Hornsea Project Four: Preliminary Environmental Information Report (PEIR)

Volume 2,
Chapter 2: Benthic and Intertidal Ecology

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Glossary

Term	Definition
Array cables (inter-array cables)	Cables which connect the wind turbines to each other and to the offshore substation(s).
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	A region of habitat associated with a particular ecological community.
Commitment	A term used interchangeably with mitigation. Commitments are embedded mitigation measures. Commitments are either primary (design) or tertiary (Inherent) and embedded within the assessment at the relevant point in the Environmental Impact Assessment (EIA) (e.g. at Scoping or Preliminary Environmental Information Report (PEIR)). The purpose of Commitments are to reduce and/or eliminate Likely Significant Effects (LSEs), in EIA terms.
Cumulative effects	The combined effect of Hornsea Four in combination with the effects from a number of different projects, on the same single receptor/resource. Cumulative impacts are those that result from changes caused by other past, present or reasonably foreseeable actions together with Hornsea Four.
Drop Down Video (DDV)	A survey method in which imagery of habitat is collected, used predominantly to survey marine environments.
Design Envelope	A description of the range of possible elements that make up the Hornsea Four design options under consideration, as set out in detail in the project description. This envelope is used to define Hornsea Four for Environmental Impact Assessment (EIA) purposes when the exact engineering parameters are not yet known. This is also often referred to as the "Rochdale Envelope" approach.
Development Consent Order (DCO)	An order made under the Planning Act 2008 granting development consent for one or more Nationally Significant Infrastructure Projects (NSIP).
Effect	Term used to express the consequence of an impact. The significance of an effect is determined by correlating the magnitude of the impact with the importance, or sensitivity, of the receptor or resource in accordance with defined significance criteria.
Environmental Impact Assessment (EIA)	A statutory process by which certain planned projects must be assessed before a formal decision to proceed can be made. It involves the collection and consideration of environmental information, which fulfils the assessment requirements of the EIA Directive and EIA Regulations, including the publication of an Environmental Impact Assessment (EIA) Report.
EUNiS habitat classification	A pan-European system which facilitates the harmonised description and classification of all types of habitat, through the use of criteria for habitat identification.
Export cables	Cables that transfer power from the offshore substation(s) or the converter station(s) to shore.
Export cable corridor (ECC)	The specific corridor of seabed (seaward of Mean High Water Springs (MHWS)) and land (landward of MHWS) from the Hornsea Four array area to the Creyke Beck National Grid substation, within which the export cables will be located.
Geophysical	Relating to the physics of the earth.
Holocene	The Holocene is the current geological epoch. It began approximately 11,650 calibrated years before present, after the last glacial period, which concluded with the Holocene glacial retreat. The Holocene and the preceding Pleistocene together form the Quaternary period.

Term	Definition
Hornsea Four	The proposed Hornsea Project Four offshore wind farm project; the term covers all elements within the DCO (i.e. both the offshore and onshore components).
HVAC booster station(s)	Offshore HVAC booster station(s) are required in HVAC transmission systems only; they are not required in HVDC transmission systems. If required for Hornsea Four, they would be located entirely offshore.
Interconnector cables	Cables that may be required to interconnect the offshore substations in order to provide redundancy in the case of cable failure elsewhere, or to connect to the offshore accommodation platforms in order to provide power for operation.
Intertidal	The area of the shoreline which is covered at high tide and uncovered at low tide.
Maximum design scenario (MDS)	The maximum design parameters of each Hornsea Four asset (both on and offshore) considered to be a worst case for any given assessment.
Megafauna	Large animals of a particular region, habitat or geological period.
Megaripples	An extensive undulation of the surface of a sandy beach or seabed, typically tens of meters from crest to crest and tens of centimetres in height.
Mini-hamon grab	Comprises of a stainless-steel box shaped sampling scoop mounted in a triangular frame, ideal for sampling seabed sediment's, as well as sampling for benthic macrofauna.
Mitigation	A term used interchangeably with Commitment(s) by Hornsea Four. Mitigation measures (Commitments) are embedded within the assessment at the relevant point in the EIA (e.g. at Scoping or PEIR).
Mollusca	Phylum of invertebrates which have a soft unsegmented body, commonly protected by a calcareous shell.
Offshore accommodation platform(s)	Used to accommodate multiple O&M staff for a number of weeks at a time and to allow spares and tools to be stored within the array area.
Offshore substation(s)	One or more offshore substations to convert the power to higher voltages and/or to HVDC and transmit this power to shore.
Planning Inspectorate (PINS)	The agency responsible for operating the planning process for Nationally Significant Infrastructure Projects (NSIPs).
RIAA	A process which helps determine likely significant effects and (where appropriate) assesses adverse impacts on the integrity of European conservation sites and Ramsar sites. The process consists of up to four stages of assessment: screening, appropriate assessment, assessment of alternative solutions and assessment of imperative reasons of over-riding public interest (IROPI).
SACFOR	An abundance scale used for both littoral and sublittoral taxa from 1990 onwards.
Scour and cable protection	In order to prevent seabed scour around foundation structures and cables, cable protection may be placed on the seabed to protect from current and wave action.
Side Scan Sonar (SSS)	Side-imaging sonar used to create an image of the seafloor.
Single-beam and multi-beam echo sounders (SBES and MBES)	A type of sonar which transmits soundwaves, using the time taken between emission and return to establish a depth. This can be done using singular or multiple beams.
Subtidal	The region of shallow waters which are below the level of low tide.
Wind turbine	All of the components of a wind turbine, including the tower, nacelle, and rotor
Wind turbine foundation	The wind turbines are attached to the seabed with a foundation structure typically fabricated from steel or concrete.

Acronyms

Acronym	Definition
BAP	Biodiversity Action Pan
CEA	Cumulative Effects Assessment
DBT	Dibenzothiophene
DCO	Development Consent Order
DMRB	Design Manual for Roads and Bridges
DTI	Department of Trade and Industry
DDV	Drop Down Video
DECC	Department of Energy and Climate Change
ECC	Export Cable Corridor
EIA	Environmental Impact Assessment
EIA Report	Environmental Impact Assessment Report (note that the new EIA Directive refers to an EIA Report and not an Environmental Statement)
ERL	Effects Range Low
ERM	Effects Range Median
EUNIS	European Nature Information System
FOCI	Feature of Conservation Importance
GES	Good Environmental Status
JNCC	Joint Nature Conservation Committee
LOD	Limit of Detection
MarLIN	Marine Life Information Network
MarESA	Marine Evidence based Sensitivity Assessment
MBES	Multi-beam echo sounders
MCA	Maritime and Coastguard Agency
MCAA	Marine and Coastal Access Act
MCZ	Marine Conservation Zone
MDS	Maximum Design Scenario
MHWS	Mean High Water Spring
MLWS	Mean Low Water Spring
MMO	Marine Management Organisation
MNCR	Marine Nature Conservation Review
MSFD	Marine Strategy Framework Directive
NERC	Natural Environment Research Council
NPD	Naphthalene, Phenanthrene and Dibenzothiophene
NPS	National Policy Statement
NSIP	Nationally Significant Infrastructure Project
OSPAR	The Convention for the Protection of the Marine Environment of the North-East Atlantic
OSS	Offshore Substation
OWF	Offshore Wind Farm
PAH	Polycyclic Aromatic Hydrocarbons
PEIR	Preliminary Environmental Information Report
PINS	Planning Inspectorate
PEMMP	Project Environmental Management and Mitigation Plan

Acronym	Definition
PSA	Particle Size Analysis
RIAA	Report to Inform Appropriate Assessment
SAC	Special Area of Conservation
SBES	Single-beam Echo Sounders
SoS	Secretary of State
SPA	Special Protected Area
SSC	Suspended Sediment Concentrations
SSS	Side Scan Sonar
SSSI	Sites of Special Scientific Interest
TBT	Tributylin
WTG	Wind Turbine Generator
VER	Valued Ecological Receptor

Units

Unit	Definition
g	gram
m	Meter
m^2	Square metre
km	Kilometre
km^2	Square kilometre

2.1 Introduction

2.1.1.1 This chapter of the Preliminary Environmental Information Report (PEIR) presents the results of the Environmental Impact Assessment (EIA) for the potential impacts of the Hornsea Project Four offshore wind farm (hereafter Hornsea Four) on benthic and intertidal ecology. Specifically, this chapter considers the potential impact of Hornsea Four seaward of Mean High Water Springs (MHWS) during its construction, operation and maintenance, and decommissioning phases.

2.1.1.2 Ørsted Hornsea Project Four Limited (the Applicant) is proposing to develop Hornsea Four. Hornsea Four will be located approximately 65 km from the East Riding of Yorkshire in the Southern North Sea and will be the fourth project to be developed in the former Hornsea Zone (please see **Volume 1, Chapter 1: Introduction** for further details on the former Hornsea Zone). Hornsea Four will include both offshore and onshore infrastructure including an offshore generating station (wind farm), export cables to landfall, and connection to the electricity transmission network (please see **Volume 1, Chapter 4: Project Description** for full details on the Project Design).

2.1.1.3 This chapter presents the results of an assessment of the potential impacts on benthic and intertidal ecology arising from the construction, operation and decommissioning of the relevant offshore components (namely the Hornsea Four array, offshore export cable corridor (ECC) and the export cable landfall site) of Hornsea Four.

2.1.1.4 This assessment is based on the characteristics of the development as currently proposed (please see **Volume 1, Chapter 4: Project Description** for full details on the Project Design), and on a characterisation of the receiving environment as defined in detail within **Volume 5, Annex 2.1: Benthic and Intertidal Ecology Technical Report**. The respective technical report includes a detailed characterisation of the benthic and intertidal study area, based on the existing literature, including for the former Hornsea Zone, and site-specific surveys undertaken for Hornsea Four.

2.2 Purpose

2.2.1.1 This PEIR presents the preliminary environmental information for Hornsea Four and sets out the findings of the EIA to date to support the pre-Development Consent Order (DCO) application consultation activities required under the Planning Act 2008.

2.2.1.2 The feedback from this consultation will be used to inform the final project design and the associated EIA (which will be reported in an Environmental Statement (ES)) that will accompany the DCO application to the Planning Inspectorate (PINS).

2.2.1.3 This PEIR chapter:

- Presents the existing environmental baseline established from site specific surveys, desk studies, and incorporating agreements made during consultation with relevant stakeholders to date;
- Presents the potential environmental effects on benthic and intertidal ecology arising from Hornsea Four, based on the information gathered and the analysis and assessments undertaken to date;
- Identifies any assumptions and limitations encountered in compiling the environmental information; and

- Highlights any necessary monitoring and/or mitigation measures which could avoid, prevent, reduce or offset the possible environmental effects identified in the EIA process.

2.3 Planning and Policy Context

2.3.1.1 Planning policy on offshore renewable energy Nationally Significant Infrastructure Projects (NSIPs), specifically in relation to benthic and intertidal ecology, is contained in the Overarching National Policy Statement (NPS) for Energy (EN-1; DECC, 2011a) and the NPS for Renewable Energy Infrastructure (EN-3, DECC, 2011b).

2.3.1.2 NPS EN-3 and NPS EN-1 include guidance on what matters are to be considered in the assessment. These are summarised in **Table 2.1**. NPS EN-3 also highlights factors relating to the determination of an application and in relation to mitigation. These are summarised in **Table 2.2** below.

Table 2.1: Summary of NPS EN-1 and EN-3 policy relevant to benthic and intertidal ecology and consideration of the Hornsea Four assessment.

Summary of NPS EN-1 and EN-3 provisions	How and where considered in the PEIR
"Sites of Special Scientific Interest (SSSIs) that are not incorporated within internationally designated sites should be provided with a high degree of protection" (Paragraph 5.3.10 of NPS EN-1). *"Where a proposed development within or outside a SSSI is likely to have an adverse effect on an SSSI (alone or together with other developments) development consent should not normally be granted. If after mitigation an adverse effect is still likely then consent should only be given where the benefits (including need) for a development outweighs the impacts on the SSSI in question and also the wider SSSI network. The Secretary of State (SoS) should use requirements and/ or planning obligations to mitigate the harmful aspects of the development, and where possible, ensure the conservation of the site's biodiversity or geological interest"* (Paragraph 5.3.11 of NPS EN-1).	Through the Route Planning and Site Selection (RPSS) process the guiding principles of site selection (using a proportional approach) included avoiding key sensitive features were possible, using Black, Red, Amber and Green (BRAG) criteria (**Volume 4, Annex 3.2: Selection and Refinement of the Offshore Infrastructure**). Flamborough Head SSSI is partially within Flamborough and Filey Coast SPA and Flamborough Head SAC, which lie outside the development area. It should be noted that through the Evidence Plan process, the Marine Ecology & Processes Technical Panel agreed on the 12/09/18 that 'Vegetated sea cliffs of the Atlantic and Baltic Coasts' of the Flamborough Head SAC and 'Sea Cliffs' that form the feature of the Flamborough Head SSSI could be screened out of the assessment as these are regarded as terrestrial features of interest. This is considered in **Section 2.7.2** of this chapter.
"The SoS is bound by the duties in relation to Marine Conservation Zones (MCZs) imposed by sections 125 and 126 of the Marine and Coastal Access Act (MCAA) 2009" (Paragraph 5.3.12 of NPS EN-1).	Hornsea Four is committed to not crossing any MCZ with any part of the development (**Table 2.12**). An MCZ assessment is being undertaken separately (**Volume 5, Annex 2.3: Marine Conservation Zone Assessment**) with a summary of the relevant habitats presented within this chapter for completeness.
"Applicants should assess the effects on the offshore ecology and biodiversity for all stages of the lifespan of the proposed offshore wind farm (OWF)" (Paragraph 2.6.64 of NPS EN-3).	The potential effects on offshore ecology and biodiversity associated with the construction, operation and decommissioning of Hornsea Four have been assessed (**Section 2.11**).

Summary of NPS EN-1 and EN-3 provisions	How and where considered in the PEIR
"Consultation on the assessment methodologies should be undertaken at an early stage with the statutory consultees as appropriate" (Paragraph 2.6.65 of NPS EN-3).	Consultation with relevant statutory and non-statutory stakeholders has been carried out from the early stages of Hornsea Four (**Section 2.4**).
"Any relevant data that has been collected as part of post-construction ecological monitoring from existing, operational OWFs should be referred to where appropriate" (Paragraph 2.6.66 of NPS EN-3).	Post-construction monitoring from other OWFs has informed the assessment of Hornsea Four (**Section 2.11**). The Marine Management Organisation (MMO) have produced a review (MMO, 2014) on post-construction monitoring that has been undertaken for offshore wind farms within which it is noted that there have been limited effects arising on benthic communities from certain impacts. Where appropriate this chapter cross refers to those studies either individually or through reference to the MMO review.
"Applicants should assess the potential for the scheme to have both positive and negative effects on marine ecology and biodiversity" (Paragraph 2.6.67 of NPS EN-3).	Both the positive and negative effects of Hornsea Four on marine ecology and biodiversity have been assessed (**Section 2.11**).
"Applicants should assess the effects on the subtidal environment from habitat loss due to foundations and seabed preparation, predicted scour, scour protection and altered sedimentary processes (Paragraph 2.6.113 of NPS EN-3) *and effects on the intertidal zone"* (Paragraph 2.6.81 of NPS EN-3).	The assessment has considered effects from all development phases on benthic and intertidal habitats and species in the vicinity of Hornsea Four. These assessments included all likely effects from temporary and long-term habitat loss and the effects of changes in physical processes (**Section 2.11**)
"Applicants should assess the effects on the benthic environment from extendible legs and anchors of construction vessels (Paragraph 2.6.113 of NPS EN-3) *and habitat disturbance in the intertidal zone during cable installation and removal (decommissioning)"* (Paragraph 2.6.81).	The Hornsea Four assessment has considered the effects of the subtidal and intertidal disturbances throughout all stages of the development (**Section 2.11**)
"Applicants should assess the effects of increased suspended sediment leads during construction on subtidal habitats (Paragraph 2.6.113 of NPS EN-3) *and intertidal habitats"* (Paragraph 2.6.81 of NPS EN-3).	The likely rates of recovery of benthic species/ habitats have been assessed for each impact discussed, and have been used to inform each assessment of the significance of the effect (**Section 2.11**)
"Applicants should include environmental appraisal of array and cable routes and installation methods" (Paragraph 2.6.113 of NPS EN-3).	Effects of cable installation, including maximum design scenario for cable installation methodologies, on benthic ecology are assessed for all stages of the development (see **paragraphs 2.11.1.3** *et seq.* for construction and **paragraphs 2.11.3.3** *et seq.*)

Table 2.2: Summary of NPS EN-3 policy on decision making relevant to this benthic ecology chapter.

Summary of EN-3 provisions	How and where considered in the PEIR
Biodiversity	
"The Secretary of State (SoS) should consider the effects of a proposal on marine ecology and biodiversity taking into account all relevant information made available to it" (Paragraph 2.6.68).	The impacts on benthic ecology, as a component of biodiversity and an element of marine ecology, have been described and considered within this assessment for Hornsea Four (**Section 2.11**).
"The designation of an area as Natura 2000 site does not necessarily restrict the construction or operation of OWFs in or near that area" (Paragraph 2.6.69).	Natura 2000 sites will be considered in the Hornsea Four draft Report to Inform Appropriate Assessment (RIAA) with potential effects on the relevant habitats described in **Section 2.11**.
"Mitigation may be possible in the form of a careful design of the development itself and the construction techniques employed" (Paragraph 2.6.70).	Where considered appropriate, and where effects associated with the project may be considered significant in the absence of mitigation, mitigation has been considered during the Hornsea Four assessment (**Table 2.12**).
"Ecological monitoring is likely to be appropriate during the construction and operational phases to identify the actual impact so that, where appropriate, adverse effects can then be mitigated and to ensure further useful information to be published relevant to future projects" (Paragraph 2.6.71).	The requirement for benthic and intertidal ecology monitoring has been considered within the impact assessment (**Section 2.11**). In summary, no benthic and intertidal monitoring for the construction, operation or decommissioning phases of Hornsea Four is considered necessary at this stage.
Benthic and intertidal Ecology	
"The conservation status of intertidal habitat (Paragraph 2.6.84) *and benthic habitat* (Paragraph 2.6.115) *is of relevance to the SoS".*	The conservation status of intertidal and subtidal benthic receptors has been considered throughout this assessment (**Section 2.11**).
"The SoS should be satisfied that activities have been designed taking into account sensitive benthic environmental aspects (Paragraph 2.6.116) *and intertidal habitats"* (Paragraph 2.6.85).	The assessment has identified potential impacts on sensitive benthic and intertidal habitats and valued ecological receptors (**Section 2.11**).
"Where adverse effects are predicted, in coming to a judgement, the SoS should consider the extent to which the effects are temporary or reversible (Paragraph 2.6.117), *this includes the installation and decommissioning of cables"* (Paragraph 2.6.86).	The duration and reversibility of effects has been considered in the assessment of effects (**Section 2.11**).
"Where it is proposed that the offshore export cables are armoured and buried at a sufficient depth to minimise heat effects, the effects of heat on sensitive species from cable infrastructure during operation are unlikely to be a reason for the SoS to refuse to grant consent for a development" (Paragraph 2.6.118).	The nature, potential burial depth, and installation of export cables has been considered in the assessment (**Section 2.11**) and in accordance with the cable design as presented in **Volume 1, Chapter 4: Project Description**.
"Descriptor 1 – Biological diversity: Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions."	The effects on biological diversity has been described and considered within the assessment for Hornsea Four alone and the cumulative effects assessment (**Section 2.11**).

Summary of EN-3 provisions	How and where considered in the PEIR
Biodiversity	
"Descriptor 2 – Non-indigenous species: Non-indigenous species introduced by human activity are at levels that do not adversely alter the ecosystems."	The potential for effects associated with non-indigenous species on benthic species and habitats that may be attributable to Hornsea Four are assessed in (Section 2.11).
"Descriptor 4 – Elements of marine food web: All elements of marine food webs, to the extent they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity."	The effects on benthic and intertidal ecology, inclusive of the interlinkages with interdependent ecological receptors described in other chapters is integral within this chapter and the wider PEIR with inter relationships described where appropriate.
"Descriptor 6 – Sea floor integrity: Seafloor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected."	The effects on benthic and intertidal ecology, inclusive of any risk to ecological integrity, have been described and considered within the assessment for Hornsea Four alone and the CEA (Section 2.11).
"Descriptor 7 – Alteration of hydrographical conditions: Permanent alteration of hydrographical conditions does not adversely affect marine ecosystems."	The potential for permanent alterations to hydrographical conditions that may be attributable to Hornsea Four to adversely affect marine ecosystems is assessed within Section 2.11.
"Descriptor 8 – Contaminants: Concentrations of contaminants are at levels not giving rise to pollution effects."	The effects of contaminants on benthic and intertidal habitats and species have been assessed in Section 2.11.
"Descriptor 10 – Marine litter: Properties and quantities of marine litter do not cause harm to the coastal and marine environment."	A Project Environmental Management and Mitigation Plan (PEMMP) will be produced and followed to cover the operations and maintenance (O&M) phase of Hornsea Four. The PEMMP will include planning for accidental spills, address all potential contaminant releases and include key emergency contact details (e.g. Environment Agency (EA), Natural England and Maritime and Coastguard Agency (MCA)). A Decommissioning Programme will be developed to cover the decommissioning phase (Section 2.8.2).

2.3.2 Other relevant policies

2.3.2.1 The Marine Policy Statement (MPS) and the East Inshore and East Offshore Coast Marine Plans (MMO, 2014) are also relevant to benthic ecology. The relevant provisions of these policies are summarised in Table 2.3 along with details as to how these have been considered within the Hornsea Four assessment.

Table 2.3: Summary of Marine Policy Statement and Marine Plan policies relevant to benthic ecology.

Policy	Key provisions	How and where considered in the PEIR
MPS	*"The high-level objective of 'Living within environmental limits' covers the points relevant to benthic ecology, this requires, that:* *• Biodiversity is protected, conserved and where appropriate recovered and loss has been halted;*	Measures designed to protect, and conserve benthic ecology features of ecological importance are outlined in Table 2.12.

Policy	Key provisions	How and where considered in the PEIR
	• *Healthy marine and coastal habitats occur across their natural range and are able to support strong, biodiverse biological communities and the functioning of healthy, resilient and adaptable marine ecosystems; and* • *Our oceans support viable populations of representative, rare, vulnerable, and valued species."*	
East Inshore and East Offshore Marine Plans – ECO1	*"Cumulative impacts affecting the ecosystem of the East Marine Plans and adjacent areas (marine, terrestrial) should be addressed in decision-making and plan implementation"*	Cumulative effects affecting the ecosystem of the East Marine Plan areas and adjacent areas are considered within **Section 2.12**.
East Inshore and East Offshore Marine Plans – MPA1	*"Any impacts on the overall marine protected area (MPA) network must be considered in strategic level measures and assessments, with due regard given to any current agreed advice on an ecologically coherent network."*	Designated nature conservation sites with relevant qualifying benthic features screened into the Hornsea Four assessment (**Volume 5, Annex 2.1: Benthic Ecology Technical Report**) have been described in **Section 2.7.2**. The predicted changes to benthic ecology have been considered within **Section 2.11**.

2.3.2.2 The Marine Strategy Framework Directive (MSFD), adopted in July 2008, has also been considered in the Hornsea Four assessment for benthic and intertidal ecology. The overarching goal of the Directive is to achieve 'Good Environmental Status' (GES) by 2020 across Europe's marine environment. To this end, Annex I of the Directive identifies 11 high level qualitative descriptors for determining GES. In the interests of avoiding repetition these are not repeated, and instead those descriptors that are considered to be relevant to the benthic and intertidal ecology assessment for Hornsea Four are listed in **Table 2.2**, including a brief description of how and where these have been addressed in the Hornsea Four assessment.

2.4 Consultation

2.4.1.1 Consultation is a key part of the DCO application process. Consultation regarding benthic and intertidal ecology has been conducted through the Evidence Plan process via Technical Panel meetings and through the EIA scoping process (Ørsted, 2018). The Marine Processes and Ecology Technical Panel is comprised of Hornsea Four, technical specialists, Natural England, MMO and Cefas. The technical panel meetings are a forum to agree relevant impacts and assessment methodologies in a cooperative manner between Hornsea Four and the statutory stakeholders, all meetings are minuted and meeting minutes will be presented within the Consultation Report that will be submitted as part of the Hornsea Four DCO application. An overview of the project consultation process is presented within **Volume 1, Chapter 6: Consultation**.

2.4.1.2 A summary of the key issues raised during the consultation conducted to date specific to benthic and intertidal ecology is summarised below in **Table 2.4**, together with an

indication of how the issues raised during consultation have been considered in the production of this PEIR chapter.

Table 2.4: Consultation responses.

Consultee	Date, Document, Forum	Comment	Where addressed in the PEIR
MMO, Natural England and Cefas	12 September 2018, Marine Processes and Ecology Technical Panel Meeting One	It was noted that consideration of cleaning turbines during operations and maintenance were starting to be considered by the regulator and should be considered within the Hornsea Four assessment	This activity is considered in the Impact Register (Volume 4, Annex 5.1: Impacts Register).
MMO, Natural England and Cefas	12 September 2018, Marine Processes and Ecology Technical Panel Meeting One	It was advised that high levels of arsenic within the muds across the former Hornsea Zone exist and therefore this may need consideration. However, no supporting evidence has been provided for this comment.	A full contaminant assessment has been undertaken across the Hornsea Four array (Section 2.7.1). There is no evidence of elevated levels of arsenic within the array. Further sediment contaminant data will be collected along the ECC and will be included in the ES to accompany the DCO application.
MMO, Natural England and Cefas	12 September 2018, Marine Processes and Ecology Technical Panel Meeting One	Point raised that EUSeaMap predictions have been inaccurate and where possible, other data would be used to attempt to 'ground-truth' the EUSeaMap predictions.	A fully comprehensive and representative ground-truth survey strategy was developed through the Evidence Plan process. Site-specific data will override large scale habitat mapping project data where these data has been combined through the predictive habitat mapping process (full methods presented within Volume 5, Annex 2.1: Benthic and intertidal Ecology Technical Report).
PINS	26 November 2018, Scoping Opinion	PINS did not agree that Hornsea Four could scope out the following impacts: • Temporary habitat disturbance in the Hornsea Four array area and offshore ECC from construction activities.; • Temporary habitat disturbance in the intertidal area from export cable installation; • Temporary increase in Suspended Sediment Concentrations (SSC) and sediment deposition in the Hornsea Four array area and offshore ECC; • Temporary increase in SSC and sediment deposition in the intertidal area;	These impacts have been assessed in Section 2.11.

Consultee	Date, Document, Forum	Comment	Where addressed in the PEIR
		• Direct and indirect seabed disturbances leading to the release of sediment contaminants; • Long-term habitat loss/ change from the presence of foundations, scour protection and cable protection; • Colonisation of the WTGs and scour/ cable protection may affect benthic ecology and biodiversity; • Direct disturbance to seabed from jack-up vessels and cable maintenance activities; • Changes to seabed habitats arising from effects on physical processes, including scour effects and changes in the sediment transport and wave regimes resulting in potential effects on benthic communities; • Temporary habitat disturbance from removal of foundations and cables; and • Loss of introduced habitat from the removal of foundations.	
MMO	26 November 2018, Scoping Opinion	Point raised that site-specific particle size data is required for assessing sand eel preferred habitat and coastal processes impacts with regard to seabed levelling and suspended sediment impacts and will also be necessary to inform mitigation commitment Co83 outlined in Table 6.6.	The assessment of PSA for sand eel preference is presented in **Chapter 3: Fish & Shellfish Ecology**.
MMO	26 November 2018, Scoping Opinion	MMO stated that site-specific information on habitats and species is required to provide confidence in the assessments, with particular reference to the lack of site-specific data from most of the export cable route and western part of the array.	Further survey work is planned across the ECC for inclusion into the final ES, as detailed in **Section 2.6.4** . To fill the data gaps for the purposes of this PEIR assessment a predictive habitat model strategy was developed and agreed with the Marine Ecology and Processes Evidence Plan Technical Panel (**Section 2.6.5**).
MMO	26 November 2018, Scoping Opinion	Advised that there is currently insufficient information on the introduction or spread of invasive non-native species due to the presence of subsea infrastructure and vessel movements due to a lack of post construction monitoring data to date.	Increased risk of introduction or spread of Marine Invasive Non-Native Species (MINNS) due to presence of subsea infrastructure and vessel movements (e.g. ballast water) and the effects on benthic ecology and biodiversity have been included within the assessment (**Section 2.11**)
MMO	26 November 2018, Scoping Opinion	MMO advised that where information from European Marine Observation and Data Network (EMODnet) has been used to infill data gaps, it may not represent the actual	This is understood and has been considered within the data limitations of the predictive habitat model. However, where site specific data have been

Consultee	Date, Document, Forum	Comment	Where addressed in the PEIR
		habitats present and reduces confidence in the final assessments.	collected this will always override large scale habitat maps (Volume 5, Annex 2.1: Benthic and Intertidal Ecology Technical Report).
MMO	26 November 2018, Scoping Opinion	The MMO notes that data from the western part of the array area and the majority of the cable route are absent, therefore further survey effort will be required to ensure confidence in the predictions made within the ES.	Further survey work is being obtained across the ECC for inclusion into the final ES, as detailed in Section 2.6.4.
MMO	26 November 2018, Scoping Opinion	The MMO advised that site specific data should be collected to avoid sensitive habitats through micro-siting.	Site specific data for the array area has been collected and used in describing the baseline environment; further survey work is planned across the ECC to provide site specific data for inclusion into the final ES, as detailed in Section 2.6.4.
MMO	26 November 2018, Scoping Opinion	The MMO stated that there should be clearer presentation of contaminant data collection and analyses, with reference to Cefas Action Level and OSPAR guidelines. They also note that contaminant data is required from within the ECC.	Contaminant sample collection and analyses is detailed within Section 2.7.1 .Further contaminant analysis will be conducted on samples collected across the ECC, these will be presented within the final ES.
EA	26 November 2018, Scoping Opinion	The EA advised that given the close proximity to the Holderness MCZ, they recommend that a sediment management plan is put in place to reduce the potential for smothering benthic habitats. Sediment sampling within the footprint of the cable path is also recommended, which would allow for mitigation for the potential release of Environmental Quality Substances, if they are present.	Indirect impacts on MCZ features are assessed fully within the MCZ assessment (Volume 5, Annex 2.3: Marine Conservation Zone Assessment) and within Section 2.11. Sediment samples will be collected within the offshore ECC (as detailed in Section 2.6.4) and the results will be presented within the final ES (and used to update the final MCZ assessment as appropriate). If the contaminant assessment of sediments within the ECC presents any unacceptable thresholds (which is not expected) mitigation will be considered, as appropriate.
Natural England	26 November 2018, Scoping Opinion	Natural England raised that clarification should be made on the reasoning behind the selection of the benthic and intertidal ecology receptors.	Details on the selection of benthic receptors or Valued Ecological Receptors (VERs) are described in Volume 5, Annex 2.1: Benthic and

Consultee	Date, Document, Forum	Comment	Where addressed in the PEIR
			intertidal Ecology Technical Report.
Natural England	26 November 2018, Scoping Opinion	Natural England stated that the commitment to avoid MCZs/rMCs 'where practical' is not sufficient to enable impacts to Holderness Inshore MCZ and Holderness Offshore rMCZ to be scoped out at this stage.	There will be no direct impact on MCZs as the project will not overlap with these sites. However, any potential indirect impacts have been assessed as part of the PEIR assessment (Section 2.11), with further assessment undertaken as part of the MCZ assessment (Volume 5, Annex 2.3: Marine Conservation Zone Assessment).
Natural England	26 November 2018, Scoping Opinion	Natural England stated there was a need to present more detail on the cable burial risk assessment and regarding foundations and cable route micro-sitting (Co84) as well as the ECC and cable landfall avoiding all statutory marine designated areas (Co86), these measures should be secured through conditioning on dML/DCO.	Details on these measures will be presented in the draft DCO/dMLs (C1.1) to accompany the PEIR for consultation.
Natural England	26 November 2018, Scoping Opinion	Natural England advised that scoping out impacts where the sensitivity of the receptor might be high, by assuming the majority is low does not represent a worst-case scenario (WCS) approach. If there is the possibility of highly sensitive habitats to be present this is the WCS that needs to be taken forward in the absence of further information, and therefore should not be scoped out while information is not yet available.	Further site-specific data is being collected for the ECC and will be presented as part of the final ES, thereby removing the uncertainty regarding the potential occurrence of sensitive habitats.
MMO, Natural England and Cefas	12 December 2018, Marine Processes and Ecology Technical Panel Meeting Two	It was noted that predictive habitat mapping is used by Cefas and that consultees agree with the Hornsea Four approach in principle but would need to see more detail on the methodology.	A technical note was provided to consultees and methodologies agreed. The full results of the predictive habitat model process are presented within Volume 5, Annex 2.1: Benthic and intertidal Ecology Technical Report.
MMO, Natural England and Cefas	12 December 2018, Marine Processes and Ecology Technical Panel Meeting Two	It was advised that the samples should be representative of all sediment types present.	A fully comprehensive and representative survey strategy has been developed through the Evidence plan process. Full methodologies are detailed within Volume 5, Annex 2.1: Benthic and intertidal Ecology Technical Report.

Consultee	Date, Document, Forum	Comment	Where addressed in the PEIR
MMO and Natural England	6 March 2019, Response to Benthic and Intertidal Technical Note, Natural England; and 12 March 2019, Response to Benthic and Intertidal Technical Note, MMO	Advice and comment were provided on the Hornsea Four Benthic & Intertidal Ecology Baseline Strategy.	All comments were addressed via the evidence plan process and the final baseline data strategy was subsequently agreed with all consultees.
MMO and Natural England	30 April 2019, Marine Processes and Ecology Technical Panel Meeting Three	It was requested that recent geophysical data be prioritised in the predictive habitat model. It was also requested that Cefas synthesis data be used.	All site-specific survey data has been prioritised in the predictive habitat model. Cefas synthesis data has been incorporated into the model (as detailed within **Volume 5, Annex 2.1: Benthic and intertidal Ecology Technical Report**).

2.5 Hornsea Four benthic and intertidal ecology study area

2.5.1.1 For the purposes of this report, the Hornsea Four benthic and intertidal study area (**Figure 2.1**) has been defined at the following two spatial scales:

- The benthic and intertidal ecology study is defined as the Hornsea Four array area along with the Hornsea Four ECC, with the cable landfall area at the Holderness coast between Bridlington and Skipsea; and
- A 10 km buffer surrounding the array area, and a 15 km buffer around the offshore ECC, to represent the tidal ellipse distance, in order to incorporate the maximum distance suspended sediments that may be disturbed by the Hornsea Four construction (or decommissioning) activities will travel in one tidal cycle (**Chapter 1: Marine Geology, Oceanography and Physical Processes**).

2.5.1.2 At the intertidal area, the Hornsea Four intertidal ecology study area considers habitats up to the MHWS mark. Habitats landward of MHWS have been considered in the onshore ecology assessment (see **Volume 3, Chapter 3: Ecology and Nature Conservation**).

2.5.1.3 The study area for the Cumulative Effects Assessment (CEA), is defined by the wider 10 km buffer surrounding the array area, and a 15 km buffer around the offshore ECC, to incorporate the maximum distance suspended sediments will travel in one tidal cycle and therefore the indirect impacts on benthic subtidal ecology arising from Hornsea Four that could interact cumulatively with impacts from other plans or projects.

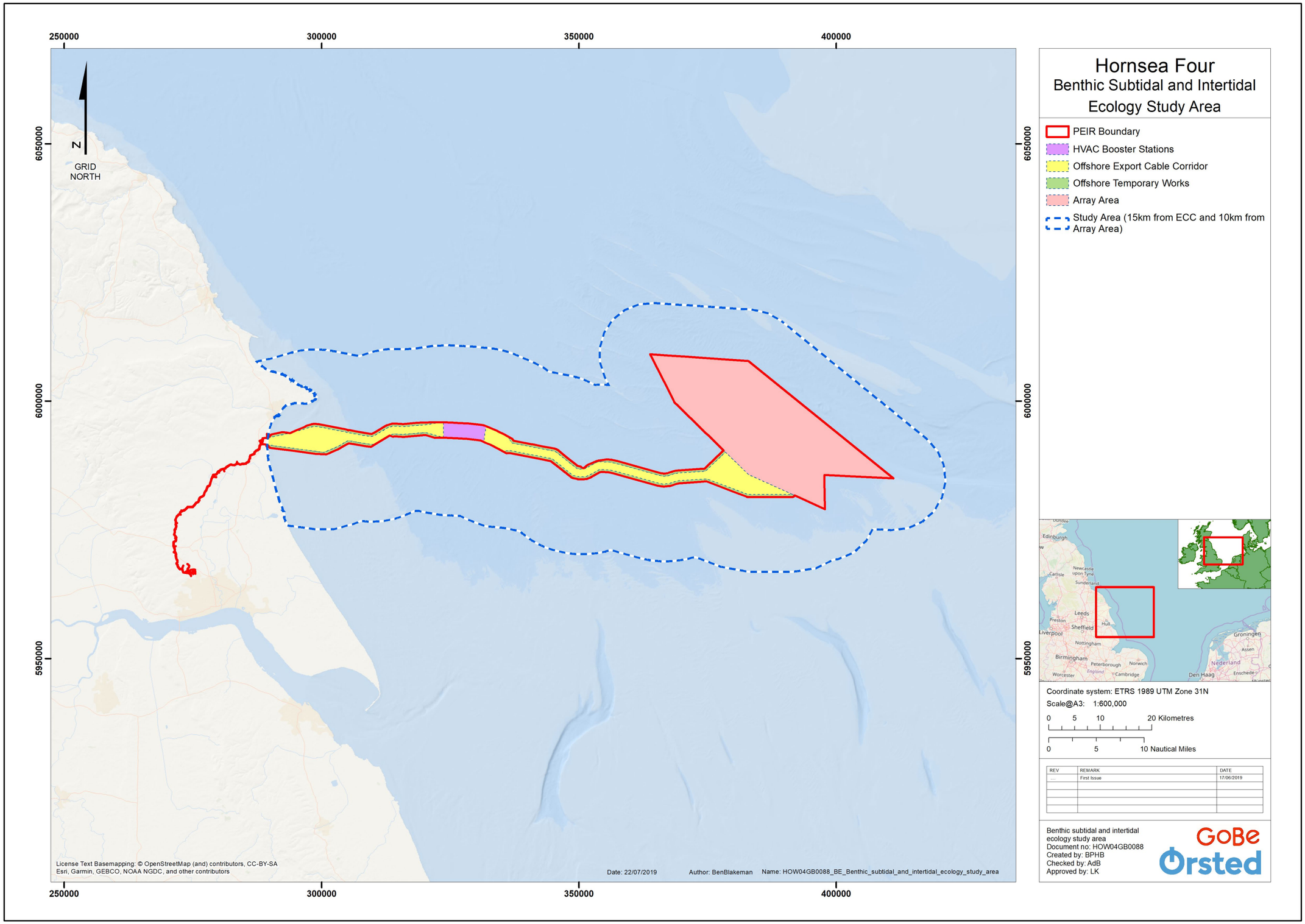


Figure 2.1: Hornsea Four benthic and intertidal ecology study area (not to scale).

2.6 Methodology to inform the Benthic and Intertidal Ecology Baseline

2.6.1 Desktop Study

2.6.1.1 The Hornsea Four array area is located within the former Hornsea Zone, for which extensive data and knowledge regarding benthic ecology is already available. This data/knowledge has been acquired through zonal studies and from the surveys and characterisations undertaken for Hornsea Project One Offshore Windfarm (hereafter Hornsea Project One), Hornsea Project Two Offshore Windfarm (hereafter Hornsea Project Two), and Hornsea Project Three Offshore Windfarm (hereafter Hornsea Three). It was therefore proposed that the benthic ecology characterisation of the Hornsea Four array area be completed, in the first instance and as a basis for providing the appropriate regional context, using a combination of desktop data and information sources, and historic survey data collected as part of the characterisations of the former Hornsea Zone, existing Hornsea projects, as well as other relevant data sets such as, for example, sampling completed for the Creyke Beck Offshore Windfarm development.

2.6.1.2 A detailed desktop review was carried out to establish the baseline information available on benthic and intertidal resources within the Hornsea Four benthic and intertidal ecology study area and the wider Southern North Sea area surrounding Hornsea Four, for contextualisation. The key data sources are summarised in Table 2.5. Further detail is presented within Volume 5, Annex 2.1: Benthic and Intertidal Ecology Technical Report.

Table 2.5: Key sources of benthic and intertidal ecology data.

Source	Summary	Coverage of Hornsea Four
Hornsea Zonal Characterisation Survey (2010)	Drop-down video (DDV) and grab sampling gear were deployed across the former Hornsea Zone in a regular grid pattern applying a 5 km x 5 km spacing to optimise sampling of the full range of habitats within the former Hornsea zone. An epibenthic beam trawl was also deployed at 11 stations within the Hornsea Four array area.	Stratified random sampling across the Hornsea Four array area.
Hornsea Project One Array Survey (2010 - 2011)	An infill survey was undertaken at the Hornsea Project One array area deploying DDV and grab sampling gear. Epibenthic beam trawls were also deployed at a number of stations.	There is overlap between the Hornsea Project One survey area and the Hornsea Four array area, furthermore the data provides some regional context with regards to benthic habitat distribution.
Hornsea Project Two Array Survey (2012)	DDV and grab sampling gear were deployed across the Hornsea Project Two zone with an epibenthic beam trawl also deployed at a number of stations.	The survey targeted Hornsea Project Two although five sampling stations were located on the periphery of the Hornsea Four array area and additional data providing more regional context.
Dogger Bank Creyke Beck Environmental Statement (Forewind, 2013)	The Dogger Bank Creyke Beck Environmental Statement (ES), submitted as part of the DCO application, presented an analysis of geophysical Acoustic Ground Discrimination	The inshore area of the Dogger Bank Creyke Beck ECC coincides with the Hornsea Four offshore ECC for

Source	Summary	Coverage of Hornsea Four
	System (AGDS) data ground-truthed with benthic grab samples and DDV to characterise the offshore array and ECC to a landfall location on the Holderness coast.	approximately 16 km from the landfall search area.
Humber Regional Environmental Characterisation (REC) (Tappin *et al.*, 2012)	Regional characterisation of wider Humber area including geophysical data, grab, epifaunal beam trawl and DDV ground truthing.	No overlap with Hornsea Four array area or offshore ECC. Closest sampling locations are located just beyond the southern boundary of the Hornsea Four array area. Dataset provides a regional context for site-specific information.
Technical reports for Strategic Environmental Assessment (SEA) Areas 2 and 3 (Department of Trade and Industry (DTI), 2001a; DTI, 2001b);	Description of survey data published in the SEA for Area 2 (northern North Sea) and Area 3 (southern North Sea).	Broadscale data with regional coverage.
UKSeaMap (2018)	EUNIS Level 4 model, detailing biological zone and substrate.	Complete coverage up to MHWS.
Spatial Models of Seabed Sediment Composition (Stephens *et al.*, 2015)	Sediment model detailing multiple different sediment classifications, including Folk and EUNIS substrate.	Complete coverage up to 0 m depth (unspecified what datum this refers to in Cefas publication)

2.6.2 Specific Surveys

2.6.2.1 Although the desktop data review provides an important and useful source of evidence in relation to the surrounding areas of seabed and the wide region, sampling within the Hornsea Four array and EEC areas is limited. Therefore, the baseline characterisation of the Hornsea Four offshore ECC and intertidal area within this PEIR has also drawn upon several Hornsea Four site-specific surveys completed in 2018 and 2019. Further surveys are planned to complete the site-specific baseline characterisation which will be reported in the final ES to accompany the DCO application. The completed and proposed sampling is summarised in the following sections and describe in more detail in **Volume 5, Annex 2.1: Benthic and Intertidal Ecology Technical Report.**

2.6.3 Completed site-specific surveys

2.6.3.1 Site-specific baseline characterisation surveys have been conducted within the Hornsea Four study area (**Figure 2.1**) in 2018 and 2019, as agreed with the Marine Processes, Benthic Ecology and Fish and Shellfish Evidence Plan Technical Panel. **Table 2.6** details the site-specific survey data collected to date. The site-specific survey coverage has been plotted in **Figure 2.2**. The detail of the sample collection and analysis are described within

Volume 5, Annex 2.1: Benthic and Intertidal Ecology Technical Report and the associated appendices.

Table 2.6: Hornsea Four site specific benthic and intertidal survey data.

Title	Summary	Coverage of Hornsea Four
Hornsea Four Geophysical Survey, 2018 Volume 5, Annex 2.1: Benthic and Intertidal Ecology Technical Report; Appendix A and B	Geophysical survey using single-beam and multi-beam echo sounders (SBES and MBES), side scan sonar (SSS), magnetometer and a sub-bottom profiler (SBP).	Hornsea Four array area and partial coverage of offshore ECC (Figure 2.2)
Hornsea Four Benthic Survey, 2018 Volume 5, Annex 2.1: Benthic and Intertidal Ecology Technical Report; Appendix A	A total of 664 images were collected across 21 benthic sample locations (Figure 2.2). Benthic sediment grab samples were collected with 0.1 m^2 mini-Hamon grab at all 21 locations. All benthic grab samples were subject to infaunal species analysis, particle size analysis (PSA) and contaminants analysis.	Hornsea Four array area (Figure 2.2).
Hornsea Four Intertidal Survey, 2019 Volume 5, Annex 2.1: Benthic and Intertidal Ecology Technical Report; Appendix C	Phase I walkover survey carried out landward to mean low water springs (MLWS). Phase I survey data including description of biotope distribution and the extent of sub-features.	Coverage of Hornsea Four intertidal zone from Bridlington to Skipsea (Figure 2.2) (IECS, 2019).

2.6.4 Planned site-specific surveys

2.6.4.1 A further benthic subtidal ecology survey is to be undertaken and reported in Q3 2019 to infill the current data gaps across the offshore ECC and will be reported in the ES. The survey will follow the methods previously used at Hornsea Four during the completed survey campaign, collecting DDV and grab samples for infaunal analysis, PSA and contaminants.

2.6.4.2 The additional 2019 benthic subtidal survey will attempt to collect data from 28 proposed sample locations which have been allocated using a strategic and iterative approach, whereby sample locations are coincident with the site-specific geophysical survey lines and representative of key modelled habitats across the offshore ECC. Furthermore, if any conservation features or sensitive habitat are identified from the geophysical and/or benthic grab data, further investigation of 'Area(s) of Focus' by DDV will be undertaken to establish the extent and quality of such features.

2.6.4.3 The surveys have been designed to fulfil the aims of the EIA to provide a basis for an assessment of the direct and indirect physical disturbance during the construction, operation and decommissioning phases of Hornsea Four. The data obtained will be used to update the characterisation of the benthic subtidal environment in terms of sediment type and associated benthic and epibenthic communities and will feed into an update of

the predictive habitat model to determine likelihood of biotope presence across the array area and offshore ECC.

Table 2.7: Hornsea Four proposed site-specific benthic subtidal field data.

Title	Summary	Coverage of Hornsea Four
2019 Geophysical Survey	Survey lines to complete the 2018 coverage of offshore ECC using single-beam and multi-beam echo sounders (SBES and MBES), side scan sonar (SSS), magnetometer and a sub-bottom profiler (SBP).	Partial coverage of Hornsea Four ECC where there are currently data gaps (Figure 2.2).
2019 Benthic Subtidal Survey	Benthic sediment DDV and grab samples to be collected with 0.1 m^2 mini-Hamon grab at 28 locations. All benthic grab samples subject to infaunal species analysis, PSA and contaminants analysis.	Representative coverage across the Hornsea Four ECC (Stephens *et al*, 2015).

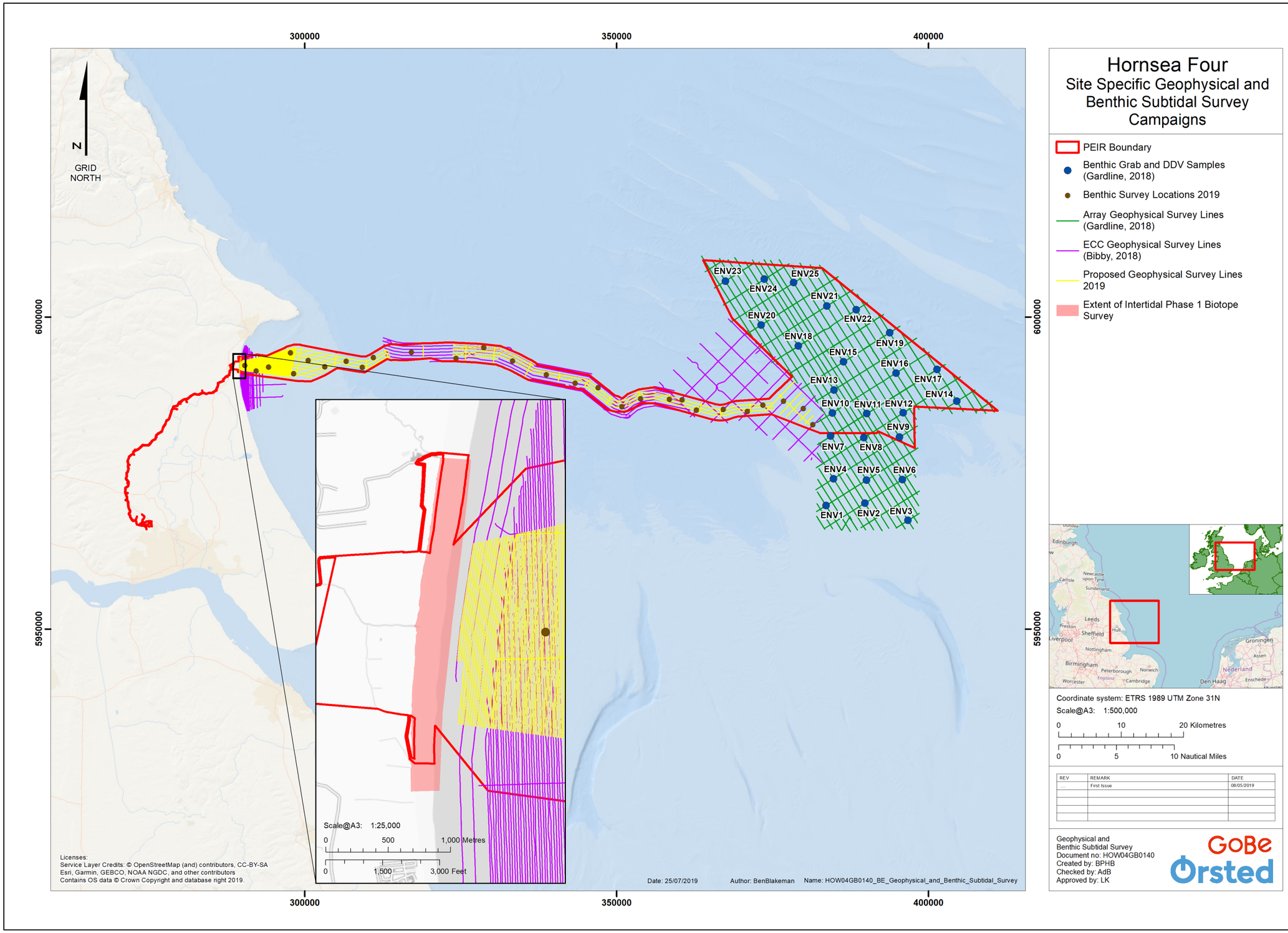


Figure 2.2: Hornsea Four site specific geophysical and benthic subtidal survey campaigns completed to date and surveys planned for 2019. The extent of the Phase 1 intertidal biotope survey is also provided (not to scale).

2.6.5 Predictive habitat modelling

2.6.5.1 The Hornsea Four predictive habitat model was developed by GoBe Consultants Ltd., as part of the **Volume 5, Annex 2.1: Benthic and Intertidal Ecology Technical Report** in order to provide the most up to date full coverage knowledge on the distribution of sediments, biological zones and biotopes across the Hornsea Four benthic ecology study area, taking into account all public datasets and those data collected for Hornsea Projects and Dogger Bank OWFs. Whilst the model improves the benthic subtidal ecology baseline across the whole area, it is of particular use along the offshore ECC where there is currently no benthic site-specific sampling. The model will, nonetheless, be updated with the data derived from the planned 2019 offshore ECC survey data with the updates presented in the ES and accompany the DCO application.

2.6.5.2 The full methodologies and results of the model are presented within **Section 7** of **Volume 5, Annex 2.1: Benthic and Intertidal Ecology Technical Report**.

2.7 Baseline Environment

2.7.1 Existing Baseline

2.7.1.1 A detailed baseline description of benthic and intertidal ecology resources across the Hornsea Four study area and wider Southern North Sea is presented within **Volume 5, Annex 2.1: Benthic and Intertidal Ecology Technical Report** based on the current data availability and predictive modelling exercise**.** A summary of the existing baseline is presented within this section.

Subtidal environment

Sediment composition and seabed features

2.7.1.2 The offshore array area is predominantly characterised by well-sorted medium or fine homogenous sands, whereas sediments along the near shore portion of the offshore ECC are more heterogeneous with more coarse and mixed sediments (**Volume 5, Annex 2.1: Benthic and Intertidal Ecology Technical Report - Appendix A**).

2.7.1.3 Particle Size Analysis (PSA) of the sediments sampled from stations within the Hornsea Four array area determined that the sediments were generally characterised by medium to coarse sand apart from fine sand at one sample location to the south of the array (Station ENV9).

2.7.1.4 The predictive habitat model identified that most of the Hornsea Four array area and offshore portion of the Hornsea Four ECC could be characterised as circalittoral sand and muddy sand. Discreet patches of mixed and coarse sediment were attributed to the array area; within the nearshore element of the ECC mixed and coarse sediments were more dominant.

2.7.1.5 The Hornsea Four study area is typical of the wider Southern North Sea seabed habitats as identified by other surveys conducted in the region where large areas of similar well-

sorted medium or fine sands were recorded (Tappin *et al.*, 2011; Department of Energy and Climate Change (DECC), 2016; Cefas, 2019).

2.7.1.6 The results of the geophysical data analysis identified that sand megaripples were the most frequently observed bedforms across the array area, while sand waves were also common. These features were also observed in the offshore portion of the ECC leading into the array area. The offshore ECC crosses the southern part of the sandbank feature Smithic Sands; further detail on this feature is presented in **paragraph 2.7.1.18**. The location of these features is presented in **Figure 16** within **Volume 5, Annex 2.1: Benthic and Intertidal Ecology Technical Report.**

Sediment contamination

2.7.1.7 The results of the sediment contaminant analyses revealed that the majority of the hydrocarbons recorded from the sediments within the Hornsea Four array occurred at expected background concentrations with some elevation in concentrations present close to existing oil and gas infrastructure. All hydrocarbons were below the threshold levels considered likely to exert an effect on the faunal community (AET; Buchman, 2008).

2.7.1.8 All metals concentrations were below their respective apparent effect thresholds (AET; Buchman, 2008), which included arsenic concentrations. It was suggested by Cefas that arsenic concentrations were high across the area, although no evidence was provided to support this (**Table 2.4**).

2.7.1.9 Values of the organotin monobutyltin (MBT) were below the limit of detection (LOD) at all stations except for seven stations: ENV10, ENV14, ENV15, ENV17, ENV19, ENV21 and ENV25, where a value of 1 ng g-1 was recorded. Values were below the limit of detection for dibutyltin (DBT) and tributyltin (TBT) across the Hornsea Four array area.

2.7.1.10 A full suite of contaminant analyses will be undertaken across the offshore ECC during the planned sampling in 2019 and reported in the ES to accompany the DCO application.

Benthic Subtidal Ecology

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

2.7.1.12 Analysis of benthic grab samples obtained across the Hornsea Four array area identified eight EUNIS categories and ranged between level 4 and level 5 depending on the level of confidence to which the data could be classified. The EUNIS habitat codes (and corresponding JNCC 04.05 biotope code) identified are presented in **Table 2.8.**

Table 2.8: Biotopes found across the Hornsea Four array area (Gardline, 2019).

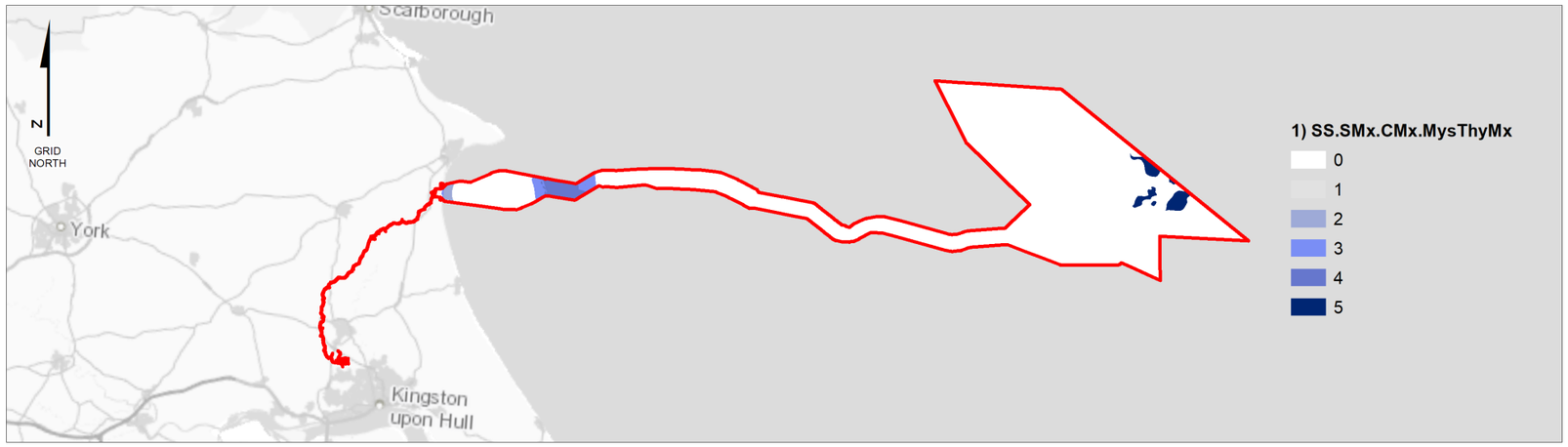
EUNIS Code	Biotope Name	JNCC 04.05 Code
A5.14	Circalittoral coarse sediment	SS.SCS.CCS
A5.233	*Nephtys cirrosa* and Bathyporeia spp. in infralittoral sand	SS.SSa.IFiSa.NcirBat
A5.25	Circalittoral fine sand	SS.SSa.CFiSa
A5.251	*Echinocyamus pusillus, Ophelia borealis* and *Abra prismatica* in circalittoral fine sand	SS.SSa.CFiSa.EpusOborApri
A5.252	*Abra prismatica*, *Bathyporeia elegans* and polychaetes in circalittoral fine sand	SS.SSa.CFiSa.ApriBatPo
A5.261	*Abra alba* and *Nucula nitidosa* in circalittoral muddy sand or slightly mixed sediment	SS.SSa.CMuSa.AalbNuc
A5.44	Circalittoral mixed sediment	SS.SMx.CMx
A5.443	*Mysella bidentata* and *Thyasira* spp. in circalittoral muddy mixed sediment	SS.SMx.CMx.MysThyMx

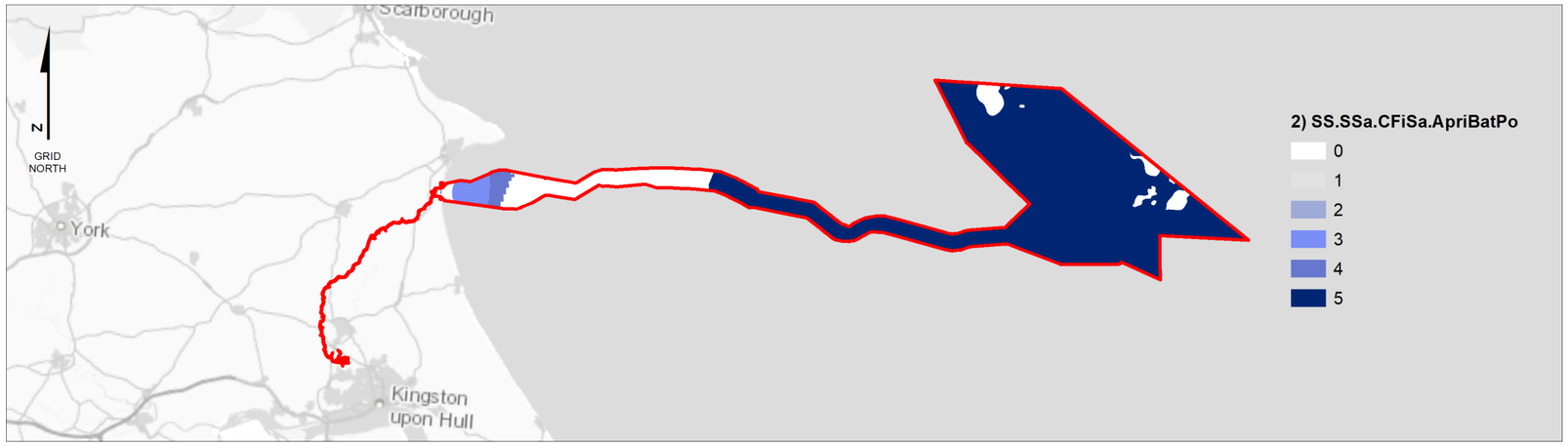
2.7.1.13 Results of seabed imagery collected across the array correlated with those geophysical and benthic grab findings, with footage revealing predominantly sandy sediments (from gravelly sand to muddy sand). Visible fauna were generally sparse, although at one station (located at the most southerly station, outside of the array) the habitat 'seapen and burrowing megafauna community' was identified (this is discussed further in **paragraphs 2.7.1.18** *et seq.*).

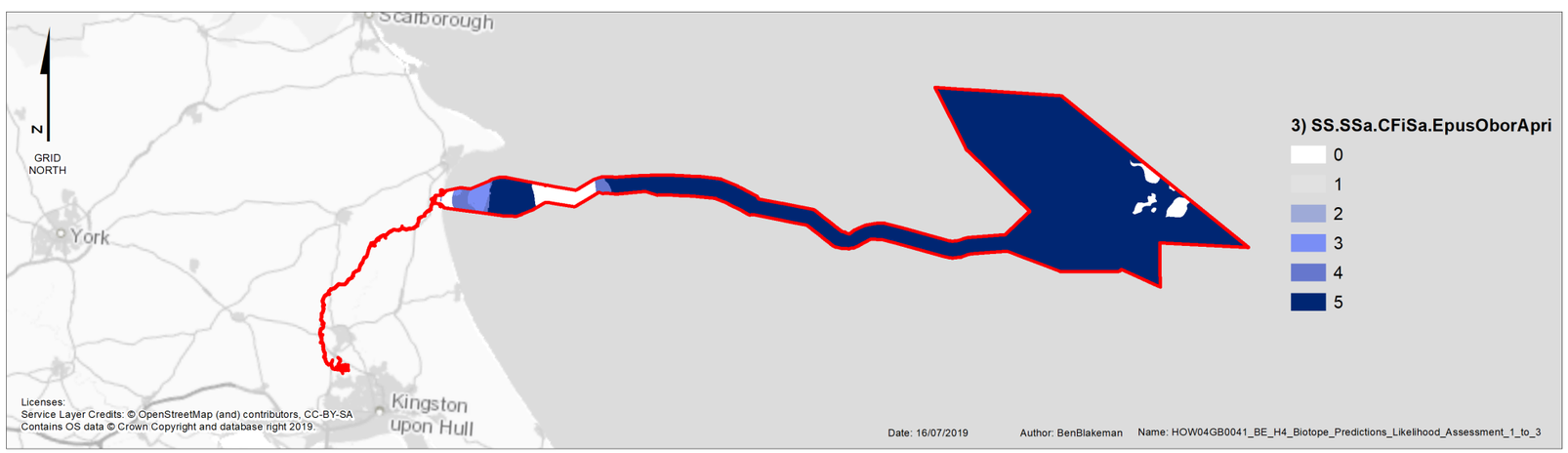
2.7.1.14 The results from the GoBe predictive habitat modelling (**Figure 2.3** and **Figure 2.4**) revealed that the biotope *Mysella bidentata* and *Thyasira* spp. in circalittoral muddy mixed sediment (SS.SMx.CMx.MysThyMx) were predominantly concentrated over the mixed sediments and coarse sediments that characterised the benthic ecology study area and were more likely to be found in the discrete mixed and coarse sediments located offshore.

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

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

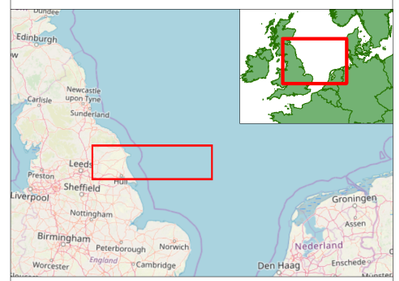






Hornsea Four
Biotope Predictions:
Likelihood Assessment

PEIR Boundary



Coordinate system: ETRS 1989 UTM Zone 31N
Scale@A3: 1:750,000

0 10 20 Kilometres

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H4 Biotope Predictions:
Likelihood Assessment
Document no: HOW04GB0041
Created by: BPHB
Checked by: AdB
Approved by: LK

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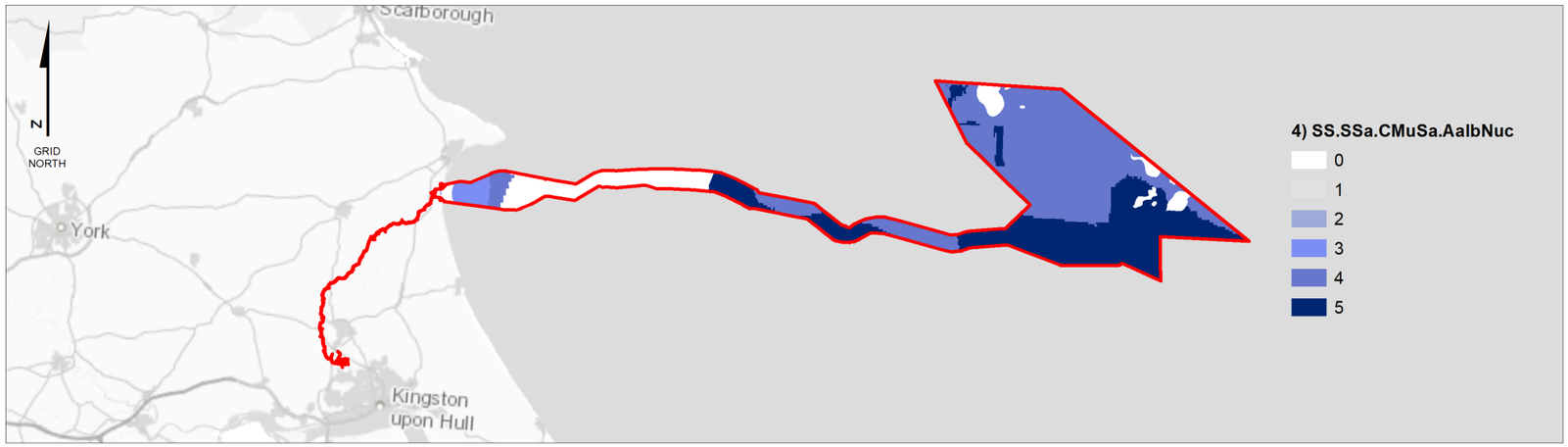
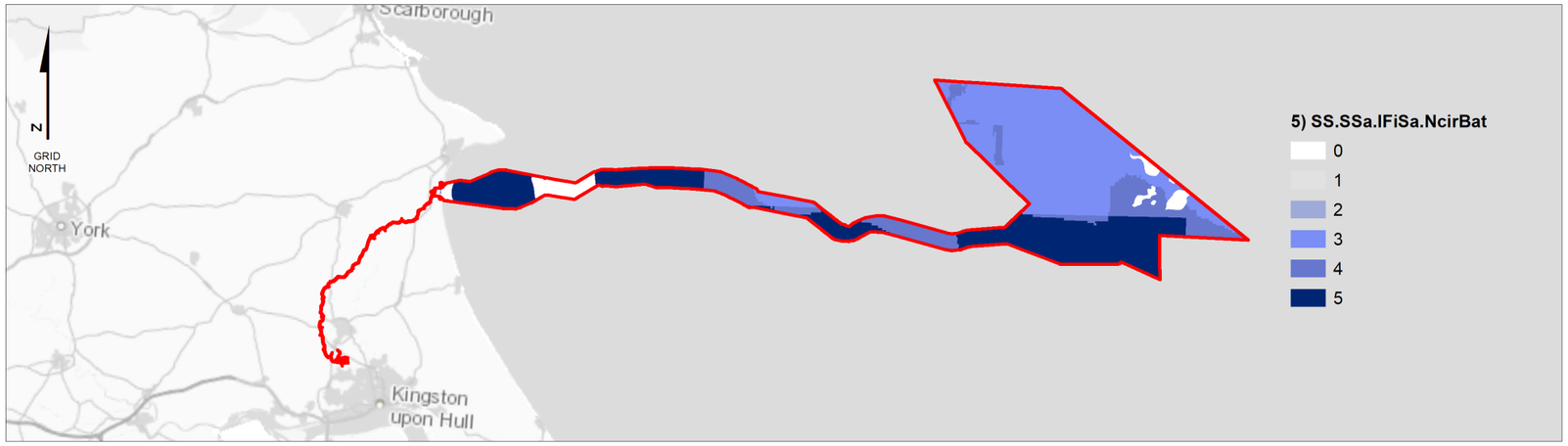
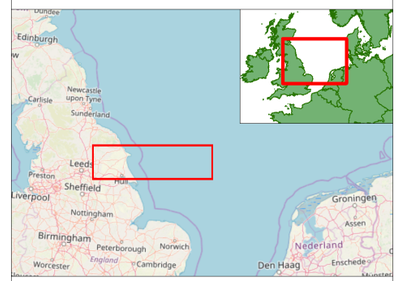
Figure 2.3. Hornsea Four biotope predictions: likelihood assessment (1 of 2) (not to scale).





Hornsea Four
Biotope Predictions:
Likelihood Assessment

PEIR Boundary



Coordinate system: ETRS 1989 UTM Zone 31N
Scale@A3: 1:750,000

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0 10 20 Nautical Miles

REV	REMARK	DATE
.....	First Issue	08/05/2019

H4 Biotope Predictions:
Likelihood Assessment
Document no: HOW04GB0042
Created by: BPHB
Checked by: AdB
Approved by: LK

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Date: 16/07/2019 Author: BenBlakeman Name: HOW04GB0042_BE_H4_Biotope_Predictions_Likelihood_Assessment_4_and_5

Figure 2.4: Hornsea Four biotope predictions: likelihood assessment (2 of 2) (not to scale).

Intertidal

2.7.1.17 The biotope that characterised the intertidal area during the Phase I walkover survey along the Holderness Coast between Bridlington and Skipsea was coarse littoral sand (LS.LSa.MoSa.Bar.Sa) (**Figure 2.5**), which is typical of clean sands in areas of high hydrodynamic energy, as seen along this portion of coastline (**Volume 5, Annex 2.1: Benthic and Intertidal Ecology Technical Report**).

Figure 2.5: Coarse Littoral Sand on upper shore T1 Site location number (left). Coarse littoral sand with cobbles and pebbles on top, T1 mid-shore (right).

Features of Conservation Interest

2.7.1.18 During the benthic DDV survey of the Hornsea Four array area (Gardline,2019), burrows were observed at 19 stations within the seabed imagery; however, seapens (*Pennatulacea*) were not observed within any of the seabed imagery data. The observed sediment type across the Hornsea Four array area was not consistent with the fine mud described as typical for the 'seapen and burrowing megafauna communities' habitat, as defined by (OSPAR, 2010). However, as a precaution, the densities of burrows at all stations were analysed and their abundance categorised using the JNCC's MNCR SACFOR classification to assess the potential for these stations to be classified as a 'seapen and burrowing megafauna communities' habitat.

2.7.1.19 As presented in **Volume 5, Annex 2.1: Benthic and Intertidal Ecology Technical Report**, of all the burrows observed within the seabed imagery, only the burrow abundances at Station ENV1 (located at the most southerly sampling station and outside of the array area), with a SACFOR score encompassing 'frequent', could be considered to present some similarity to a 'seapen and burrowing megafauna community' habitat as defined by OSPAR (2010). It is noted that this habitat is widespread across the central North Sea, around the south and west coasts of Norway and around the north of the British Isles (OSPAR, 2010).

2.7.1.20 The Smithic Sands is a sandbank feature, which will be crossed at its southern extent by the offshore ECC. The sandbank feature does not form a feature of the Flamborough Head SAC and is therefore not characterised as Annex I habitat. Further detail on the physical

structure and functioning of this feature is presented within the **Volume 5, Annex 1.1: Marine Processes Technical Report.** In terms of ecology, communities found on sandbank crests are predominantly those typical of mobile sediment environments and tend to have low diversity. Troughs or areas between banks generally contain more stable (often coarser) sediments and tend to support more diverse infaunal and epifaunal communities. Here sediment movement tends to be reduced and therefore the areas are able to support an abundance of attached bryozoans, hydroids and sea anemones. The benthic and epifaunal communities typical of such features fall into the category of sublittoral sands and gravels that have been identified across the site and will be assessed as Valued Ecological Receptors (VERs) (**Section 2.7.3**).

2.7.1.21 Visible fauna in seabed imagery included an individual specimen of a sand eel (*Ammodytidae*). Additionally, a single lesser sand eel (*Ammodytes tobianus*) was also identified from one grab sample within the array. Members of the Ammodytes genus (specifically *Ammodytes marinus* and *Ammodytes tobianus*) are listed as a priority species under UK Post 2010 Biodiversity Framework (JNCC and Defra, 2012) and listed under the NERC Act (2006). Further assessment of the effects of Hornsea Four on sand eel is presented within **Chapter 3: Fish and Shellfish Ecology**.

2.7.1.22 Three juvenile ocean quahog (*A. islandica)* were recorded from grab samples across the Hornsea Four array area. *A. islandica* is a long-lived species with a slow growth rate and is listed on the OSPAR list of threatened and/or declining species and habitats (OSPAR, 2008), as well as listed under the Marine Conservation Zone (MCZ) guidance as a species feature of conservation importance (FOCI) (Natural England and Joint Nature Conservation Committee, 2010) and a feature of the Holderness Offshore MCZ. An assessment of potential effects of Hornsea Four on the feature is presented in **Section 2.11**.

2.7.2 Designated Sites

2.7.2.1 As detailed within **Volume 5, Annex 2.1: Benthic and Intertidal Ecology Technical Report,** Hornsea Four does not overlap spatially with any international Natura 2000 designated sites with benthic ecology features (i.e. Special Areas of Conservation (SACs) and Special Protection Areas (SPAs) or nationally designated sites (i.e. MCZs and SSSIs)), as detailed within the project commitments (**Table 2.12**) The sites that lie in the wider vicinity (defined by the area of potential secondary impact) of Hornsea Four are identified in **Table 2.9**, which also summarises the qualifying features that relate to seabed habitats and benthic ecology and the distance from the closest part of Hornsea Four. The location of designated sites are presented in **Figure 16** within **Volume 5, Annex 2.1: Benthic and Intertidal Ecology Technical Report**

2.7.2.2 As no designated sites with benthic ecology features directly overlap with Hornsea Four, there will be no direct impact assessment on any designated sites. An assessment of indirect impacts (e.g. changes in suspended sediment concentrations (SSC) and/or sediment deposition) as determined by the assessment presented in **Chapter 1: Marine**

Geology, Oceanography and Physical Processes has been undertaken on relevant benthic ecology features within relevant sites that have the potential to be indirectly affected by Hornsea Four.

2.7.2.3 For the PEIR, those benthic ecology and seabed habitat features of designated sites with a 10 km buffer surrounding the array area, and a 15 km buffer around the offshore ECC study areas have been screened into the assessment.

2.7.2.4 It should be noted that through the evidence plan processes the Marine Ecology & Processes Technical Panel agreed on the 12/09/18 that 'Vegetated sea cliffs of the Atlantic and Baltic Coasts' of the Flamborough Head SAC and 'Sea Cliffs' that form the feature of the Flamborough Head SSSI could be screened out of the assessment as these are regarded as terrestrial features of interest.

2.7.2.5 An assessment of the potential impacts on MCZs is provided in **Volume 5, Annex 2.3: Marine Conservation Zones Assessment**. Several of the benthic ecological qualifying broadscale habitat features of the MCZs were found within Hornsea Four (although there is no spatial overlap with the MCZ sites) and have therefore been assessed for both direct and indirect impacts, as per the normal assessment. Where broad scale habitat features were not found within Hornsea Four, these features have only been assessed under the indirect impact assessment.

Table 2.9: National and international conservation designations within the area of potential indirect impact of Hornsea Four.

Site and Status	Qualifying features	Distance from Hornsea Four
Flamborough Head SAC	Annex I habitats: • Chalk Reefs • Vegetated sea cliffs of the Atlantic and Baltic Coasts • Submerged or partially submerged sea caves	1.2 km distance from the nearshore section of the Hornsea Four ECC
Holderness Inshore MCZ	• Intertidal sand and muddy sand • Moderate energy circalittoral rock • High energy circalittoral rock • Subtidal coarse sediment • Subtidal mixed sediments • Subtidal sand • Subtidal mud • Spurn head (subtidal geological feature)	4.5 km distance from the nearshore section of the Hornsea Four ECC
Holderness Offshore MCZ	• North Sea Glacial Tunnel valleys • Subtidal coarse sediment • Subtidal sand Subtidal mixed sediments • Ocean Quahog (*Arctica islandica*)	0.75 km distance from the nearshore section of the Hornsea Four ECC

2.7.3 Valued Ecological Receptors

2.7.3.1 The value of ecological features is dependent upon their biodiversity, social, and economic value within a geographic framework of appropriate reference (CIEEM, 2016). The most straightforward context for assessing ecological value is to identify those species and habitats that have a specific biodiversity importance recognised through international or national legislation or through local, regional or national conservation plans (e.g. Annex I habitats under the Habitats Directive, OSPAR, Biodiversity Action Plan (BAP) habitats and species, habitats/species of principal importance listed under the Natural Environment and Rural Communities (NERC) Act 2006 and habitats/species listed as features of MCZs/rMCZs). However, only a very small proportion of marine habitats and species are afforded protection under the existing legislative or policy framework and therefore evaluation must also assess value according to the functional role of the habitat or species. For example, some features may not have a specific conservation value in themselves but may be functionally linked to a feature of high conservation value.

2.7.3.2 **Table 2.10** presents the VERs, their conservation status and importance within the Hornsea Four benthic ecology study area and the justification and regional importance of each receptor.

Table 2.10: Valued ecological receptors (VERs) within the Hornsea Four benthic and intertidal ecology study area.

Valued ecological receptors	Representative biotope	Protection status	Conservation interest	Distribution within Hornsea Four benthic and intertidal ecology study area	Importance within Hornsea Four benthic and intertidal ecology study area and justification
Coarse and mixed sediments with moderate to high infaunal diversity and scour tolerant epibenthic communities	MysThyMx	None	UK BAP priority habitat	This habitat is found within the Hornsea Four array area and modelling predicted its presence within the inshore portion of the ECC.	Regional – although this habitat is representative of a nationally important marine habitat, the southern North Sea is not a key geographic area.
Sandy sediments with low infaunal diversity and sparse epibenthic communities	ApriBatPo; EpusOborApri; NcirBat	None	UK BAP priority habitat	This habitat is likely to be located across much of the study area, with ApriBatPo, more likely offshore, EpusOborApri found throughout the whole Hornsea Four area and NcirBat, in the southern nearshore and offshore areas.	Regional – UK BAP with regional distribution from outer Humber to Thames region.
Fine muddy sands with moderate species diversity, characterised by bivalves in areas of moderate to high wave exposure	AalbNuc;	None	UK BAP priority habitat	This habitat was found widely spread across the Hornsea Four array area.	Regional - although this habitat is representative of a nationally important marine habitat, the southern North Sea is not a key geographic area.
Seapen and burrowing megafauna communities	SS.SMu.CFiMu.SpnMeg	None	OSPAR List of Threatened and/or Declining Species and Habitats (Region II – North Sea, Region III – Celtic Sea)	Habitat recorded as 'rare' across the Hornsea Four array, but frequent at the most southerly sample station (outside the array area).	National - however, it should be noted that this habitat is widespread across the central North Sea, around the south and west coasts of Norway and around the north of the British Isles (OSPAR, 2010).
Coarse littoral barren sand	LS.LSa.MoSa.BarSa	None	n/a	Across the whole intertidal ecology study area.	Local – Habitat is not protected under any conservation legislation and is widespread around much of the UK.

Valued ecological receptors	Representative biotope	Protection status	Conservation interest	Distribution within Hornsea Four benthic and intertidal ecology study area	Importance within Hornsea Four benthic and intertidal ecology study area and justification
Ocean quahog *Arctica islandica*	N/A	MCZ	OSPAR List of threatened and/or declining species for the Greater North Sea (OSPAR Region II). FOCI under the Nature Conservation part (Part 5) of the MCAA 2009	Three individuals were found within the Hornsea Four array.	National – UK BAP with nationally important populations close to the Hornsea Four benthic subtidal ecology study area. Also, a protected feature within Holderness Offshore MCZ. Ocean quahogs are found all around and offshore from, British and Irish coasts, particularly the southern North Sea and the English Channel.
Annex I habitat features of Flamborough Head SAC					
Subtidal chalk reefs	N/A	Annex I Habitats Directive	Annex I 'Reefs' within an SAC. UK BAP priority habitat.	The SAC does not overlap with Hornsea Four. However, indirect impacts using a 15 km tidal excursion from the ECC have been screened into the assessment on a precautionary basis. The 15 km tidal excursion from the offshore ECC overlaps with the SAC.	International – part of European designated sites (Flamborough Head SAC).
Submerged or partially submerged sea caves	N/A	Annex I Habitats Directive	Annex I within an SAC. UK BAP priority habitat.	The SAC does not overlap with Hornsea Four. However, indirect impacts using a 15 km tidal excursion from the ECC have been screened into the assessment on a precautionary basis. The 15 km tidal excursion from the offshore ECC overlaps with the SAC.	International – part of European designated sites (Flamborough Head SAC).

2.7.4 Predicted Future Baseline

2.7.4.1 The Infrastructure Planning (Environmental Impact Assessment) Regulations 2017 requires that "an outline of the likely evolution thereof without implementation of the development as far as natural changes from the baseline scenario can be assessed with reasonable effort on the basis of the availability of environmental information and scientific knowledge" is included within the Environmental Statement (EIA Regulations, Schedule 4, Paragraph 3).

2.7.4.2 An assessment of the future baseline conditions has been carried out (in the event of no development) and is described within this section. The baseline environment is not static and will exhibit some degree of natural change over time, with or without Hornsea Four in place, due to naturally occurring cycles and processes. Therefore, when undertaking impact assessments, it will be necessary to place any potential impacts in the context of the envelope of change that might occur naturally over the timescale of the project.

2.7.4.3 Further to potential change associated with existing cycles and processes, it is necessary to take account of the potential effects of climate change on the marine environment. Variability and long-term changes on physical influences may bring direct and indirect changes to benthic and intertidal habitats and communities in the mid to long term future (UK Offshore Energy Strategic Environmental Assessment 3 (OESEA3), 2016). A strong base of evidence indicates that long-term changes in the benthic ecology may be related to long-term changes in the climate or in nutrients (OESEA3, 2016), with climatic process driving shifts in abundances and species composition of benthic communities (Marine Climate Change Impacts Partnership (MCCIP), 2015). Studies of the benthic ecology over the last three decades have shown that biomass has increased by at least 250 to 400%; opportunistic and short-lived species have increased; and the abundance of long-living sessile animals has decreased (Krönke, 1995; Krönke, 2011). Modelling sea surface temperature in relation to climate change in the UK has shown that the rate of temperature increase over the previous 50 years has been greater in waters off the east coast of the UK compared to the west and this is predicted to continue for the next 50 years (MCCIP, 2013).

2.7.4.4 Furthermore, most literature to date focuses on specifically temperature, with regards to the effects of climate change on marine habitats. Climatic warming also causes deoxygenation within the water column. Over the past 50 years oxygen content has decreased from 0.06-0.43% (Stramma *et al.*,2010) with a further 7% decrease predicted for the year 2100 (IPCC,2013). It was concluded from 26 years of monitoring a benthic community within the Firth of Clyde, UK that the benthic communities had been affected by the decreasing levels of oxygen. This finding agreed with other short-term studies (Breitburg *et al.*,2018, Levin *et al.*,2009). Specific changes included changes in morphology, burrow depth, bioturbation and feeding mode (Caswell *et al.*,2018).

2.7.4.5 As such, the baseline in the Hornsea Four study area described in **Section 2.7** is a 'snapshot' of the present benthic ecosystem within a gradually yet continuously changing environment. Any changes that may occur during the 35-year design life span of Hornsea Four should be considered in the context of both greater variability and sustained trends occurring on national and international scales in the marine environment.

2.7.5 Data Limitations

2.7.5.1 The key data limitation with the currently available baseline data described in this PEIR is the lack of site-specific data across the offshore ECC. As described in **Section 2.6.4** further survey efforts across the offshore ECC are planned for 2019, with the results to be reported in the final ES. To partly mitigate this data absence at PEIR, a predictive habitat model strategy was developed by GoBe Consultants Ltd. and agreed in the Hornsea Four Evidence Plan process in consultation with the Marine Ecology and Processes Evidence Plan Technical Panel.

2.7.5.2 The key data limitations with the habitat model output data and its ability to materially influence the outcome of the EIA are attributed to i) the accuracy of the data used to inform the model; and ii) the predictive nature of the model.

2.7.5.3 Grab sampling and video surveys, while providing detailed information on the infauna and epifauna present, cannot cover wide swaths of the seabed and consequently represent point samples that must be interpreted in combination with the geophysical datasets to produce benthic maps that provide comprehensive cover.

2.7.5.4 Classification of survey data into benthic habitats and the production of benthic habitat maps from the survey data, while highly useful for assessment purposes, has two main limitations:

- Difficulties in defining the precise extents of each biotope, even when using site specific geophysical survey data to characterise the seabed; and
- There is generally a transition from one biotope to another, rather than fixed limits and therefore, the boundaries of where one biotope ends and another starts often cannot be precisely defined.

2.7.5.5 Consequently, the biotope maps presented in this chapter should not be considered as definitive, nor should the habitat boundaries be considered to be fixed, they do however represent a robust characterisation of the receiving environment.

2.7.5.6 Despite the above uncertainties, the Marine Ecology and Processes Technical Panel considered that the current information on the benthic communities across the study area is sufficient to provide the basis for a preliminary assessment of the impacts of Hornsea Four on benthic and intertidal ecology for this PEIR. The further planned data collection and predictive habitat modelling will be used to confirm and update the baseline presented in the final ES to accompany the DCO application.

2.8 Project basis for assessment

2.8.1 Impact register and impacts "scoped out"

2.8.1.1 Based on the baseline environment, the project description outlined in **Volume 1, Chapter 4: Project Description** and the commitments in **Volume 4, Annex 5.2: Commitments Register**, several impacts have been "scoped out" of the PEIR assessment for benthic and intertidal

ecology in accordance with the PINS Scoping Opinion. These impacts are summarised in **Table 2.11**. Further detail is provided in **Volume 4, Annex 5.1: Impacts Register**.

2.8.1.2 Please note that the term "scoped out" relates to the Likely Significant Effect (LSE) in EIA terms and not "scoped out" of the EIA process *per se*. All impacts "scoped out" of LSE are assessed for magnitude, sensitivity of the receiving receptor and conclude an EIA significance in the Impacts Register (see **Volume 4, Annex 5.1**). This approach is aligned with Hornsea Four's Proportionate approach to EIA (see **Volume 1, Chapter 5: EIA Methodology**).

Table 2.11: Impacts scoped out of the assessment and justification.

Project activity and impact	Likely significance of effect	Approach to assessment	Justification
Construction: Impacts on benthic ecology from noise arising from foundation installation (BIE-C-5).	No likely significant effect	Scoped Out	It is generally accepted that the particle motion component of noise is most relevant to benthic species. While there are few studies looking at reactions of benthic invertebrates and in particular polychaetes and infaunal bivalves it is likely that particle motion will dissipate in close proximity to the noise source. In addition, the noise will be temporary in nature and conditions will return to baseline following cessation of piling. The MarESA sensitivity assessment suggest that the potential effects associated with the construction of a wind farm is 'not relevant' for the biotopes present. Therefore, this impact has been scoped out of the assessment.
Construction: Accidental release of pollutants (e.g. from accidental spillage/leakage) may affect benthic ecology (BIE-C-7).	No likely significant effect	Scoped Out	The magnitude of an accidental spill incident will be limited by the size of chemical or oil inventory on construction vessels. In addition, released hydrocarbons would be subject to rapid dilution, weathering and dispersion and would be unlikely to persist in the marine environment. The likelihood of an incident will be reduced by implementation of a project PEMMP, undertaken in accordance with Co111 (**Table 2.12**). Furthermore, the biotopes present within the array area and ECC are considered to be tolerant of chemical pressures, as presented within the MarESA assessment. This impact has therefore been scoped out of the assessment.
Operation: Indirect disturbance to benthic species from Electromagnetic Fields (EMF) generated by inter-array and export cables (BIE-O-12).	No likely significant effect	Scoped Out	EMFs are likely to increase above background levels in close proximity to the cables only. As the cable will be buried (Co83) or protected across the majority of the array area and EEC any behavioural responses would be further mitigated. Furthermore, monitoring to date has not recorded any changes in invertebrate behaviour resulting from EMF exposure. However, it is

Project activity and impact	Likely significance of effect	Approach to assessment	Justification
			acknowledged that there are limited studies in this field. It is considered that benthic communities are not sensitive to EMF around subsea cables. This impact has therefore been scoped out.
Operation: Accidental release of pollutants (e.g. from accidental spillage/leakage) may affect benthic ecology (BIE-O-14).	No likely significant effect	Scoped Out	As above for construction impact.
Decommissioning: Accidental release of pollutants (e.g. from accidental spillage/leakage) may affect benthic ecology (BIE-D-18).	No likely significant effect	Scoped Out	As above for construction impact.

Notes:
Grey - Potential impact is scoped out and both PINS and Hornsea Four agree.

2.8.2 Commitments

2.8.2.1 Hornsea Four has made several commitments that act to reduce or eliminate the potential environmental impacts of Hornsea Four (primary design principles inherent as part of the project, installation techniques and engineering designs/modifications as part of their pre-application phase, to avoid a number of impacts or reduce impacts as far as possible). Further commitments (adoption of best practice guidance) have also been adopted by Hornsea Four and are embedded mitigation for the purposes of the assessment.

2.8.2.2 The full list of Commitments can be found in **Volume 4, Annex 5.2: Commitments Register**. The commitments adopted by Hornsea Four in relation to benthic and intertidal ecology are presented in **Table 2.12**.

Table 2.12: Relevant benthic and intertidal ecology commitments.

Commitment ID	Measure Proposed	How the measure will be secured
Co44	Primary: The Holderness Inshore Marine Conservation Zone (MCZ) will not be crossed by the offshore export cable corridor including the associated temporary works area.	DCO Schedule 1, Part 1 Authorised Development.
Co45	Primary: The Holderness Offshore MCZ not be crossed by the offshore export cable corridor including the associated temporary works area.	DCO Schedule 1, Part 1 Authorised Development.

Commitment ID	Measure Proposed	How the measure will be secured
Co48	Primary: Annex I habitats will be avoided where possible, informed through the undertaking of geophysical survey works pre-construction. This excludes features of Smithic Sands which at the time of application is not designated.	DCO Schedule 11, Part 2 - Condition 12(1)(a) and; DCO Schedule 12, Part 2 - Condition 12(1)(a) (Pre-construction plans and documentation)
Co83	Primary: Where possible, cable burial will be the preferred option for cable protection.	DCO Schedule 11, Part 2 - Condition 12(1)(h) and; DCO Schedule 12, Part 2 - Condition 12(1)(h) (Cable specification and installation plan)
Co84	Primary: Presence of sensitive habitats will be identified through a review of the latest available benthic datasets and pre-construction surveys. Wind turbine foundations and the offshore export cable will be micro-sited around annex one habitat wherever reasonably practicable (subject to agreement with the MMO) to an extent not resulting in a hazard for marine traffic and Search & Rescue capability.	DCO Schedule 11, Part 2 - Condition 12(1)(a) and; DCO Schedule 12, Part 2 - Condition 12(1)(a) (Pre-construction plans and documentation)
Co86	Primary: The offshore export cable corridor and cable landfall (below MHWS) will not cross the Greater Wash SPA, Flamborough & Filey Coast SPA and the Flamborough Head SAC.	DCO Schedule 1, Part 1 Authorised Development.
Co111	Tertiary: A Marine Pollution Contingency Plan (MPCP) will be developed. This MPCP will outline procedures to protect personnel working and to safeguard the marine environment and mitigation measures in the event of an accidental pollution event arising from offshore operations relating to Hornsea Four. The MPCP will also include relevant key emergency contact details.	DCO Schedule 11, Part 2 - Condition 12(1)(d)(i) and; DCO Schedule 12, Part 2 - Condition 12(1)(d)(i) (Marine pollution contingency plan)

2.9 Maximum Design Scenario (MDS)

2.9.1.1 The Maximum Design Scenarios (MDS) identified in **Table 2.13** have been selected as those having the potential to result in the greatest effect on an identified receptor or receptor group. These scenarios have been selected based on the design parameters provided in the project description (**Volume 1, Chapter 4: Project Description**). Effects of greater adverse significance are not predicted to arise should any other development scenario (based on the design parameters within the project description) be taken forward in the final design of the scheme.

Table 2.13: MDS for impacts on benthic and intertidal ecology.

Impact and Phase	Embedded Mitigation Measures	Maximum Design Scenario	Justification
Construction			
Temporary habitat disturbance in the Hornsea Four array area and offshore ECC from construction activities (BIE-C-1).	Primary: Co44 Co45 Co48 Co84 Co86	Temporary habitat disturbance of 41,725,097 m^2. Breakdown provided below. **Array Area:** *Foundation seabed preparation = 680,294 m^2* • 180 suction bucket jacket foundations for WTGs = 511,379 m^2 • Six small OSS on GBS foundations and three large OSS on suction caisson jacket foundations = 156,594 m^2 • One accommodation platform on a suction bucket jacket foundation (small OSS) = 12,321 m^2 *Jack up and anchoring operations = 1,063,200 m^2* • WTG installation jack up vessel (JUV) footprint (six legs, 170m^2 per foot, 4 jack-up operations per turbine) = 734,400 m^2 • WTG installation vessel anchor footprints (100m^2 per anchor, 8 anchors per vessel, 2 anchored vessels per turbine) = 288,000m^2 • OSS and accommodation platform installation JUV footprint (six legs, 170m^2 per foot, 4 jack-up operations per structure) = 40,800 m^2 *Cable seabed preparation and installation = 10,391,400 m^2* • Boulder clearance in array area - 30 m corridor = 20,700 m^2 • Sandwave clearance in array area – 30 m corridor = 20,700 m^2 • Burial of 600 km of array cables (15 m width) = 9,000,000 m^2 • Burial of 90 km of inter-connector cables (15 m width) = 1,350,000 m^2 **Offshore ECC:** *Foundation seabed preparation = 36,963 m^2* • Three small OSS on suction caisson jacket foundations = 36,963 m^2 *Jack up operations = 12,240 m^2* • OSS installation JUV footprint (six legs, 170m2 per foot, 4 jack-up operations per structure) = 12,240 m^2 *Cable seabed preparation and installation = 29,541,000 m^2* • Boulder clearance in offshore ECC - 30 m corridor = 19620,000 m^2 • Sandwave clearance in offshore ECC – 30 m corridor = 757,000 m^2 • Burial of 654 km of export cables (15 m width) = 9,810,000 m^2 • Cable jointing (4 joints per cable, 6 cables, 3,500 m^2 per joint) = 84,000 m^2	The temporary disturbance relates to seabed preparation and cable installation. The footprint of infrastructure is assessed as a permanent impact in O&M. It should be noted that the seabed preparation area for foundations is less than the footprint of the foundation scour protection.

Impact and Phase	Embedded Mitigation Measures	Maximum Design Scenario	Justification
Temporary habitat disturbance in the intertidal area from export cable installation (BIE-C-2).	Primary: Co44 Co84 Co86	**Intertidal open cut trenching:** • 6 cables within a 280 m corridor (40m per circuit (6 × 40) with 20m temporary works area either side (2 × 20) across 200 m long intertidal (MLWS to MHWS) = 56,000 m^2. • Excavation to a depth of 3 m.	The MDS for temporary habitat disturbance in the intertidal area from the installation of cables has considered the installation of all cables via open cut trenching, as the total potential temporary disturbance associated with this method is greater than the potential temporary disturbance associated with either the HDD option.
Temporary increase in SSC and sediment deposition in the Hornsea Four array area and offshore ECC (BIE-C-3).	Primary: Co44 Co45 Co84 Co86	**Array Area:** *WTG Foundations* • 180 turbines on suction caisson jacket foundations requiring seabed preparation, resulting in the suspension of 2,134,440 m^3 of sediment; *OSS Foundations* • Nine suction caisson foundations requiring seabed preparation, resulting in the suspension of 737,130 m^3 of sediment; *Offshore Accommodation Platform Foundations* • One suction caisson foundation requiring seabed preparation, resulting in the suspension of 57,245 m^3 of sediment; *Sandwave Clearance* • Sandwave clearance across 18 km^2 of seabed with an impact width of 15 m per cable resulting in the suspension of 961,000 m^3 of sediment. *Cable Trenching* • Cable installation by MFE of array cables, interconnector cables, and part of the export cables within the array resulting in the suspension of 4,140,000 m^3 of sediment. **Offshore ECC** *HVAC Booster Station Foundations* • 3 suction caisson foundations requiring seabed preparation, resulting in the suspension of 171,735 m^3 of sediment; *Sandwave Clearance*	The maximum design scenario for foundation installation results from the largest volume suspended from seabed preparation (suction caisson jackets) and the largest volume suspended from potential drilling of foundations (monopiles), both at the maximum number of foundations (180). For cable installation, the maximum design scenario results from the greatest volume from sandwave clearance and installation using energetic means (jetting). This also assumes the largest number of cables and the greatest burial depth.

Impact and Phase	Embedded Mitigation Measures	Maximum Design Scenario	Justification
		• Sandwave clearance across a 99 km corridor for 6 cables resulting in the suspension of 757,000 m^3 of sediment. *Cable Trenching* • Installation of 6 cables by MFE resulting in the suspension of 3,543,000 m^3 of sediment (excluding the part of the export cable within the array Cable Jointing • Up to 17,500 m^3 of sediment from up to four cable joints per export cable. **Total:** In the case of seabed preparation for suction caisson foundations, a maximum volume of 12,879,050 m^3.	
Temporary increase in SSC and sediment deposition in the intertidal area (BIE-C-4).	Primary: Co44 Co84 Co86	• Excavated volume of material for HDD exit pits is 2,500 m^3. Material would either be taken away to a temporary stockpile or stored adjacent to the exit pit prior to backfilling. • Open cut trenching of 6 cables within a 280 m corridor (40m per circuit; i.e. 20 m either side 6 × 40 + 2 × 20 = 280 m) across the intertidal (200 m) to a depth of 3m. • All installation techniques described for export cable installation (except dredging) may be applied to installation within the intertidal. For MFE, an equivalent volume of 7,162 m^3 of sediment may be dredged across a 200 m stretch of beach for six export cables.	This scenario represents the maximum footprint from the greatest number of cables and the largest excavation volume from cofferdams.
Direct and indirect seabed disturbances leading to the release of sediment contaminants (BIE-C-6).	None	The MDS for seabed disturbance are presented in the rows above. The risk of release of contaminants will be assessed further within the PEIR.	This scenario represents the maximum total seabed disturbance and therefore the maximum amount of contaminated sediment that may be released into the water column during construction activities.
Operation			
Long-term habitat loss/ change from the presence of foundations, scour protection and cable protection (BIE-O-8).	Primary: Co44 Co45 Co83 Co84 Co86	Habitat change of 3,707,730 m^2. Breakdown provided below. **Array Area**: • Turbine footprint with scour protection, based on 180 suction bucket jackets for WTG = 795,216 m^2 • Offshore transformer substation foundation footprint and scour protection, based on 6 small and 3 large OSS (HVDC: GBS (Box-type) & GBS (Large OSS)) = 371,250 m^2 • Offshore HVAC booster substations and associated scour , based on three subsea structures (GBS (Box-type)) = 91,875 m^2 • Offshore accommodation platform and associated scour protection (GBS (Box-type)) = 30,625 m^2 • Maximum rock protection area for array cable = 624,000 m^2	The maximum design scenario is defined by the maximum area of seabed lost by structures, scour protection, cable protection and cable crossings.

Impact and Phase	Embedded Mitigation Measures	Maximum Design Scenario	Justification
		• Maximum rock protection area for interconnector cable = 94,000 m^2 • Pre- and post-lay rock berm area, based on 40 cable crossings within the array area = 255,000 m^2 **Offshore ECC:** • Maximum rock protection area for the export cable = 792,000 m^2 • Pre- and post-lay rock berm area, based on 10 cable crossings within the export ECC area = 268,000 m^2	
Colonisation of the WTGs and scour/ cable protection may affect benthic ecology and biodiversity (BIE-O-9).	None	Total area of introduced hard substrate = 3,707,730 m^2 (calculated from total of cell above)	The maximum design scenario is defined by the maximum area of structures, scour protection, cable protection and cable crossings introduced to the water column, including surface area of vertical structures.
Increased risk of introduction or spread of Marine Invasive Non-Native Species (MINNS) due to presence of subsea infrastructure and vessel movements (e.g. ballast water) may affect benthic ecology and biodiversity (BIE-O-10).	None	Total area of introduced hard substrate = 3,707,730 m^2 (calculated from total of cell above).	Defined by the maximum surface area introduced as described above.
Direct disturbance to seabed from jack-up vessels and cable maintenance activities (BIE-O-11).	None	Direct disturbance to seabed from jack-up vessels and cable maintenance activities = 3,252,500 m^2. Breakdown provided below. **WTG O&M activities**: • Component replacement = 378,000 m^2 • Access ladder replacement = 378,000 m^2 • Foundation anode replacement = 378,000 m^2 • J-Tube repair/ replacement = 108,000 m^2	Defined by the maximum number of jack-up vessel operations and maintenance activities that could have an interaction with the seabed anticipated during operation.

Impact and Phase	Embedded Mitigation Measures	Maximum Design Scenario	Justification
		Array cable activities: • Remedial burial of array cables = 200,000 m^2 • Array cable repairs = 200,000 m^2 • Cable protection replacement = 156000 m^2 **Offshore substations and accommodation platform activities:** • Offshore substation component replacement = 6000 m^2 • Foundation anode replacement = 21,000 m^2 • J-Tube repair/ replacement = 6000 m^2 **ECC activities:** • Cable remedial burial = 200,000 m^2 (per event) • Cable protection replacement = 198,000 m^2 • Array cable repairs = 700,000 m^2 **Interconnector cable activities:** • Cable remedial burial = 200,000 m^2 (per event) • Cable protection replacement = 23,500 m^2 • Array cable repairs = 100,000 m^2 **Vessel return trips per year:** • 2,580 for wind turbine visits • 780 for wind turbine foundation visits • 65 for platform visits - Structural Scope • 100 for platform visits - Electrical Scope • 260 crew shift transfer • 124 jack-up visits • 1,205 crew vessel wind turbine visits • 104 supply vessel visits to accommodation platform	
Changes to seabed habitats arising from effects on physical processes, including scour effects and changes in the sediment transport and wave regimes resulting in potential effects on benthic	None	**Array Area:** *WTG Foundations* • Mono suction bucket has a 40 m diameter base which is also proud of the seabed by 10 m before tapering into the main support column (unspecified width), however, the suction bucket jacket has 4 * 20 m buckets which reach 5 m about the seabed. The total structure footprint of these two foundation types is actually the same, however, group scour is probable around all suction buckets as well as local scour around any single bucket, making this option the MDS for scouring prior to placement of scour protection. The total width of the suction bucket foundation is also wider at 65 m when face on to flows and wider at 45° to flows when the equivalent width is 92 m.	This impact is defined by any anticipated changes to physical processes as defined in the Marine Geology, Oceanography and Physical Processes assessment.

Impact and Phase	Embedded Mitigation Measures	Maximum Design Scenario	Justification
communities (BIE-O-13).		*OSS foundations* • The (3) large box-type GBS of 150 m width (150 * 150) has a greater seabed footprint than the Pontoon GBS (2 * 179 * 35). The MDS option for the 6 small/medium foundations is the 75 m GBS box-type. *Offshore accommodation* • The 6-legged suction bucket Jacket (Medium) has the largest total width at the seabed, although the total area of structures is less than the 75 m GBS (box-type) structure. The 6-legged suction bucket is likely to have local scour around each leg and group scour around all legs, making scouring of the unprotected seabed larger than the 75 m GBS (box-type) which is likely to have edge scour at corners. • Rock berms at cable crossings:34 potential crossings over new pipelines (TQ), potential for scouring dependent on rock size and grading to perimeter. Some alignments may inhibit bedload transport. **Offshore ECC** • HVAC booster area – pre-scour protection period around a 75 m GBS (box-type) • Rock berms at cable crossings – 10 crossings over existing assets, potential for scouring dependent on rock size and grading to perimeter with heights of 1.5 m.	
Decommissioning			
Temporary habitat disturbance from decommissioning of foundation substructures and cables (BIE-D-15).	None	**Foundations:** • Total disturbance from removal of all foundations = 1.93 km^2 **Cables:** • Total disturbance from removal of all cables = 102.6 km^2 • Although it is expected that most array and export cables will be left in situ, it has been assumed that all cables will be removed during decommissioning, though any cable protection installed will be left in situ.	Maximum design scenario is assumed to be as per the construction phase, with all infrastructure removed in reverse-construction order. The removal of cables is considered a worst-case, however the necessity to remove cables will be reviewed at the time of decommissioning.
Increased SSC and sediment deposition from removal of foundations and cables (BIE- D- 16).	None	This impact is a subset of MP-C-2 for structures that are removed from the seabed. The impacts are expected to be equivalent to MP-C-2 apart from the structures that may remain. E.G. cables to be removed but not cable protection measures.	As above

Impact and Phase	Embedded Mitigation Measures	Maximum Design Scenario	Justification
Loss of introduced habitat from the removal of foundations (BIE-D-17).	None	MDS based on the removal of all foundations = 1.67 km^2	Defined by the maximum surface area introduced as above. Some materials may be left in situ and this will be reviewed closer to the time of decommissioning.

2.10 Assessment Methodology

2.10.1 Impact Assessment Criteria

2.10.1.1 The criteria for determining the significance of effects is a two-stage process that involves defining the sensitivity of the receptors and the magnitude of the impacts. This section describes the criteria applied in this chapter to assign values to the sensitivity of receptors and the magnitude of potential impacts. The terms used to define magnitude are based on those used in the Design Manual for Roads and Bridges (DMRB) methodology, which is described in further detail in **Volume 1, Chapter 5: Environmental Impact Assessment Methodology**.

2.10.1.2 The sensitivities of different biotopes have been classified by the Marine Life Information Network (MarLIN) on the Marine Evidence based Sensitivity Assessment (MarESA) four-point scale (high – medium – low – not sensitive). The scale takes account of the resistance and recoverability (resilience) of a species or biotope in response to a stressor. Specific benchmarks (duration and intensity) are defined for the different impacts for which sensitivity has been assessed (e.g. smothering, abrasion, habitat alteration etc.). Detailed information on the benchmarks used and for further information on the definition of resistance and resilience can be found on the MarLIN website.

2.10.1.3 For the purposes of this assessment, four sensitivity categories have been defined, each drawing on the four MarLIN MarESA categories (**Table 2.14**).

Table 2.14: Definition of terms relating to the sensitivity of the receptor.

Value	Criteria
Very High	Equivalent to MarLIN MarESA sensitivity category 'High'. The habitat or species is noted as exhibiting 'None' or 'Low' resistance (tolerance) to an external factor, whether that arises from natural events or human activities, and is expected to recover only over very extended timescales i.e. >25 years or not all (resilience is 'Very Low'); OR The habitat or species is noted as exhibiting 'None' or 'Low' resistance (tolerance) to an external factor, whether that arises from natural events or human activities, and is expected to recover only over very extended timescales i.e. > 10 or up to 25 years (resilience is 'Low').
High	Equivalent to MarLIN MarESA sensitivity category 'Medium'. The habitat or species is noted as exhibiting 'None' or 'Low' resistance (tolerance) to an external factor, whether that arises from natural events or human activities, and is expected to recover over medium timescales i.e. > 2 or up to 10 years (resilience is 'Medium'); OR The habitat or species is noted as exhibiting 'None' resistance (tolerance) to an external factor, whether that arises from natural events or human activities, and is expected to recover over <2 years (resilience is 'High'); OR The habitat or species is noted as exhibiting 'Medium' resistance (tolerance) to an external factor, whether that arises from natural events or human activities, and is expected to recover over medium to very long timescales, i.e. > 2 years or up to 25 years or not at all (resilience is 'Medium', 'Low' or 'Very Low').
Medium	Equivalent to MarLIN MarESA sensitivity category 'Low'. The habitat or species is noted as exhibiting 'Low' or 'Medium' resistance (tolerance) to an external factor, whether that arises from natural events or human activities, and is expected to recover over <2 years (resilience is 'High'); OR

Value	Criteria
	The habitat or species is noted as exhibiting 'High' resistance (tolerance) to an external factor, whether that arises from natural events or human activities, and is expected to recover over medium to very long timescales, i.e. > 2 years or up to 25 years or not at all (resilience is 'Medium', 'Low' or 'Very Low').
Low	Equivalent to MarLIN MarESA sensitivity category 'Not Sensitive'. The habitat or species is noted as exhibiting 'High' resistance (tolerance) to an external factor, whether that arises from natural events or human activities, and is expected to recover over short timescales, i.e. < 2 years (resilience is 'High').

2.10.1.4 The magnitude of potential impacts is defined by a series of factors, including the spatial extent of any interaction, the likelihood, frequency and duration of a potential impact. The definitions of magnitude used in the assessment are defined in in **Table 2.15**.

Table 2.15: Definition of terms relating to magnitude of an impact.

Magnitude	Criteria
Major	Fundamental, permanent / irreversible changes, over the whole receptor, and / or fundamental alteration to key characteristics or features of the particular receptors character or distinctiveness.
Moderate	Considerable, permanent / irreversible changes, over the majority of the receptor, and / or discernible alteration to key characteristics or features of the particular receptors character or distinctiveness.
Minor	Discernible, temporary (throughout project duration) change, over a minority of the receptor, and / or limited but discernible alteration to key characteristics or features of the particular receptors character or distinctiveness.
Negligible	Discernible, temporary (for part of the project duration) change, or barely discernible change for any length of time, over a small area of the receptor, and/or slight alteration to key characteristics or features of the particular receptors character or distinctiveness.

2.10.1.5 The significance of the effect upon benthic and intertidal ecology is determined by correlating the magnitude of the impact and the sensitivity of the receptor. The method employed for this assessment is presented in **Table 2.16** where a range of significance of effect is presented, the final assessment for each effect is based upon expert judgement.

2.10.1.6 For the purposes of this assessment, any effects with a significance level of minor or less have been concluded to be not significant in terms of the EIA Regulations.

Table 2.16: Matrix used for the assessment of the significance of the effect.

Value, Importance, Sensitivity	Magnitude of Impact/Degree of Change			
	Negligible	Minor	Moderate	Major
Low	Not Significant	Not Significant or Minor (Not Significant)	Minor (Not Significant)	Minor (Not Significant) or Moderate (Significant)
Medium	Not Significant	Minor (Not Significant)	Moderate (Significant)	Moderate (Significant) or Major (Significant)
High	Not Significant	Minor (Not Significant) or Moderate (Significant)	Moderate (Significant) or Major (Significant)	Major (Significant) or Substantial (Significant)
Very High	Not Significant	Moderate (Significant) or Major (Significant)	Major (Significant) or Substantial (Significant)	Substantial (Significant)

2.10.1.7 This chapter summarises the assessments made on the interest features of internationally designated sites protected under the Habitats and Birds Directives and Ramsar Convention, as described within Section 2.7.2 of this chapter (with the assessment on the site itself deferred to the RIAA Report for Hornsea Four). The RIAA Report has been prepared in accordance with PINS Advice Note Ten: Habitats Regulations Assessment Relevant to Nationally Significant Infrastructure Projects (PINS, 2017) and will be submitted as part of the DCO Application.

2.10.1.8 With respect to nationally and locally designated sites, where these sites fall within the boundaries of an internationally designated site (e.g. SSSIs which have not been assessed within the RIAA Report for Hornsea Four), only the international site has been taken forward for assessment. This is because potential effects on the integrity and conservation status of the nationally designated site are assumed to be inherent within the assessment of the internationally designated site (i.e. a separate assessment for the national site is not undertaken). However, where a nationally designated site falls outside the boundaries of an international site, but within the benthic ecology and intertidal study area, an assessment of the impacts on the overall site is made in this chapter using the EIA methodology.

2.11 Impact Assessment

2.11.1 Construction phase

2.11.1.1 The impacts of the offshore construction of Hornsea Four have been assessed on benthic and intertidal ecology. The environmental impacts arising from the construction of Hornsea Four are listed in Table 2.13 along with the MDS against which each construction phase impact has been assessed. A description of the potential effect on benthic and intertidal ecology receptors caused by each identified impact is given below.

Temporary habitat disturbance in the Hornsea Four array area and offshore ECC from construction activities (BIE-C-1).

Magnitude of impact

2.11.1.2 The total maximum area of temporary loss/disturbance of subtidal habitat loss due to construction activities described in **Table 2.13** is predicted to be up to approximately 41.7 km^2. This equates to approximately 4.5% of the total seabed area within the Hornsea Four benthic subtidal ecology study area (which totals approximately 926 km^2, constituting the array area (600 km^2) and the offshore ECC (320 km^2)).

2.11.1.3 Of the total area of temporary habitat loss described in **Table 2.13**, a maximum of approximately 12 km^2 is predicted to be temporarily lost/ disturbed within the Hornsea Four array area as a result of seabed preparations for foundations, jack-up barge operations and the installation and burial of inter-array and interconnector cables (including associated anchor placements). This equates to approximately 2% of the total seabed area within the Hornsea Four array area.

2.11.1.4 Of the total temporary habitat loss/disturbance described in **Table 2.13**, a maximum of approximately 30 km^2 will be temporarily disturbed within the subtidal areas of the Hornsea Four ECC as a result of export cable installation and burial, pre-sweeping (dredging), boulder and sandwave clearance and associated anchor placements. This equates to approximately 9% of the total seabed area within the Hornsea Four offshore ECC.

2.11.1.5 Given that the habitats are common and widespread throughout the wider region (as described in **Section 2.7** and in **Volume 5, Annex 2.1: Benthic and Intertidal Ecology Technical Report**, the temporary habitat disturbance during construction activities would have an impact on a very limited footprint compared to their overall extent.

2.11.1.6 The impact on benthic habitats is predicted to be of local spatial extent (i.e. restricted to discrete areas within Hornsea Four), short term duration (as it is limited to the duration of construction activities), intermittent and with high reversibility. It is predicted that the impact will affect the receptor directly. The magnitude is therefore, considered to be **minor.**

2.11.1.7 The ocean quahog (*Arctica islandica*) is included as a VER (**Table 2.10**). The total area of long-term habitat loss is considered to represent a very small percentage loss (0.04%) of the total area of the OSPAR Region II (Greater North Sea) within which *A. islandica* is listed as under threat and/or decline. Furthermore, Hornsea Four is committed to avoiding direct impact to the Holderness Offshore MCZ, of which *A. islandica* is a conservation feature. The magnitude of the impact on *A. islandica* is **negligible.**

Sensitivity of the receptor

2.11.1.8 The sensitivity of all biotopes/VER habitats that are known to characterise Hornsea Four have been assessed according to the detailed MarESA sensitivity assessments (**Table 2.16**) and are determined as having a low to medium sensitivity to a disturbance of this nature. None of the biotopes likely to be affected are rare or geographically restricted. As

detailed within the baseline characterisation (Section 2.7.1), comparable habitats are distributed within the wider region and Southern North Sea. Therefore, given the relatively small spatial scales for the total long-term habitat loss outlined above, this loss is not expected to undermine regional ecosystem functions or diminish biodiversity.

2.11.1.9 The communities that characterise most of the biotopes are predominantly infaunal mobile species that include polychaetes and venerid bivalves. Such species can re-enter the substratum following temporary disturbance. The recoverability of such communities is likely to occur as a result of the combination of recruitment from surrounding unaffected areas and larval dispersal, and recovery is likely to occur within one to ten years (based on the MarESA assessments).

2.11.1.10 Further evidence to support recovery is supported by research at aggregate extraction sites, where it was reported that the characteristic recovery time for sand communities may be two to three years, following cessation of dredging activity (Newell et al., 2004). Research indicated that following the initial suppression of species' diversity, abundance and biomass recovery of species' diversity to within 70 – 80% of that in non-dredged areas was achieved within 100 days (Newell et al., 2004). Species' abundance also recovered within 175 days (Newell et al., 2004). It is important to acknowledge however, that the activities associated with aggregate extraction are different to those associated with offshore wind farm construction activities. (i.e. they involve the complete removal of sediment). Data collated from more analogous activities such as the burial of telecommunications cables, as well as the monitoring of offshore wind farm sites, indicate that recovery is rapid with limited, if any, significant effects being discernible (Foden et al., 2011).

2.11.1.11 It should be noted that the biotope 'seapens and burrowing megafauna in circalittoral fine mud', has a low resilience to an impact of this type; however, it was noted that this biotope was not recorded within the array area itself but burrows typical of seapen were observed from 'rare' to 'occasional' using the SACFOR abundance scale (Gardline, 2019). Whilst this biotope was not recorded, it has been included within the assessment as a precautionary measure. The MarESA resilience assessment states that where the seapens survive impact undamaged, that the biotopes resistance is 'High' and recovery is rapid. However, where a proportion of the population is removed or killed, then the species has a high dispersal potential and long-lived benthic larvae, but larval recruitment is probably sporadic and patchy and growth is slow, suggesting that recovery may take many years. Given the low magnitude of the impact it is not expected a large proportion of seapen population would be removed.

Table 2.17: MarESA assessment for the benthic subtidal habitats for abrasion / disturbance.

Biotope code	Biotope name	MarESA sensitivity assessment	Assessment confidence
SS.SSa.IFiSa.NcirBat[1]	*Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand	Low (based on low resistance and high resilience)	Confidence is high as the assessment is based on published literature, with the baseline assessment using tramping as the impact (however the applicability of this as a low confidence).
SS.SSa.CMuSa.AalbNuc[2]	*Abra alba* and *Nucula nitidosa* in circalittoral muddy sand or slightly mixed sediment	Low (based on medium resistance and high resilience)	Confidence is low as the assessment is based on expert judgement and therefore a baseline is not available.
SS.SSa.CFiSa.ApriBatPo[3]	*Abra prismatica*, *Bathyporeia elegans* and polychaetes in circalittoral fine sand	Low (based on medium resistance and high resilience)	Confidence is low as the assessment is based on expert judgement and therefore a baseline is not available.
SS.SSa.CFiSa.EpusOborApri[4]	*Echinocyamus pusillus*, *Ophelia borealis* and *Abra prismatica* in circalittoral fine sand	Low (based on medium resistance and high resilience)	Confidence is low as the assessment is based on expert judgement and therefore a baseline is not available.
SS.SMx.CMx.MysThyMx[5]	*Mysella bidentata* and *Thyasira spp.* in circalittoral muddy mixed sediment	Low (based on medium resistance and high resilience)	Confidence is low as the assessment is based on expert judgement and therefore a baseline is not available.
SS.SMu.CFiMu.SpnMeg[6]	Seapens and burrowing megafauna in circalittoral fine mud	Medium (based on medium resistance and low resilience)	Confidence is low as the assessment is based on expert judgement and therefore a baseline is not available.

2.11.1.12 The benthic subtidal habitats that characterise the Hornsea Four array area are deemed to be a maximum of medium vulnerability, a worst-case of low recoverability and of regional to national value. The maximum sensitivity of the receptors is therefore, considered to be medium (but in most cases low) according to the MarLIN MarESA sensitivity category, which is defined by the value **high** in this assessment methodology.

2.11.1.13 Despite its thick and solid shell, *A. islandica* is described as intolerant to displacement and abrasion/physical disturbance. *A islandica* is a slow growing, long lived species with a very low recruitment rate and, therefore, recoverability from this type of impact is predicted to be low. Therefore *A. islandica* are deemed to be of medium vulnerability, very low

[1] http://www.marlin.ac.uk/habitats/detail/154
[2] https://www.marlin.ac.uk/habitats/detail/62
[3] https://www.marlin.ac.uk/habitats/detail/1133
[4] https://www.marlin.ac.uk/habitats/detail/1131
[5] http://www.marlin.ac.uk/habitats/detail/374
[6] https://www.marlin.ac.uk/habitats/detail/131

recoverability and national value, and the sensitivity of this receptor is therefore considered to be **very high**.

Significance of the effect

2.11.1.14 Overall, it is predicted that the sensitivity of the benthic subtidal biotopes is **medium** to **high** and the magnitude of the impact is **minor**. The effect is, therefore, a maximum significance of **minor (adverse)**, which is not significant in EIA terms.

2.11.1.15 The MarESA assessments identify that the confidence for the sensitivity of the specified habitats to abrasion/ disturbance of the surface is generally low for all habitats. For SS.SSa.CMuSa.AalbNuc, SS.SSa.CFiSa.ApriBatPo, SS.SMX.CMx.MysThyMx and SS.SSa.CFiSa.EpusOborApri the low confidence is associated with the resistance measure, with high confidence associated with the recovery (resilience) of the habitats. For SS.SSa.IFiSa.NcirBat, the only measure which was assessed as having a low confidence score was the applicability of the sensitivity, which originates from a low confidence score for the applicability of the resilience assessment; however, since the evidence agrees in terms of direction and magnitude of the impact this is a conservative and robust assessment. As such, the assessment of the significance of effects as not significant is considered to be robust.

2.11.1.16 Overall, the sensitivity of *A. islandica* is considered to be **very high** and the magnitude of the impact is deemed to be **negligible**. The effect will, therefore, be **not significant**. This has been concluded on the basis that only a very small proportion of the habitat for this species in the Southern North Sea is predicted to be affected (0.014%) and, furthermore, as described in **paragraph 2.7.1.22**, this species was recorded in very low abundances within the Hornsea Four benthic ecology study area, indicating that it is not an especially important area for this species.

Temporary habitat disturbance in the intertidal area from export cable installation (BIE-C-2).

Magnitude of impact

2.11.1.17 Direct loss/disturbance of habitat will occur in the intertidal area from the installation of the export cables at the landfall. As detailed in **Table 2.13**, open cut installation represents the MDS for temporary habitat disturbance across the intertidal habitat. The total maximum area of temporary habitat loss/disturbance as part of the intertidal works is expected to be approximately 56,000 m^2. Given that the intertidal habitats are common and widespread throughout the region (as described in **Section 2.7** and in **Volume 5, Annex 2.1: Benthic and Intertidal Ecology Technical Report**) this maximum area is considered to represent a very small footprint compared to the overall extent of this habitat type.

2.11.1.18 The impact is predicted to be of local spatial extent, short term duration, intermittent and with high reversibility. It is predicted that the impact will affect the receptor directly. The magnitude is therefore, considered to be **minor**.

Sensitivity of the receptor

2.11.1.19 The habitat identified during the intertidal characterisation survey LS.LSa.MoSa.Bar.Sa 'coarse littoral barren sand' are distinctive of freely draining sandy beaches on open stretches of coastline, typical of the surrounding area where there is a relatively high degree of wave exposure (**Section 2.7**). The sands are non-cohesive, with low water retention, and thus subject to drying out between tides, especially on the upper shore and where the shore profile is steep. Trial excavations revealed no macrofauna across most of the intertidal area, with only one *Lanice conchilega* found at one low shore location and a single *Talitrus* found at one of the upper shore locations. Oligochaetes, probably mainly enchytraeids, and the isopod *Eurydice pulchra* are expected to be found in extremely low abundances. Burrowing amphipods (*Bathyporeia* spp.) may be present on very rare occasions. Occasionally, other species may be left behind in low abundance by the ebbing tide.

2.11.1.20 This biotope is subject to naturally high levels of abrasion resulting from sediment mobility. The species present (if any) are, therefore, naturally able to withstand some physical disturbance and/or recover rapidly or migrate as adults into the biotope. The recovery of this biotope is therefore assessed as 'high' for any level of impact (Tillin, 2018).

2.11.1.21 The benthic intertidal habitats that characterise the Hornsea Four project area are deemed to be of low vulnerability, high recoverability and low value. The sensitivity of the receptor is therefore, considered to be **low.**

Significance of the effect

2.11.1.22 Overall, it is predicted that the sensitivity of the receptor is **low**, and the magnitude is **minor**. The effect is **not significant**, in EIA terms.

Temporary increase in SSC and sediment deposition in the Hornsea Four array area and offshore ECC (BIE-C-3).

Magnitude of impact

2.11.1.23 Temporary increases in SSC and associated sediment deposition are expected from the foundation and cable installation works and seabed preparation works (including sandwave clearance). **Chapter 1: Marine Geology, Oceanography and Physical Process** provides a full assessment of the impacts on marine processes including the development and fate of suspended sediments and seabed deposition.

2.11.1.24 **Table 2.13** presents the MDS associated with increases in SSC and deposition. MDS for SSC and deposition during the construction phase of Hornsea Four to be the total release of 12,879,050 m^3 of sediment in the array area and offshore ECC, from seabed preparation for suction caisson foundations.

2.11.1.25 Seabed preparation for foundation cables, sandwave clearance, cable trenching, drilling for foundations and spoil dispersal are all predicted to cause sediment plumes. Plumes are expected to be restricted to well-within the tidal excursion from slack water to peak flows, with plumes expected to occur over a maximum distance of 2 km. An increase in SSC of

2 mg/l above background levels is predicted local to the source; these concentrations are expected to reduce with dispersion, with sediments remaining in suspension for up to three hours.

2.11.1.26 At the disposal site the sediment plume is expected to an increase in SCC of > 10 mg/l above background over an excursion distance of up to 13.5 km from the foundations. Peak concentrations of 500 to 800 mg/l were predicted at a site very close to the release of spoil. All peak concentrations were localised and short-lived.

2.11.1.27 Sediment deposition from the plume is predicted to occur up to 2 km from the source, with maximum depth of 2 mm from the deposition of finer sediments (silts and muds). Coarser sediments are predicted to be deposited local to the source. In the case of drilling for monopiles the deposition of coarse sediments may result in the accumulation of sediment of up to tens of centimetres to meters. For the purpose of this assessment, this will be considered as habitat loss, which is considered in **paragraphs 2.11.2.23** *et seq*.

2.11.1.28 The magnitude of the maximum potential increase in SSC resulting from construction activities is within the natural range of SSC (2 to 14 mg/l closer inshore, reducing offshore to around 2 to 3 mg/l.) within the region and the impact to subtidal benthic receptors will be short-term, intermittent and of localised extent (within one tidal excursion) and reversible to baseline conditions following cessation of the construction activities. It is predicted that the impact will affect benthic receptors indirectly. The magnitude is therefore, considered to be **minor**.

2.11.1.29 Sandwave clearance and cable installation are likely to occur where the ECC is in relatively close proximity to the Flamborough Head SAC and the Holderness Offshore and Inshore MCZ. It is likely that effects of deposition from the construction works for Hornsea Four would be limited primarily to the immediate vicinity of the cable trench, with fine material distributed more widely and becoming so dispersed that it is unlikely to settle in measurable thickness locally. The magnitude of impact on these protected features is therefore, considered to be **minor**.

Sensitivity of the receptor

2.11.1.30 The subtidal habitats in this region are accustomed to high levels of SSC that occur naturally within this region. The communities that characterise these biotopes are predominantly infaunal mobile species or sessile species including polychaetes and bivalves, many of which are suspension or deposit feeders and capable of tolerating high levels of SSC and localised events of sediment deposition.

2.11.1.31 The MarESA assessment recorded medium to high resilience to changes in SSC and light to heavy smothering for all the biotopes recorded across the Hornsea Four study area. The recoverability of such communities is likely to occur as a result of the combination of recruitment from surrounding unaffected areas and larval dispersal, and recovery is likely to occur within <two to ten years depending on the depth of burial (with areas that are affected by lighter levels of deposition recovering within two years; based on the MarESA assessments).

2.11.1.32 The benthic subtidal habitats that characterise the Hornsea Four study area are deemed to be a maximum of medium vulnerability, a reasonable worst-case of medium recoverability and of regional to national value. The sensitivity of the receptors is therefore considered to be in the range from **low** to **high** according to the EIA assessment values**,** however Table 2.18 demonstrates that lower levels of sensitivity are recorded for most biotopes.

Table 2.18: MarESA assessment for the benthic subtidal habitats for temporary increase in SSC and sediment deposition (changes in suspended solids, smothering and siltation rate).

Biotope code	Biotope name	MarESA sensitivity assessment	Assessment confidence
SS.SSa.IFiSa.NcirBat	*Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand	Low sensitivity to changes in SSC; Not sensitive to light smothering (< 5 cm); Low sensitivity to heavy smothering (5 – 30 cm)	Confidence is low for changes in SSC. Confidence in the quality of the evidence and the agreement of the evidence is high and the applicability of the evidence is medium for smothering.
SS.SSa.CMuSa.AalbNuc	*Abra alba* and *Nucula nitidosa* in circalittoral muddy sand or slightly mixed sediment	Low sensitivity to changes in SSC; Not sensitive to light smothering (< 5 cm); Medium sensitivity to heavy smothering (5 – 30 cm)	Confidence is low for the SSC assessment as assessment is based on expert judgement. Confidence is low to medium for smothering and siltation. Confidence in the quality of the evidence is high for the smothering assessments, although the applicability and agreement between the evidence is low to medium.
SS.SSa.CFiSa.ApriBatPo	*Abra prismatica*, *Bathyporeia elegans* and polychaetes in circalittoral fine sand	Low sensitivity to changes in SSC; Not sensitive to light smothering (< 5 cm); Medium sensitivity to heavy smothering (5 – 30 cm)	Confidence is low for the SSC assessment as assessment is based on expert judgement. Confidence is low to medium for smothering and siltation. Confidence in the quality of the evidence is high for the smothering assessments, although the applicability and agreement between the evidence is low.
SS.SSa.CFiSa.EpusOborApri	*Echinocyamus pusillus, Ophelia borealis* and *Abra prismatica* in circalittoral fine sand	Low sensitivity to changes in SSC; Not sensitive to light smothering (< 5 cm); Medium sensitivity to heavy smothering (5 – 30 cm)	Confidence is low for the SSC assessment as assessment is based on expert judgement. Confidence is low to medium for smothering and siltation. Confidence in the quality of the evidence is high for the smothering assessments, although the applicability and agreement

Biotope code	Biotope name	MarESA sensitivity assessment	Assessment confidence
			between the evidence is low to medium.
SS.SMx.CMx.MysThyMx	*Mysella bidentata* and *Thyasira spp.* in circalittoral muddy mixed sediment	Not sensitive to changes to SSC; Not sensitive to light smothering (< 5 cm); Low sensitivity to heavy smothering (5 – 30 cm)	Confidence is low for the SSC assessment as assessment is based on expert judgement. Confidence in the quality of the evidence is high for the smothering assessments, although the applicability and agreement between the evidence is low.
SS.SMu.CFiMu.SpnMeg	Seapens and burrowing megafauna in circalittoral fine mud	Not sensitive to changes to SSC; Not sensitive to light smothering (< 5 cm); Not sensitive to heavy smothering (5 – 30 cm)	Confidence is medium for the SSC assessment as assessment is based on some peer reviewed papers but relies on grey literature and expert judgement. Confidence in the quality of the evidence is low for the smothering assessments.

2.11.1.33 *A. islandica* is not considered to be sensitive to increases in SSC, which is likely to increase food availability. Similarly, it is not sensitive (**low** sensitivity) to sediment deposition, with individuals known to burrow to the sediment surface through any deposited sediment, with no mortality observed (Tyler-Walters and Sabatini, 2017).

2.11.1.34 The impact of increased SSC and deposition on biotopes typical of the soft sediment broadscale habitat features of the Holderness Offshore and Inshore MCZ are presented in **Table 2.18** above and are considered not to be sensitive to light smothering (<5 cm). Impacts to broadscale habitats moderate to high energy circalittoral rock are also considered to be not sensitive to light smothering, with the moderate to high energy water flow likely to remove sediment rapidly and therefore deposition on characterising rock species such as bryozoans and hydroids.

2.11.1.35 The broadscale habitat features of the Holderness Offshore and Inshore MCZ is deemed to be not vulnerable, with high recoverability and national importance. The sensitivity of these receptors to light smothering is therefore, considered to be **medium.**

2.11.1.36 The communities associated with subtidal chalk reef habitat, which is a protected feature of the Flamborough Head SAC are expected to have some tolerance to increases in SSC (De-Bastos and Hill, 2016c; Tillin and Hill, 2016), particularly as these habitats are near the coast, where SSC are highest. Sensitivity of many animals associated with soft rock habitats to light sediment deposition would also be expected to be limited due to the resilience of some characterising species (De-Bastos and Hill, 2016c) and the natural sediment mobility in these areas.

2.11.1.37 The subtidal chalk reef habitat exposures of the Flamborough Head SAC is deemed to be of worst-case medium vulnerability, medium to high recoverability and international

importance. The sensitivity of these receptors to light smothering is therefore, considered to be worst-case **high**.

2.11.1.38 A not-sensitive to low MarESA sensitivity is recorded for 'submerged or partially submerged sea caves', which is a protected feature of the Flamborough Head SAC (Tyler-Walters, 2018). The upper, vertical walls of caves are unlikely to be subject to any smothering, but the inner reaches of caves with shallow slopes or horizontal ledges may be. In the wave exposed conditions experienced by biotopes typical of this habitat, light smothering of sediment may be removed quickly, depending on the shape of the cave. It is unlikely that the magnitude of this impact would result in any localised anoxia occurring at the base of any flora that might inhabit the cave, and a Low vulnerability is therefore recorded. Recovery is likely to be high and the habitat is of international value. The sensitivity of the receptor to light smothering is considered to be **low**.

Significance of the effect

2.11.1.39 Overall, it is predicted that the sensitivity of the benthic subtidal habitats is at worst-case **high** and the magnitude is **minor.** The effect is considered to be, at worst, of **minor (adverse)** significance, which is not significant in EIA terms.

2.11.1.40 The MarESA assessments identify that some aspects of the confidence for the sensitivity of the specified habitats to changes in SSC and for sediment deposition (smothering) is low for all habitats. For all habitats, the low confidence score for the sensitivity assessment is associated with the resistance assessment rather than the resilience assessment. The significance of effect has been assessed based on the lowest resistance score of medium and resilience of medium as part of the sensitivity assessments. Therefore, while the confidence score is low, the assessment is using the most conservative sensitivity. As such, the assessment of the significance of effects as **not significant,** is considered to be robust.

Temporary increase in SSC and sediment deposition in the intertidal area (BIE-C-4).

Magnitude of impact

2.11.1.41 Temporary increases in SSC and associated sediment deposition in the intertidal area are expected from the cable installation works. **Chapter 1: Marine Geology, Oceanography and Physical Process** provides an assessment of the impacts on marine processes including the development and fate of suspended sediments and seabed deposition.

2.11.1.42 **Table 2.13** presents the MDS associated with increases in SSC and deposition associated with cable installation across the intertidal. The scenario that results in the greatest impact is open cut trenching. Sediment disturbance will occur during the trenching works and the maximum amount of sediment that would be removed is predicted to be 7,162 m^3.Any loosened fine material remaining in an open trench will be subject to being transported away when the tide washes in and out of the trench. This is likely to introduce

a relatively low volume of sediment. SSCs will be increased locally but rapidly attenuate to natural levels.

2.11.1.43 After the trench has been backfilled, it is expected that re-working by waves and currents will quickly (in the order of days to weeks) redistribute and smooth any remaining local disturbances. As such all impacts will be short term and highly localised.

2.11.1.44 Given the impact is predicted to be of local spatial extent, short term duration, intermittent and high reversibility. It is predicted that the impact will affect the receptor directly. The magnitude is therefore, considered to be **minor**.

Sensitivity of the receptor

2.11.1.45 As described above, the species and habitats identified during the intertidal characterisation survey (LS.LSa.MoSa.Bar.Sa 'coarse littoral barren sand) are typical of the wider region. This biotope is assessed (according to the MarLin and MarESA criteria) as having a high recoverability to any level of impact as this biotope is characterized by the absence, rather than the presence of species which are subject to naturally high levels of abrasion resulting from sediment mobility. The benthic intertidal habitats that characterise the Hornsea Four intertidal study area are deemed to be of low vulnerability, high recoverability and local value. The sensitivity of the receptor is therefore, considered to be **low.**

Significance of the effect

2.11.1.46 Overall, it is predicted that the sensitivity of the receptor is **low**, and the magnitude is **minor**. The effect is **not significant** in EIA terms.

Direct and indirect seabed disturbances leading to the release of sediment contaminants (BIE-C-6).

Magnitude of impact

2.11.1.47 There is the potential for sediment bound contaminants, such as metals, hydrocarbons and organic pollutants, to be released into the water column and lead to an effect on benthic ecology receptors.

2.11.1.48 The assessment of contaminants undertaken in the Hornsea Four array (the full details of which are presented in **Volume 5, Annex 2.1: Benthic, Subtidal and Intertidal Technical Report**) revealed that hydrocarbon concentrations across most of the array area were within the expected UKOOA (2001) background concentrations. Some elevation in total hydrocarbon (THC) concentrations was noted nearby existing oil and gas infrastructure which is as expected. All metals concentrations, when compared to Buchman (2008) Apparent Effects Threshold's (AETs), were below their respective AETs indicating that toxicological impacts on the fauna were unlikely.

2.11.1.49 Total Polycyclic Aromatic Hydrocarbon(s) (PAH) and Naphthalenes phenanthrenes and dibenzothiophenes (NPD) PAH values, were well below the Effects Range Low (ERL) and the Effects Range Median (ERM) values (Long *et al.*, 1995) indicating that toxic effects to

fauna were unlikely. In addition, PAH concentrations were below the apparent effect threshold (AET) (Buchman, 2008) further suggesting that adverse biological impacts would be unlikely.

2.11.1.50 All metals concentrations, when compared to Buchman (2008) AETs, were below their respective AETs indicating that toxicological impacts on the fauna were unlikely.

2.11.1.51 Following disturbance as a result of construction activities, the majority of re-suspended sediments are expected to be deposited in the immediate vicinity of the works. The release of contaminants from the small proportion of fine sediments is likely to be rapidly dispersed with the tide and/ or currents and therefore increased bio-availability resulting in adverse eco-toxicological effects are not expected.

2.11.1.52 The impact is predicted to be of local spatial extent, short term duration, intermittent and high reversibility. It is predicted that the impact will affect the receptor directly. The magnitude is therefore, considered to be **negligible**. A negligible magnitude is not considered further in this assessment, as it will not lead to a significant effect based on the matrix used for the assessment of significance and expert judgement (Table 2.16).

2.11.2 Operation and maintenance phase

2.11.2.1 The potential impacts of the offshore operation and maintenance of Hornsea Four have been assessed on benthic and intertidal ecology. The potential environmental impacts arising from the operation and maintenance of Hornsea Four are listed in Table 2.13 along with the MDS against which each operation and maintenance phase impact has been assessed.

2.11.2.2 A description of the potential effect on benthic ecology receptors caused by each identified impact is given below.

Long-term habitat loss/ change from the presence of foundations, scour protection and cable protection (BIE-O-8).

Magnitude of impact

2.11.2.3 The presence of the WTG and OSS foundations and the associated scour protection, along with the cable protection measures used at cable crossings and areas where cable burial is not possible, will lead to a change from a sedimentary habitat to one characterised by hard substrate. This will be a permanent change (for the 35-year design life duration of the project) and is therefore considered an impact of the operational phase of the development. It is assessed here as habitat loss and a potential adverse effect (due to the potential shift in the baseline condition), although it is noted that this also comprises potential beneficial effects (providing new habitats for different faunal assemblages to colonise, resulting in a likely increase in biodiversity and biomass).

2.11.2.4 Table 2.13 identifies the MDS foundation, scour and cable protection footprint. The total habitat loss arising from these components would be 3,707,730 m^2, which equates to approximately 0.4% of the Hornsea Four benthic subtidal ecology study area.

2.11.2.5 The impact is predicted to be of local spatial extent (the footprint of the area affected is highly localised), comprise a long-term duration (permanent change, until removal) and high reversibility. As the habitats and characterising biotopes are common and widespread throughout the wider region, the magnitude is assessed as **negligible**. A negligible magnitude is not considered further in this assessment, as it will not lead to a significant effect based on the matrix used for the assessment of significance and expert judgement (Table 2.16).

2.11.2.6 No long-term habitat loss will occur in the intertidal area of the Hornsea Four ECC as cable protection will not be used in this area.

Colonisation of the WTGs and scour/ cable protection may affect benthic ecology and biodiversity (BIE-O-9).

Magnitude of impact

2.11.2.7 The introduction of hard substrate will change the type of available habitats within the benthic subtidal ecology study area. However, the amount of introduced substrate is relatively small at approximately 3,707,730 m^2, which accounts for approximately 0.4% of the total benthic subtidal ecology study area.

2.11.2.8 Hard substrate habitats are comparatively rare within the Hornsea Four benthic ecology study area which is dominated by sedimentary habitats. The introduction of hard substrate, and associated increases in biodiversity, will alter the biotopes that characterise the area at the location of the introduction of the Hornsea Four infrastructure and will be long term, lasting for the duration of the development. Any effects on benthic ecology, arising from the introduction of hard substrates will likely be localised to the Hornsea Four array area and offshore ECC (where cable protection is laid).

2.11.2.9 The impact is therefore predicted to be of local spatial extent, long-term duration but reversable once the infrastructure is removed. It is predicted that the impact will affect the receptor directly. The magnitude is therefore, considered to be **minor.**

Sensitivity of the receptor

2.11.2.10 The introduction of new hard substrate will represent a potential shift in the baseline condition within a small proportion of the Hornsea Four benthic subtidal ecology study area. Potential beneficial effects that may occur are associated with the likely increase in biodiversity and biomass, as has been observed at the Egmond aan Zee Offshore Windfarm (OWEZ) (Lindeboom *et al.*, 2011). Individual species with the potential to benefit from the introduction of hard substrate due to increased substrate for attachment are those which are typical of rocky habitats and intertidal environments.

2.11.2.11 The species potentially introduced may also have indirect and adverse effects through increased predation on, or competition with, neighbouring soft sediment species.

However, such effects are difficult to predict. The increased biodiversity associated with the structures could provide benefits at higher trophic levels as the benthic organisms colonising the structures provide an additional food source. Studies at the Horns Rev Offshore Windfarm in Denmark provided evidence that offshore wind farm structures are used as successful nursery habitats for the edible crab *Cancer pagurus* (BioConsult, 2006). However, any direct benefits are only likely to occur on a very localised basis (i.e. near the infrastructure).

2.11.2.12 Given the presence of epifaunal species and colonising fauna within discrete parts of the Hornsea Four benthic subtidal ecology study area already (i.e. associated with coarser sediment habitats), it is predicted that colonisation of hard substrates by common species such as bryozoans and ascidians will occur.

2.11.2.13 The soft sediment biotopes likely to be affected are deemed to be of low vulnerability, high recoverability (following removal of the infrastructure) and of local to regional value. The sensitivity of these receptors is therefore, considered to be **medium**.

Significance of the effect

2.11.2.14 Any beneficial effects associated with an increase in biodiversity will be highly localised in nature and is not regarded as mitigation for the loss of sedimentary habitat associated with the installation of these structures. The introduction of hard structures such as scour protection can lead to an increase in biomass and biodiversity which may be considered beneficial, but it also represents a change from the baseline environment which may be considered adverse. Overall, it is predicted that the sensitivity of the receptor is **medium** and the magnitude is **minor**. The effect is of **minor (adverse** or **beneficial)** significance, which is not significant in EIA terms.

Increased risk of introduction or spread of Marine Invasive Non-Native Species (MINNS) due to presence of infrastructure and vessel movements (e.g. the discharge of ballast water) may affect benthic ecology and biodiversity (BIE-O-10).

Magnitude of impact

2.11.2.15 There is a risk that the introduction of hard substrate into a sedimentary habitat will enable the colonisation of the introduced substrate by invasive/ non-indigenous species that might otherwise not have had a suitable habitat for colonisation, thereby enabling their spread. This along with the movement of vessels in and out of the benthic subtidal study area has the potential to impact upon benthic ecology and biodiversity in the study area and broader region.

2.11.2.16 As presented in **Table 2.13**, up to 3,707,730 m^2 of new hard substrate habitat will be introduced into the Hornsea Four benthic subtidal ecology study area, which has the potential to provide new habitat for colonisation by MINNS.

2.11.2.17 In addition to this, there will be up to 6,032 round trips to port during the construction phase and up to 3,525 round trips to port by operational and maintenance vessels, which

will contribute to the risk of introduction or spread of INNS through ballast water discharge.

2.11.2.18 Designed-in measures including a PEMMP with a biosecurity plan (see **Table 2.12**) will, however, ensure that the risk of potential introduction and spread of INNS will be minimised.

2.11.2.19 The impacts on biotopes and VER within the Hornsea Four benthic ecology study area is predicted to be of low spatial extent (though the introduction of structures may serve as 'stepping stones' and extend the impact beyond a local scale, however based on current scientific knowledge it is not possible to predict whether such a spread will occur and to what extent and which species, if any, this may involve), long term duration, continuous and irreversible. It is predicted that the impact will affect the receptors indirectly. The magnitude of this impact is therefore considered to be **negligible** and is not considered further in this assessment, as it will not lead to a significant effect based on the matrix used for the assessment of significance and expert judgement (**Table 2.16**).

Direct disturbance to seabed from jack-up vessels and cable maintenance activities (BIE-O-11).

Magnitude of impact

2.11.2.20 The total maximum area of temporary subtidal habitat loss will arise from the use of jack-up vessels for operational and maintenance activities as well as from cable maintenance and cable repair (including de-burial and re-burial of export and array cables). A total of up to 3,252,500 m^2 of temporary habitat disturbance is predicted to arise over the 35-year design life of Hornsea Four (equating to approximately 0.3% of the Hornsea Four benthic subtidal ecology study area). Given that the habitats are common and widespread throughout the region impacts from the individual O&M activities will represent a very small footprint compared to their overall extent.

2.11.2.21 With respect to available habitat for *A. islandica*, the total area of temporary habitat loss during the operational phase represents a very small percentage loss (0.0004%) of the total area of the OSPAR Region II within which *A. islandica* is listed as under threat and/or decline.

2.11.2.22 The impacts are predicted to be temporary and of short-term duration and only a single event in each location, intermittent and reversable. It is predicted that the impact will affect the receptors directly. The magnitude of this impact is therefore considered to be **negligible** and is not considered further in this assessment, as it will not lead to a significant effect based on the matrix used for the assessment of significance and expert judgement (**Table 2.16**).

Changes to seabed habitats arising from effects on physical processes, including scour effects and changes in the sediment transport and wave regimes resulting in potential effects on benthic communities (BIE-O-13).

Magnitude of impact

2.11.2.23 The presence of foundations, scour protection and cable protection material may introduce changes to the local hydrodynamic and wave regime (**Table 2.13**), resulting in changes to the sediment transport pathways and associated effects on benthic ecology. Scour and increases in flow rates can change the characteristics of the sediment potentially making the habitat less suitable for some species.

2.11.2.24 The use of correctly designed scour protection at foundations and sufficiently buried cables will prevent scour occurring (**Chapter 1: Marine Geology, Oceanography and Physical Processes**). The impacts of the use of this scour protection has been assessed within this chapter (**paragraph 2.11.1.30** *et seq.*) and found to have no significant effects on the benthic environment.

2.11.2.25 The Marine Geology, Oceanography and Physical Processes assessment has determined that the impacts on hydrodynamic and wave regimes will be Not Significant and would therefore not result in any significant changes to sediment transport and consequently will not have any impacts on benthic ecology. The magnitude of this impact is therefore considered to be **negligible** and is not considered further in this assessment, as it will not lead to a significant effect based on the matrix used for the assessment of significance and expert judgement (**Table 2.16**).

2.11.3 Decommissioning phase

2.11.3.1 The impacts of the offshore decommissioning of Hornsea Four have been assessed on benthic and intertidal ecology. The environmental impacts arising from the decommissioning of Hornsea Four are listed in **Table 2.13** along with the MDS against which each decommissioning phase impact has been assessed. A description of the significance of effect upon benthic and intertidal receptors caused by each identified impact is provided below.

Temporary habitat disturbance from decommissioning of foundation substructures and cables (BIE-D-15).

2.11.3.2 The nature and extent of temporary habitat loss/disturbance during decommissioning is assumed (for the purposes of this assessment) to be similar to that described for the equivalent activities during the construction phase in **paragraphs 2.11.1.1** *et seq.* unless otherwise stated (i.e. activities involved in the decommissioning process that give rise to

impacts that are similar to those arising from the construction process such as sandwave clearance, cable installation, anchor placements and jack-up operations).

2.11.3.3 The MDS has assumed the same quantitative requirements for sandwave clearance and boulder clearance activities, prior to decommissioning, as that required during the construction phase, although this is also likely to be over precautionary.

2.11.3.4 Decommissioning has the potential to cause temporary loss of, or disturbance to, benthic habitats within Hornsea Four, similar to those described during the construction phase. However, as seabed preparation works would not be required, the magnitude of this impact will be lower than during the construction phase.

2.11.3.5 The details of the proposed decommissioning process will be included within the Decommissioning Programme which will be developed and updated throughout the lifetime of Hornsea Four to account for changing best practice.

2.11.3.6 The magnitude of the worst-case impact and the sensitivities of the benthic habitats to temporary habitat disturbance are as described for the construction phase (described in detail in **paragraph 2.11.1.2** *et seq.* for subtidal habitats and for the intertidal habitats in **paragraph 2.11.1.17** *et seq.*).

Significance of the effect

2.11.3.7 Based on the assessment undertaken for construction, which represents a worst-case scenario, it is predicted that the maximum sensitivity of the receptors is **high** (Table 2.17) and the magnitude is **minor**. The effect is **not significant** in EIA terms.

Increased SSC and sediment deposition from removal of foundations and cables (BIE- D- 16).

2.11.3.8 Increases in SSC and sediment deposition from the decommissioning works are expected to be less than that for construction and are therefore of a reduced magnitude. The magnitude of the worst-case impact and the sensitivities of the benthic habitats to SSC and sediment deposition are as described for the construction phase (described in detail in **paragraph 2.11.1.23** *et seq.).*

Significance of the effect

2.11.3.9 Based on the assessment undertaken for construction, which would be considered to be a very precautionary MDS for the decommissioning process, it is predicted that the maximum sensitivity of the receptors is **medium** (Table 2.18) and the magnitude is **low**. The effect is of **minor (adverse)** significance, which is not significant in EIA terms.

Loss of introduced habitat from the removal of foundations (BIE-D-17).

2.11.3.10 As detailed in **paragraph 2.11.1.30** *et seq.*, hard substrate introduced into Hornsea Four will become colonised by epifauna. The removal of the foundations during decommissioning would therefore remove these species and associated habitats they had created.

Magnitude of impact

2.11.3.11 The removal of the foundations and associated scour protection will result in a permanent loss of 1.67 km^2 of hard substrate within the Hornsea Four array area (and correspondingly the recovery of sedimentary habitats lost at the time of construction as the infrastructure is removed).

2.11.3.12 The impact is predicted to be of long-term duration (i.e. the colonising species will be permanently lost) and irreversible but it will be of highly localised spatial extent. It is predicted that the impact will affect receptors directly. The magnitude is therefore considered to be **minor**.

Sensitivity of the receptor

2.11.3.13 While the removal of the substrate will result in localised declines in biodiversity, areas of bare habitat, lost during construction, will be exposed and will be open to recolonization by the original soft benthic species. It is expected that the baseline benthic communities will recover in these areas to their pre-construction state based on the recovery rates for disturbed sediment, which would equate to a maximum sensitivity for the baseline habitats of **high**.

Significance of the effect

2.11.3.14 The loss of species colonising the hard substrate will be highly localised, there will be a typically high recoverability of the subsequently exposed substrate and communities back to their pre-construction state (see **paragraphs 2.7.1.11** *et seq.*). Overall, the maximum sensitivity of the receptors is considered to be **high** and the magnitude of the impact is considered to be **minor**. The effect is of **minor (beneficial** and **adverse)** significance, which is not significant in EIA terms.

2.12 Cumulative Effect Assessment (CEA)

2.12.1.1 Cumulative effects can be defined as effects upon a single receptor from Hornsea Four when considered alongside other proposed and reasonably foreseeable projects and developments. This includes all projects that result in a comparative effect that is not intrinsically considered as part of the existing environment and is not limited to offshore wind projects.

2.12.1.2 A screening process has identified a number of reasonably foreseeable projects and developments which may act cumulatively with Hornsea Four. The full list of such projects that have been identified in relation to the offshore environment are set out in **Volume 4, Annex 5.3: Offshore Cumulative Effects** and are presented in a series of maps within **Volume 4, Annex 5.4: Location of Offshore Cumulative Schemes**.

2.12.1.3 In assessing the potential cumulative impacts for Hornsea Four, it is important to bear in mind that some projects, predominantly those 'proposed' or identified in development plans, may not actually be taken forward, or fully built out. There is therefore a need to build in some consideration of certainty (or uncertainty) with respect to the potential impacts which might arise from such proposals. For example, those projects under

construction are likely to contribute to cumulative impacts (providing effect or spatial pathways exist), whereas those proposals not yet approved are less likely to contribute to such an impact, as some may not achieve approval or may not ultimately be built due to other factors.

2.12.1.4 With this in mind, all projects and plans considered alongside Hornsea Four have been allocated into 'tiers' reflecting their current stage within the planning and development process. This allows the cumulative impact assessment to present several future development scenarios, each with a differing potential for being ultimately built out. This approach also allows appropriate weight to be given to each scenario (tier) when considering the potential cumulative impact. The proposed tier structure that is intended to ensure that there is a clear understanding of the level of confidence in the cumulative assessments provided in the Hornsea Four PEIR. An explanation of each tier is included in **Table 2.19**.

Table 2.19: Description of tiers of other developments considered for CEA (adapted from PINS Advice Note 17).

Tier 1	Project under construction.
	Permitted applications, whether under the Planning Act 2008 or other regimes, but not yet implemented.
	Submitted applications, whether under the Planning Act 2008 or other regimes, but not yet determined.
Tier 2	Projects on the Planning Inspectorate's Programme of Projects where a Scoping Report has been submitted.
Tier 3	Projects on the Planning Inspectorate's Programme of Projects where a Scoping Report has not been submitted.
	Identified in the relevant Development Plan (and emerging Development Plans with appropriate weight being given as they move closer to adoption) recognising that much information on any relevant proposals will be limited.
	Identified in other plans and programmes (as appropriate) which set the framework for future development consents/approvals, where such development is reasonably likely to come forward.

2.12.1.5 The plans and projects selected as relevant to the CEA of impacts to benthic and intertidal ecology are based on an initial screening exercise undertaken on a long list (see **Volume 4, Annex 5.3: Offshore Cumulative Effects**). Consideration of effect-receptor pathways, data confidence and temporal and spatial scales has allowed the selection of the relevant projects for a topic-specific cumulative short-list. For the majority of potential effects for benthic and intertidal ecology, planned projects were screened into the assessment based on a 10 km screening range surrounding the array, and a 15 km range around the offshore ECC (**Figure 2.1**), representing the tidal ellipse distance for a single tidal cycle.

2.12.1.6 The specific projects scoped into the CEA for to benthic and intertidal ecology, as well as the tiers into which they have been allocated are presented in **Table 2.20** below and are illustrated in **Figure 2.6**. The operational projects included within the table are included due to their completion/ commissioning subsequent to the data collection process for Hornsea Four and as such not included within the baseline characterisation. Note that this table only includes the projects screened into the assessment for benthic and intertidal ecology based on the criteria outlined above. For the full list of projects considered,

including those screened out, please see the Cumulative Effects Annex (**Volume 4, Annex 5.3: Offshore Cumulative Effects**).

Table 2.20: Projects screened into the benthic and intertidal ecology cumulative assessment.

Tier	Project/plan	Details/ relevant dates	Distance to Hornsea Four Array	Distance to Hornsea Four ECC	Distance to Hornsea Four HVAC Booster Area	Reason for inclusion in CEA
1	Hornsea Project Two	Consented: Will be operational during Hornsea Four construction.	0.00	5.84	66.43	Temporal overlap of operational activity with Hornsea Four construction. High confidence.
1	Hornsea Project One	Consented: Will be operational during Hornsea Four construction.	5.08	21.32	82.50	Temporal overlap of operational activity with Hornsea Four construction. High confidence.
1	Bridlington A	Disposal site	>50	27.75	2.10	Potential temporal overlap of operational activity overlapping with Hornsea Four construction

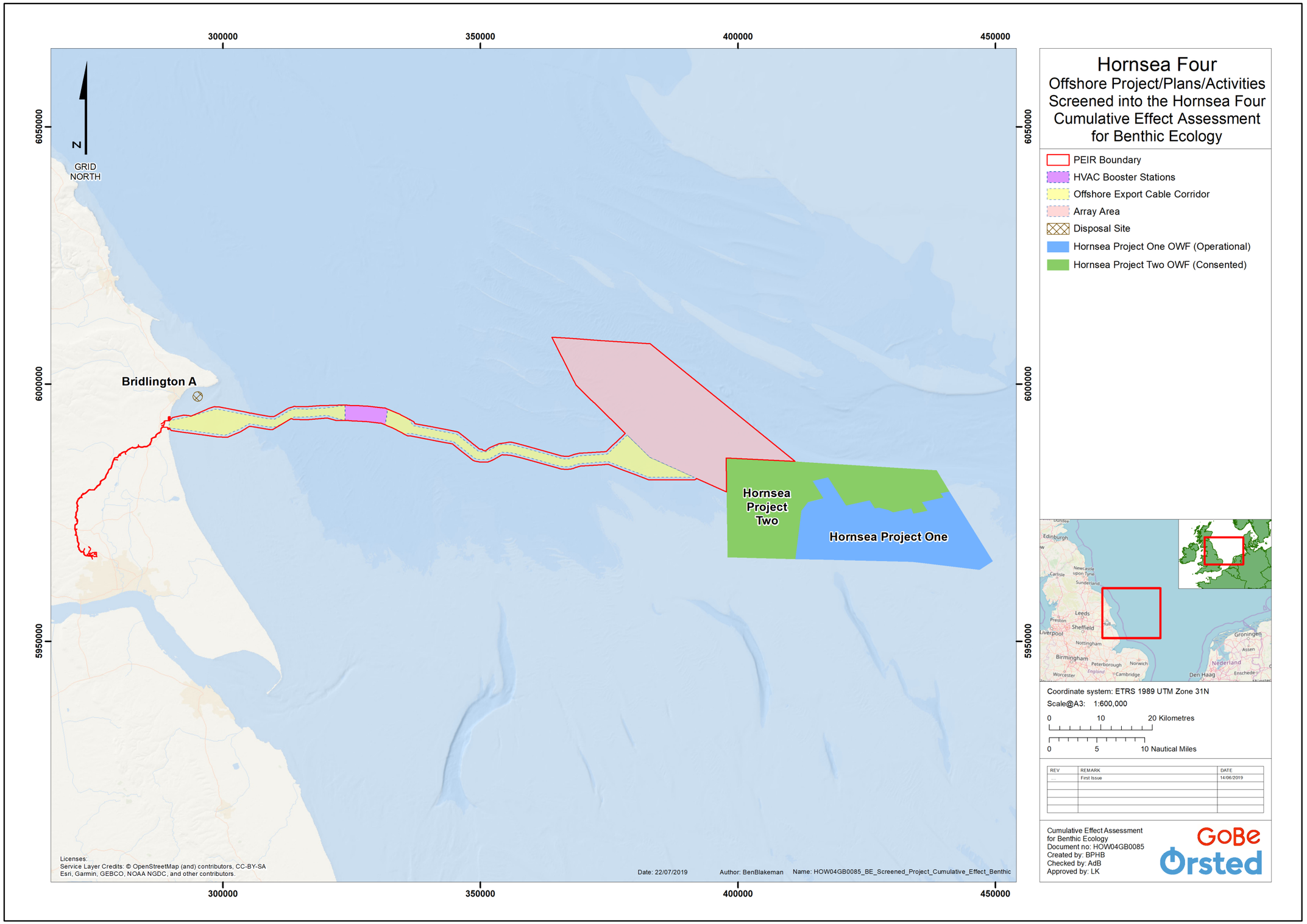

Figure 2.6: Offshore projects/plans/activities screened into the Hornsea Four cumulative effect assessment on benthic ecology (not to scale).

2.12.1.1 Certain impacts assessed for the project alone are not considered in the cumulative assessment due to:

- The highly localised nature of the impacts (i.e. they occur entirely within the Hornsea Four boundary only);
- Management measures in place for Hornsea Four will also be in place on other projects reducing the risk of impacts occurring; and/or
- Where the potential significance of the impact from Hornsea Four alone has been assessed as negligible.

2.12.1.2 The impacts excluded from the CEA for the above reasons are:

Construction phase:
- Temporary habitat disturbance: the impact is highly localised in nature; and
- Direct and indirect seabed disturbances leading to the release of sediment contaminants: the potential significance of the impact from Hornsea Four alone has been assessed as not significant.

Operation and maintenance phase:
- Direct disturbance to seabed from jack-up vessels and cable maintenance activities: the impact is highly localised in nature; and
- Increased risk of introduction or spread of Marine Invasive Non-Native Species (MINNS) due to presence of subsea infrastructure and vessel movements (e.g. ballast water) may affect benthic ecology and biodiversity: the potential significance of the impact from Hornsea Four alone has been assessed as not significant.

2.12.1.3 The impacts that have been considered in the CEA are as follows:

Construction phase:
- Temporary increase in SSC and sediment deposition.

Operation and maintenance phase:
- Long-term habitat loss/ change from the presence of foundations, scour protection and cable protection;
- Colonisation of the WTGs and scour/ cable protection may affect benthic ecology and biodiversity; and
- Changes to seabed habitats arising from effects on physical processes, including scour effects and changes in the sediment transport and wave regimes resulting in potential effects on benthic communities.

2.12.1.4 The cumulative MDS described in **Table 2.21** have been selected as those having the potential to result in the greatest cumulative effect on an identified receptor group. The cumulative impacts presented and assessed in this section have been selected from the details provided in the project description for Hornsea Four (summarised for benthic and intertidal ecology in **Table 2.13**), as well as the information available on other projects and plans in order to inform a cumulative MDS. Effects of greater adverse significance are not predicted to arise should any other development scenario, based on details within the project design envelope to that assessed here, be taken forward in the final design scheme.

Table 2.21: Cumulative MDS for benthic and intertidal ecology.

Project Phase	Potential Impact	Maximum Design Scenario	Justification
Construction	Cumulative temporary increase in SSC and sediment deposition	MDS as described for the construction phase of Hornsea Four (for both foundations and cable installation) assessed cumulatively with the following licensed disposal sites. **Tier 1:** - Licenced disposal site Bridlington A. **Tier 2:** - No Tier 2 projects identified. **Tier 3:** - No Tier 3 projects identified.	Maximum potential for interactive effects from increases in SSC and consequent deposition within a 10 km buffer surrounding the array area, and a 15 km buffer around the offshore ECC. Habitats within this buffer fall within the Hornsea Four benthic ecology impact area. The use of the Bridlington A disposal site is intermittent, and the volume used is unknown in advance and therefore it is not possible to determine if the use of the site will overlap with impacts from the construction of Hornsea Four. However, while the volume is likely to be greater, the impacts are likely to be similar to those for the deposition of the drilling arisings predicted for Hornsea Four.
Operation	Cumulative long-term habitat loss/ change from the presence of foundations, scour protection and cable protection	13,379,674 m^2 total cumulative long-term habitat loss of benthic ecology MDS for Hornsea Four plus the cumulative full development of the following projects within the Hornsea Four extended study area: **Tier 1:** - Operational effects arising from wind farm projects Hornsea Project One and Hornsea Project Two. **Tier 2:** - No Tier 2 projects identified. **Tier 3:** - No Tier 3 projects identified.	Maximum cumulative long-term habitat loss is calculated within a 10 km buffer surrounding the array area, and a 15 km buffer around the offshore ECC. Habitats within this buffer fall within the Hornsea Four benthic ecology impact area.
Operation	Cumulative colonisation of the WTGs and scour/ cable protection may affect benthic	14,807,857 m^2 total cumulative introduction of subtidal hard substrates. MDS as described for operation and maintenance phase assessed cumulatively with the following marine projects within a	Maximum cumulative long-term habitat loss is calculated within a 10 km buffer surrounding the array area, and a 15 km buffer around the offshore ECC. Habitats within this buffer fall within the Hornsea Four benthic ecology impact area.

Project Phase	Potential Impact	Maximum Design Scenario	Justification
	ecology and biodiversity	representative 10 km buffer surrounding the array area, and a 15 km buffer around the offshore ECC boundary. **Tier 1:** - Operational effects arising from wind farm projects Hornsea Project One and Hornsea Project Two **Tier 2:** - No Tier 2 projects identified. **Tier 3:** - No Tier 2 projects identified.	
Operation	Cumulative changes to seabed habitats arising from effects on physical processes, including scour effects and changes in the sediment transport and wave regimes resulting in potential effects on benthic communities	MDS as described for the operation and maintenances phase of Hornsea Four assessed cumulatively with the following offshore wind farms: **Tier 1:** - Licenced disposal site Bridlington A. - Operational effects arising from wind farm projects Hornsea Project One and Hornsea Project Two. **Tier 2:** - No Tier 2 projects identified. **Tier 3:** - No Tier 3 projects identified.	Maximum potential cumulative effects on the tidal and wave regimes (see **Volume 2, Chapter 1: Marine Geology, Oceanography and Physical Processes**).

2.12.1.5 A description of the significance of cumulative effects upon benthic and intertidal ecology arising from each identified impact is given below. The cumulative effects assessment has been based on information available in the ESs for the other projects where these are available; it is noted that the project parameters quoted within these ESs are often refined during the determination period and in the post-consent phase such that the final schemes built out may have a reduced impact compared to what has been concluded in the ES.

2.13 Construction Phase

Cumulative temporary increase in SSC and sediment deposition

Tier 1

2.13.1.1 There is potential for cumulative impacts from increased SSC and associated sediment deposition as a result of construction activities associated with Hornsea Four and other projects. The only project identified as having the potential to act cumulatively is the Tier 1 licensed disposal site Bridlington A (**Figure 2.6** and
2.13.1.2). No other projects were identified as adding any cumulative impact under Tiers 2 or 3.

2.13.1.3 The magnitude assessment for Hornsea Four is presented in **paragraphs 2.11.1.23** *et seq.* The impact on subtidal benthic receptors from construction related activities is expected to be low. It is not known what volumes of sediment, if any, will be deposited at the disposal site. However, as the disposal events are discrete and temporally distinct, it is considered unlikely that there will be a cumulative impact. However, based on a worst-case scenario, it is unlikely that combined increases in SSC and sediment deposition resulting from the use of the disposal sites and Hornsea Four will cumulatively exceed the natural variation or the 5 cm smothering baseline to be considered 'light' smothering for the sensitivity assessments.

2.13.1.4 The cumulative impact of temporary increase in SSC and sediment deposition is predicted to be of regional spatial extent, of medium term (i.e. construction phase), of intermittent duration, and reversible to baseline conditions following cessation of activities. It is predicted that the impact will affect benthic receptors indirectly. The magnitude is therefore, considered to be, at worst-case, **minor** magnitude due to the limited interaction between the impacts of the different projects.

2.13.1.5 As discussed in **paragraphs 2.11.1.30** *et seq.*, the maximum sensitivity of benthic receptors in the benthic ecology study area is **high** and the magnitude has been assessed as **minor**. Therefore, the significance of effect from the temporary increase in SSC and sediment deposition of Hornsea Four cumulatively with the licensed disposal site Bridlington A is **minor**, which is not significant in EIA terms.

2.14 Operation and maintenance phase

Cumulative long-term habitat loss / change from the presence of foundations, scour protection and cable protection

Tier 1

2.14.1.1 There is potential for cumulative impacts from long-term habitat loss as a result of the presence of Hornsea Four and the other OWFs which will be operational within a representative 10 km buffer surrounding the array area, and a 15 km buffer around the offshore ECC of Hornsea Four. Long term habitat loss may result from the physical presence of foundations, scour protection and cable protection. The only projects identified for this tier are Hornsea Project One and Hornsea Project Two (**Figure 2.6** and
2.14.1.2). No other projects were identified as adding any cumulative impact under Tier 2 or 3.

2.14.1.3 The magnitude assessment for Hornsea Four is presented in **paragraphs 2.11.2.3** *et seq.* below describes the cumulative impact scenarios for Tier 1. This demonstrates that the cumulative long-term habitat loss/change is estimated to be 13.3 km^2.

Table 2.22: Cumulative magnitude of impact for long-term habitat loss/ change from the presence of foundations, scour protection and cable protection.

Tier	Project	MDS	Data source
Tier 1	Hornsea Four	3.7 km^2	See **Table 2.13**
	Hornsea Project One	4.2 km^2	Values taken from ES (SMart Wind, 2013)
	Hornsea Project Two	5.4 km^2	Values taken from ES (SMart Wind, 2015)
	Total Tier 1	**13.3 km^2**	

2.14.1.4 The cumulative impact of from long-term habitat loss is of local spatial extent, long-term and reversable following removal of hard substrate. It is predicted that the impact will affect benthic receptors directly. The magnitude is therefore, considered to be **negligible** and is not considered further in this assessment, as it will not lead to a significant effect based on the matrix used for the assessment of significance and expert judgement (**Table 2.16**).

Cumulative colonisation of the WTGs and scour/ cable protection may affect benthic ecology and biodiversity

Tier 1

2.14.1.5 There is potential for cumulative impacts from colonisation of the WTGs and scour / cable protection may affect benthic ecology and biodiversity as a result of construction activities associated with Hornsea Four and other projects. For the purposes of this PEIR, this additive impact has been assessed within a representative 10 km buffer surrounding

the array area, and a 15 km buffer around the offshore ECC. The only projects identified for this tier are Hornsea Project One and Hornsea Project Two (Figure 2.6 and
2.14.1.6). No other projects were identified as adding any cumulative impact under Tier 2 or 3.

2.14.1.7 The magnitude assessment for Hornsea Four is presented in paragraph 2.11.2.7 et seq. The impact to subtidal benthic receptors from colonisation of the WTGs and scour/ cable protection is assessed as Minor. Table 2.23 below describes the worst-case cumulative impact scenarios for Tier 1. This demonstrates that the cumulative introduction of hard substrate is estimated to be approximately 14.8 km^2.

2.14.1.8 The cumulative impact of colonisation of the WTGs and scour/ cable protection on benthic ecology is predicted to be of local spatial extent, long-term duration but reversable once the infrastructure is removed. It is predicted that the impact will affect the receptor directly. The magnitude is therefore, considered to be **minor**.

Table 2.23: Cumulative magnitude of impact for the colonisation of the WTGs and scour/ cable protection may affect benthic ecology and biodiversity.

Tier	Project	MDS	Data source
Tier 1	Hornsea Four	3.7 km^2	See Table 2.13
	Hornsea Project One	4.9 km^2	Values taken from ES (SMart Wind, 2013)
	Hornsea Project Two	6.2 km^2	Values taken from ES (SMart Wind, 2015)
	Total Tier 1	**14.8 km^2**	

2.14.1.9 The sensitivities of the benthic habitats and VERs to the introduction of new hard substrate is described in paragraphs 2.11.2.11 *et seq.*, which conclude that the soft sediment biotopes likely to be affected by an increase in species diversity are deemed to be of low vulnerability, high recoverability (once the hard substrate is removed) and local to regional value. The sensitivity of these receptors is therefore, considered to be **medium**.

2.14.1.10 The maximum sensitivity of receptors to an increase in species diversity has been assessed as **medium** and the magnitude has been assessed as **minor**. Therefore, the significance of effect from cumulative colonisation of the WTGs and scour/cable protection has been assessed as **minor** significance, which is/is not significant in EIA terms.

2.14.1.11 There is little evidence to date from other OWF development within the North Sea of MINNS having any adverse effects on key species and habitats. Overall, it is predicted that the sensitivity of the receptor is (as a worst case) **high** and the magnitude is **minor**. The effect from cumulative colonisation from MINNS at Hornsea Project One, Hornsea Project Two and Hornsea Four has been assessed as **minor** significance, which is not significant in EIA terms.

Cumulative changes to seabed habitats arising from effects on physical processes, including scour effects and changes in the sediment transport and wave regimes resulting in potential effects on benthic communities

Tier 1

2.14.1.12 The cumulative presence of offshore structures associated with Hornsea Four and other OWFs has the potential to introduce changes to the local hydrodynamic and wave regime, resulting in cumulative changes to the sediment transport pathways and associated effects on benthic ecology. For the purposes of this PEIR, this additive impact has been assessed within the representative SSC and deposition impact buffer for Hornsea Four (10 km buffer around the array area and 15 km around the ECC). The only projects identified for this tier are the wind farms Hornsea Project One and Hornsea Project Two (which will be operational at construction) and the licensed disposal site Bridlington A (**Figure 2.6**). No other projects were identified as adding any cumulative impact under Tier 2 or 3.

2.14.1.13 The Marine Geology, Oceanography and Physical Processes assessment (**Volume 2, Chapter 1: Marine Geology, Oceanography and Physical Processes**) has determined that the impacts on hydrodynamic and wave regimes from cumulative impacts would be **not significant** and would therefore not result in any significant changes to sediment transport and consequently will not have any significant adverse impacts on benthic ecology.

2.15 Transboundary effects

2.15.1.1 Transboundary effects are defined as those effects upon the receiving environment of other European Economic Area (EEA) states, whether occurring from Hornsea Four alone, or cumulatively with other projects in the wider area. A transboundary screening exercise was undertaken at Scoping (Annex K of the Scoping Report), which identified that there was no potential for significant transboundary effects to occur in relation to benthic and intertidal ecology.

2.16 Inter-related effects

2.16.1.1 Inter-related effects consider impacts from the construction, operation or decommissioning of Hornsea Four on the same receptor (or group). The potential inter-related effects that could arise in relation to benthic and intertidal ecology are presented in **Table 2.24**. Such inter-related effects include both:

- Project lifetime effects: i.e. those arising throughout more than one phase of the project (construction, operation, and decommissioning) to interact to potentially create a more significant effect on a receptor than if just one phase were assessed in isolation; and
- Receptor led effects: Assessment of the scope for all effects to interact, spatially and temporally, to create inter-related effects on a receptor (or group). Receptor-

led effects might be short term, temporary or transient effects, or incorporate longer term effects.

2.16.1.2 A description of the process to identify and assess these effects is presented in **Section 5.8** of **Volume 1 Chapter 5: Environmental Impact Assessment Methodology**.

Table 2.24: Inter-related effects assessment for benthic and intertidal ecology.

Project phase(s)	Nature of inter-related effect	Assessment alone	Inter-related effects assessment
Project-lifetime effects			
Construction, O&M and, decommissioning	Temporary habitat loss across all three project phases	Impacts were assessed as being Not Significant in the construction O&M and decommissioning phases.	When habitat loss or disturbance is considered additively across all phases, although the total area of habitat affected is larger, the habitats affected are widespread. Furthermore, all benthic habitats are predicted to recover to the baseline condition within 2 to 10 years. Therefore, across the project lifetime, the effects on benthic ecology receptors are not anticipated to in such a way as to result in combined effects of greater significance than the assessments presented for each individual phase. There will therefore be no inter-related effects of greater significance compared to the impacts considered alone.
Construction, O&M and, decommissioning	Background traffic growth across projects result in cumulative nutrient nitrogen deposition which may impact Saltmarsh in the Humber estuary.	N/A	Air quality modelling (**Volume 3, Chapter 9: Air Quality and Health**) indicated that consideration should be given to a small area of saltmarsh in the Humber estuary, where nutrient nitrogen deposition was above 1% of the Critical Loads. A full assessment will be included within the RIAA.
Construction and decommissioning	Indirect impacts to benthic ecology as a result of the temporary increase in SSC and sediment deposition.	As pathways, there is limited potential for inter-related effects to occur upon marine processes. An inter-related effects screening was undertaken at Scoping (Annex J of the Scoping Report), which screened out	The majority of the seabed disturbance (resulting in the highest SSC and sediment deposition) will occur during the construction and decommissioning phases, with any effects being short-lived. Due to this, and the recoverability of the species and habitats affected, the interaction of these impacts across all stages of the development is not predicted to result in an effect of any greater significance than those assessed in the individual project phases.

Project phase(s)	Nature of inter-related effect	Assessment alone	Inter-related effects assessment
		inter-related effects associated with marine processes.	
O&M	Long-term habitat loss/ change due to the presence of project infrastructure.	Impacts were assessed as being Not Significant in the O&M phase.	There is limited scope for significant inter-related effects to occur on benthic ecology receptors as a result of these predicted impacts in the O&M phase. Due to the negligible significance attributed to these impacts in isolation, it is not predicted that inter-related effects of greater significance will occur than those predicted in isolation.
O&M	Effects on benthic ecology and biodiversity due to the presence of project infrastructure.	Impacts were assessed as being of Minor adverse significance in the O&M phase.	As above
O&M	Indirect impacts on benthic subtidal and intertidal ecology as a result of effects on physical processes, including scour effects and changes in the sediment transport and wave regimes	The assessment of this potential impact concluded that impacts would not be significant in the O&M phase.	As above.

Receptor-led effects

There is the potential for spatial and temporal interactions between the effects arising from habitat loss/ disturbance and increases SSC and sediment deposition during the project lifetime. The greatest potential for inter-related effects is predicted to occur through the interaction of both temporary and permanent habitat loss/ disturbance from foundation installation/ jack-up vessels/ anchor placement/ scour, indirect habitat disturbance due to sediment deposition and indirect effects of changes in physical processes due the presence of infrastructure in the operational wind farm.

With respect to this interaction, these individual impacts were assigned a significance of negligible to minor adverse significance as standalone impacts and although potential combined impacts may arise (i.e. spatial and temporal overlap of direct habitat disturbance), it is predicted that this will not be any more significant than the individual impacts in isolation. This is because the combined amount of habitat potentially affected would be very limited, the

Project phase(s)	Nature of inter-related effect	Assessment alone	Inter-related effects assessment
biotypes affected are widespread across the southern North Sea, and where temporary disturbance occurs, full recovery of the benthos is predicted. In addition, any effects due to changes in the physical processes are likely to be limited, both in extent and in magnitude, with receptors having low sensitivity to the scale of changes predicted. As such, these interactions are predicted to be no greater in significance than that for the individual effects assessed in isolation.			

2.16.1.3 Overall, the inter-related assessment for Hornsea Four does not identify any significant interrelated effects that were not already covered by the topic-specific assessment set out in the preceding chapters. However, certain individual effects were identified that did interact with each other whilst not leading to any greater significance of effect.

2.17 Conclusion and Summary

2.17.1.1 This chapter has investigated the potential effects on intertidal and subtidal benthic ecology receptors arising from Hornsea Four. The range of potential impacts and associated effects has been informed by scoping responses and consultation responses from stakeholders, alongside reference to existing legislation and guidance.

2.17.1.2 The benthic habitat types present at Hornsea Four are widespread in the surrounding area and the impacts of the construction of offshore wind farms and associated infrastructure is well studied. The impacts considered include those brought about directly (e.g. by the presence of infrastructure on the seafloor) and indirectly (e.g. increased SSC from installation methods). Potential impacts considered in this chapter are listed below (**Table 2.25**).

2.17.1.3 Cumulative impacts were also considered, and an assessment was carried out examining the potential for interaction of direct and indirect impacts (including the interaction of sediment plumes) as a result of the combined activities of Hornsea Four and other activities in the study area. This includes offshore wind farm operations and disposal sites.

2.17.1.4 These potential impacts have been investigated using a combination of methods including analytical techniques and the existing evidence base. In accordance with the requirements of the Rochdale Envelope approach to EIA, the MDS has been defined and considered for each potential impact, thereby providing a likely conservative assessment.

2.17.1.5 Even based on this conservative assessment approach, it has been found that all of the potential impacts arising from the construction, operation and decommissioning of Hornsea Four (including cumulatively) on intertidal and subtidal benthic ecology receptors will result in a significance of **minor** or **negligible**. The potential effects to intertidal and subtidal benthic ecology receptors are therefore **not significant** in terms of the EIA Regulations (**Volume 1, Chapter 5: Environmental Impact Assessment Methodology**).

2.17.1.6 **Table 2.25** presents a summary of the significant impacts assessed within this PEIR, any mitigation and the residual effects.

Table 2.25: Summary of potential impacts assessed for benthic and intertidal ecology.

Impact and Phase	Receptor and value/sensitivity	Magnitude and significance	Mitigation	Residual impact
Construction				
Temporary habitat disturbance in the Hornsea Four array area and offshore ECC from construction activities (BIE-C-1).	SS.SSa.IFiSa.NcirBat, SS.SSa.CMuSa.AalbNuc, SS.SSa.CFiSa.ApriBatPo, SS.SSa.CFiSa.EpusOborApri, SS.SMx.CMx.MysThyMx: Medium SS.SMu.CFiMu.SpnMeg: High *A. islandica:* Very High	Minor Negligible (*A. Islandica*) Minor adverse significance	None proposed beyond existing commitments.	Minor adverse
Temporary habitat disturbance in the intertidal area from export cable installation (BIE-C-2).	LS.LSa.MoSa.Bar.Sa: Low	Minor Not Significant	None proposed beyond existing commitments.	Not Significant
Temporary increase in SSC and sediment deposition in the Hornsea Four array area and offshore ECC (BIE-C-3).	<u>Sensitivity to heavy smothering (5 – 30 cm)</u> *A. islandica,* SS.SMu.CFiMu.SpnMeg: Low SS.SSa.IFiSa.NcirBat, SS.SMx.CMx.MysThyMx: Medium SS.SSa.CMuSa.AalbNuc, SS.SSa.CFiSa.ApriBatPo, SS.SSa.CFiSa.EpusOborApri: High <u>Sensitivity to light smothering (<5 cm)</u> Chalk reef habitat of Flamborough Head SAC: Medium Submerged or partially submerged sea caves of Flamborough Head SAC: Low Broadscale habitat features of the Holderness Offshore and Inshore MCZ: Medium	Minor Minor adverse significance	None proposed beyond existing commitments.	Minor adverse
Temporary increase in SSC and sediment deposition in the intertidal area (BIE-C-4).	LS.LSa.MoSa.Bar.Sa: Low	Minor Not Significant	None proposed beyond existing commitments.	Not Significant

Impact and Phase	Receptor and value/sensitivity	Magnitude and significance	Mitigation	Residual impact
Direct and indirect seabed disturbances leading to the release of sediment contaminants (BIE-C-6).	The magnitude is Negligible therefore receptor sensitivity is not considered further in this assessment, as it will not lead to a significant effect based on the matrix used for the assessment of significance and expert judgement.	Negligible Not Significant	None proposed beyond existing commitments.	Not Significant
Operation & maintenance				
Long-term habitat loss/ change from the presence of foundations, scour protection and cable protection (BIE-O-8).	The magnitude is Negligible therefore receptor sensitivity is not considered further in this assessment, as it will not lead to a significant effect based on the matrix used for the assessment of significance and expert judgement.	Negligible Not Significant	None proposed beyond existing commitments.	Not Significant
Colonisation of the WTGs and scour/ cable protection may affect benthic ecology and biodiversity (BIE-O-9).	SS.SSa.IFiSa.NcirBat, SS.SSa.CMuSa.AalbNuc, SS.SSa.CFiSa.ApriBatPo, SS.SSa.CFiSa.EpusOborApri, SS.SMx.CMx.MysThyMx, SS.SMu.CFiMu.SpnMeg, and *A. islandica:* Medium	Minor Minor adverse or beneficial significance	None proposed beyond existing commitments.	Minor adverse or beneficial significance
Increased risk of introduction or spread of Marine Invasive Non-Native Species (MINNS) due to presence of subsea infrastructure and vessel movements (e.g. ballast water) may affect benthic ecology and biodiversity (BIE-O-10).	The magnitude is Negligible therefore receptor sensitivity is not considered further in this assessment, as it will not lead to a significant effect based on the matrix used for the assessment of significance and expert judgement.	Negligible Not Significant	None proposed beyond existing commitments.	Not Significant
Direct disturbance to seabed from jack-up vessels and cable maintenance activities (BIE-O-11).	The magnitude is Negligible therefore receptor sensitivity is not considered further in this assessment, as it will not lead to a significant effect based on the matrix used	Negligible Not Significant	None proposed beyond existing commitments.	Not Significant

Impact and Phase	Receptor and value/sensitivity	Magnitude and significance	Mitigation	Residual impact
	for the assessment of significance and expert judgement.			
Changes to seabed habitats arising from effects on physical processes, including scour effects and changes in the sediment transport and wave regimes resulting in potential effects on benthic communities (BIE-O-13).	The magnitude is Negligible therefore receptor sensitivity is not considered further in this assessment, as it will not lead to a significant effect based on the matrix used for the assessment of significance and expert judgement.	Negligible Not Significant	None proposed beyond existing commitments.	Not Significant
Decommissioning				
Temporary habitat disturbance from decommissioning of foundation substructures and cables (BIE-D-15).	SS.SSa.IFiSa.NcirBat, SS.SSa.CMuSa.AalbNuc, SS.SSa.CFiSa.ApriBatPo, SS.SSa.CFiSa.EpusOborApri, SS.SMx.CMx.MysThyMx: Medium SS.SMu.CFiMu.SpnMeg: High *A. islandica:* Very High	Minor Negligible (*A. Islandica*) Minor adverse significance	None proposed beyond existing commitments.	Minor adverse
Increased SSC and sediment deposition from removal of foundations and cables (BIE- D- 16).	Sensitivity to heavy smothering (5 – 30 cm) *A. islandica,* SS.SMu.CFiMu.SpnMeg: Low SS.SSa.IFiSa.NcirBat, SS.SMx.CMx.MysThyMx: Medium SS.SSa.CMuSa.AalbNuc, SS.SSa.CFiSa.ApriBatPo, SS.SSa.CFiSa.EpusOborApri: High Sensitivity to light smothering (<5 cm) Chalk reef habitat of Flamborough Head SAC: High Broadscale habitat features of the Holderness Offshore and Inshore MCZ: Medium	Minor Minor adverse significance	None proposed beyond existing commitments.	Minor adverse

Impact and Phase	Receptor and value/sensitivity	Magnitude and significance	Mitigation	Residual impact
Loss of introduced habitat from the removal of foundations (BIE-D-17).	SS.SSa.IFiSa.NcirBat, SS.SSa.CMuSa.AalbNuc, SS.SSa.CFiSa.ApriBatPo, SS.SSa.CFiSa.EpusOborApri, SS.SMx.CMx.MysThyMx, SS.SMu.CFiMu.SpnMeg: High	Minor Minor adverse significance	None proposed beyond existing commitments.	Minor adverse

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