches of Quaternary Sediments from KP39 to the intertidal area in areas which were surveyed (see volume 5, annex 9.1: Marine Archaeological Technical Report).

3.1.5 Seabed sediments

Hornsea Three Array Disposal Site

3.1.5.1 The Hornsea Three Array Disposal Site 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 Disposal Site predominantly 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 Disposal Site, 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 Disposal Site, including the area of Markham's Triangle recommended Marine Conservation Zone (rMCZ; see Figure 1.1), tidal currents are the main influence on offshore sediment transport, rather than the wave climate due to water depth (see volume 2, chapter 1: Marine Processes). Existing regional-scale mapping suggests that bedload sediment transport is broadly to the northwest in the vicinity of the Hornsea Three Array Disposal Site (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 Hornsea Three Array Disposal 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 Disposal Site meets the Hornsea Three Array Disposal Site, 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 Disposal Site. 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 SAC (Figure 1.1). 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 Suspended sediment concentrations (SSC) within the Hornsea Three Array Disposal Site 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 Disposal Site, increasing to around 50 mg/l within inshore areas of the Hornsea Three Offshore Cable Corridor Disposal Site. 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. See volume 2, chapter 1: Marine Processes, for further details.

3.2 Biological characteristics

3.2.1 Benthic subtidal ecology

3.2.1.1 Across much of Hornsea Three 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). The biotopes have been grouped into broad habitat/community types according to the results of the statistical analyses described in volume 5, annex 2.1: Benthic Ecology Technical Report. Habitats with similar physical, biological characteristics (including species complement and richness/diversity) as well as conservation status/interest have been grouped together for the purposes of the EIA. Consideration was also given to the inherent sensitivities of different habitats in assigning the groupings presented in paragraphs 3.2.1.2 to 3.2.1.5, such that habitats and species with similar vulnerability and recoverability, often because of similar broad sediment types and species complements, were grouped together.

Hornsea Three Array Disposal Site

3.2.1.2 The following describes the broad habitat types, the representative Valued Ecological Receptors (VERs) and the biotopes that these encompass, recorded within the Hornsea Three Array Disposal Site:

- Sandy sediments with low infaunal diversity and sparse epibenthic communities (Habitat A and 'Subtidal Sand', the latter representing the broad scale habitat feature 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 Disposal Site;
- Brittlestar dominated communities in deep muddy sands (Habitat B) characterised by AfilMysAnit[7]. This habitat was recorded in the central and northern sections of the Hornsea Three Array Disposal Site; and
- Coarse and mixed sediments with moderate to high infaunal diversity and scour-tolerant epibenthic communities (Habitat C and 'Subtidal Coarse Sediments', the latter representing the broad scale habitat feature 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 northeastern parts of the Hornsea Three Array Disposal Site.

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

[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.
[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.

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 Disposal Site:

- Sandy sediments with low infaunal diversity and sparse epibenthic communities (Habitat A and 'Subtidal Sand', the latter representing the broad scale habitat feature 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 Disposal Site;
- Brittlestar dominated communities in deep muddy sands (Habitat B) characterised by AfilMysAnit[14]. This habitat was recorded in two isolated areas in the central and northern sections of the Hornsea Three Offshore Cable Corridor Disposal Site:
- Coarse and mixed sediments with moderate to high infaunal diversity and scour-tolerant epibenthic communities (Habitat C and 'Subtidal Coarse Sediments', the latter representing the broad scale habitat feature within an MCZ or rMCZ) are characterised by MedLumVen/EpusOborApri, MedLumVen, MoeVen, MysThyMx, PoVen, ScupHyd and FluHyd. This habitat was mostly recorded in the very offshore and inshore extents of the Hornsea Three Offshore Cable Corridor Disposal Site; and
- Mixed sediments with high infaunal and epifaunal diversity (Habitat D and 'Subtidal Mixed Sediments', the latter representing the broad scale habitat feature within an MCZ or rMCZ) are characterised by SspiMx[15]. This habitat was recorded along much of the Hornsea Three Offshore Cable Corridor Disposal Site.

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

- Potential Annex I reef outside an SAC/SCI with high infaunal and epifaunal diversity (Habitat E) was recorded in a small in northern section of the Hornsea Three Offshore Cable Corridor Disposal Site;
- Annex I 'Sandbanks which are slightly covered by seawater all the time' within an SAC occurs in the Hornsea Three Offshore Cable Corridor Disposal Site which coincides with the North Norfolk and Saturn Reef SAC;
- Annex I reefs (biogenic reefs, circalittoral rock and stony reefs) within an SAC has the potential to occur in the part of the Hornsea Three Offshore Cable Corridor Disposal Site which coincides with the North Norfolk and Saturn Reef SAC (although noting that non was recorded during the Hornsea Three site specific surveys);
- Subtidal Chalk reefs occurs in the inshore area relatively close to the Hornsea Three Offshore Cable Corridor Disposal Site, within the Cromer Shoal Chalk Beds MCZ; and
- Peat and Clay Exposures occurs in the inshore area relatively close to the Hornsea Three Offshore Cable Corridor Disposal Site, 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 Ecology.

3.2.2 Fish and shellfish ecology

3.2.2.1 Fish and shellfish VERs identified as being important in the Hornsea Three fish and shellfish study area included eight demersal fish species, three pelagic fish species, sandeel, eight migratory fish species and four key 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 Disposal Site 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 Disposal Site.

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 Disposal Site 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.

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

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

Hornsea Three Offshore Cable Corridor Disposal Site

3.2.2.6 The Hornsea Three Offshore Cable Corridor Disposal Site 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 Hornsea Three Offshore Cable Corridor Disposal Site, 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 Disposal Site (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 VERs in the Hornsea Three Array Disposal Site were 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 Disposal Site, as described in paragraph 3.2.3.1, are also relevant within the Hornsea Three Offshore Cable Corridor Disposal Site; 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 Disposal Site coincides with Markham's Triangle rMCZ (see Figure 1.1 and volume 2, chapter 2: Benthic Ecology). This site is proposed for three broadscale habitats: Subtidal Coarse Sediment, Subtidal Sand and Mixed Sediments. The shallow sandy sediments within Markham's Triangle rMCZ 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), although these are not proposed for designation as part of the rMCZ.

3.2.4.2 With the exception of the Southern North Sea candidate Special Area of Conservation (cSAC) which is designated for the harbour porpoise (see Figure 1.1 and volume 5 annex 4.1: Marine Mammal Technical Report), the Hornsea Three Array Disposal Site does not lie within the boundary of any international designated site of nature conservation (e.g. Special Protection Area (SPA), Ramsar site or Site of Special Scientific Interest (SSSI)).

3.2.4.3 The closest designated site to the Hornsea Three array is North Norfolk Sandbanks and Saturn Reef SAC, which is located 9.4 km south of the Hornsea Three array (Figure 1.1). Klaverbank SCI lies in Dutch waters 10.5 km to the east of Hornsea Three array (see volume 2, chapter 2: Benthic Ecology). Far-field impacts (increased SSC and deposition; see volume 2, chapter 2: Benthic Ecology) via sediment plumes arising from disposal activities are unlikely to reach the North Norfolk Sandbanks and Saturn Reef SAC. Elevations in SSC above background levels at distances of hundreds of metres to a few kilometres are predicted to be relatively low (i.e. less than ~20 mg/l) and within the range of natural variability and after 24 hours, elevations in SSC are predicted to typically be less than 5 mg/l. Therefore, by the time a plume might reach the North Norfolk Sandbanks and Saturn Reef SAC or the Klaverbank SCI, the SSC and any associated deposition are predicted to be at background levels, and will therefore have negligible effects on benthic receptors in this site.

3.2.4.4 Klaverbank SCI site was screened out of the impact assessment in volume 2, chapter 2: Benthic Ecology on the basis that qualifying features are unlikely to be impacted by Hornsea Three (see also volume 4, annex 5.3: Transboundary Screening for further detail).

Hornsea Three Offshore Cable Corridor Disposal Site

3.2.4.5 The Hornsea Three Offshore Cable Corridor Disposal Site coincides with the North Norfolk Sandbanks and Saturn Reef SAC (Figure 1.1). The North Norfolk Sandbanks and Saturn Reef SAC 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. The entire SAC is assigned to the Annex I sandbank habitat, as it is designated and viewed as one integrated sandbank system (JNCC, 2010).

3.2.4.6 The very inshore section of the Hornsea Three Offshore Cable Corridor Disposal Site coincides with the Cromer Shoal Chalk Beds MCZ and the Wash and North Norfolk Coast SAC sites (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 Biodiversity Action Plan (BAP) priority habitats) and broadscale habitats including Subtidal Sand (see section 3.2.1). The Wash and North Norfolk Coast SAC is designated for a number of intertidal and subtidal features, although the only features which potentially coincide with the Hornsea Three Offshore Cable Corridor Disposal Site are the Annex I habitats 'sandbanks which are slightly covered by sea water all the time' and 'reefs'; see volume 2, chapter 2: Benthic Ecology.

3.2.4.7 Sections of the Hornsea Three Offshore Cable Corridor Disposal Site coincide with the Southern North Sea cSAC which is designated for the harbour porpoise; see Figure 1.1 and 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, followed by a significant increase in 2016. 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 €385,000 from 36F2. Landings of *Nephrops* from 36F2 have remained fairly consistent across the five-year period from 2012 to 2016.

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 Hornsea Three Offshore Cable Corridor Disposal Site extends over an area which includes significant fishing grounds for whelk, lobster and brown crab, with an average annual first sales value of £1.6 million.. The commercial fishery within the Hornsea Three Offshore Cable Corridor Disposal Site 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 Disposal Site. There are two out of service cables crossing the Hornsea Three Array Disposal Site, 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 Disposal Site.

3.3.2.2 There are no pipelines located within the Hornsea Three Array Disposal Site or within 500 m of the Hornsea Three Array Disposal Site, however the Topaz to Schooner gas export and methanol umbilical pipelines are located within 1 km of the Hornsea Three Array Disposal Site, 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 Disposal Site, with North Sea Offshore, Stratos and Weybourne to Esbjerg making landfall close to the Hornsea Three landfall. The Hornsea Three Offshore Cable Corridor Disposal Site also crosses the export cables for the Dudgeon and Sheringham Shoal offshore wind farms in the nearshore environment with the Hornsea Three landfall located in close proximity to the landfalls for these other 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 Disposal Site, and a further two active pipelines within 1 km of the Offshore Cable Corridor Disposal Site. 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 nine licenced blocks coincident with the Hornsea Three Array Disposal Site operated by Spirit Energy North Sea Ltd (formerly Centrica North Sea Ltd) and Spirit Energy Resources Ltd (formerly Centrica Resources Ltd), INEOS and Shell. There are eight unlicensed blocks coincident with the Hornsea Three Array Disposal Site. There are an additional three blocks (49/1a operated by INEOS, 49/10a operated by Spirit Energy Resources and 49/10e unlicensed) within 1 km of the Hornsea Three Array Disposal Site. All of the unlicensed acreage has been offered in the 30th licence round.

3.3.3.2 There are no completed or drilling wells within the Hornsea Three Array Disposal Site and consultation has advised that well 49/08c-4 formerly operated by Wintershall is plugged and abandoned. There is one suspended well within 1 km of the Hornsea Three Array Disposal Site. See volume 2, chapter 11: Infrastructure and Other Users for further information.

Hornsea Three Offshore Cable Corridor Disposal Site

3.3.3.3 There are currently ten licenced blocks coincident with the Hornsea Three Offshore Cable Corridor Disposal Site, operated by Shell, INEOS, Independent Oil and Gas and ConocoPhillips, with one of these blocks (48/24b operated by Independent Oil and Gas) coinciding with the offshore HVAC booster station search area. There are 14 unlicensed blocks within the Hornsea Three Offshore Cable Corridor Disposal Site, with one of these blocks (48/24a) coinciding with the offshore HVAC booster station search area. There is one additional licenced block (49/16a licenced to ConocoPhillips) within 1 km of the Hornsea Three Offshore Cable Corridor Disposal Site. All of the unlicensed acreage has been offered in the 30th licence round.

3.3.3.4 There are no completed, drilling or suspended wells within the Hornsea Three Offshore Cable Corridor Disposal Site however there are four completed wells within 1 km of the Hornsea Three Offshore Cable Corridor Disposal Site.

3.3.3.5 Unlicensed blocks 49/2, 49/7 and 49/8 overlap with both the Hornsea Three Array Disposal Site and the Hornsea Three Offshore Cable Corridor Disposal Site (volume 2, chapter 11: Infrastructure and Other Users).

3.3.3.6 See volume 2, chapter 11: Infrastructure and Other Users for further information.

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 Disposal Site; 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 Disposal Site, 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 169 live wrecks and 79 dead wrecks within the regional marine archaeology study area. Of these, a total of 12 lie within the Hornsea Three Array Disposal Site (two live and two dead wrecks, and one live and seven dead obstructions). 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 259 contacts of archaeological potential have been recognised within the Hornsea Three Array Disposal Site and Hornsea Three Offshore Cable Corridor Disposal Site. Of these 123 were identified within the Hornsea Three Array Disposal Site. In addition, a total of 31 magnetic anomalies with an intensity >100 nT with no strong correlating seabed contact were identified across the Hornsea Three Array Disposal Site. A total of four magnetic anomalies of greater than 500 nT are located within the Hornsea Three Array Disposal Site, 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 Disposal Site. Several such features were also identified in the area traversed by the Hornsea Three Offshore Cable Corridor Disposal Site. 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 14 wrecks lie within the Hornsea Three Offshore Cable Corridor Disposal Site (eight live and four dead wrecks, and one live and one dead obstructions). The National Record of the Historic Environment (NRHE) lists 126 recorded positions in the regional marine archaeology study area, of these, 19 are located in the Hornsea Three Offshore Cable Corridor Disposal Site (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 Disposal Site (including temporary working areas). Together these Named Locations in the regional marine archaeology study area, contain records of 449 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 136 contacts of archaeological potential have been recognised within the Hornsea Three Offshore Cable Corridor Disposal Site (not including the temporary working areas). In addition, a total of 96 magnetic anomalies with an intensity >100 nT with no strong correlating seabed contact were identified across the Hornsea Three Offshore Cable Corridor Disposal Site (not including the temporary working areas). A total of eight magnetic anomalies of greater than 500 nT are located within the Hornsea Three Offshore Cable Corridor Disposal Site, 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 zonal studies and from the site specific surveys and characterisations undertaken for Hornsea Three. It was therefore proposed that the characterisation of physical, chemical and biological properties of the sediments within the Hornsea Three array area (as presented in the benthic ecology assessment; see volume 2, chapter 2: Benthic ecology) be completed using a combination of Hornsea Three site specific survey data (i.e. geophysical data, sediment sampling and seabed imagery) alongside desktop data and information sources, and historic survey data collected as part of the characterisations of the Hornsea Project One and Hornsea Project Two offshore wind farms and the former Hornsea Zone (see Table 2.1). Over a series of Export Working Group (EWG) meetings undertaken between June 2016 and publication of this Environmental Statement, it was agreed that this approach (further detailed in the sections below) was appropriate and sufficient for the purposes of characterising these aspects of Hornsea Three (see volume 2, chapter 2: Benthic Ecology).

4.1.1.2 The baseline characterisation of the Hornsea Three offshore cable corridor within the Environmental Statement was informed by several Hornsea Three site-specific surveys completed in 2016 and 2017 together with desktop information from third-party surveys, including surveys targeting areas within and near designated sites.. The site-specific surveys of the Hornsea Three offshore cable corridor comprised geophysical data acquisition along the corridor, and in the nearshore area around the Cromer Shoal Chalk Beds MCZ, benthic sampling and drop-down video (DDV) surveys, to establish a robust and up-to-date characterisation of the baseline environment in the Hornsea Three offshore cable corridor (Table 2.1). The site-specific Hornsea Three offshore cable corridor surveys were discussed and agreed through the Marine Processes, Benthic Ecology and Fish and Shellfish EWG and the results have been used to update the Hornsea Three benthic ecology baseline characterisation (volume 2, chapter 2: Benthic Ecology).

4.1.1.3 Survey data collected across Hornsea Three array area and the offshore cable corridor ensured 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. A summary of datasets relevant to seabed sediments in Hornsea Three array area and the offshore cable corridor is provided in Table 2.1, along with a cross-reference to chapters and/or annexes of the Environmental Statement where additional detail on these surveys is provided.

4.1.2 Key characteristics of the material to be disposed of within the Hornsea Three Array Disposal Site

4.1.2.1 As outlined in paragraphs 2.1.3.1 to 2.1.3.7 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 arising from drilling activities associated with piled foundation installation, sandwave clearance prior to cable installation and material excavated from the HDD exit pits.

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 subtidal seabed level and down to a maximum of 6 m depth beneath the existing intertidal zone at the HDD pits), 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 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 Disposal Site 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.

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 4.1.

Table 4.1: 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	0.70 ± 1.13	95.20 ± 7.26	4.09 ± 7.39
Coarse sediment	31.80 ± 17.63	66.16 ± 17.74	1.93 ± 1.84
Mixed sediment	37.61 ± 15.33	52.55 ± 13.59	9.84 ± 4.01

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, sandwave clearance works and HDD pit excavation 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 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 Disposal Site 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, sediment chemistry grab sampling was undertaken at 63 stations across the central section of the former Hornsea Zone and the Hornsea Three Offshore Cable Corridor Disposal Site. The data from these sampling events, which are presented in full in volume 5, annex 2.1: Benthic Ecology Technical Report, have been used to inform the sediment conditions at the Hornsea Three Array Disposal Site and Hornsea Three Offshore Cable Corridor Disposal Site.

Metals analysis

4.1.2.12 The results of the heavy metals analysis for the subtidal samples revealed that, except for arsenic, cadmium, mercury and nickel, concentrations of all metals within sediments were present at concentrations below the Cefas Action Level 1 (AL1) and the Canadian Threshold Effect Levels (TEL), and were therefore at levels below which biological effects in benthic organisms would be expected. In general contaminant levels in dredged material below Action level 1 are not considered to be of concern and are unlikely to influence a dredging disposal licencing decision. The TEL is the minimal effect range within which adverse effects rarely occur.

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 (note this study area fully encompasses the Hornsea Three Array Disposal Site and the Hornsea Three Offshore Cable Corridor Disposal Site; see volume 2, chapter 2: Benthic Ecology), including at all eight sampling locations along the Hornsea Three offshore cable corridor and at a station on the northwestern margin of the Hornsea Three Array Disposal Site. Of the sites with elevated levels of arsenic, there were five recorded concentrations above the Canadian Probable Effect Level (PEL) at levels where a toxicity effect would be evident, though these were not located within Hornsea Three. Levels of arsenic exceeded OSPAR Background Assessment Concentration (BAC) of 25 mg/kg in sediments at 20 sites within the wider Hornsea Three benthic ecology study area, although within the Hornsea Three Offshore Cable Corridor Disposal Site arsenic concentrations were within the BAC at all locations. Any direct comparisons between the site specific data and OSPAR BAC should be made with caution as Hornsea Three data were not normalised to 5% aluminium (aluminium was not part of the heavy metal suite analysed). Arsenic exceeded the Cefas AL1 of 20 mg/kg at 24 sites including three on the Hornsea Three Offshore Cable Corridor Disposal Site, however all sites were well within 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) and therefore are considered unlikely to represent excessive levels for the region.

4.1.2.15 The level of cadmium marginally exceeded the Cefas AL1 at two sites within the Hornsea Three benthic ecology study area (outside Hornsea Three) but were well within the Cefas AL2, the Canadian PEL and the OSPAR BAC (noting concentrations were not normalised to 5% aluminium in the absence of aluminium results; see paragraph 4.1.2.13). The concentration of nickel marginally exceeded the Canadian TEL (15.9 mg/kg) at one site in the central former Hornsea Zone and the concentration of mercury exceeded the Canadian TEL (0.13 mg/kg) at one site in the cable fan of the Hornsea Three Offshore Cable Corridor Disposal Site, though both concentrations were below the respective Cefas AL1 thresholds for those metals.

4.1.2.16 Levels of mercury were within the OSPAR BAC of 0.07 mg/kg at all sampling locations, with the exception of one within the cable fan at the northern end of the Hornsea Three Offshore Cable Corridor Disposal Site where 0.23 mg/kg was recorded (noting that any direct comparisons with the OSPAR BAC should be made with caution as the site specific sediment chemistry data were not normalised to 5% aluminium; see paragraph 4.1.2.13). However, the level of mercury at that sampling location was below the Cefas AL1 threshold and, as outlined in paragraph 4.1.2.12, dredged material with this concentration would typically be considered suitable for disposal at sea.

Organotins

4.1.2.17 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

4.1.2.18 All recorded TPH values in the Hornsea Three benthic study area were well below the Cefas AL1 of 100 mg/kg. Polycyclic aromatic hydrocarbons (PAHs) at most sites were within the range typical for sediments in the North Sea and all single PAH (including United States Environmental Protection Agency (US EPA) 16 listed PAHs) levels at all sites throughout the Hornsea Three benthic ecology study area were well below the Cefas AL1 concentration for individual PAHs and the Canadian TELs. The PAH Dibenzothiophene was recorded at concentrations up to 0.006 mg/kg in Hornsea Three and naphthalene was recorded at up to 0.03 mg/kg, which were both well within the Cefas AL1 concentrations for individual PAHs. Therefore, concentrations of EPA 16 listed PAHs, dibenzothiophene and naphthalene were recorded at levels that would typically be considered suitable for disposal at sea.

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 Hornsea Three Offshore Cable Corridor Disposal Site

4.1.3.1 As outlined in paragraphs 2.1.3.1 to 2.1.3.7, the source of any sediment disposed of within the Hornsea Three Offshore Cable Corridor Disposal Site 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 Hornsea Three Offshore Cable Corridor Disposal Site and material excavated from the HDD exit pits. Therefore, the materials potentially disposed of in the Hornsea Three Offshore Cable Corridor Disposal Site 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 Ecology and chapter 3: Fish and Shellfish Ecology.

Physical characteristics

Dredged material

4.1.3.3 The Hornsea Three Offshore Cable Corridor Disposal Site generally comprises gravels and mixed sediments with varying proportions of mud. The dominant sediment types identified from the PSA samples in the Hornsea Three Offshore Cable Corridor Disposal Site 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 Hornsea Three Offshore Cable Corridor Disposal Site. 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 The chemical characteristics of the seabed sediments likely to be dredged in the Hornsea Three Offshore Cable Corridor Disposal Site as part of seabed preparation prior to box GBF installation for the offshore HVAC booster stations and sandwave clearance prior to cable installation, are described in paragraph 4.1.2.12 to paragraph 4.1.2.18.

Biological characteristics

4.1.3.7 The biological characteristics of the seabed sediments likely to be dredged in the Hornsea Three Offshore Cable Corridor Disposal Site as part of seabed preparation prior to GBF installation for the offshore HVAC booster stations 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 2.1.3.1 to 2.1.3.7, 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 trailing suction hopper dredger and/or static dredger, as used to extract sand and gravel for the marine aggregates industry. 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.

4.2.2.2 The shape and thickness of the seabed deposit resulting from the release of material from the dredger at the water surface cannot be predicted accurately in advance and is likely to vary. A range of possible configurations of area and thickness are presented in volume 5, annex 1.1: Marine Processes Technical Annex. From this range an average thickness of 0.5 m has been considered in the benthic ecology assessment (see volume 2, chapter 2: Benthic Ecology). The area of seabed affected by this scenario broadly aligns with the scenario of a cone shaped mound of 1.7 m maximum height. In practice, the deposit may comprise several individual releases from multiple dredging cycles and the deposits are likely to be relatively thicker, with a correspondingly smaller area of effect.

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 this Site Characterisation provides an overview of the key findings of the Hornsea Three EIA, as reported in the Environmental Statement, which are relevant to the disposal of dredged and/or drilled material *in situ* within the Hornsea Three Array Disposal Site and the Hornsea Three Offshore Cable Corridor Disposal Site. Two physical receptors have 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 volume 2, 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 Environmental Statement for Hornsea Three provides detailed 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 Environmental Statement. The relevant section of the Environmental Statement, 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 Environmental Statement	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).
Changes to hydrodynamics, sediment transport and beach morphology at the landfall.	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 and sandwave clearance), spud-can leg impacts from jack-up operations and seabed preparation works for GBFs, may affect benthic ecology.	Volume 2, chapter 2: Benthic Ecology	Minor (Habitats A to E, ocean quahog, Annex I sandbanks in North Norfolk Sandbanks and Saturn Reef SAC and The Wash and North Norfolk Coast SAC; Subtidal Coarse Sediments, Subtidal sand and Subtidal Mixed Sediments in Markham's Triangle rMCZ and Subtidal sand in Cromer Shoal Chalk Beds MCZ).	Low to medium (Habitats A to E, ocean quahog, Annex I sandbanks in North Norfolk Sandbanks and Saturn Reef SAC and The Wash and North Norfolk Coast SAC; Subtidal Coarse Sediments, Subtidal sand and Subtidal Mixed Sediments in Markham's Triangle rMCZ and Subtidal sand in Cromer Shoal Chalk Beds MCZ). High (ocean quahog *A. islandica*).	**Minor** adverse (not significant in EIA terms; Habitats A to E, ocean quahog, Annex I sandbanks in North Norfolk Sandbanks and Saturn Reef SAC and The Wash and North Norfolk Coast SAC; Subtidal Coarse Sediments, Subtidal Sand and Subtidal Mixed Sediments in Markham's Triangle rMCZ; and subtidal sand in Cromer Shoal Chalk Beds MCZ).
Temporary increases in suspended sediment concentrations (SSC) 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 Ecology	Minor (Habitats A to E, ocean quahog, Annex I sandbanks and Annex I Sabellaria reefs in North Norfolk Sandbanks and Saturn Reef SAC and the Wash and North Norfolk Coast SAC; Subtidal Coarse Sediments, Subtidal Sand and Subtidal Mixed Sediments in Cromer Shoal Chalk Beds MCZ and Markham's Triangle rMCZ); Subtidal Chalk reef and Peat and Clay exposures in Cromer Shoal Chalk Beds MCZ).	Low (Habitats A to E, ocean quahog, Annex I sandbanks and Annex Sabellaria I reefs in North Norfolk Sandbanks and Saturn Reef SAC and the Wash and North Norfolk Coast SAC; Subtidal Coarse Sediments, Subtidal Sand and Subtidal Mixed Sediments in Cromer Shoal Chalk Beds MCZ and Markham's Triangle rMCZ). Medium (Subtidal Chalk reef and Peat and Clay Exposures in Cromer Shoal Chalk Beds MCZ).	**Minor** adverse (not significant in EIA terms; Habitats A to E, ocean quahog, Annex I sandbanks and Annex I Sabellaria reefs in North Norfolk Sandbanks and Saturn Reef SAC and the Wash and North Norfolk Coast SAC; Subtidal Coarse Sediments, Subtidal Sand and Subtidal Mixed Sediments in Cromer Shoal Chalk Beds MCZ and Markham's Triangle rMCZ; Subtidal Chalk reef and Peat and Clay Exposures in Cromer Shoal Chalk Beds MCZ).
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 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).
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 adverse (not significant in EIA terms).

Potential impact	Relevant section of Environmental Statement	Magnitude of impact	Sensitivity of receptor	Significance of effect including designed in measures
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** adverse (not significant in EIA terms).
Birds				
Indirect effects, such as changes in habitat or abundance and distribution of prey.	Volume 2, chapter 5: Offshore Ornithology	No change (common scoter) Negligible (red-throated diver, fulmar, gannet, kittiwake, puffin, razorbill, guillemot, lesser black-backed gull, great black-backed gull) Medium (sandwich tern)	Low (gannet, lesser black-backed gull, great black-backed gull) Low to medium (kittiwake, razorbill, guillemot). Medium (fulmar) Medium to high (puffin). High (common scoter, red-throated diver)	**Negligible** (common scoter, puffin; not significant in EIA terms). **Negligible** or **minor** adverse (fulmar, gannet, kittiwake, razorbill, guillemot, sandwich tern, lesser black-backed gull, great black-backed gull; not significant in EIA terms). **Minor** adverse (red-throated diver; 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** (not significant in EIA terms).

6. Conclusions

6.1.1.1 This document represents the findings of the site characterisation for the proposed Hornsea Three Array Disposal Site and the Hornsea Three Offshore Cable Corridor Disposal Site as required by the MMO. This site characterisation, alongside 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 the detailed information required for site characterisation to support a disposal application is contained within the Hornsea Three Environmental Statement, 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 Environmental Statement.

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 trailing suction hopper dredger as part of seabed preparation works prior to GBF installation and sandwave clearance prior to the installation of cables within the Hornsea Three array area 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 trailing suction hopper dredger has been considered in this Site Characterisation. Additionally material from up to four offshore HVAC booster station will be disposed in the Hornsea Three Offshore Cable Corridor Disposal Site as described above, in paragraph 6.1.1.3 as well as material from the excavation of HDD exit pits in the nearshore.

6.1.1.5 Within the boundaries of the Hornsea Three Array Disposal Site, an upper estimate of 2,289,137 m^3 of material is proposed to be disposed of approximately 500 m from the seabed preparation sites 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 1,467,956 m^3 of material is proposed to be disposed of approximately 500 m from the seabed preparation sites.

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 also comprise areas of coarse and mixed sediments.

6.1.1.7 Sediment chemistry survey data indicated 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. The Hornsea Three Array Disposal Site is dominated by three broad habitat types; sandy sediments with low infaunal diversity and sparse epibenthic communities, brittlestar dominated communities in deep muddy sands and coarse and mixed sediments with moderate to high infaunal diversity and scour-tolerant epibenthic communities. The Hornsea Three Offshore Cable Corridor Disposal Site is dominated by four broad habitat types: sandy sediments with low infaunal diversity and sparse epibenthic communities, brittlestar dominated communities in deep muddy sands, coarse and mixed sediments with moderate to high infaunal diversity and scour-tolerant epibenthic communities and mixed sediments with high infaunal and epifaunal diversity.

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 Environmental Statement. 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 Environmental Statement on the impact of these activities on physical, biological and human receptors, no significant adverse impacts are predicted.

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