Hornsea Project Four: Preliminary Environmental Information Report (PEIR) Volume 4,

Chapter 4 : Project Description

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Glossary

Term	Definition
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 EIA (e.g. at Scoping or PEIR). The purpose of Commitments is to reduce and/or eliminate Likely Significant Effects (LSE's), in EIA terms.
Code of Construction Practice (CoCP)	A document detailing the overarching principles of construction, contractor protocols, construction-related environmental management measures, pollution prevention measures, the selection of appropriate construction techniques and monitoring processes
Design Envelope	A description of the range of possible elements that make up the Hornsea Project Four design options under consideration, as set out in detail in the project description. This envelope is used to define Hornsea Project 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.
Habitats Regulations Assessment (HRA)	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).
High Voltage Alternating Current (HVAC)	High voltage alternating current is the bulk transmission of electricity by alternating current (AC), whereby the flow of electric charge periodically reverses direction.
High Voltage Direct Current (HVDC)	High voltage direct current is the bulk transmission of electricity by direct current (DC), whereby the flow of electric charge is in one direction.
Hornsea Project Four offshore wind farm	The term covers all elements of the project (i.e. both the offshore and onshore). Hornsea Four infrastructure will include offshore generating stations (wind turbines), electrical export cables to landfall, and connection to the electricity transmission network. Hereafter referred to as Hornsea Four.

Acronyms

Acronym	Definition
CAA	Civil Aviation Authority
CBRA	Cable Burial Risk Assessment
CD	Chart Datum
CoCP	Code of Construction Practice
CTV	Crew Transport Vessels
DCO	Development Consent Order
DECC	Department of Energy and Climate Change
DRC	Dynamic Reactive Power Compensation plant
DNO	Distribution Network Operator
ECC	Export Cable Corridor
ECoW	Ecological Clerk of Works
EIA	Environmental Impact Assessment
ES	Environmental Statement
EBI	Energy Balancing Infrastructure
GBS	Gravity Base Structure
GIS	Geographical Information System
GPR	Ground Penetrating Radar
HRA	Habitats Regulations Assessment
HDD	Horizontal Directional Drilling
HGV	Heavy Goods Vehicle
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
JB	Joint Bays
JUV	Jack up vessel
LAT	Lowest Astronomical Tide
LB	Link Box
MCA	Maritime Coastguard Agency
MFE	Mass Flow Excavation
MHW	Mean High Water
MHWS	Mean High Water Springs
MLW	Mean Low Water
MLWS	Mean Low Water Springs
MMO	Marine Management Organisation
NGET	National Grid Energy Transmission
NPS	National Policy Statement
NSIP	Nationally Significant Infrastructure Project
NtM	Notice to Mariners
OSS	Offshore substation
PEIR	Preliminary Environmental Information Report
PLGR	Pre-lay Grapnel Run
PINS	Planning Inspectorate

Acronym	Definition
SoS	Secretary of State
SOV	Special Operational Vessels
SWMP	Site Waste Management Plan
TCE	The Crown Estate
TJB	Transition Joint Bays
TSHD	Trailer Suction Hopper Dredger
UKHO	UK Hydrographic Office
UXO	Unexploded Ordinance
WTG	Wind turbine generator

Units

Unit	Definition
GW	Gigawatt (power)
kV	Kilovolt (electrical potential)
kW	Kilowatt (power)
KJ	Kilojoules (energy)
m	meters
km	kilometers

4.1 Introduction

4.1.1.1 This chapter of the Preliminary Environmental Information Report (PEIR) presents a description of the design of Hornsea Project Four Offshore wind farm. It sets out the Hornsea Four design and components for both the onshore and offshore infrastructure, as well as the main activities associated with the construction, operation and maintenance, and decommissioning of Hornsea Four.

4.1.1.2 The Design Envelope approach has been used to include sufficient flexibility to accommodate further project refinement during detailed design, post consent. This chapter therefore sets out a series of options and parameters for the design of Hornsea Four. The final design will be refined after consent has been granted from within the parameters stated within this project description.

4.1.1.3 This Project Description sets out:

- Design envelope Approach;
- Commitments;
- Consultation;
- Project location;
- Project infrastructure overview;
- Offshore infrastructure construction;
- Onshore infrastructure construction; and,
- Operation and maintenance.

4.2 Design Envelope Approach

4.2.1.1 At this stage in the Hornsea Four development process, the project description is indicative, and the 'envelope' has been designed to include flexibility to accommodate further project refinement during detailed design, post consent. Hornsea Four requires flexibility in choice of foundation options, transmission technology (i.e. High Voltage Alternating Current (HVAC) or High Voltage Direct Current (HVDC)), specific siting of infrastructure, construction methodologies etc. to ensure that anticipated changes in available technology and project economics can be accommodated within the Hornsea Four design. The final project design will depend on factors including ground conditions, wave and tidal conditions, project economics and procurement approach. This chapter therefore sets out a series of options and parameters for the design of Hornsea Four, which are encompassed within the Design Envelope.

4.2.1.2 It should be noted that Hornsea Four has developed this Design Envelope based on a series of integrated design workshops and integrated risk registers to ensure environmental issues are significant design decision factors. This process has used best practice and experience from the industry to inform decision making. The development of a Commitments Register (see **Volume 4, Annex 5.2**) and mitigation by design approach (Commit, Consult, Design; see **Figure 5.1** of **Chapter 5: EIA Methodology**) are crucial elements of this process.

4.2.1.3 The use of the Design Envelope approach has been recognised in the Overarching National Policy Statement (NPS) for Energy (EN-1) (DECC, 2011a) and the NPS for Renewable Energy Infrastructure (EN-3) (DECC, 2011b). This approach has been used in most offshore wind farm applications.

4.2.1.4 In the case of offshore wind farms, NPS EN-3 (paragraph 2.6.42) recognises that:
"Owing to the complex nature of offshore wind farm development, many of the details of a proposed scheme may be unknown to the applicant at the time of the application, possibly including:

- *Precise location and configuration of turbines and associated development;*
- *Foundation type;*
- *Exact turbine tip height;*
- *Cable type and cable route; and*
- *Exact locations of offshore and/or onshore substations."*

4.2.1.5 NPS EN-3 (paragraph 2.6.43) continues:

"The IPC [Infrastructure Planning Commission] should accept that wind farm operators are unlikely to know precisely which turbines will be procured for the site until sometime after any consent has been granted. Where some details have not been included in the application to the IPC, the applicant should explain which elements of the scheme have yet to be finalised, and the reasons. Therefore, some flexibility may be required in the consent. Where this is sought and the precise details are not known, then the applicant should assess the effects the project could have (as set out in EN-1 paragraph 4.2.8) to ensure that the project as it may be constructed has been properly assessed (the Rochdale [Design] Envelope)". (DECC, 2011b)."

4.2.1.6 NPS EN-3 also states (in footnote 23, on page 32) that:

"The 'Rochdale [Design] Envelope' is a series of maximum extents of a project for which the significant effects are established. The detailed design of the project can then vary within this 'envelope' without rendering the ES [Environmental Statement] inadequate".

4.2.1.7 The Design Envelope approach is consistent with PINS Advice Note Nine: Rochdale Envelope (PINS, 2012) which states (page 11, conclusions) that:

"The 'Rochdale [Design] Envelope' is an acknowledged way of dealing with an application comprising EIA development where details of a project have not been resolved at the time when the application is submitted".

4.2.1.8 Throughout the EIA Report the Design Envelope approach has been taken to allow meaningful assessments of Hornsea Four to proceed, whilst still allowing reasonable flexibility for future project design decisions.

4.2.2 Relationship to the Maximum Design Scenario

4.2.2.1 To avoid excessive conservatism in the EIA, the parameters assessed throughout the assessments are not necessarily a combination of the maximum design parameters for each component. For example, the maximum seabed disturbance will not coincide with the maximum number of piles, as the first relates to Suction Caisson Jacket foundations, whilst the second relates to piled Jacket foundations. Hence the maximum design scenario is chosen on a receptor by receptor and an impact by impact basis, based on a range of build-out scenarios. The details of these maximum design scenarios are set out within the topic chapters of this PEIR and summarised within the Impacts Register (**Volume 4, Annex 5.1**.)

4.2.3 Developable Area Approach and relationship to Agreement for Lease (AfL) area

4.2.3.1 The Hornsea Four Developable Area Approach (DAA) is set out in **Volume 1, Chapter 6: Consultation**. In keeping with the Hornsea Four approach to Proportionate EIA, due consideration was given to the size and location (within the exiting offshore Agreement for Lease (AfL) area) of the Project taken forward at PEIR. Hornsea Four have adopted a major site reduction from the AfL presented at Scoping (868km^2) to the PEIR boundary (600km^2) presented in **Figure 4.1**. The narrative of the site reduction is captured in **Chapter 3: Site Selection and Consideration of Alternatives and Volume 2, Chapter 5: Offshore and intertidal Ornithology**.

4.2.4 Turbine capacity and Hornsea Four capacity

4.2.4.1 The EIA is not linked directly to the wind turbine generator capacity, but rather its physical dimensions such as tip height and rotor diameter. It is therefore not considered necessary to constrain the Design Envelope based on wind turbine generator capacity and as such is not referred to within this Project Description. In recent years, the capacity of wind turbine generators has become more flexible and may be different depending on the environmental conditions at the sites.

4.2.4.2 Hornsea Four will have a maximum of 180 wind turbine generators. In line with the above discussion on individual wind turbine generator capacity the total capacity of Hornsea Four is not defined within this Project Description. The ultimate capacity of Hornsea Four will be determined based on the capacity awarded at auction, the grid connection capacity and available technology as constrained by the Design Envelope presented in this chapter.

4.2.5 Transmission technology

4.2.5.1 Hornsea Four may use HVAC or HVDC transmission or could use a combination of both technologies in separate electrical systems. Hornsea Four is applying for both HVAC and HVDC transmission to allow for suitable flexibility to ensure a low cost of energy to the UK consumer and to facilitate successful completion of Hornsea Four in a competitive market. If a combination of the two technologies is used, the total infrastructure installed will not exceed the maximum values assessed within this project description.

4.3 Commitments

4.3.1.1 The Applicant has systematically identified impacts and effects (see **Volume 4, Annex 5.1: Impacts Register**) and taken into consideration mitigation measures that may be adopted to reduce or eliminate environmental impacts (see **Volume 4, Annex 5.2: Commitments Register**). These commitments (mitigation measures) include both avoidance, best practice and design commitments, which are classified into primary or tertiary measures in accordance with the IEMA 'Guide to Shaping Quality Development' (2015) definitions.

4.3.1.2 The Hornsea Four Project Description incorporates Primary (inherent) mitigations, which are measures that form an intrinsic part of the design that are described in the design evolution narrative e.g. reducing onshore substation development height to reduce visual impact. These primary design commitments are summarised in **Table 4.1**.

Table 4.1: Primary (inherent) mitigations which form an intrinsic part of Hornsea Four.

Commitment	Description	Purpose	How it is secured
Co1	Primary: All main rivers, Internal Drainage Board (IDB) maintained drains, main roads and railways will be crossed by HDD or other trenchless technology as set out in the Onshore Crossing Schedule. Where HDD technologies are not practical, the crossing of ordinary watercourses may be undertaken by open cut methods. In such cases, temporary measures will be employed to maintain flow of water along the watercourse.	To minimise effects upon the terrestrial and aquatic environment	DCO Requirement 16 (Code of construction practice)
Co2	Primary: The following sensitive sites will be avoided by the permanent project footprint: Listed Buildings (580 sites), Registered Parks and Gardens (Thwaite Hall and Risby Hall), Scheduled Monuments (30 sites), Conservation Areas (19 sites), non-designated built heritage assets (368	To minimise effects upon the biological, human and built environment	DCO Works Plan - Onshore DCO Requirement 6 (Detailed design

Commitment	Description	Purpose	How it is secured
	sites) and Ancient Woodland (10 sites). Please refer to PEIR Volume 6, Annex 6.5.1 Appendix B Designated Assets Gazetteer for detailed lists of designated heritage assets that are avoided by Hornsea Four. With the exception of River Hull Headwaters SSSI and Bryan Mills Field, sensitive sites have been avoided. Please refer to PEIR Volume 6, Annex 1.1: Land Quality PRA for details. Where possible, unprotected areas of woodland, mature, and protected trees (those with Tree Preservation Orders TPOs) shall also be avoided or micro sited around.		approval onshore) DCO Works Plans DCO Requirement
Co25	Primary: The onshore export cable corridor will be completely buried underground for its entire length. No overhead pylons will be installed as part of the consented works for Hornsea Four.	To minimise landscape and visual effects	DCO Schedule 1, Part 1 Authorised Development
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.	To minimise effects upon the biological, human and marine environment	DCO Schedule 1, Part 1 Authorised Development
Co46	Primary: The offshore export cable corridor and the array will be routed so as to avoid any identified archaeological receptors pre construction, with buffers as detailed in the Marine Written Scheme of Investigation WSI.	To minimise effects upon the historic and marine environment	DCO Schedule 11, Part 2 - Condition 12(2) and; DCO Schedule 12, Part 2 - Condition 14(2) (Marine Written Scheme of Archaeological Investigation)
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.	To minimise effects upon the biological and marine environment	DCO Schedule 1, Part 1 Authorised Development
Co87	Primary: Proposed developable area has been selected from the larger Hornsea Four Agreement for Lease (AfL) area to avoid areas with the highest concentrations of birds (kittiwake, gannet and guillemot) that are more likely to be displaced by the construction activities, and birds that are more likely to fly at heights that brings them within the rotor swept zone and hence at risk of collision	To minimise effects on ornithology.	DCO Schedule 1, Part 1 Authorised Development

Commitment	Description	Purpose	How it is secured
Co133	Primary: The onshore export cable corridor (ECC) will be routed to avoid residential receptors by at least 50 m.	To minimise noise and dust effects upon the local community	DCO Works Plan - Onshore
Co134	Primary: Cable installation works at the landfall area will be located at least 200 m from residential receptors.	To minimise noise and dust effects upon the local community	DCO Works Plan - Onshore
Co150	Primary: A new access will be taken directly from the A1079, to route construction traffic away from Cottingham and Dunswell.	To minimise noise and dust effects upon the local community	DCO Works Plan - Onshore
Co151	Primary: No above ground infrastructure associated with Hornsea Four will obstruct the view from St Mary's Church Cottingham to Beverley Minister through considered design of the OnSS and site selection.	To minimise visual impacts upon users of St Mary's Church and Beverley Minster.	DCO Requirement 6 (Detailed design approval onshore)

4.4 Consultation

4.4.1.1 Consultation is a key part of the DCO application process. Consultation regarding the Project Description has been conducted through the Scoping Report (Orsted, 2018), section 42 consultation and consultation on the draft Habitats Regulations Assessment (HRA) report and via the Evidence Plan process (see **Section 6.3: Evidence Plan Process** of **Chapter 6: Consultation**). An overview of the project consultation process is presented within Chapter 6: Consultation.

4.4.1.2 A summary of the key issues raised during consultation specific to the Project Description are outlined below in **Table 4.2,** together with how these issues have been considered in the production of this PEIR. A summary of consultation specific to the Project Description applicable to Hornsea Four, are also set out below.

Table 4.2: Consultation Responses

Consultee	Date, Document, Forum	Comment	Where addressed in the PEIR
Planning Inspectorate	26 November Scoping Opinion.	The anticipated generating capacity of the wind farm is not provided in the Scoping Report, and the description of the Proposed Development in Chapter 3 does not state parameters for the generating capacity of turbines being considered.	Turbine capacity and Hornsea Four capacity are described in **Section 4.2.4.** The relevant elements of the

Consultee	Date, Document, Forum	Comment	Where addressed in the PEIR
		The Applicant should adequately describe the relevant elements of the technical capacity of the Proposed Development in the ES, on which the assessment has been based.	proposed development, on which assessment has been based are set out in the relevant Maximum Design Scenario MDS) tables for each receptor chapter.
Planning Inspectorate	26 November Scoping Opinion.	The Scoping Report indicates that proposed energy balancing equipment will be included within parameters applicable to the proposed onshore substation. The Scoping Report includes no further detail in regard to these features. The ES should include more defined information with regards to parameters applicable to such equipment in order to provide confidence that any potential effects have been assessed in the ES. The Applicant should consider how this equipment may affect the technical capacity of the Proposed Development and ensure this is adequately described in the ES.	The Electrical Balancing Infrastructure (EBI) is summarised in **Section 4.5.6** and the detail of its design set out in **Section 4.10.3.**
Planning Inspectorate	26 November Scoping Opinion.	The Scoping Report identifies that works to install both onshore and offshore cables may comprise either open-cut trenching or Horizontal Directional Drilling (HDD). The Inspectorate notes that details of the extent and locations of these different methods are yet to be determined and advises that the ES should describe the construction techniques on which the assessment of significant environmental effects has been based.	The locations of all HDDs are presented in **Volume 4, Annex 4.2: Onshore Crossing Schedule**. The relevant Maximum Design Scenario (MDS) tables for each receptor chapter sets out the construction techniques on which the assessment of significant environmental effects has been based.
Planning Inspectorate	26 November Scoping Opinion.	The scoping boundary presented in the Scoping Report is stated as containing any land requirements for the purposes of construction and operation, including construction compounds and HDD launch sites. The intention to include areas for proposed access for operation and maintenance in the Preliminary Environmental Information Report (PEIR) and DCO application is noted from Table 4.1 of the Scoping Report. The ES should provide information on these elements in particular where they are likely to be located, and how these elements have been considered within the assessment of significant environmental effects.	The design envelope for the proposed access for operation and maintenance on the Export Cable Corridor (ECC) are presented in **Table 4.35** and for the Onshore Substation (OnSS) at **Paragraph 4.10.2.7**. The relevant Maximum Design Scenario MDS) tables for each receptor chapter sets out the construction techniques on which the assessment of

Consultee	Date, Document, Forum	Comment	Where addressed in the PEIR
			significant environmental effects has been based.
Planning Inspectorate	26 November Scoping Opinion.	Figure 3.7 of the Scoping Report provides an indicative construction programme for the Proposed Development. The Inspectorate acknowledges that this information is currently at a high level and lacks certain detail; however, the ES should contain sufficient detail to support the assessment and to enable consideration of the temporal extent of impacts.	The construction programme for Hornsea Four is presented in **Figure 4.4** and discussed in **Section 4.7**.
Planning Inspectorate	26 November Scoping Opinion.	The Scoping Report provides outline information on the operation and maintenance activities considered at the scoping stage. The ES should provide a full description of the nature and scope of these activities, including the types of activity, their frequency, and how works will be carried out.	A full description of the nature and scope of the operation and maintenance activities, including the types of activity, their frequency, and how works will be carried out is provided in **Section 4.11**.

4.5 Hornsea Four project location

4.5.1.1 The location of Hornsea Four is delineated on Figure 4.1 and Figure 4.2 and consists of the:

- Hornsea Four array area: This is where the offshore wind generating station will be located, which will include the turbines, array cables, offshore accommodation platforms and a range of offshore substations as well as offshore interconnector cables and export cables;
- Hornsea Four offshore export cable corridor: This is where the permanent offshore electrical infrastructure (offshore export cable(s), as well as the offshore HVAC booster station(s) (if required), will be located;
- Hornsea Four intertidal area: This is the area between Mean High Water Springs (MHWS) and Mean Low Water Springs (MLWS) through which all of the offshore export cables will be installed;
- Hornsea Four onshore export cable corridor: This is where the permanent onshore electrical cable infrastructure will be located, and
- Hornsea Four onshore substation, including energy balancing infrastructure. This is where the permanent onshore electrical substation infrastructure (onshore HVDC converter/HVAC substation, energy balancing infrastructure and connections to the National Grid) will be located

4.5.1.2 The location of all aspects of Hornsea Four are presented graphically in the Location Plan(s) (**Annexes 1.1, 1.2 and 1.3**) and Works Plans (**Annexes 4.1 and 4.2**). The following sections of this project description describe the physical environment of these areas.

4.5.2 Hornsea Four array area

4.5.2.1 The Hornsea Four array area is approximately 65 km due east of Flamborough Head, at its closest point and adjacent to Hornsea Project Two on the eastern boundary. Water depths generally vary from around 30 m below Chart Datum (CD) in the south of the Hornsea Four array area to more than 60 m below CD in the north, although the greatest depths are on the north-eastern flank which shelves into Outer Silver Pit. Sandwaves are present within the Hornsea Four array area, particularly across the north western corner and also along the southern margin. Surficial sediments across the Hornsea Four array area are typically sandy material with small amounts of gravel and muds. The main exception is along the southern boundary where there is a slightly higher percentage of gravels and a coarser substrate described as slightly gravelly sand

4.5.3 Hornsea Four offshore export cable corridor

4.5.3.1 Depths across the Hornsea Four offshore export cable corridor are relatively similar to the Hornsea Four array area until closer to the coastline. Sediments across the Hornsea Four offshore Export Cable Corridor show an increasing gravel content towards the coast, transiting from the sandy Hornsea Four array area into slightly gravelly sand, gravelly sand to sandy gravel. The beach at landfall, south of Bridlington, itself is a thin veneer of sand over rock.

4.5.4 Hornsea Four onshore export cable corridor

4.5.4.1 Cables connecting the landfall first to the onshore substation and then on to the National Grid substation at Creyke Beck. Where possible and practical, less intrusive construction methods will be adopted for example by using HDD to cross environmentally sensitive water courses, major roadways and railways. Cables will be delivered in sections and buried in trenches, which will subsequently be reinstated to pre-existing condition as far as reasonably practical. Sections will be connected within jointing bays.

4.5.5 Hornsea Four onshore substation

4.5.5.1 The onshore substation will be located as close as practical to the National Grid substation at Creyke Beck and will include all necessary electrical plant to meet the requirements of the National Grid. The onshore substation contains the electrical components for transforming the power supplied from the wind farm to 400 kV and to adjust the power quality and power factor, as required to meet the UK Grid Code for supply to the National Grid.

4.5.6 Hornsea Four electrical balancing infrastructure

4.5.6.1 Hornsea Four will incorporate Energy Balancing Infrastructure (EBI) to provide valuable services to the electrical grid; such as importing, storing and exporting energy to meet the grid needs and improve stability and reliability. Because the way we produce and use electricity is changing at and increasingly accelerated rate, traditional methods used to operate our electricity networks also need to change. Energy balancing equipment such as energy storage is therefore becoming increasingly widespread to effectively and cost efficiently balance the supply and demand of electricity within the electrical transmission network, thus improving the overall performance and utilisation of renewable energy generation and its interaction with the grid.

4.5.6.2 EBI will comprise of: energy storage technology such as batteries or a more suitable alternative, energy conversion technology such as power converters, balance of plant equipment such as transformers and switchgear and cables to connect it to the onshore substation. It may be constructed in 2 parts on either side of the substation to maximise availability by ensuring one part is always running even if the other is undergoing maintenance, with the exact configuration determined post-consent.

4.5.6.3 EBI is proposed to be housed in single or multiple building(s), several containers, in an open yard or a combination of the above. All energy balancing equipment will be housed wholly within the footprint of the onshore substation (see **Figure 4.21**).

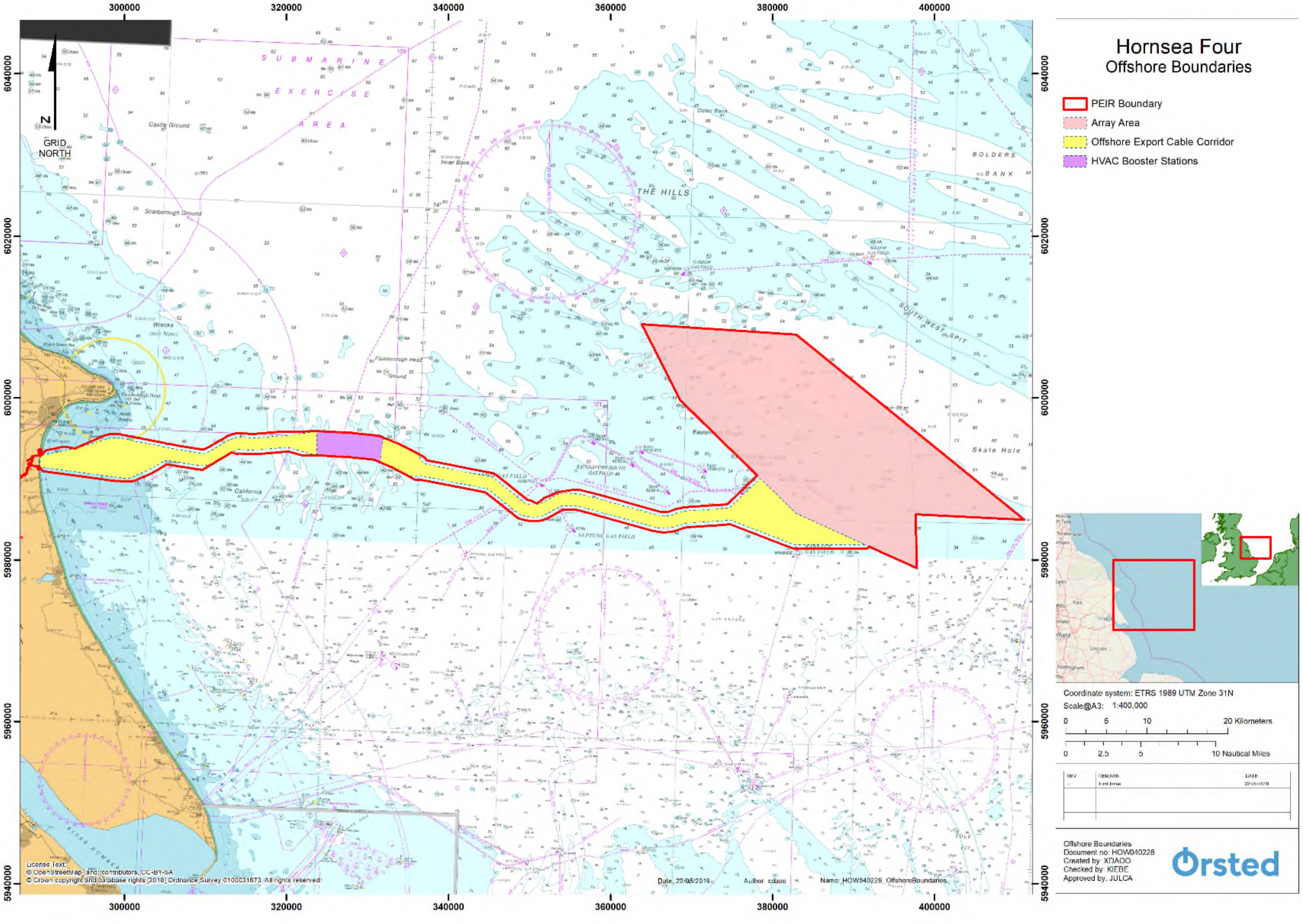

Figure 4.1: Offshore Location of Hornsea Four (not to scale).

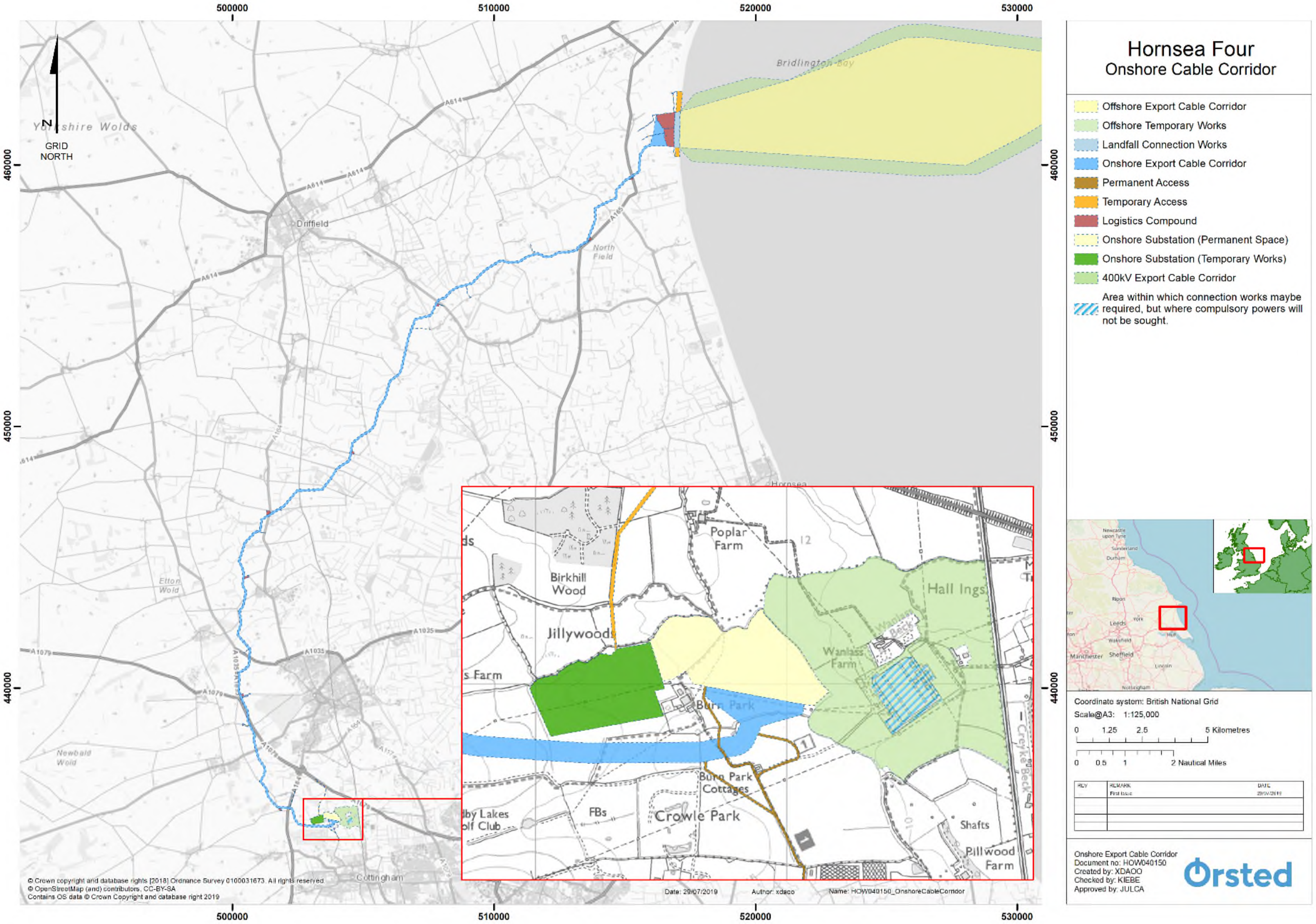

Figure 4.2: Onshore Location of Hornsea Four (not to scale).

4.6 Project Infrastructure Overview

4.6.1.1 Hornsea Four will comprise of wind turbine generators and all infrastructure required to transmit the power generated by the turbines to the Creyke Beck National Grid substation, which is located near Cottingham, Humberside (see **Figure 4.2**). It will also comprise of any offshore infrastructure required to operate and maintain the wind farm, such as wave buoys and FLiDAR.

4.6.1.2 Hornsea Four will have a maximum of 180 wind turbine generators. These will be connected to offshore substations via array cables, and then to offshore export cables. Up to six offshore export cables will transfer power from the Hornsea Four array area to the landfall.

4.6.1.3 At landfall, the offshore export cables will be joined to onshore export cables at transition joint bays. There will be up to 18 onshore export cables buried in up to six trenches connecting to an onshore substation to allow the power to be transferred to the National Grid via the existing Creyke Beck National Grid substation.

4.6.1.4 Hornsea Four may use HVAC or HVDC transmission or could use a combination of both technologies in separate electrical systems. If a combination of the two technologies is used, the total infrastructure installed will not exceed the maximum values assessed within this PEIR.

4.6.1.5 Hornsea Four is also applying for an Energy Balancing Infrastructure (EBI) in relation to the onshore HVDC converter or HVAC substation. The EBI would have the capability of energy balancing for the windfarm to buffer forecasted production with actual production reducing the reliance on energy produced from gas-fired power plants that is currently the main source of balancing energy. Please refer to **Chapter 2: Planning and Policy Context** for more details on the need for the EBI.

4.6.1.6 **Table 4.3** lists the key components of Hornsea Four and the links within this chapter to their descriptions. **Figure 4.3** show schematic representations of Hornsea Four for both the HVDC and HVAC configurations.

Table 4.3: Main components of Hornsea Four.

Component	Maximum number / length / area	Section
Wind turbine generators	180	4.8.1
Offshore transformer substations	6	4.8.2
Offshore HVAC booster station (HVAC only)	3	4.8.2
Offshore HVDC converter substation (HVDC only)	3	4.8.2
Offshore accommodation platform	1	4.8.3
Offshore HVDC converter substation(s) are mutually exclusive with HVAC booster station(s) in a single transmission system. Therefore, these two figures should not be combined in the total number. The maximum number of structures within the Hornsea Four array area is 190 (i.e. 180 turbines, one accommodation platform, 6 offshore transformer substations and 3 offshore HVDC converter substations).		
Foundations (for wind turbine generators, Offshore transformer substations, Offshore HVAC booster station or Offshore HVDC converter substation and offshore accommodation platform)	n/a	4.8.4
Array cables linking wind turbine generators to offshore transformer substations	600 km	4.8.5
Offshore interconnector cables(s)	90 km	4.8.5
Offshore export cables	654 km	4.8.5
Scour protection (for foundations and cables)	n/a	4.8.4 and 4.8.5
Landfall	n/a	4.9
Onshore export cables (including connection to existing national Grid Substation)	40 km	4.10
Temporary logistics compounds, including storage areas	8	4.10
Permanent and temporary access roads	n/a	4.10
Onshore HVAC substation (HVAC only)		4.10.2
Onshore HVDC converter substation (HVDC only)		4.10.2
Energy Balancing Infrastructure		4.10.3

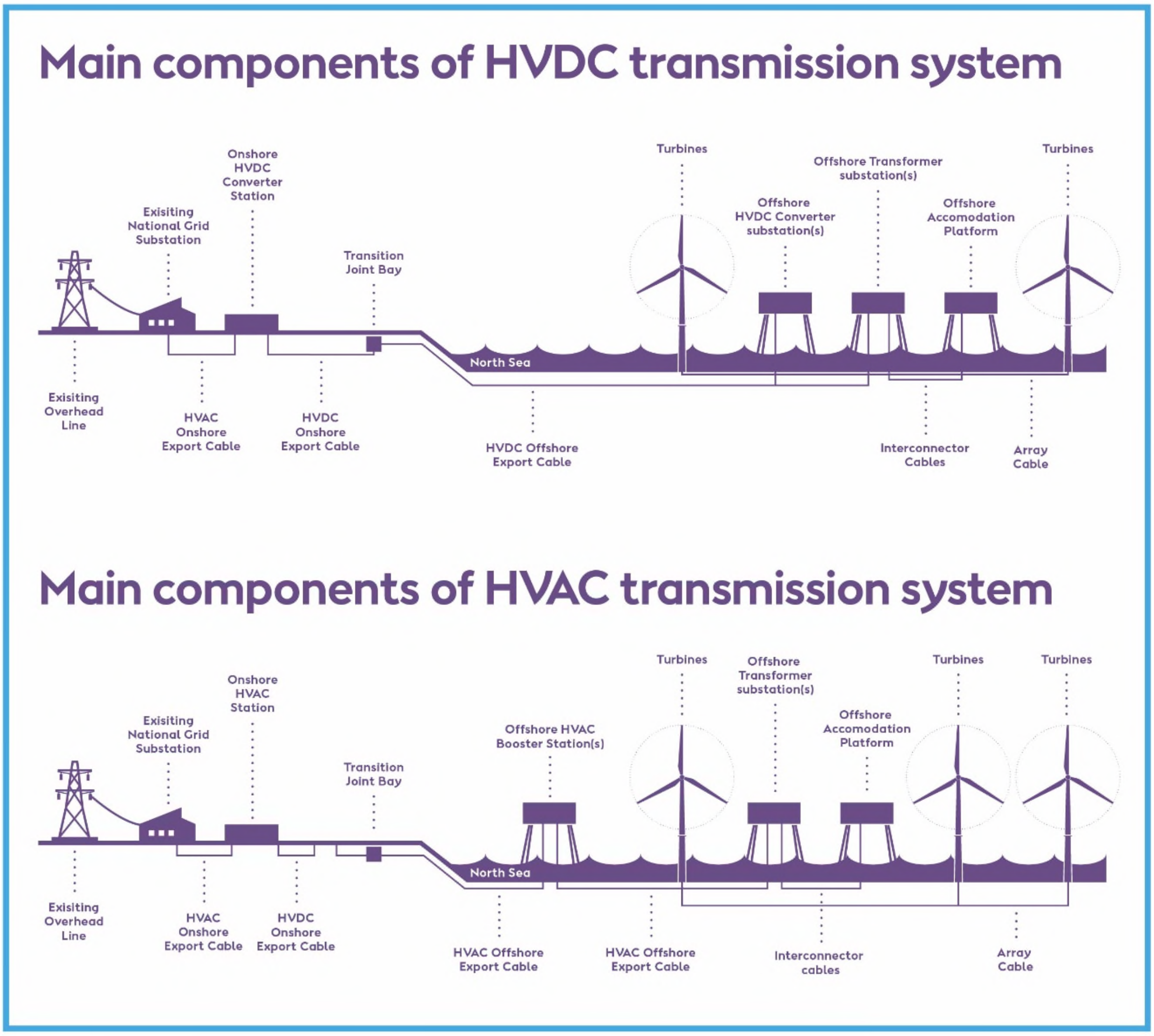

Figure 4.3: Main components of Hornsea Four (indicative only).

4.7 Project Construction Programme

4.7.1.1 An indicative construction programme for Hornsea Four is presented in **Figure 4.4**. The programme illustrates the likely duration of the major installation elements, and how they may relate to one another in the construction campaign. It covers installation of the major components and does not include elements such as preliminary site preparation, and commissioning of Hornsea Four post-construction. The earliest possible date that Onshore construction could commence is August 2023. The maximum total construction duration is four years and six months (54 months).

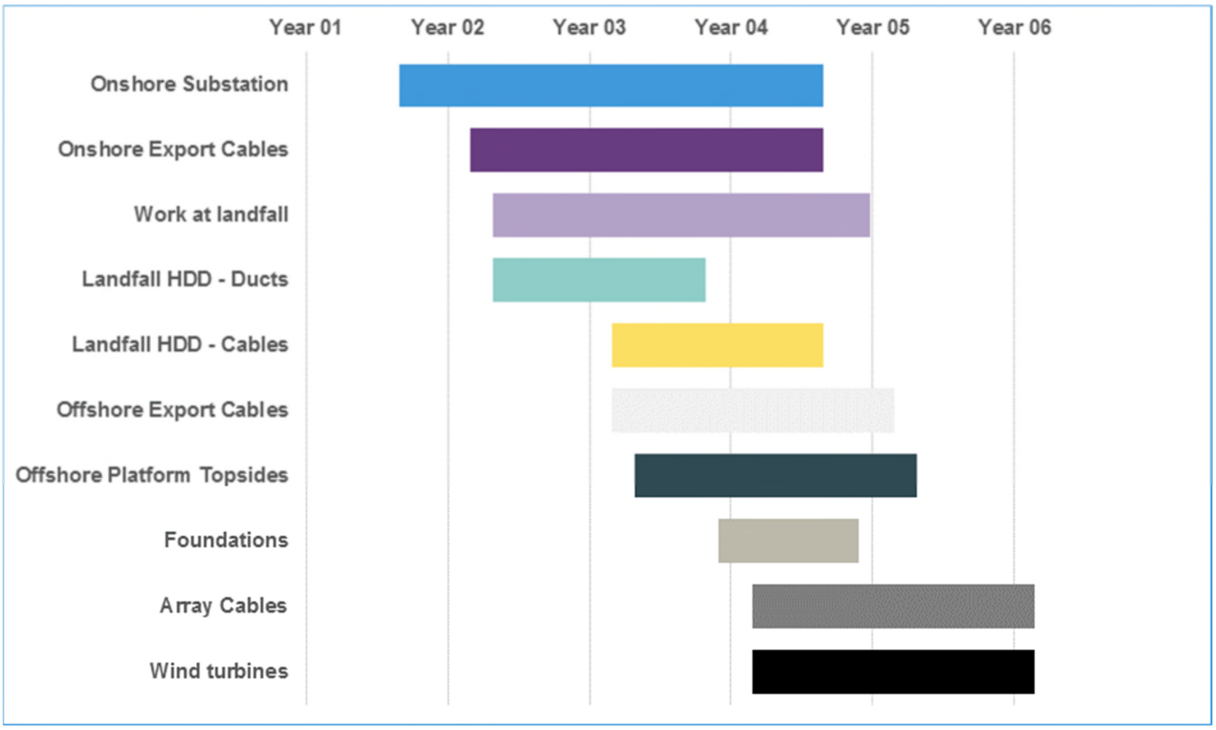

Figure 4.4: Indicative construction programme for Hornsea Four.

4.7.1.2 Offshore platform topside installation is indicated to occur before foundation installation in Figure 4.4. If this occurs the foundations would be non-piled solutions such as suction caisson jackets or monopod types.

4.8 Offshore Infrastructure Construction

4.8.1 Wind turbines

Design

4.8.1.1 Hornsea Four may construct up to 180 wind turbine generators. A range of wind turbine generator models will be considered; however, they will follow the traditional wind turbine generators design with three blades and a horizontal rotor axis. The blades will be connected to a central hub, forming a rotor which turns a shaft connected to the generator or gearbox (if required). The generator and gearbox will be located within a containing structure known as the nacelle situated adjacent to the rotor hub. The nacelle will be supported by a tower structure affixed to the transition piece or foundation. The nacelle will be able to rotate or 'yaw' on the vertical axis in order to face the oncoming wind direction.

4.8.1.2 The maximum design scenario for the Hornsea Four wind turbine generators is shown in Table 4.4.

Table 4.4: Maximum Design Scenario: Wind Turbine Generators.

Parameters	Design Envelope
Maximum number of wind turbine generators	180
Minimum height of lowest blade tip above LAT (m)	35 m
Maximum blade tip height above LAT (m)	370 m
Maximum rotor blade diameter (m)	305 m

4.8.1.3 An illustration of this design can be seen in **Figure 4.5**.

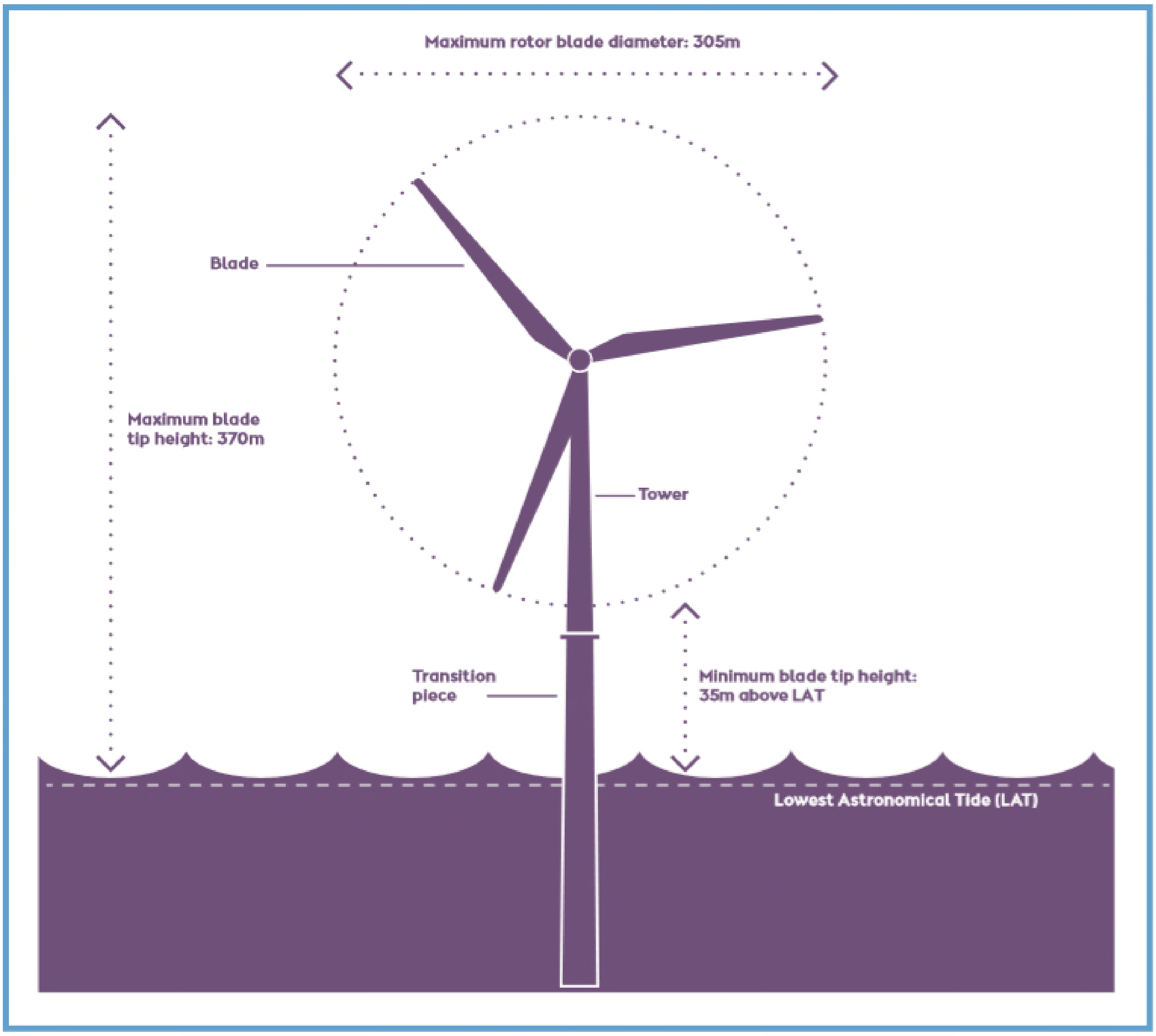

Figure 4.5: Overview of a Typical Wind Turbine Generator (indicative only).

4.8.1.4 The wind turbine generators may be accessed either from a vessel via a boat landing or a stabilised gangway via the foundation or transition piece, or by hoisting from a helicopter to a heli-hoist platform on the nacelle. Any helicopter access would be designed in accordance with relevant Civil Aviation Authority (CAA) guidance and standards.

Installation

4.8.1.5 Generally, turbines are installed using the following process:

- Wind turbine generators (WTGs) are installed upon their respective foundation type (see **Section 4.8.4**).
- WTG components (blades, nacelles, and towers) are picked up from a port. This vessel will typically be a JUV to ensure a stable platform for installation vessels when on site. JUVs are assumed to have up to six legs with an average spudcan area of 170 m^2 per foot. In general, the JUV will carry components for several turbines during on single trip);
- The installation vessel will then transit to the Hornsea Four array area and the components will be lifted onto the existing transition piece or foundation substructure, by the crane on the installation vessel. Each wind turbine generator will be assembled on site in this fashion with technicians fastening components together as they are lifted into place. The exact methodology for the assembly is dependent on wind turbine generator type and installation contractor, and will be defined in the pre-construction phase after grant of consent; or
- Alternatively, the wind turbine generator components may be loaded onto barges or dedicated transport vessels at port and installed as above by an installation vessel that remains on site throughout the installation campaign.

4.8.1.6 The total duration of the installation campaign for wind turbine generator foundations is expected to be a maximum of 12 months for the subsea component, with the installation of the transition piece, tower, nacelle and blades taking 24 months maximum.

4.8.1.7 Each installation vessel or barge may be assisted by a range of support and transport vessels. These are typically smaller vessels that may be tugs, guard vessels, anchor handling vessels, or similar. These vessels will primarily make the same movements to, from and around the Hornsea Four array area as the installation vessels they are supporting.

4.8.1.8 For the purposes of the EIA, assumptions have been made on the maximum number of vessels and helicopters and the number of return trips to the Hornsea Four array area from port/airfield that are required throughout construction. These are shown in **Table 4.27**.

4.8.2 Offshore Substations

4.8.2.1 Offshore substations are offshore structures housing electrical equipment to provide a range of functions, such as changing the voltage (transformer substations), current type (converter substations) or power factor of the power (offshore HVAC booster stations). Each of the different offshore substation types are detailed below.

Offshore transformer substations

4.8.2.2 One or more offshore transformer substations will collect the electricity generated by the wind turbine generators via the array cables. The voltage will be "stepped up" by transformers on the substation before transmission onshore by export cables; this will be via the offshore HVDC converter substation in the case of the HVDC transmission option, or the offshore HVAC booster station(s) in the case of the HVAC transmission option.

4.8.2.3 Either six separate offshore transformer substations are required if they are built in small size and up to three separate offshore transformer substations are required if they are built in large size. All offshore transformer substations will be in the Hornsea Four array area.

Design

4.8.2.4 The offshore transformer substations will comprise a platform with one or more decks, and helicopter platform, attached to the seabed by means of a foundation, containing equipment required to switch and transform electricity generated at the wind turbine generators. They may also house auxiliary equipment and facilities for operating, maintaining, controlling the substation and to access the substation by vessels and helicopters. Accommodation, storage, workshop and logistic facilities for operating and maintaining the wind turbine generators may also be included, such as LiDAR. It may also be beneficial to site multiple differing substations (transformer and convertor), or substation and offshore accommodation platform next to each other so that access can be gained from one to the other. In this case a bridge link may be constructed at deck level, with a length of up to 100 m. See **Figure 4.6** for an example of an Offshore substation.


Figure 4.6: Offshore substations at Gode Wind offshore wind farm.

4.8.2.5 The maximum design parameters for offshore transformer substations are presented in Table 4.5 and a schematic of an offshore transformer substation is presented in Figure 4.7.

Table 4.5: Maximum design parameters for offshore transformer substations.

Parameter	Maximum design parameters	
	Small	Large
Number of offshore transformer substations	6	3
Topside – main structure length (m)	90	180
Topside – ancillary structure width (m)	90	90
Topside - height (including auxiliary structures, such as helipad, crane, lightning protection, however excluding antennae and masts) (m LAT)	90	100
Topside thickness (from topside to upper level of foundation) (m)	30	40
Topside - area (m^2)	10,000	16,200

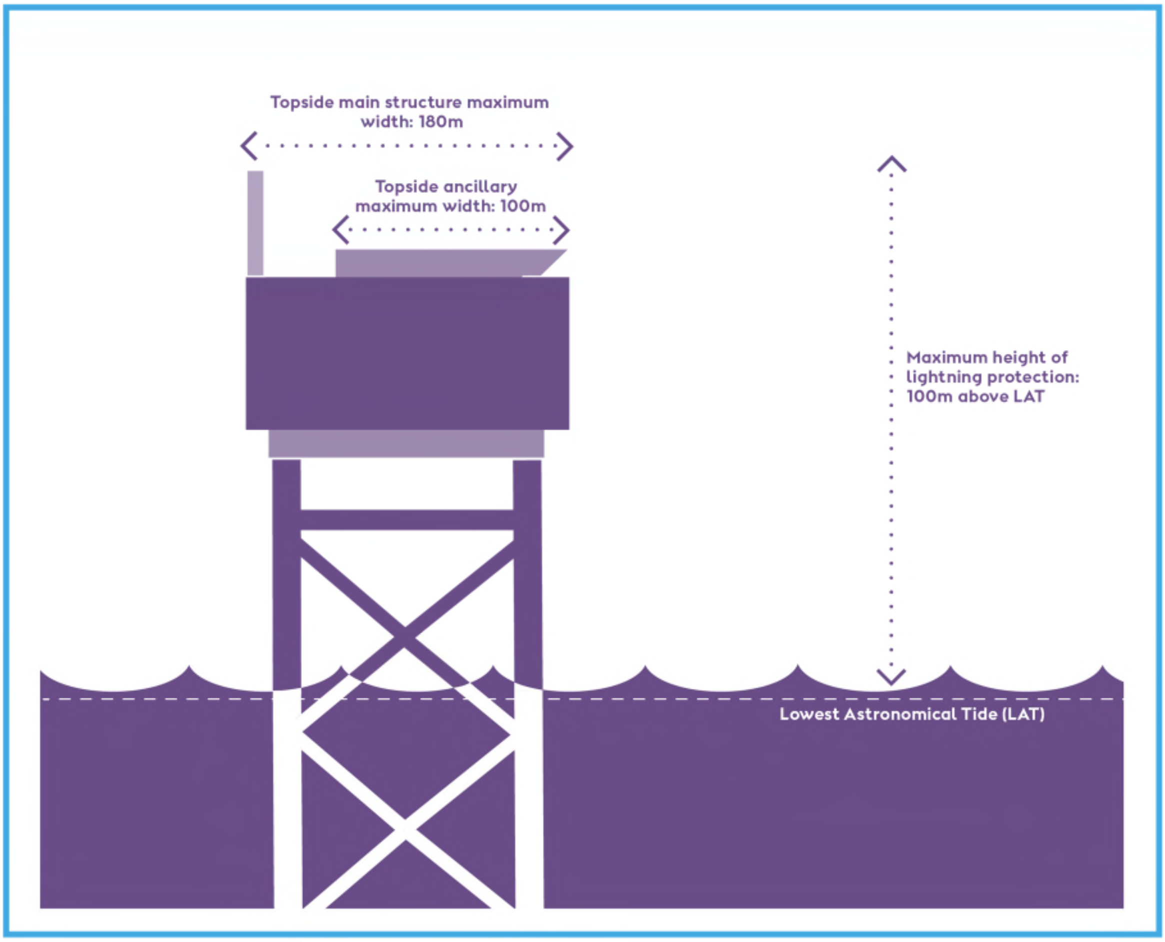

Figure 4.7: Schematic of an offshore transformer substation (indicative only).

Installation

4.8.2.6 Offshore transformer substations are generally installed in two stages, firstly the foundation will be installed as described in **Section 4.8.4**, secondly the topside will be lifted from a transport vessel/barge, onto the foundation. The foundation and topside may be transported on the same transport vessel/barge, or separately. The foundation may also be transported by the installation vessel.

4.8.2.7 The vessel requirements for installation of the offshore transformer substations are shown in **Table 4.27**.

Offshore HVDC converter substation (HVDC only)

4.8.2.8 Offshore HVDC converter substations are required in HVDC transmission systems only. Offshore HVDC converter substations convert the three-phase AC power generated at the turbines into DC power. The power is then transmitted to the onshore substation via the export cables.

Design

4.8.2.9 As for the offshore transformer substations, the offshore HVDC converter substation unit is pre-fabricated in the form of a multi-layered cube. All offshore HVDC convertor substations will be located in the Hornsea Four array area.

4.8.2.10 The maximum design parameters for offshore HVDC converter substations would be as per the offshore transformer substations with small or large options (see **Table 4.5**). The design approach for offshore HVDC converter substations may move towards multiple smaller units (e.g. three small units), rather than fewer large units (e.g. one or two large units). However, the total number of offshore transformer substations would be up to six, with up to three offshore HVDC converter substations. The maximum number of substations will therefore not exceed nine in total.

Installation

4.8.2.11 Dependent on the design of the offshore HVDC converter substations, installation may be as for the offshore transformer substations, alternatively a 'float-over' installation may be used. This type of installation, usually used with gravity base structures, is similar to that described in **Table 4.12**. The vessel requirements for installation of the offshore HVDC converter substations are shown in **Table 4.27**.

Offshore HVAC booster station(s) (HVAC only)

4.8.2.12 Long distance, large capacity HVAC transmission systems require reactive compensation equipment to reduce the reactive power generated by the capacitance of the offshore export cable in order to allow the power delivered to the National Grid to be useable. The electrical equipment required to provide the reactive compensation, in the form of an HVAC booster station, will be located on an offshore platform.

4.8.2.13 The Offshore HVAC booster station(s) would be located in the Hornsea Four offshore export cable corridor, rather than in the Hornsea Four array area. For the purposes of the PEIR, an area approximately half-way along the Hornsea Four cable corridor (offshore and onshore) has been identified as the offshore HVAC booster station location search area (see **Figure 4.1**). This area has been chosen based on preliminary electrical design studies.

4.8.2.14 The final location of the offshore HVAC booster station(s) within the identified search area will be defined in the detailed design stage, post consent. The siting will take into account final electrical design, water depth, ground conditions, marine traffic, proximity to shore, other existing/planned offshore infrastructure and other engineering and economic factors.

Surface HVAC booster station(s)

4.8.2.15 The external design of an offshore surface HVAC booster station will be very similar to the offshore transformer substations described above. These will comprise a platform with one or more decks, and helicopter platform. They will contain equipment required to provide reactive power compensation and housing auxiliary equipment and facilities for operating, maintaining, controlling the substation and to access the substation by vessels and helicopters.

4.8.2.16 The maximum number of offshore surface HVAC booster station(s) would be three. The maximum design parameters for offshore surface HVAC booster station(s) would be as per the small offshore transformer substations presented in **Table 4.5**. Installation will be as for the offshore transformer substations. The vessel requirements for installation of the offshore surface HVAC booster stations, as well as all other offshore substations, are shown in are shown in **Table 4.27**.

4.8.3 Offshore accommodation platforms

4.8.3.1 Hornsea Four may construct one offshore accommodation platform to allow up to 150 operations staff to be housed at the Hornsea Four array area for several weeks at a time, and to allow spares and tools to be stored at the Hornsea Four array area. This aims to reduce trips to the Hornsea Four array area and time spent in transit and decreases down time for faults and repairs. The accommodation platform will be located within the Hornsea Four array area. The offshore accommodation platform would be accessed by vessel and/or helicopter and may have associated captive vessels to access the turbines and substations. An illustrative example of an offshore accommodation platform adjacent to an offshore substation can be seen in **Figure 4.8**.

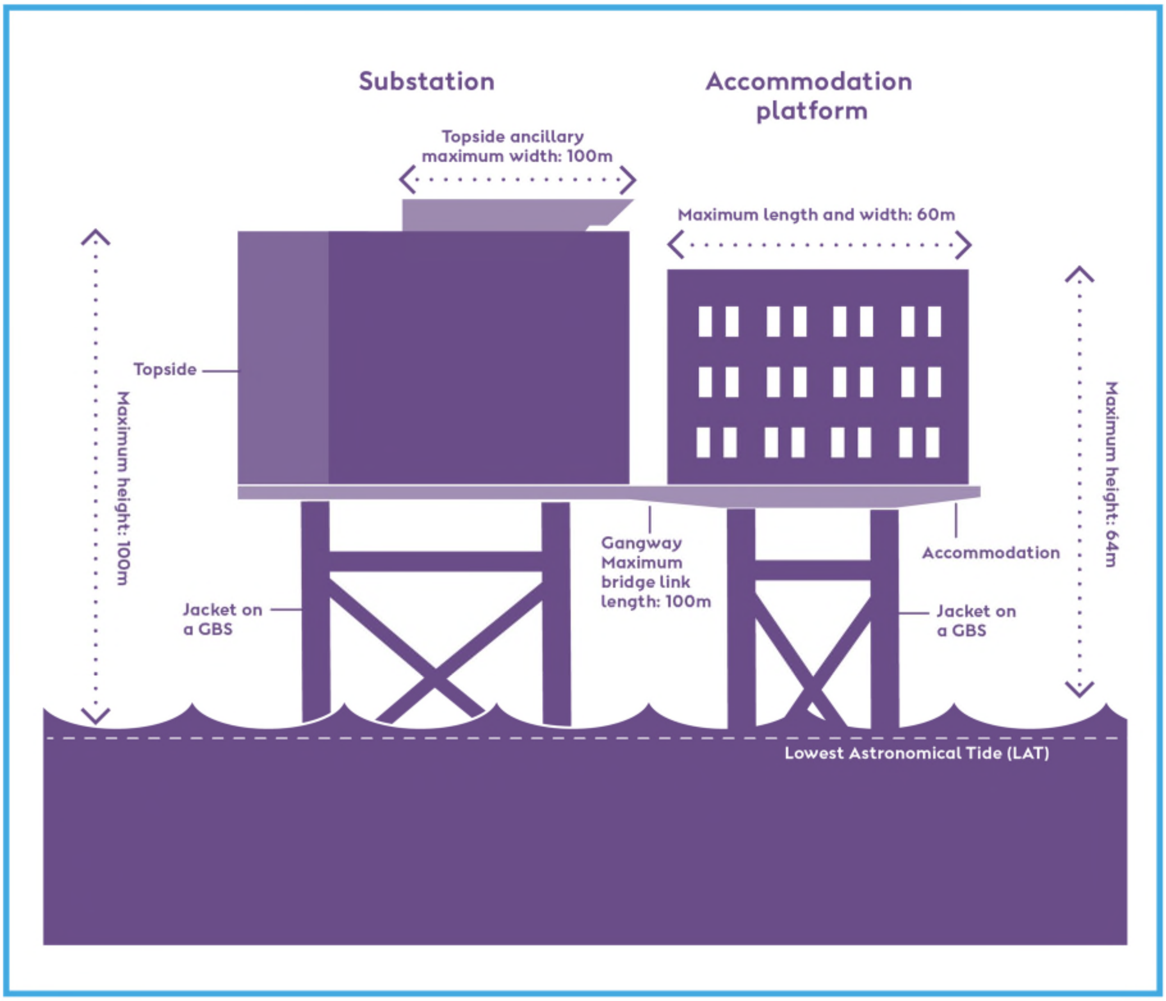

Figure 4.8: Offshore accommodation platform (64m above LAT), sited next to an offshore substation (left) (indicative only).

Design

4.8.3.2 Offshore accommodation platform comprises of a platform with one or more decks and helicopter platform, attached to the seabed by means of a foundation. The offshore accommodation platform will contain accommodation, storage, workshop and logistic facilities for operating and maintaining the wind turbine generators and housing auxiliary equipment, facilities for operating, maintaining and controlling the substation and to access the substation by vessels and helicopters. The offshore accommodation platform may also be co-sited with offshore substations, including bridge access (bridge link) between the two platforms. The maximum design parameters for the offshore accommodation platform are presented in **Table 4.6**.

Table 4.6: Maximum design parameters for offshore accommodation platform.

Parameter	Maximum design parameters
Number	1
Length and width (m)	60
Main structure height above LAT (m)	60
Structure height max above LAT (m)	64
Maximum bridge link length (m)	100

Installation

4.8.3.3 The installation procedure would be as described for the offshore transformer substations in **Section 4.8.2**. The vessel requirements for this process are presented in **Table 4.27**.

4.8.4 Foundations

4.8.4.1 The wind turbines generators, offshore substation(s) and offshore accommodation platform are attached to the seabed by foundation structures (**Figure 4.9**). The foundation types that are being considered for Hornsea Four, the range is presented in **Table 4.7**.

Table 4.7: Foundation options for turbines and offshore structures.

	Turbine	Offshore transformer substation (Small size)	Offshore HVDC converter substation/ Large offshore HVAC substation	Offshore HVAC booster station (located within ECC not within the Hornsea Four Array)	Offshore accommodation platform
Maximum number of structures	180	6	3	3	1
Monopile	Y	Y	Y	Y	Y
Mono suction bucket	Y	Y	Y	Y	Y
Piled jacket (WTG type)	Y	Y	Y	Y	Y
Suction bucket jacket (WTG type)	Y	Y	Y	Y	Y
Suction bucket jacket (Medium OSS)	N	Y	Y	Y	Y
Piled jacket (Small OSS)	N	Y	Y	Y	Y
Box-type gravity base	N	Y	Y	Y	Y
Piled jacket (Large OSS)	N	N	Y	N	N
Suction bucket jacket (Large OSS)	N	N	Y	N	N
Box-type gravity base (Large OSS)	N	N	Y	N	N
Pontoon GBS type 1	N	N	Y	N	N
Pontoon GBS type 2	N	N	Y	N	N

4.8.4.2 Figure 4.9 presents an overview of the different types of foundation. Inset A presents the key maximum design parameters for the WTG foundation. Inset B presents an aerial plan view of the maximum design scenario for temporary disturbance and permanent seabed take, for all electrical infrastructure foundation types. Inset C presents graphically the foundation types being considered by Hornsea Four for all locations at PEIR. The numbers in brackets in Inset C relate to the number of legs for jacket foundations utilised at other electrical infrastructure that is not a WTG (e.g. offshore substation).

4.8.4.3 The technical feasibility of the foundation types is currently being considered via the development of a ground model and driveability assessments. Upon conclusion of these works the foundation types taken forward to DCO shall be confirmed and update to the assessments presented in the ES.

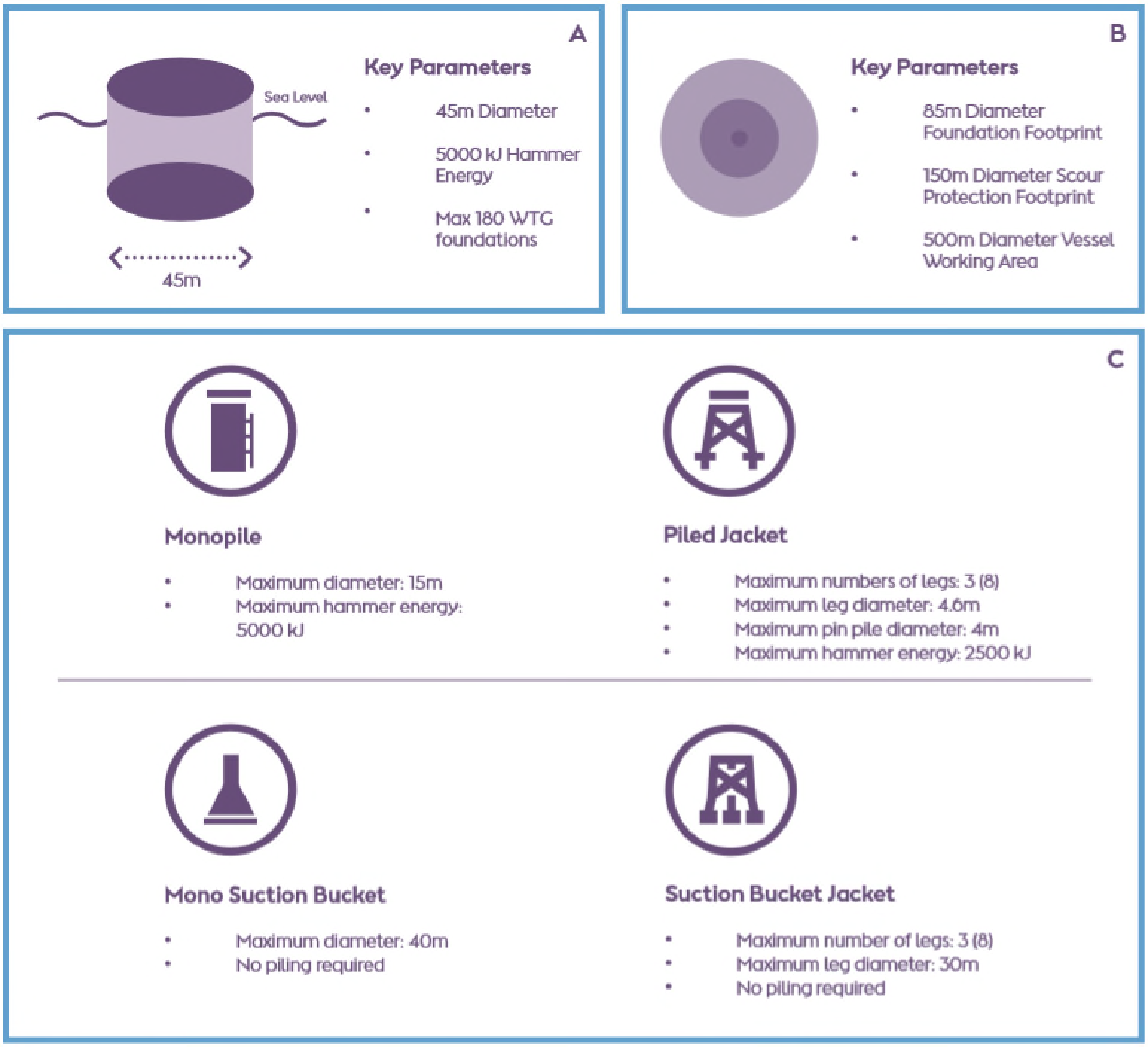

Figure 4.9: Foundation types (indicative only).

Description of foundation types

Monopile

4.8.4.4 Monopile foundations typically consist of a single steel tubular section, consisting of a number of sections of rolled steel plate welded together. A transition piece is fitted over, or is integral to, the monopile and secured via bolts or grout. The transition piece may include boat landing features, ladders, a crane, and other ancillary components as well as a flange for connection to the turbine tower. The transition piece is usually painted yellow and marked per relevant regulatory guidance and may be installed separately following the monopile installation. The maximum design dimensions of the monopile foundations can be seen in **Table 4.8**.

Table 4.8: Maximum design parameters for monopiles.

Parameter	Maximum design parameters
Number of piles	1
Diameter of monopile at seabed (m)	15
Diameter of monopile at sea surface (m)	10
Typical embedment depth (below seabed) (m)	40
Maximum impact hammer energy (kJ)	5,000

Piled jacket foundations

4.8.4.5 Piled jacket foundations are formed of a steel lattice construction (comprising tubular steel members and welded joints) secured to the seabed by hollow steel pin piles attached to the jacket feet. Unlike monopiles, there the transition piece and ancillary structure is fabricated as an integrated part of the jacket. Pin piles will typically have a smaller diameter than monopiles.

4.8.4.6 Larger jackets may be required for offshore substations or the offshore accommodation platform. These would have more legs and may also require the use of mud-mats, which are flat plates attached to the bottom of the jacket legs to support the foundation structure before piles are installed (if piles are installed after the jacket). The offshore HVDC converter substations / Large offshore HVAC substations could each be supported by four jacket structures, or a single larger jacket.

4.8.4.7 The maximum design scenario for jacket foundations with pin piles is shown in **Table 4.9**.

Table 4.9: Maximum design parameters for piled jacket foundation.

	Maximum design parameters		
Parameter	**WTG type**	**Small substation**	**Large substation**
Number of legs per jacket foundation	3	6	8
Piles per leg	1	4	2
Max number of piles per foundation	3	16	16
Separation of adjacent legs at seabed level (m)	45	70	100
Platform height above sea level (LAT) (m)	40		
Separation of adjacent legs at LAT (m)	25	70	100
Leg diameter (m)	4.6	5	4.6
Pin pile diameter (m)	4	4	3.5
Typical embedment depth (below seabed)	70	100	100
Hammer energy (kJ)	2,500	2,500	2,500
Mud-mats footprint (m^2)	n/a	100	400

Suction bucket jacket foundations

4.8.4.8 Suction bucket jacket foundations are formed with a steel lattice construction (comprising tubular steel members and welded joints) fixed to the seabed by suction buckets installed below each leg of the jacket. The suction buckets are typically hollow steel cylinders, capped at the upper end, which are fitted underneath the legs of the jacket structure. They do not require a hammer or drill for installation. As with piled jacket foundations, there is no separate transition piece. The maximum design parameters for jacket foundations with suction buckets are presented in **Table 4.10**.

Table 4.10: Maximum design parameters for suction bucket with jacket foundations.

	Maximum design parameter		
Parameter	**WTG type**	**Small / medium substation**	**Large substation**
Number of legs per jacket foundation	3	6	8
Separation of adjacent legs at seabed level (m)	45	70	100
Separation of adjacent legs at LAT (m)	25	70	100
Suction bucket diameter (m)	20	25	30
Suction bucket height above seabed (m)	5	5	5
Typical embedment depth (below seabed)	20	25	30

Mono-suction bucket foundations

4.8.4.9 A mono suction bucket consists of a single suction bucket supporting a single steel or concrete structure, which supports the wind turbine. As with the jacket structures and suction bucket foundations, this foundation type does not require a transition piece to be installed offshore. The maximum design parameters for mono suction bucket foundations are presented in **Table 4.11**.

Table 4.11: Maximum design parameters for mono suction bucket.

Parameter	Maximum design parameters
Suction bucket diameter (m)	40
Suction bucket height above seabed (m)	10
Typical embedment depth (below seabed)	20

Box-type gravity base foundations

4.8.4.10 Gravity base foundations will only be used for the support of offshore transformer/convertor substations, HVAC booster stations and accommodation platforms. They will not be used for WTG foundations. Gravity base foundations are heavy steel, concrete, or steel and concrete structures, sometimes including additional ballast, that sit on the seabed to support structure. Gravity bases vary in shape but are normally significantly wider at the base (at seabed level) to provide support and stability to the structure. They then generally taper to a smaller width at or below seabed level. The Box type gravity base foundation has a square base that supports the steel or concrete supporting structure for the substation topsides. The maximum design parameters for the box type gravity base foundation are presented in Table 4.12.

Table 4.12: Maximum design parameters for box type gravity base foundations.

Parameter	Maximum design parameter
Length and width at seabed level (m)	150
Area on seabed (m^2)	22,500m^2
Length and width at LAT (m)	150
Seabed preparation buffer around base (m)	50
GBS Height (relative to LAT) (m)	-1
Seabed preparation depth (m)	5

Pontoon gravity base foundations

4.8.4.11 This foundation type is a variant of the gravity base foundation, however rather than having a single unit base, this type of foundation has several pontoons or an open rectangular pontoon that support the steel or concrete supporting structure for the substation topside. The parameters for the pontoon gravity base are presented in Table 4.13.

Table 4.13: Maximum design parameters for pontoon gravity base.

	Maximum design parameter	
Parameter	**Type 1**	**Type 2 (open rectangle)**
Number of pontoons per platform	2	1
Pontoon length (m)	170	120
Pontoon width (m)	35	35
Pontoon area m^2 (per structure)	5,950	4,200
Pontoon spacing (m)	36	-
Pontoon base width (m)	90	-

Foundation installation

4.8.4.12 Table 4.14 summarises the steps required for installation for each of the foundation types.

Table 4.14: Foundation installation summary.

<table>
<tr><th rowspan="2"></th><th colspan="5">Foundation type</th></tr>
<tr><th>Monopile</th><th>Piled jacket</th><th>Suction bucket jacket</th><th>Mono-suction bucket</th><th>Gravity base (all types)</th></tr>
<tr><td>Site preparation (also see below)</td><td colspan="2">Usually minimal. If preconstruction surveys show the presence of boulders or other seabed obstructions at foundation locations, these may be removed if the foundation cannot be microsited.</td><td colspan="3">As well as boulder and obstruction removal this foundation type may also require some seabed levelling, to ensure that all of the buckets / gravity bases for each structure can be placed at the same level. The suction buckets needs to have level ground beneath to form a sealed chamber within each bucket once the foundation has been lowered to the seabed..</td></tr>
<tr><td>Transport to site</td><td colspan="4">Either on the installation vessel (either JUV or Dynamic Positioning Vessel (DPV)), or on feeder barges.</td><td>Brought to site on barges or installation vessels or alternatively they can be floated to site. Structures designed to be buoyant and towed them to site using tugs.</td></tr>
<tr><td>Installation</td><td>Lift monopile into the pile gripper on the side of the installation vessel;
Lift hammer onto monopile and drive monopile into seabed to required embedment depth;
Lift hammer from monopile and remove pile gripper;
Lift transition piece onto monopile; and
Secure transition piece
Where conventional piling is unable to achieve necessary pile penetration, additional methods may be used (e.g drilling, vibro-piling and/or electro-osmosis).</td><td>Piling template placed on seabed
Piles installed
Jacket lowered onto piles
OR
Jacket lowered onto seabed
Piles installed
Pin piles are driven, drilled or vibrated into the seabed.</td><td colspan="2">Jacket lowered onto seabed
Water pumped from bucket(s)
At desired depth, the pump is turned off</td><td>Foundations lowered to the seabed in a controlled manner either by pumping in water, or installation of ballast (or both)</td></tr>
</table>

	Foundation type				
	Monopile	**Piled jacket**	**Suction bucket jacket**	**Mono-suction bucket**	**Gravity base (all types)**
Finalisation	Transition piece bolted or grouted to the monopile. The grout used is an inert cement mix that is pumped into a specially designed space between the transition piece and the monopile.	As the there is no separate transition piece, there is no requirement for installing an additional structure offshore.	A thin layer of grout is injected under each bucket to fill the air gap and ensure contact between the soil within the bucket, and the top of the bucket itself. As there is no separate transition piece, there is no requirement for installing an additional structure offshore.		None
Vessels	The full vessel requirements for installation of foundations are shown in **Table 4.27**.				
Installation vessels	4				2
Support vessels	16				12
Transport vessels (barges)	10				4
Transport vessels (tugs)	30				0

Seabed preparation

4.8.4.13 Some form of seabed preparation may be required for each foundation type (see **Table 4.14**). Seabed preparations may include seabed levelling and removing surface and subsurface debris such as (for example) boulders, lost fishing nets or lost anchors. If debris is present below the seabed surface, then excavation may be required for access and removal.

4.8.4.14 Gravity base foundations need to be placed in pre-prepared areas of seabed. Seabed preparation would involve levelling and dredging of the soft mobile sediments as required, as well as any boulder and obstruction removal. Unexploded ordinance (UXO), boulder and sandwave clearance for foundations are further discussed in **Section 4.8.8**.

4.8.4.15 It is likely that dredging would be required if using the gravity base foundations. If dredging is required it would be carried out by dredging vessels using suction hoppers or similar, and the spoil would be deposited on site adjacent to the turbine locations. In some cases, it may be required to place a layer of gravel on the seabed prior to installation of gravity base foundations.

Scour protection

4.8.4.16 Scour protection is designed to prevent foundation structures for turbines, offshore substations and offshore accommodation platform, being undermined by hydrodynamic and sedimentary processes, resulting in seabed erosion and subsequent scour hole formation. The shape of the foundation structure is an important parameter influencing the potential depth of scour hole formation. Scour around foundations is typically mitigated by the use of scour protection measures. Several types of scour protection exist, including mattress protection, sand bags, stone bags and frond mats. However, the placement of large quantities of crushed rock around the base of the foundation structure is the most frequently used solution ('rock placement').

4.8.4.17 The preferred scour protection solution may comprise a rock armour layer resting on a filter layer of smaller graded rocks. The filter layer can either be installed before the foundation is installed or afterwards. Alternatively, by using heavier rock material with a wider gradation, it is possible to avoid using a filter layer and pre-install a single layer of scour protection.

4.8.4.18 The amount of scour protection required will vary for the different foundation types being considered for Hornsea Four. Flexibility in scour protection choice is required to ensure that anticipated changes in available technology and project economics can be accommodated within the Hornsea Four design.

4.8.4.19 The maximum diameter of the rocks used would be 1 m and the maximum thickness of scour protection layer would be 2 m.

Maximum design parameters for foundations for Hornsea Four

4.8.4.20 Each relevant assessment within the PEIR considers the range of foundations options (including monopiles, suction bucket jacket foundations, piled jacket foundations, mono suction buckets and gravity base structures) and assesses the foundation type which presents the maximum design scenario for the relevant receptor(s). The MDS for wind turbine generators (**Table 4.15**), offshore substation(s) (**Table 4.16** and **Table 4.17**) and offshore accommodation platform (**Table 4.18**). The MDS includes for the foundation as part of the total seabed disturbance.

Table 4.15: Maximum design parameters for wind turbine generator foundations.

	Maximum design parameters	Maximum related foundation type
Total Number	180	n/a
Totals for Hornsea Four array area		
Number of Piles	540	Piled Jacket
Seabed Preparation Area	511,379 m^2	Suction bucket Jacket
Seabed Structure Area	226,195 m^2	Monopod Suction bucket
Seabed Scour Protection Area	763,408 m^2	Monopile
Seabed Total Permanent Area	795,216 m^2	Monopile
Drill Spoil Volume (average; assumes 10% drilling)	127,235 m^3	Monopile
Seabed Preparation (Spoil) Volume	924,240 m^3	Suction bucket Jacket
Scour Protection Volume	1,526,814 m^3	Monopile
Pile-structure grout volume	25,447 m^3	Piled Jacket
Structure-seabed grout volume	158,337 m^3	Monopod Suction bucket

4.8.4.21 **Table 4.16** presents the MDS for offshore transformer substation(s). Each assessment within the relevant receptor chapter of the PEIR considers the range of foundations options (including gravity base structures) and assesses the foundation type which presents the maximum design scenario for the relevant receptor(s).

Table 4.16: Maximum design parameters for the offshore transformer substation foundations.

	Maximum design parameters	Maximum related foundation type
Total Number	6 small and 3 large OSS (in Hornsea Four array area)	-
Totals for Hornsea Four array area		
Number of Piles	144	HVDC: 9x Piled Jacket for OSS, each structure x16 piles
Seabed Preparation Area	156,594 m^2	HVDC: Suction Caisson Jacket (Small OSS) & GBS (Large OSS)
Seabed Gravel Bed Area	116,226 m^2	HVDC: GBS (Box-type) & GBS (Large OSS)
Seabed Structure Area	101,250 m^2	HVDC: GBS (Box-type) & GBS (Large OSS)
Seabed Scour Protection Area	270,000 m^2	HVDC: GBS (Box-type) & GBS (Large OSS)
Seabed Total Permanent Area	371,250 m^2	HVDC: GBS (Box-type) & GBS (Large OSS)
Drill Spoil Volume (average; assumes 10% drilling)	13,854 m^3	HVDC: Piled Jacket (Small OSS) & Piled Jacket (Small OSS)
Seabed Preparation (Spoil) Volume	737,130 m^3	HVDC: Suction Caisson Jacket (Small OSS) & GBS (Large OSS)
Seabed Preparation (Gravel Bed) Volume	198,531 m^3	HVDC: GBS (Box-type) & GBS (Large OSS)
Scour Protection Volume	540,000 m^3	HVDC: GBS (Box-type) & GBS (Large OSS)
Pile-structure grout volume	2,375 m^3	HVDC: Piled Jacket (Small OSS) & Piled Jacket (Large OSS)
Structure-seabed grout volume	66,177 m^3	HVDC: GBS (Box-type) & GBS (Large OSS)

4.8.4.22 Table 4.17 presents the MDS for offshore HVAC booster substation(s). Each assessment within the relevant receptor chapter of the PEIR considers the range of foundations options (including gravity base structures for HVACs) and assesses the foundation type which presents the maximum design scenario for the relevant receptor(s).

Table 4.17: Maximum design parameters for the offshore HVAC booster substations.

Surface offshore HVAC booster station foundations	Maximum design parameters	Maximum related foundation type
Total Number of Structures	3	
Maximum dimensions per HVAC booster station		
Maximum Seabed Preparation Dimension	107 m	Suction Caisson Jacket (Small OSS)
Maximum Gravel bed Dimension	83 m	GBS (Box-type)
Maximum Scour Protection Dimension	175 m	GBS (Box-type)
Maximum Structure Dimension at Seabed	75 m	GBS (Box-type)
Maximum Structure Dimension at Sea Surface	75 m	GBS (Box-type)
Totals for offshore export cable corridor		
Number of Piles	48	Piled Jacket (Small OSS)
Seabed Preparation Area	36,963 m^2	Suction Caisson Jacket (Small OSS)
Seabed Gravel Bed Area	20,667 m^2	GBS (Box-type)
Seabed Structure Area	16,875 m^2	GBS (Box-type)
Seabed Scour Protection Area	75,000 m^2	GBS (Box-type)
Seabed Total Permanent Area	91,875 m^2	GBS (Box-type)
Drill Spoil Volume (average; assumes 10% drilling)	4,618 m^3	Piled Jacket (Small OSS)
Seabed Preparation (Spoil) Volume	171,735 m^3	Suction Caisson Jacket (Small OSS)
Seabed Preparation (Gravel Bed) Volume	37,265m^3	GBS (Box-type)
Scour Protection Volume	150,000 m^3	GBS (Box-type)
Pile-structure grout volume	713 m^3	Piled Jacket (Small OSS)
Structure-seabed grout volume	12,422 m^3	GBS (Box-type)

4.8.4.23 Table 4.18 presents the MDS for offshore accommodation platform(s). Each assessment within the relevant receptor chapter of the PEIR considers the range of foundations options (including gravity base structures for HVACs) and assesses the foundation type which presents the maximum design scenario for the relevant receptor(s).

Table 4.18: Maximum design parameters for offshore accommodation platform foundation.

	Maximum design parameters	Maximum related foundation type
Totals for Hornsea Four array area		
Number of Piles	16	Piled Jacket (Small OSS)
Seabed Preparation Area	12,321 m^2	Suction bucket Jacket (Small OSS)
Seabed Gravel Bed Area	6,889 m^2	GBS (Box-type)
Seabed Structure Area	5,625 m^2	GBS (Box-type)
Seabed Scour Protection Area	25,000 m^2	GBS (Box-type)
Seabed Total Permanent Area	30,625 m^2	GBS (Box-type)
Drill Spoil Volume (average; assumes 10% drilling)	1,540 m^3	Piled Jacket (Small OSS)
Seabed Preparation (Spoil) Volume	57,245 m^3	Suction bucket Jacket (Small
Seabed Preparation (Gravel Bed) Volume	12,422 m^3	GBS (Box-type)
Scour Protection Volume	50,000 m^3	GBS (Box-type)
Pile-structure grout volume	238 m^3	Piled Jacket (Small OSS)
Structure-seabed grout volume	4141 m^3	GBS (Box-type)

Piling

4.8.4.24 The MDS for monopiles installation (piling) and jacket pin piles will assume a maximum four-hour duration. Analysis of recent piling records at other Ørsted wind farms indicates that piling of monopiles typically averages two hours or less for installation (including the slow start procedure), with timings slightly longer at the beginning of the construction phase and then reducing as experience is gained. Piling at substations has usually taken a little longer, typically averaging three hours or less. The number of positions where piling work exceeds four hours is typically a small percentage, around 5% or less; this exceedance will be due to breaks in the construction work caused by reasons such as particularly challenging ground conditions or break-down of equipment and therefore does not reflect an uninterrupted four hour start-to-finish hammer strike piling duration.

4.8.4.25 The maximum hammer energy for Hornsea Four is 5,000 kJ for monopiles. The rationale for using a maximum hammer energy of 5,000 kJ is to maximise the opportunity to successfully drive all piles. Although a hammer energy of 5,000 kJ is considered as the maximum design scenario, the actual energy used when piling will be significantly lower for most of the time and the driving energy will be raised to 5,000 kJ only when necessary. To minimise fatigue loading on the monopiles, hammer energies are continuously set at the minimum required, which also reduces the likelihood of breakdown of the equipment, hence will typically start low (15% soft start of 750 kJ) and gradually increase to the maximum required installation energy during the piling of the final metres (typically significantly less than the maximum consented hammer energy).

4.8.4.26 As pin piles are smaller, the maximum hammer energy to be used would be 2,500 kJ.

4.8.4.27 The most likely hammer energy for monopiles is anticipated to be 4,000 kJ and 1,750 kJ for pin piles.

4.8.4.28 The definition of maximum hammer energy may allow the maximum piling durations to be reduced. Other reasons why higher hammer energies are required include the greater effectiveness at pile driving (due in part to the additional weight of the hammer) and greater reliability, since they are working far under their design rating for much of the time. Knowledge of the anticipated construction work will improve as additional geoscience survey campaigns are undertaken and corresponding design work is completed for Hornsea Four. Though this is not anticipated to be complete pre-Application.

4.8.4.29 Analysis of recent piling records at other Ørsted wind farms (Burbo Bank Extension, Walney Extension, Race Bank and Hornsea One) indicates that piling of monopiles typically averages two hours or less for installation (including the slow start procedure), with timings slightly longer at the beginning of the construction phase and then reducing as experience is gained. Piling at substations has usually taken a little longer, typically averaging three hours or less. The number of positions where piling work exceeds four hours is typically a small percentage, around 5% or less; this exceedance will be due to breaks in the construction work caused by reasons such as particularly challenging ground conditions or break-down of equipment and therefore does not reflect an uninterrupted four hour start-to-finish hammer strike piling duration.

4.8.4.30 The rationale for using a lower energy than the maximum hammer energy is to maximise the opportunity to successfully drive all piles. Although a maximum hammer energy will be considered as the maximum design scenario in the Environmental Statement (ES), the actual energy used when piling will be significantly lower for most of the time and the driving energy will be raised to the maximum design scenario only when absolutely necessary. To minimise fatigue loading on the monopiles, hammer energies are continuously set at the minimum required, which also reduces the likelihood of breakdown of the equipment, hence will typically start low (20% soft start) and gradually increase to the maximum required installation energy during the piling of the final metres (typically significantly less than the maximum consented hammer energy).

4.8.4.31 A characteristic four-hour piling scenario with maximum durations for each energy level is provided in **Table 4.19**. The most likely scenario is presented in **Table 4.20**.

Table 4.19: Typical piling scenario for pile installation using a most likely hammer energy. Piling for four hours.

% of max hammer blow energy	20%	40%	60%	80%	100%
Monopile blow energy	1000	2000	3000	4000	5000 kJ
Pin pile blow energy	500	1000	1500	2000	2500 kJ
Strike Rate	10 bl/min	10 bl/min	15 bl/min	15 bl/min	30 bl/min
Duration	7.5 mins	7.5 mins	7.5 mins	7.5 mins	210 mins

Table 4.20: Most likely piling scenario ramp up.

% of max hammer blow energy	20%	40%	60%	80%	100%
Monopile blow energy	800	1,600	2,400	3,200	4,000
Pin pile blow energy	350	700	1,050	1,400	1,750
Strike Rate	1	10	15	15	30
Duration	30 mins	7.5 mins	7.5 mins	7.5 mins	75 mins

4.8.4.32 If piling is not possible due to the presence of rock or hard soils, the material inside the monopile may be drilled out before the monopile is driven to the required depth. This can either be done in advance of the driving or if the piling rate slows significantly during piling. If drilling is required, it is conducted at a speed of 0.5 to 1.0m/hr with any spoil arising from the drilling disposed of adjacent to the foundation location on the sea surface.

4.8.4.33 There would be no more than four piles being driven simultaneously, and eight piles being drilled simultaneously across the Hornsea Four array area.

4.8.4.34 It may also be possible that the piles are installed via another novel method such as vibropiling or electro-piling. For vibro-pilin the pile is embedded via vibration rather than hammering or drilling. If any such methods were employed, it would be ensured that the noise emissions were within the envelope consented for hammering.

4.8.5 Offshore Cables (array, export & interconnector)

Array cables

4.8.5.1 Cables carrying the electrical current produced by the turbines will link the turbines to an offshore transformer substation or offshore HVDC converter station. A small number of turbines will typically be grouped together on the same cable 'string' connecting those turbines to the substation, and multiple cable 'strings' will connect back to each offshore substation.

4.8.5.2 It is likely that the array cable system will use HVAC technology, but it is also possible that the system will consist of an alternative option such as a HVDC. The array cables will consist of several conductor cores, usually made from copper or aluminium surrounded by layers of insulating material, as well as material to armour the cable for protection from external damage. The maximum design parameters for array cables are presented in **Table 4.21**.

Table 4.21: Maximum design parameters for array cables.

Parameter	Maximum design parameters
Cable diameter (mm)	200
Total length of cable (km)	600
Voltage (kV)	170

Offshore interconnector cables

4.8.5.3 Hornsea Four may require cables to interconnect the offshore substations to provide redundancy in the case of cable failure elsewhere, or to connect to the offshore accommodation platform to provide power for operation. The cables will have a similar design and installation process to the array and export cables. The parameters for design and installation of the offshore interconnector cables are presented in **Table 4.22**.

Table 4.22: Maximum design parameters for offshore interconnector cables.

Parameter	Maximum design parameters
Number of circuits/cables	6
Total length of cables/circuits (km)	90
Voltage (kV)	600

Offshore export cables

4.8.5.4 The offshore export cables are typically larger in diameter than array cables. The maximum design parameters for offshore export cables are presented in **Table 4.23**.

Table 4.23: Maximum design parameters for offshore export cables.

Parameter	Maximum design parameters	
	HVAC	HVDC
HVAC - number of circuits	6	4
HVAC – voltage (kV)	400	600
Cable diameter (mm)	320	
Maximum number of cables	6	
Length per cable – including export cable within the Hornsea Four array area (km)	109	
Total length of cables (km)	654	
Length of Hornsea Four offshore cable corridor (km) (excluding within array)	99	
Width of Hornsea Four offshore cable corridor (km) (permanent cables)	1.5	
Width of Hornsea Four offshore cable corridor temporary works buffer (km)	0.5	
Total width of ECC (permanent and temporary) (km)	2.5	

Installation

4.8.5.5 Cables will be buried below the seabed wherever possible. The installation method and target burial depth will be defined post consent based on a cable burial risk assessment (CBRA) (or similar) considering ground conditions as well as the potential for impacts upon cables such as from trawling and vessel anchors. The depth will likely vary across the Hornsea Four array area and offshore export cable corridor. Possible installation methods include jetting, vertical injection, cutting and ploughing whereby the seabed is opened and the cable laid within the trench simultaneously using a tool towed behind the installation vessel. Alternatively, a number of these operations such as jetting, cutting or Mass Flow Excavation (MFE) may occur post cable lay.

4.8.5.6 It may also be necessary to install the cable by pre-trenching or rock cutting whereby a trench is opened in one operation and then the cable laid subsequently from another vessel. Hornsea Four may also need to dredge the cable route prior to installation to level sandwaves that may hinder installation. This is discussed in paragraph **4.8.8.11**. Where pre-trenching or rock cutting is employed, and there is a gap between this activity and cable installation, in some areas the trench may partially collapse, or infill. In these cases, pre-sweeping may have to be performed to clear the trench prior to installation. Pre-sweeping typically comprises the use of a jetting tool, pre-trenching plough or pre-trenching draghead mounted to a Trailer Suction Hopper Dredger (TSHD) or similar, targeted to remove the material that has partially infilled the trench.

4.8.5.7 If the cables must cross third party infrastructure, such as existing cables, both the third-party asset and the installed cable must be protected.

4.8.5.8 Cables will need to be made secure where the route crosses obstacles such as exposed bedrock, pre-existing cables or pipelines which means that the cable cannot be buried. This is typically achieved through some form of armouring like rock placement or concrete mattress (see **Paragraph 4.8.5.13** and **4.8.5.14**) to maintain the integrity of the cable.

4.8.5.9 Cable installation and route preparation will be undertaken by specialist vessels. Based on previous experience within Ørsted at other offshore wind farms, it is possible that a small jack-up vessel or a flat top barge will be required for export cable installation in shallow water near to landfall. The full vessel requirements for installation of foundations are shown in **Table 4.27**. The maximum design parameters for cable installation are presented in **Table 4.24**. A Cable Burial Risk Assessment (CBRA) will inform cable burial depth, dependent on ground conditions as well as external risks. This assessment will be undertaken post-consent.

Table 4.24: Maximum design parameters for cable installation.

Parameter	Maximum design parameters		
	Array cables	Offshore interconnector cables	Offshore export cables
Installation methodology	Surface lay, mechanical trenching, dredging, jetting, ploughing, mass flow excavation, vertical injection, rock cutting.	Mechanical trenching, dredging, jetting, ploughing, mass flow excavation, vertical injection, rock cutting.	
Burial depth; Vertical Injection (Ploughing and Mass Flow Excavation) (m)	3 (2)		
Total length of cable (km)	600	90	654
Boulder and Sandwave Clearance width (m), per cable	30		
Cable installation width (m)	15 (NOTE: 15m is within the 30m not additional)		
Total seabed disturbed (full corridor width 1.5km) (km^2)	9	1.4	9.8

Parameter	Maximum design parameters		
	Array cables	Offshore interconnector cables	Offshore export cables
Boulder Clearance - Seabed Disturbance (km^2)	18	2.7	19.5
Sand wave Clearance -- Seabed Disturbance (km^2)	18	2.7	19.5
Sandwave Clearance - Material Volumes (m^3)	769,000	115,000	834,000
Burial spoil: jetting (m^3)	199,000		
Jetting excavation rate soft soil (soft or loose soil)	300 (125) m/hr		
Burial spoil: Vertical Injection (m^3)	1,326,000	n/a	1,438,000
Ploughing excavation rate medium soil (hard soil)	125 (55) m/hr		
Burial spoil: ploughing/mass flow excavation (m^3)	3,600,000	540,000	3,903,000
Duration: total (months)	24	24	24

Cable protection

4.8.5.10 Cable protection will be required at cable crossings, as well as areas where cable burial is not possible. Up to 10% of the total cable length (including export, array and interconnector cables and excluding cable crossings) may require protection due to unforeseen ground conditions and tool failure. Cable protection methods are described below.

Rock Placement

4.8.5.11 Rocks of different grade sizes are placed, from a fall pipe vessel over the cable. Initially smaller stones are placed over the cable as a covering layer. This provides protection from any impact from larger grade size rocks, which are then placed on top of this smaller scale level.

4.8.5.12 This rock grading generally has mean rock size in the range of 90 to 125 mm and maximum rock up to 250 mm. The rocks generally form a trapezium shape, up to approximately 1.5 m above the seabed (though may be up to 2.7m to protect from anchor strike) with a 3:1 gradient (see **Figure 4.10**). Larger rocks may be necessary if protection from larger anchors is required (e.g. up to 500mm in shipping corridors). In such cases the berm width would be 20.2 m (10.4 m in all other cases). The cross section may vary dependent on expected scour. The length of the berm is dependent on the length of cable which is either unburied or has not achieved target depth. The trapezium shape is designed to provide protection from both direct anchor strikes and anchor dragging. Should this protection method be used for crossings, a separation layer may first be laid on the seabed. This layer is approximately 30 cm deep with a rectangular or oval plan view.

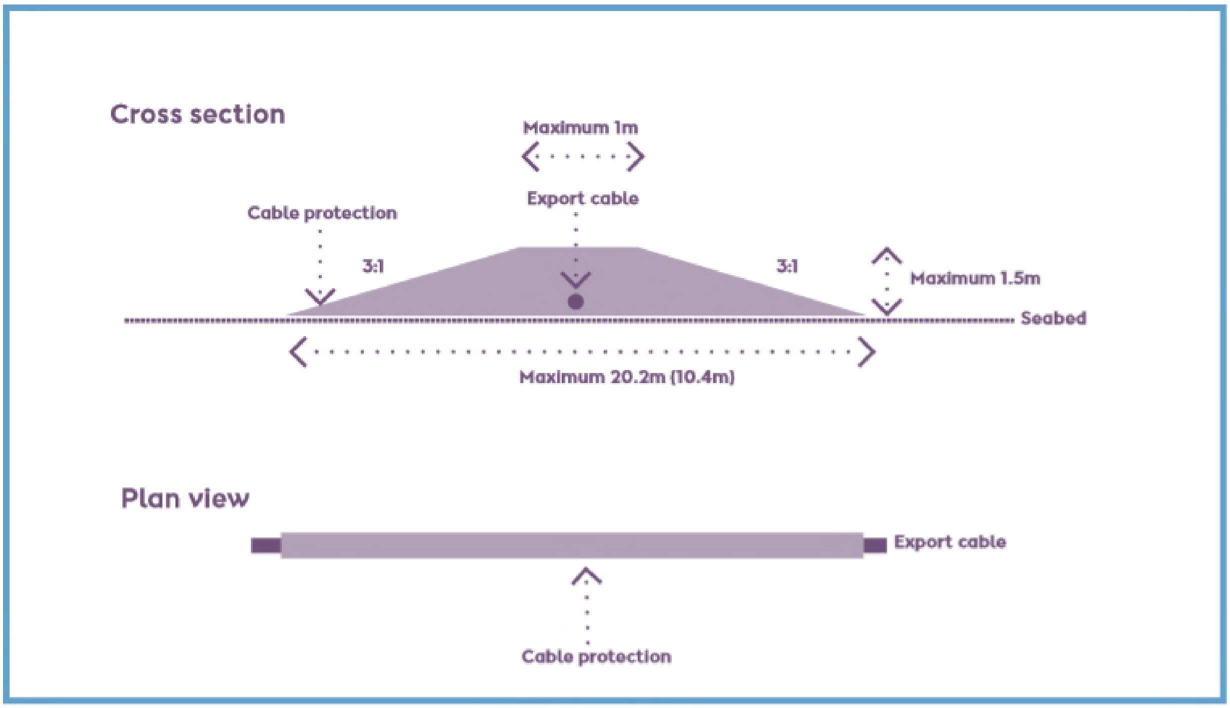

Figure 4.10: Cable protection via rock placement (indicative only).

Mattresses

4.8.5.13 Mattresses generally have dimensions of 6 m by 3 m by 0.3 m. They are formed by interweaving a number of concrete blocks with rope and wire. They are lowered to the seabed on a frame. Once positioning over the cable has been confirmed, the frame release mechanism is triggered, and the mattress is deployed. This single mattress placement will be repeated over the length of cable which is either unburied or has not achieved target depth. Mattresses provide protection from direct anchor strikes but are less capable of dealing with anchor drag. Should this protection method be used for crossings, a mattress separation layer may first be laid on the seabed.

Frond Mattresses

4.8.5.14 Frond mattresses are installed following the same procedure as general mattress placement operations. The fronds are designed with the aim to form protective, localised sand berms.

Rock Bags

4.8.5.15 Rock bags consist of various sized rocks constrained within a rope or wire netting containment. They are placed via a crane and deployed to the seabed in the correct position. Rock bags are more suited for cable stability or trench/scour related issues.

Seabed Spacers

4.8.5.16 Propriety separation consists of plastic, or metal, half shell sections that are bolted together forming a circular protection barrier around the cable. Additionally, rock may be placed on top to provide protection from anchors or fishing gear. As they are placed onto the cable during installation, they cannot be used for remedial protection. Thus, their only use is for crossings or areas, such as rock, where it is known that burial will not be achieved.

Crossings

4.8.5.17 Within the Hornsea Four offshore export cable corridor and array area there are several existing assets, and others planned, primarily oil and gas pipelines that connect to production wells in the North Sea. The design and methodology of these crossings will be confirmed in agreement with the asset owners, however it is likely that a berm of rock will be placed over the existing asset for protection, known as a pre-lay berm, or separation layer (**Figure 4.11**). The Hornsea Four cable will then be laid across this, at an angle close to 90 degrees. The Hornsea Four cable will then be covered by a second post lay berm to ensure that the export cable remains protected and in place.

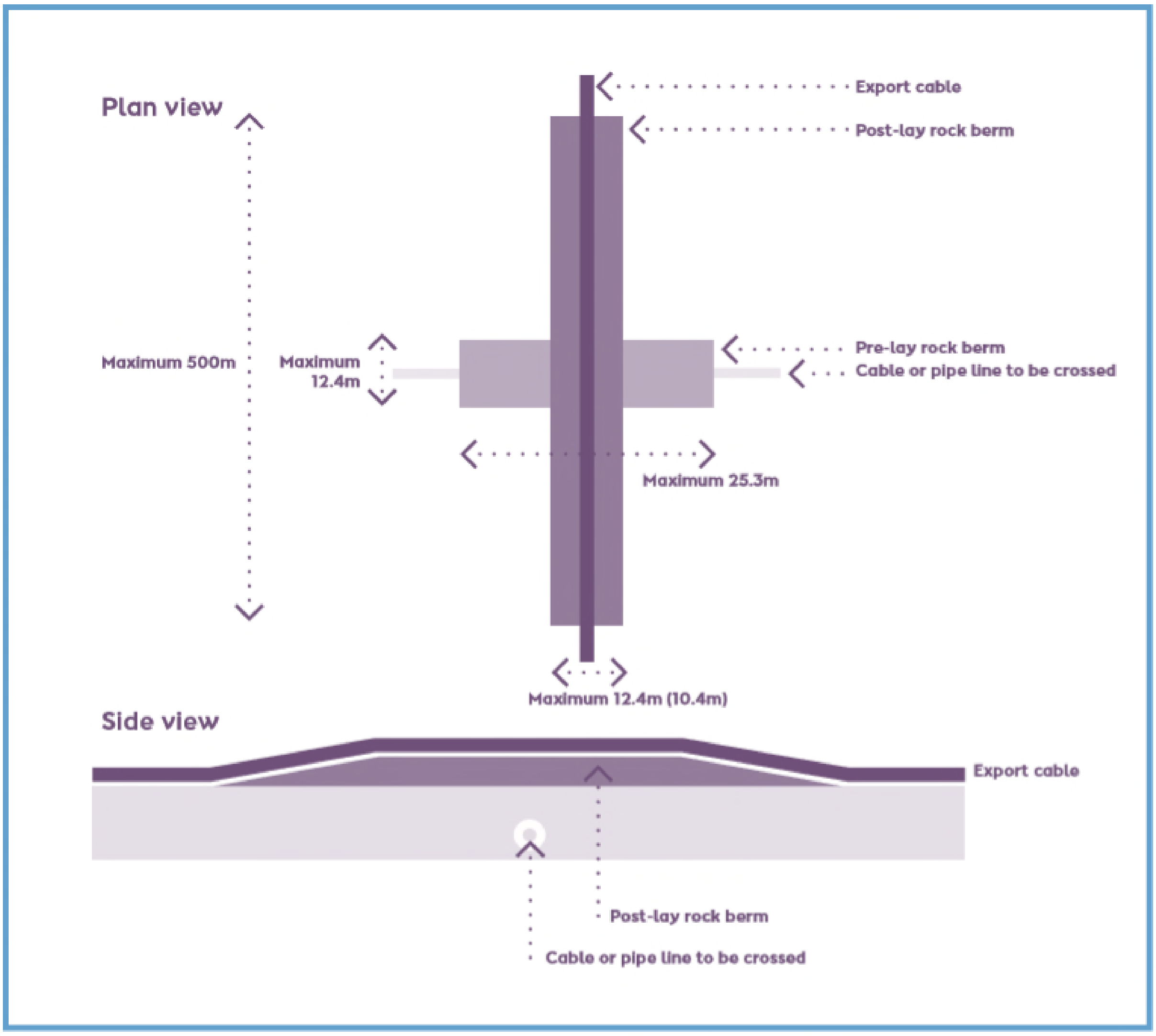

Figure 4.11: Offshore Cable Crossing (indicative only).

4.8.5.18 The rock berms will be inspected at regular intervals and may need to be replenished with further rock placement dependent on their condition. This operational rock placement would not exceed 25% of the estimated rock volume and would occur in areas already disturbed by rock placement (i.e. no new areas of disturbance above what is assessed in the 10% of ECC area).

Maximum design parameters for cable protection

4.8.5.19 **Table 4.25** presents the total requirements for cable protection for Hornsea Four incorporating both crossings and allowances for areas where cable burial is not possible.

Table 4.25: Maximum design parameters for cable protection.

	Maximum design parameters		
Parameter	**Array cables**	**Offshore interconnector cables**	**Offshore export cables**
Height of rock berm (m)	1.5		
Pre-lay width of rock berm at seabed (m)	12.4		
Pre-lay length of rock berm at seabed (m)	55		
Post-lay width of rock berm at seabed (m)	10.4		
Post-lay length of rock berm at seabed (m)	500		
Percentage of route requiring protection (%)	10		
Replenishment during operation (% of construction total)	25		
Cable rock protection: maximum rock size (m) (if required to protect from anchor strike)	0.25 (0.5)		
Rock protection area (m^2)	624,000	94,000	792,000
Rock protection volume (m^3)	522,000	78,000	849,000
Number of crossings	40		15
Cable/pipe crossings: pre- and post-lay rock berm area (m^2)	255,000		293,000
Cable/pipe crossings: pre- and post-lay rock berm volume (m^3)	283,000		326,000

Cable jointing

4.8.5.20 Cable installation vessels are limited in the length of cable they can transport in a single load-out. Where lengths of offshore export cable must be jointed to one another it is not possible to bury the cable joint using conventional cable burial tools. It is therefore necessary to excavate a jointing pit to accommodate the joint and ensure its protection. The pit will normally be excavated via a dredging vessel. Material will be removed to a nearby designated disposal site and recovered for backfilling once jointing is complete (see **Figure 4.1**). It may be necessary to recover additional material from the licensed dredge/disposal area bordering the ECC, to make up for any lost during the dredge/recovery operation due to winnowing of material by hydrodynamic processes. The maximum design parameters for cable jointing are presented in **Table 4.26**.

Table 4.26: Maximum design parameters for cable jointing activities.

Parameter	Maximum design parameters
Maximum number of offshore cable joints (per cable)	4
Depth of offshore jointing pit (m)	5
Area of offshore jointing pit (m^2)	3,500
Volume of offshore jointing pit (m^3)	17,500
Material loss during dredge/recover (subject to make-up)	50%

4.8.6 Surface Infrastructure Layout

4.8.6.1 Designing and optimising the layout of the wind turbine generators and offshore substations and offshore accommodation platforms is a complex, iterative process considering many inputs and constraints including;

- Site conditions:
  - Wind speed and direction;
  - Water depth;
  - Ground conditions;
  - Environmental constraints (anthropogenic and natural);
  - Seabed obstructions (e.g. wrecks, UXO, existing cables); and
  - Order limits (i.e. site boundary)
- Design considerations:
  - Turbine type;
  - Installation set-up;
  - Foundation design;
  - Electrical design; and
  - Operation and maintenance requirements.

4.8.6.2 Hornsea Four requires flexibility in location of the wind turbine generators and other offshore surface infrastructure, within the final approved layout, to ensure that anticipated changes in available technology and project economics can be accommodated within the Hornsea Four Design Envelope. However, to inform the EIA, Hornsea Four has created an indicative layout containing 180 potential wind turbine generator positions and the 10 potential platform positions (offshore substations and accommodation platform). The layout is shown in **Figure 4.12** and conforms to the layout principles set out in **Volume 4, Annex 4.7: Layout Principles,** except for Principle 8.

4.8.6.3 The layout principles are design criteria agreed in consultation with the relevant stakeholders (e.g. MCA and THLS) to inform the layout design of all surface infrastructure. The aim of the layout principles is to improve the final the layout submitted by Hornsea Four taking account of the technical and consenting considerations at an early stage and thereby hopefully facilitating the final sign off for the layout.

4.8.6.4 The layout includes a single line of orientation which aligns (northwest to southeast) with Hornsea Project Two. The minimum spacing for all development scenarios between turbines is 810m (see **Volume 4, Annex 4.7: Layout Principles**). As the locations of the infrastructure are not yet defined, the layouts do not distinguish between what type of infrastructure is placed in each location. Individual assessment chapters have therefore made assumptions as to which locations are turbines or platforms to inform the maximum design scenario for the relevant assessment.

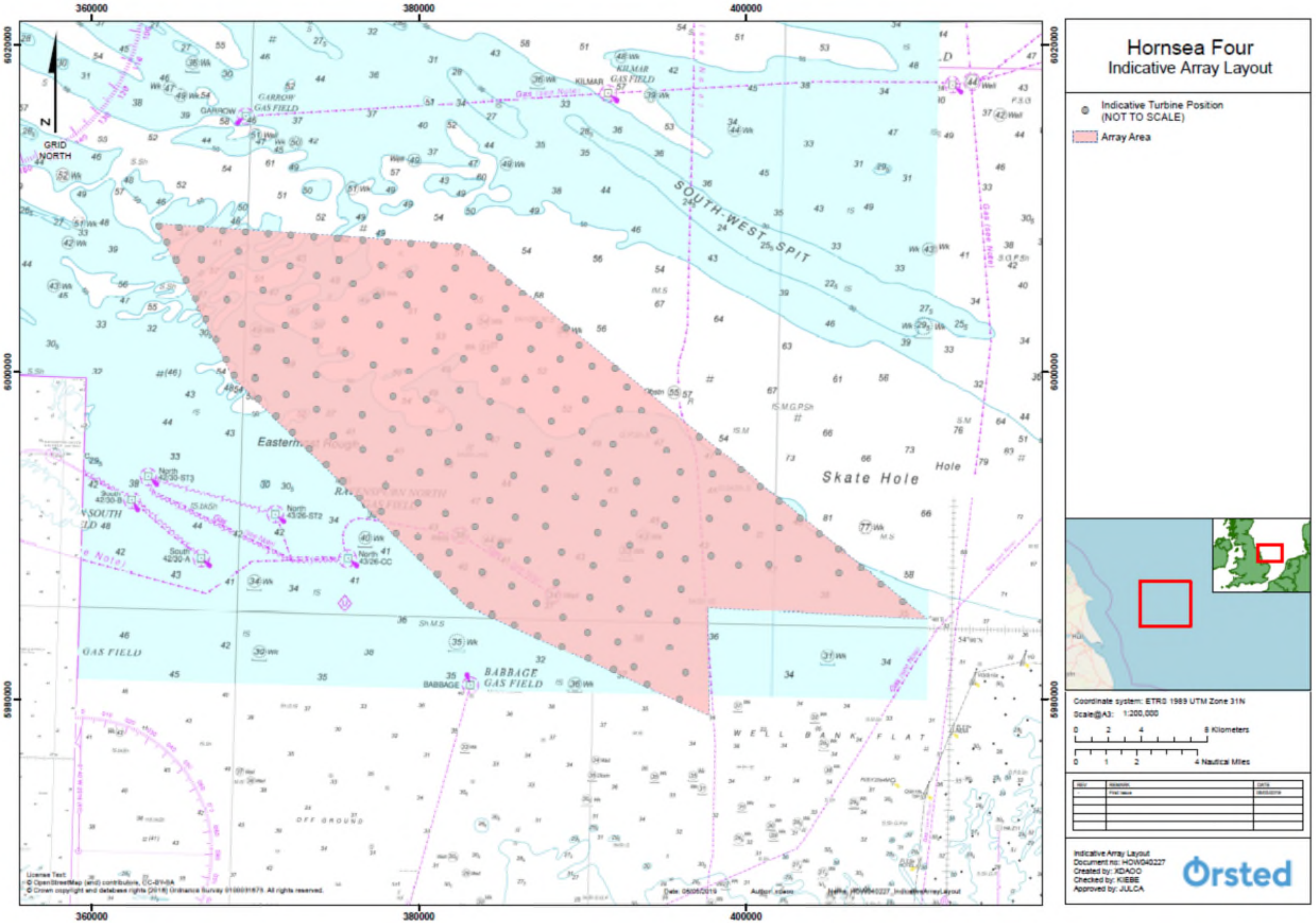

Figure 4.12: Hornsea Four Indicative layout with 190 positions. (180 WTGs, 9 substations and 1 offshore accommodation platform) (not to scale).

4.8.7 Vessel Activities

4.8.7.1 During the construction of Hornsea Four, a number and variety of vessels will be utilised for installation, support and transport of equipment and infrastructure to the Hornsea Four array area and the offshore export cable corridor.

4.8.7.2 The total vessel numbers, vessel movements and durations are presented in **Table 4.27**. Each vessel movement represents a return trip to and from the Hornsea Four array area.

4.8.7.3 Indicatively, the busiest period during construction in terms of vessel traffic would be when up to eight vessels (installation and commissioning vessels) could be found in a given 5 km^2 area. This level of activity is unlikely to occur across the entire Hornsea Four array area at any one time, rather this intensity is expected across approximately three or four 5 km^2 blocks.

Table 4.27: Total values for vessel activities during construction.

Vessels	Number of Vessels	Maximum number of return trips per vessel type
Wind turbine generator installation		
Installation vessel (JUV or anchored)	2	90
Support vessel	12	270
WTG installation support vessels include: crew boats or SOVs (x4), service vessels for pre-rigging of towers (x2), diver vessels (x2), PLGR (x2) and post-lay inspection (x2)		
Transport vessel	24	540
Helicopter	-	135
Wind turbine generator foundation installation		
Installation vessel (JUV and anchored)	4 (2 x JUV ,2 x anchored or 4 DP2)	90
Support vessel	16	360
Foundation installation support vessels include: Tug boats (x10), crew boats (x2), drilling vessels (x2) and guard boats (x2).		
Transport / Feeder vessel (incl. Tugs)	40	360
of which Anchored	2	360
Anchor dimensions are 10 x 10 m (area 100m^2) with 8 anchors (4 pair) per vessel.		
Helicopter	-	180
Substation installation (all offshore substations and accommodation platform)		

Vessels	Number of Vessels	Maximum number of return trips per vessel type
Installation vessel	2	36
Support vessel	12	162
Transport vessel	4	72
Helicopter	-	63
Substation foundation installation (all offshore substations and accommodation platform)		
Installation vessel	2	24
Support vessel	12	108
Transport vessel	4	48
Helicopter	-	42
Inter-array and offshore interconnector cables installation		
Main laying vessel	3	204
Main burial vessel	3	204
Support vessel	12	1080
Helicopter	-	396
Offshore export cables installation		
Main Cable Laying vessel	3	96
Main Cable Jointing Vessel	3	72
Main Cable Burial vessel	3	96
Support vessel	15	144
Helicopter	-	800

Aids to Navigation and marking

4.8.7.4 All surface infrastructure (including wind turbine generators, offshore substations), including any required aids to navigation, will be designed in accordance with relevant guidance from Trinity House, the CAA and the Maritime and Coastguard Agency (MCA). This will include colours, marking and lighting. The positions of all infrastructure will be conveyed to the UK Hydrographic Office (UKHO) so that they can be incorporated into Admiralty Charts and the Notice to Mariners (NtM) procedures.

4.8.7.5 Lighting and marking of subsea structures will be discussed with Trinity House, having a statutory duty as a General Lighthouse Authority, where there may be a risk to shipping. In this case, the marking would be based on the recommendations of the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA, 2013).

Safety Zones

4.8.7.6 During construction and decommissioning, Hornsea Four will apply for a 500 m safety zone around infrastructure that is under construction, including at the Hornsea Four intertidal area. Safety zones of 50 m will be sought for incomplete structures at which construction activity may be temporarily paused (and therefore the 500 m safety zone has lapsed) such as installed monopiles without transition pieces or where construction works are completed but Hornsea Four has not yet been commissioned

4.8.7.7 During the operation and maintenance phase, Hornsea Four may apply for a 500 m safety zone around manned infrastructure (such as offshore accommodation platform) in order to ensure the safety of the individuals aboard. Hornsea Four may also apply for 500 m safety zones for infrastructure undergoing major maintenance (for example a blade replacement).

4.8.7.8 Further information regarding the Safety Zones which Hornsea Four intends to apply for post consent will be outlined in the Safety Zone Statement.

4.8.8 Ancillary operations

4.8.8.1 Several activities will be required to prepare the seabed prior to construction. These activities are detailed below.

Unexploded ordnance clearance

4.8.8.2 It is common to encounter UXO originating from World War I or World War II during construction. This poses a health and safety risk where it coincides with the planned location of infrastructure and associated vessel activity, and therefore it is necessary to survey for and carefully manage UXO. If UXOs are found, they are either avoided, removed or detonated in situ.

4.8.8.3 It is not possible at this time to define the number of UXO which may require detonation. As a result, a separate Marine Licence will be applied for pre-construction for the detonation (where required) of any UXO which may be identified in pre-construction surveys. To define a design scenario for consideration in the EIA a review of recent publicly available information on UXO disposal was undertaken, along with experience from Hornsea Project One. Hornsea Project One identified 23 large net explosive quantity (NEQ) items of UXO that required in-situ detonation and 30 incendiary units. These large NEQ items comprised 12 Allied 1000lb HE bombs, 2 German 500kg HE bombs and 9 Allied 500lb HE bombs.

4.8.8.4 Based on the recent report conducted by Ordtek for Hornsea Project Three, the number of UXO requiring inspection and detonation has been scaled for Hornsea Four. The numbers are scaled for the wind farm and ECC. It is assumed that one UXO will be cleared in any 24hr period:

- Estimates targets requiring inspection: 2263;
- Estimates for high order disposal (detonation): 86.

Boulder clearance

4.8.8.5 Geophysical surveys will be undertaken within the Hornsea Four array area and offshore export cable corridor and will be used to inform boulder clearance requirements.

4.8.8.6 Where large volumes of boulders are present, micrositing of cables around these would be onerous and impractical. If left in-situ, these boulders will pose the following risks to Hornsea Four:

- Exposure of cables and/or shallow buried cables, that might lead to the requirement for post-lay cable protection such as rock dumping or concrete mattressing;
- Obstruction risk to the cable installation equipment, leading to damage and/or multiple passes and therefore, a delayed cable installation programme (with no guarantee of achieving target burial depth); and
- Risk of damage to the cable assets.

4.8.8.7 Based on current industry experience within similar geological conditions, the following assumptions are made

- Boulders greater than 0.3 m in any dimension must be cleared;
- For cables within the Hornsea Four offshore export cable corridor, a corridor of up to 30m per cable (circuit) must be cleared to ensure that all the export cable burial tools being considered in the envelope can operate in the cleared corridors; and
- For cables within the Hornsea Four array area, a corridor of up to 30 m must be cleared per cable circuit as this width is sufficient for the operation of the array cable burial tools under consideration.

4.8.8.8 There are two key methods of clearing boulders, dredging or use of a subsea grab. Where a high density of boulders is seen, the expectation is that a plough will be required to clear the cable installation corridor. Where medium and low densities of boulders are seen, a subsea grab is expected to be employed.

4.8.8.9 As no geophysical/geotechnical information, of sufficient spatial resolution. is available at this point in time the worst-case scenario is used for PEIR is presented in **Table 4.28**. The acquisition of further geophysical and geotechnical data is not anticipated to conclude until the post-Consent and pre-Construction phase. At this point sandwave clearance volumes and boulder and UXO clearance numbers and assessment will be updated.

Table 4.28: Maximum design parameters for boulder clearance in the Hornsea Four.

Parameter	Maximum value
Hornsea Four array area	
Array cable clearance corridor width per cable (circuit) – SCAR RCS (m)	30
Export and interconnector cable clearance corridor width per cable (circuit) – SCAR RCS (m)	30
Clearance corridor width – subsea grab (m)	Size of individual boulders within 15 m corridor
Total seabed Potential Disturbed (Full Corridor Width) (km^2)	11.3
Total clearance impact area (km^2)	22.5
Offshore export cable corridor	
Clearance corridor width per cable (circuit) – SCAR RCS (m)	30
Clearance corridor width – subsea grab (m)	Size of individual boulders within 30 m corridor
Total seabed Potential Disturbed (Full Corridor Width) (km^2)	8.9
Total clearance impact area (km^2)	17.8

Pre-lay grapnel run

4.8.8.10 Following the pre-construction route survey and boulder clearance works, a Pre-Lay Grapnel Run (PLGR) and an associated route clearance survey of the final cable route will be undertaken. A vessel will be mobilised with a series of grapnels, chains, recovery winch and survey spread suitable for vessel positioning and data logging. Any items recorded will be recovered onto deck where possible and the results of this survey will be used to determine the need for any further clearance. The PLGR work will take account of and adhere to any archaeological protocols developed for Hornsea Four.

4.8.8.11 These works will be within the 30m footprint of seabed disturbance (sandwave and boulder clearance), within which is the 15m footprint for trenching in the Hornsea Four offshore export cable corridor and therefore any footprint for PLGR disturbance is already accounted for.

Sandwave clearance

4.8.8.12 In some areas within the Hornsea Four array area and along the Hornsea Four offshore export cable corridor existing sandwaves and similar bedforms may be required to be removed before cables are installed. This is done for two reasons. Firstly, many of the cable installation tools require a relatively flat seabed surface in order to work properly as it may not be possible to install the cable up or down a slope over a certain angle, nor where the installation tool is working on a camber. Secondly, the cable must be buried to a depth where it may be expected to stay buried for the duration of Hornsea Four's project lifetime. Sandwaves are generally mobile in nature therefore the cable must be buried beneath the level where natural sandwave movement would uncover it. Sometimes this can only be done by removing the mobile sediments before installation takes place.

4.8.8.13 Because surveys have not yet been undertaken for Hornsea Four at the point of PEIR, calculations performed on the adjacent Hornsea Two and Hornsea Three sites have been used to determine the maximum design parameters for sandwave clearance. The method used takes a bathymetric surface and performs a series of GIS operations on it to create a lowest seabed level. This is a surface which would theoretically indicate the level at which the seabed morphology would never uncover. This surface is then used as a reference for calculating depth of cable burial, which reduces the risk of the cable becoming exposed if sandwave migration occurs.

4.8.8.14 The result of the found maximum design parameters for sandwave clearance are shown in **Table 4.29**. Values will be updated upon the completion of pre-construction high-resolution geophysical surveys for inclusion in the Environmental Statement.

Table 4.29: Maximum design parameters for sandwave clearance for Hornsea Four.

Parameter	Maximum value
Hornsea Four array area	
Sandwave clearance impact width – array, interconnector and export cables (m)	30
Sand-wave clearance: Array cables (m^3)	769,000
Sand-wave clearance: Interconnector cables (m^3)	115,000
Sand-wave clearance: Export cable (Within Array Area Only) Total (m^3)	77,000
Sand-wave clearance: Total in array area (export cables, array cables, interconnector cables, foundations) (m^3)	961,000
Hornsea Four offshore export cable corridor	
Sandwave clearance impact width (m) per cable (circuit)	30
Sandwave clearance – total (m^3)	757,000

Wave buoys

4.8.8.15 Hornsea Four will require two wave buoys for the full construction period, one of which will be decommissioned following completion of construction, and the other retained for the first three years of operations. The exact mooring locations are currently undefined.

4.9 Landfall

4.9.1 Overview

4.9.1.1 The offshore export cables will make landfall north of Barmston. **Figure 4.13** presents the Hornsea Four intertidal area, and the onward Hornsea Four onshore cable corridor and all associated works areas. The works at the Hornsea Four intertidal area would primarily be the same irrespective of whether HVAC or HVDC transmission is selected. **Figure 4.13** presents two landfall compound options which have been assessed in the respective PEIR receptor chapters. A decision on the preferred landfall (A3 or A4) will be made post-PEIR and the Project Description and assessments updated for the ES and DCO for the preferred 200 x 200m compound within the landfall location.

4.9.1.2 Landfall works include:

- Construction of Landfall Compound (see A3 and A4 in **Figure 4.13**);
- HDD Works;
- Construction of Transition Joint Bays;
- Installation of Offshore High Voltage Cables;
- Installation of Onshore High Voltage (HV) Cables;
- Transition Jointing Offshore / Onshore Cables;
- Backfilling of Joint Bays; and,
- Reinstatement Works.

4.9.1.3 HDD Works may include offshore works:

- Excavation of HDD exit pit;
- Potential sheet piling of cofferdam;
- Pull-in of HDD duct from offshore towards to TJB (may conclude in opposite direction); and,
- Capping and burial of HDD duct end.

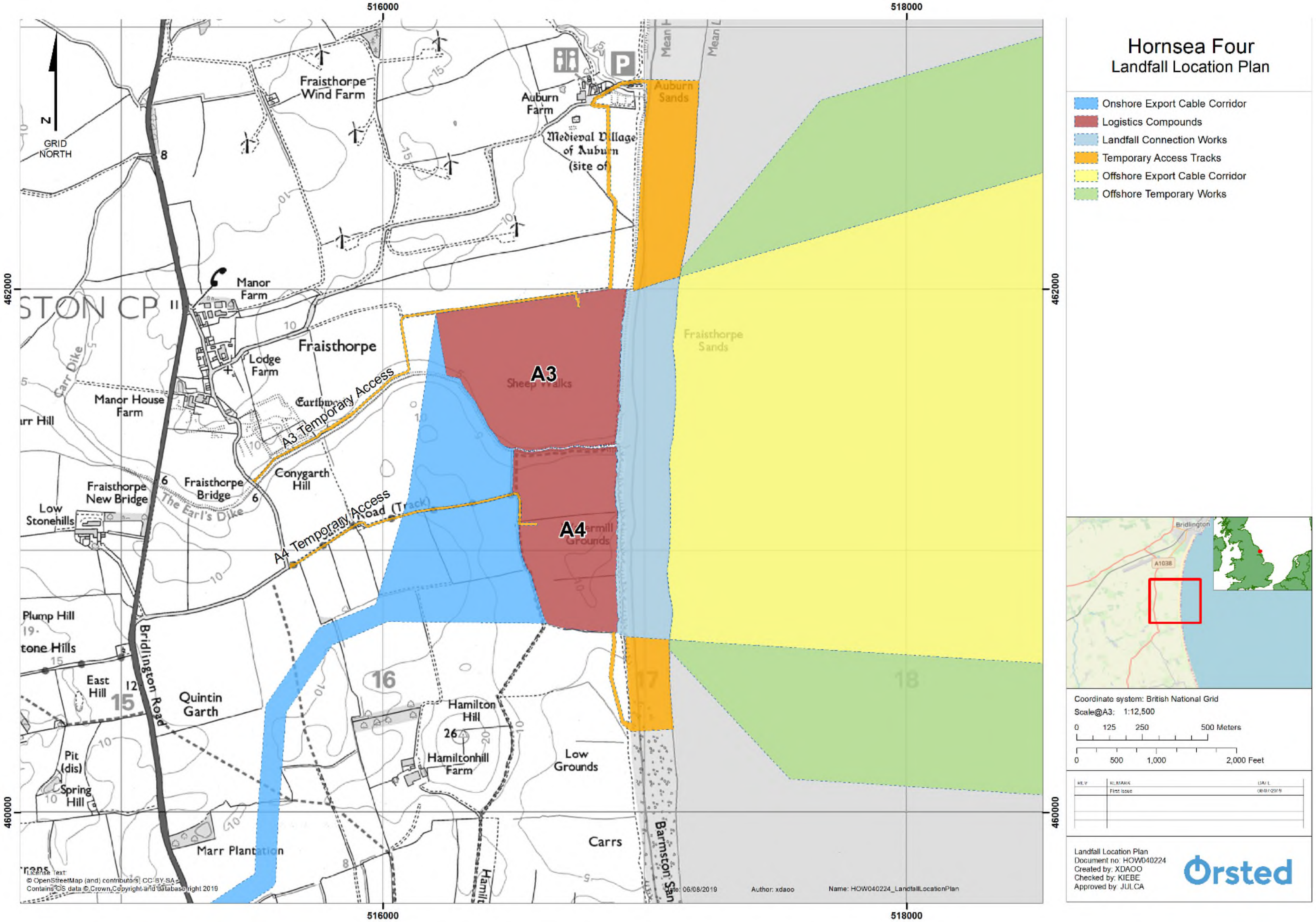

Figure 4.13: Hornsea Four Landfall Area. Two different options for the Export cable corridor through the landfall area (not to scale).

4.9.1.4 The offshore export cables are connected to the onshore export cables at the Transition Joint Bays (TJBs), located onshore. TJBs are pits dug and lined with concrete, in which the jointing of the offshore and onshore export cables takes place. One TJB is required per export cable circuit. They are constructed to ensure that the jointing can take place in a clean, dry environment, and to protect the joints once completed. Once the joint is completed the TJBs are covered and the land above reinstated. It is not expected that the TJBs will need to be accessed during the operation of Hornsea Four, however link boxes need to be located nearby that do require access during the operational phase, these will also be reinstated but may have manhole covers for access. In certain locations these may then be fenced to prevent damage.

4.9.1.5 The techniques used to carry out the landfall works broadly fall in to two categories; trenchless techniques (Horizontal Directional Drilling (HDD)) or open cut installation. It may be possible to carry out an HDD to beyond the Hornsea Four intertidal area and install the rest of the cable using an offshore installation spread. The technical feasibility of this approach will require confirmation via an intrusive geotechnical survey campaign, currently programmed to be complete in late summer 2019 (the findings will be reported in the Environmental Statement). However, it may also be the case that the HDD is not possible or preferred (due to ground conditions, cable design, or other factors), in which case open cut techniques would be required to install the cable from offshore to the TJBs; or a combination of these two methodologies may be preferred.

4.9.2 Construction

4.9.2.1 During intertidal works, a landfall logistics compound is required on the onshore side of the Hornsea Four intertidal area. The location of the landfall logistics compound will be located in the landfall area shown in **Figure 4.13**. This will house the TJB works as well as any HDD works required, including supporting equipment and facilities. The maximum design parameters for the TJBs and Hornsea Four intertidal area are presented in **Table 4.30**.

4.9.2.2 Durations for activities provided in **Table 4.30** demonstrate that certain activities forming part of the landfall HDD works have a significantly shorter duration than the overall construction window. However, the duration of works from start to finish must allow flexibility for these activities to shift within the overall timeframe to account for variables such as the timings of offshore and onshore works reaching landfall and weather, etc. In addition, the overall duration of works allows for mobilisation and demobilisation of equipment and vessels.

Table 4.30: Maximum design parameters for TJBs and landfall works.

Parameter	Maximum design parameters
Number of TJBs (allowing for 2 failures)	6 (8)
TJB depth (m)	6
Landfall logistics compound (m^2)	40,000
Duration of trenching works (per cable) if open cut (months)	1
Duration of works for each HDD (months)	4
Duration of works (start – finish) (months)	32 (8 x 4)

Trenchless techniques (HDD)

4.9.2.3 HDD involves drilling a long borehole underneath the Hornsea Four intertidal area using a drilling rig located in the TJB works area (**Figure 4.14**). The technique avoids interaction with surface features and is used to install ducts under the intertidal area and out to sea into which the offshore export cables can be installed. For HDD works, the site will be set up in the following way:

- Demarcation of the required compound will be made using security fencing.
- Topsoil will be removed and stored within the allocated compound areas.
- Stone and tarmac will be imported for final surfacing, followed by site setup works and Porta cabin deliveries.
- Existing access roads may be upgraded, or new access roads may be constructed into the landfall logistics compound.

4.9.2.4 As the drill is carried out between a start and end point, pits must be dug at both ends of the planned drill to below the level required for the cable, so the drilling rig can carry out the drill horizontally, and the ducts can be installed. Two pits would be required per duct, one on the landward side and one offshore. The HDD exit pits will be located up to 1,500 m from the TJB.

4.9.2.5 The process uses a drilling head controlled from the rig to drill a pilot hole along a predetermined profile to the exit point. This pilot hole is then widened using larger drilling heads until the hole is wide enough to fit the cable ducts. Drilling mud is pumped to the drilling head during the drilling process to stabilise the hole and ensure that it does not collapse.

4.9.2.6 An example of an HDD rig undertaking HDD for an export cable landfall can be seen in **Figure 4.15**.

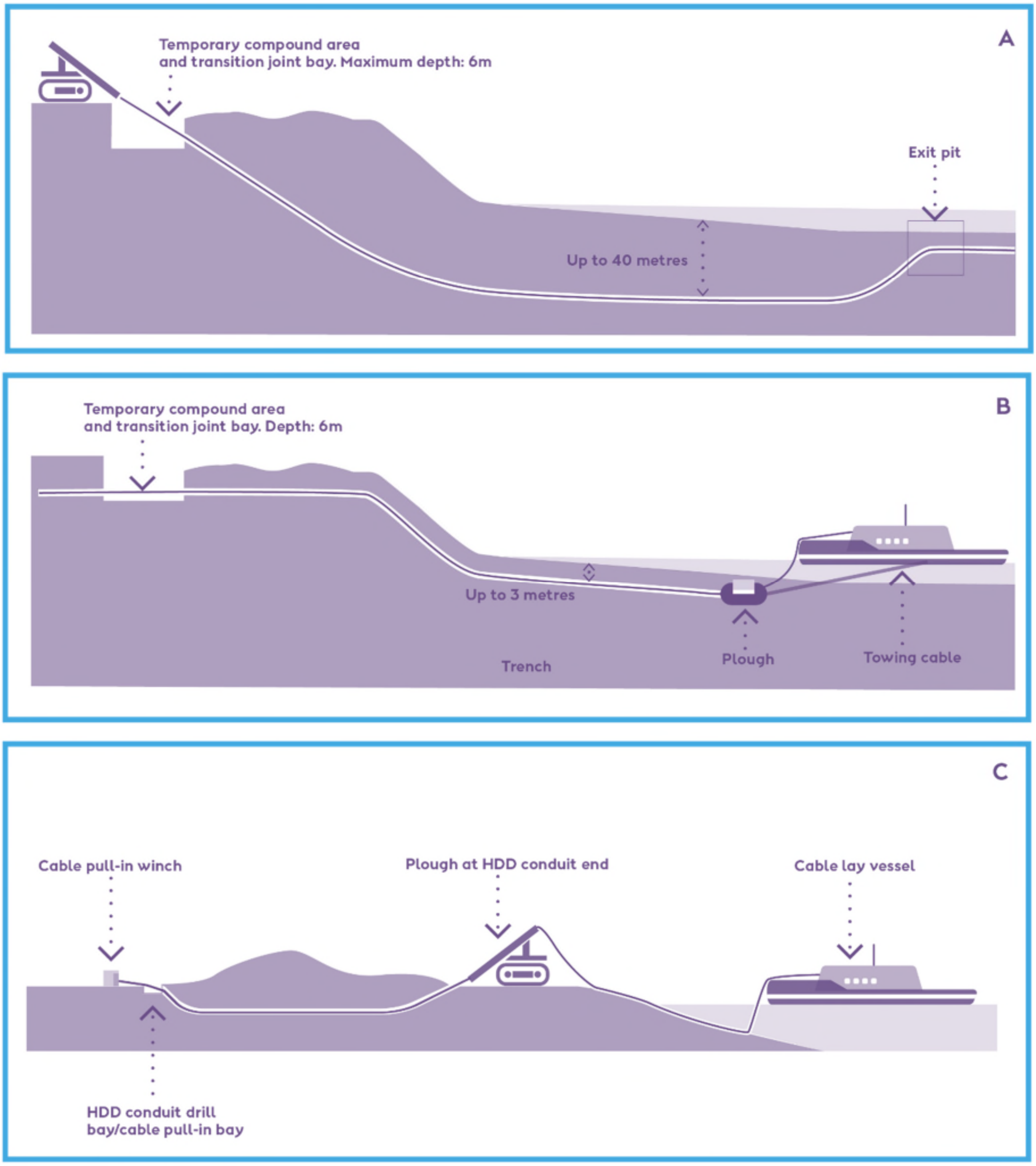

Figure 4.14: Indicative HDD and open cut arrangement (indicative only).

Figure 4.15: HDD rig carrying out landfall works at the Westermost Rough offshore wind farm

4.9.2.7 The HDD exit pit may be located above mean high water (MHW), within the Hornsea Four intertidal area (intertidal punch out) or below mean low water (MLW). Exit pits will be excavated or dredged to the required depth. Depending upon the final methodology and location of the exit pits, it may be necessary to consider dewatering (pumping dry) and water exclusion (e.g. cofferdams). Measures for management and containment of drilling slurry will need to be implemented at the exit pit, and these may comprise the use of a mud return line to recover and recycle fluid from the punch out location. The detailed landfall construction methodology will be defined once further site-specific surveys and feasibility studies have been conducted.

4.9.2.8 There will be up to four exit pits open at any given time. If the pits are dredged, they will be backfilled immediately following duct installation.

4.9.2.9 Once the drilling operation has taken place the ducts (within which the cables will be installed) are pulled through the drilled holes. These ducts are either constructed offsite, then sealed and floated to the site by tugs, or will be constructed within the landfall logistics compound and, if required within the Hornsea Four onshore export cable corridor, then pulled over the beach on rollers. The ducts are then pulled back through the drilled holes either by the HDD rig or by separate winches. When the offshore export cables are installed they are pulled through the pre-installed HDD ducts by winches in the TJB working area.

4.9.2.10 Once the ducts have been installed, the pits will likely be temporarily back filled until the time for cable pull-in. The ducts will then need to be re-exposed (dredged) for a period of up to two weeks (no coffer dams are necessary for this operation) to pull in the cables.

4.9.2.11 If material is removed by barge to a designated disposal site, before being recovered for backfilling, excavated material will need to be re-imported from the storage area. Some additional material (e.g. rocks) may be necessary to make up for any loss, or in case the onward plough cannot bury the cable within the exit pit.

4.9.2.12 The maximum duration for landfall works is 6 months, within a 32-month period. Wherever possible access will be maintained across the beach and public diversions established, however should open cut works be necessary, certain activities such as cable pulling, or excavations would require that parts of the beach or intertidal area are closed off to the public temporarily. Where PRoWs are required to be closed during the construction of the onshore connection works, they will not be closed for any longer than three months at any one time, or for six months in total over the whole construction period. Where closures are required for longer period, East Riding of Yorkshire Council will be informed in writing.

4.9.2.13 The maximum design parameters for HDD at the landfall are presented in Table 4.31.

Table 4.31: Maximum design parameters for landfall HDD.

Parameter	Maximum design parameters
HDD cable ducts	8
Diameter of ducts (m)	1
Length of ducts (km)	1.5
HDD entry pit area (m^2)	125
HDD entry pit depth (m)	6
HDD burial depth maximum (m) (along ECC)	40 (20)
HDD burial depth minimum (m)	5
HDD exit pits number	8
HDD exit pit area –HDD (m^2)	900
HDD exit pit excavated material volume (m^3)	2,500
HDD exit pits depth (m)	5

Parameter	Maximum design parameters
Temporary onshore/intertidal HDD exit pit working area (m^2)	1,600
HDD operational noise (dB)	120
Duration	6 months (1 month per circuit)

4.9.2.14 Overall, individual HDD operations may take up to four months per drill; an indicative program is described below:

- Maximum one-month site setup (including pit excavation);
- Two months pit fully open, drilling & duct pull-in happening; and
- Maximum one-month reinstatement (including backfill and cofferdam removal).

Open cut

4.9.2.15 Open cut installation would be carried out using one of several methods. Installation tools, such as ploughs, rock cutters or jetting tools, similar to those used offshore, can be pulled from the offshore installation vessel, or from winches within the TJB working area (within the landfall logistics compound), over a pre-laid cable to simultaneously open a trench, place the cable in the trench, and cover the cable. Alternatively, the trenching tool may open a trench in advance, the cable would be lowered into this trench and covered, after it has been pulled across the beach. These tools are usually pulled along the beach on skids or are tracked. All the installation techniques described for the offshore export cable installation are applicable to the landfall installation, excluding dredging. **Figure 4.16** shows an example of this type of installation tool.

Figure 4.16: Example of a cable plough pulled from an installation vessel. source: http://www.4coffshore.com/s/about/equipmentTypes.aspx).

4.9.2.16 A landfall logistics compound will be established up to one month before installation. This would include plant storage, consumable storage area including fuel, welfare facilities, parking, pulling winches, anchor points and TJB. In addition, whilst works are ongoing on the beach, a temporary closure or diversion may be required from MLW to the landfall logistics compound for operational, and health and safety reasons. This would be up to one month per cable.

4.9.2.17 Prior to the vessel arrival, rollers may be placed from the MLW to the plough grade in position, if a plough is used. Upon vessel arrival, the plough is landed and pulled back to the grade in position. Tugs may be required for anchor placement. This would take approximately two days. Rollers would be placed between the plough and the vessel. The offshore export cable would be pulled from the vessel, through the plough to the TJB in the duration of one day

4.9.2.18 Rollers would then be removed, and cable would be laid on the beach. Burial works would then commence, with excavators entering the beach and excavate a trench next to the cable, after which the cable would be lowered into the trench. Mattresses (or similar) may be placed over the cable. The trench is then reinstated followed by the removal of the landfall logistics compound.

4.9.2.19 The maximum design parameters for open cut installation at the Hornsea Four intertidal area are presented in Table 4.32.

Table 4.32: Maximum design parameters for open cut installation.

Parameter	Maximum design parameters
Landfall logistics compound (m^2)	15,000
Distance between circuits (m)	30
Burial depth (m)	1 to 3
Intertidal burial progress rates (m/day)	100
Corridor width per circuit (m)	15
Potential disturbance corridor from plant movements, excavation, etc (m, per cable)	60m

Other methods

4.9.2.20 Alternatively, self-powered bespoke installation tools may be used. These are usually tracked vehicles, that excavate a trench, lay the cable, and then bury the cable simultaneously. Alternatively, they may excavate a trench in advance, then post lay the cable after the pull to the TJB. They are similar to the tools described above but are self-powered vehicles that are either controlled from on board the vehicles themselves or are Remotely Operated Vehicle (ROV) type systems, controlled from and connected to the offshore installation vessel.

4.9.2.21 Traditional mechanical excavators, like those that would be used to dig TJBs and exit pits etc., can also be used for cable installation. In this process, the offshore export cable would be pulled from the offshore installation vessel through the Hornsea Four intertidal area on rollers placed on the ground. The cable would then be moved from the rollers into a neighbouring trench usually excavated before the cable is laid across the beach.

4.10 Onshore Infrastructure Construction

4.10.1 Onshore export cables

4.10.1.1 The Hornsea Four onshore export cable corridor consists of an 80 m onshore temporary easement (although a wider corridor of 120m is provided for at the crossing of the National Rail Network at Beswick), within which a 60 m permanent easement post installation is located. An overview of the Hornsea Four onshore export cable corridor is presented in Figure 4.17.

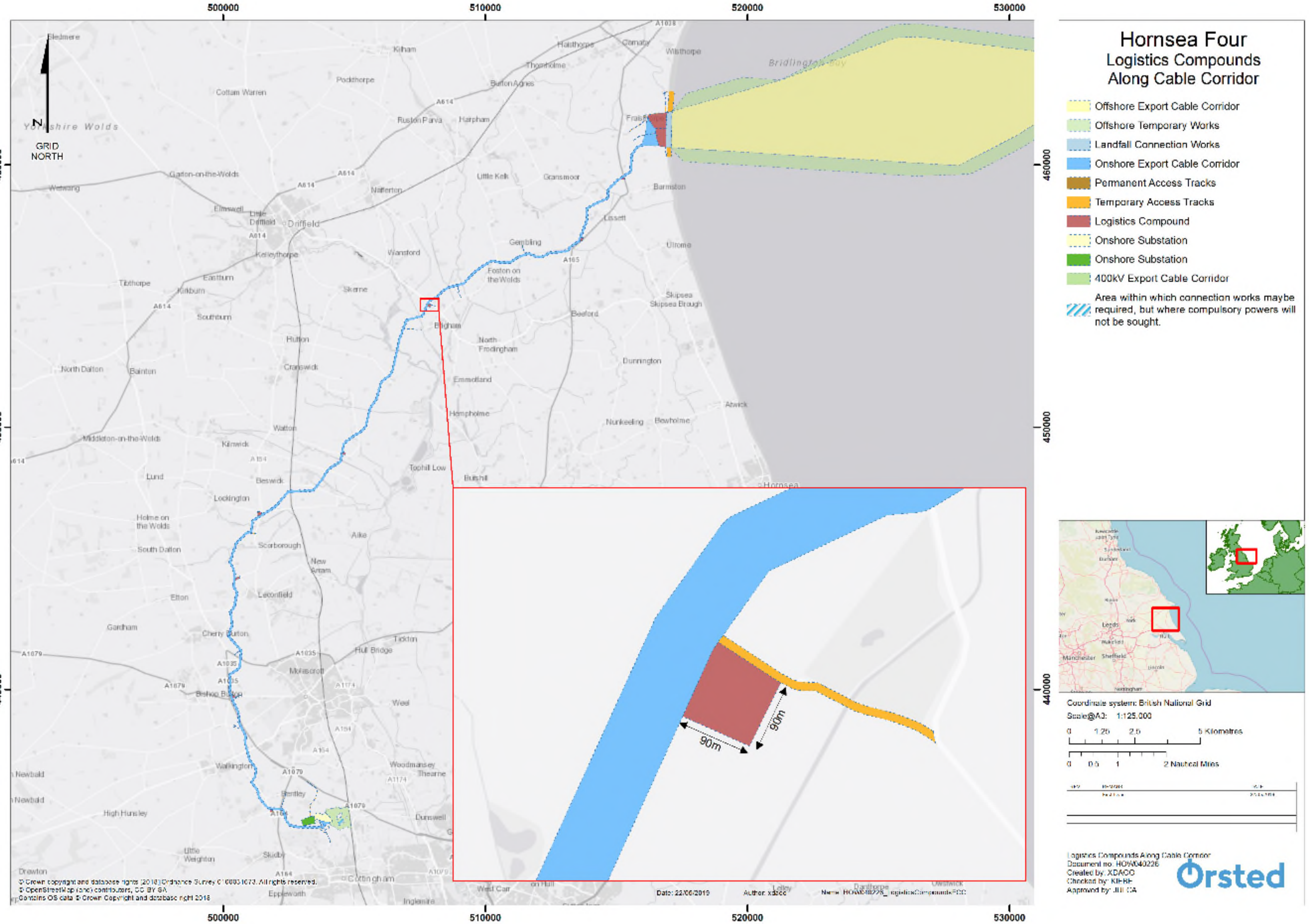

Figure 4.17: Hornsea Four onshore cable corridor and access and compound locations (not to scale).

Components of the onshore export cable corridor

Onshore export cables

4.10.1.2 **Table 4.33** shows the maximum design scenario for the onshore export cables. Small fibre optic cables may also be buried alongside the onshore export cables in order to allow for communication to the wind farm for the various control systems in place for the project.

Table 4.33: Maximum design parameters for onshore export cables.

Parameter	Maximum design parameters
HVAC - number of cable circuits	6
HVAC - number of cables	18
HVDC – number of circuits	3
HVDC – number of cables	6
Approximate Hornsea Four onshore cable corridor length (km)	40
HVDC cable - Voltage (kV)	600
HVDC cable – Current using 300kV cable (kA)	2.59
HVAC cable – Voltage (kV)	400
HVAC cable – current using 220kV cable (kA)	1.62
Diameter of cable (mm)	320
Diameter of duct (mm)	480

4.10.1.3 The cables will be installed within the Hornsea Four onshore export cable corridor, with an expected width of 80 m (this includes both the permanent installation area and temporary working area). The layout for the Hornsea Four onshore export cable corridor can be seen in **Figure 4.18**. The width of the permanent and/or temporary areas may change where obstacles are encountered, such as the crossing of the National Rail Network at Beswick where the ECC has been extended to 120m to facilitate HDD of the railway line.

4.10.1.4 Network Rail places stringent conditions upon any party seeking to cross their assets in order to ensure the safety and operability of the rail network. A standard restriction is on the level of subsidence or heave which can be tolerated as a deflection of the rails. HDDs inherently, due to the drilling, reaming, duct pulling operations as well as the pressure of the drilling fluid itself, have the potential to result in some small change in ground level directly above. The exact value of this will depend upon site specific factors such as the geometry of the railway embankment, ground conditions, the number of drills, drill depth, the size of the duct diameter, the spacing of the drill shots, the required pressure of the drilling fluid.

4.10.1.5 The project considers that 120m would provide sufficient design flexibility. This is based on experience from similar operations on previous projects. The exact design, spacing & configuration of this and all HDDs will be defined in the detailed design phase, once a contractor is appointed and crossing methodologies are agreed with affected third parties.

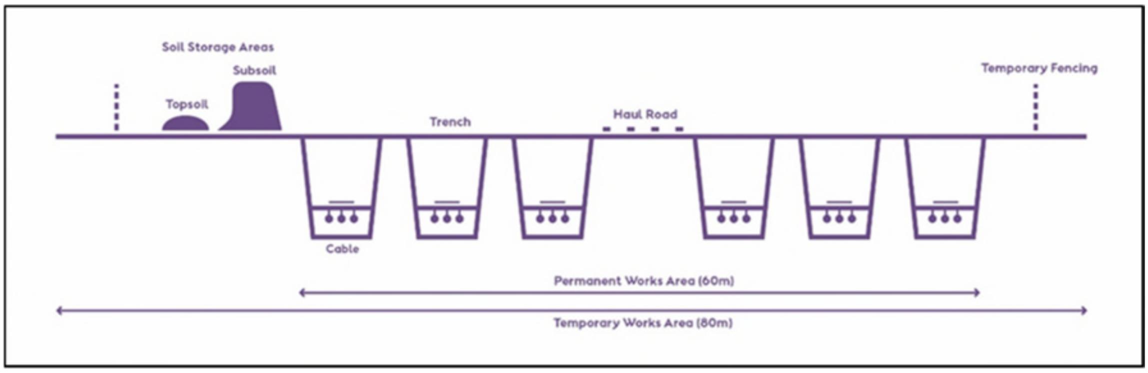

Figure 4.18: Onshore export cable corridor indicative layout showing the maximum of 6 onshore circuits (indicative only).

4.10.1.6 The cables will be buried in multiple separate trenches (up to six trenches, each containing one circuit), however in some circumstances some trenches may be combined to aid installation. The total combined numbers and volumes will not exceed those stated in Table 4.33. The onshore export cables will typically be installed in sections of between 750 and 3,000m at a time.

4.10.1.7 The installation of the onshore export cable is a linear construction project with an expected overall construction duration of up to 30 months in total. The construction works associated with the installation of the export cables encompasses a number or discrete activities undertaken along the length of the cable route, the duration of each activity at any location being dependent on the nature of the construction activity being undertaken.

4.10.1.8 These discrete construction activities can be broadly described as preliminary right of way works, HDD works, cable trenching, installation and jointing works and re-instatement works. The preliminary works aim to secure and prepare the cable route corridor for the main construction activities to follow and generally consist of fencing, vegetation clearance, preparation of access routes, drainage works, top soil removal and storage and construction of the haul road. Such preliminary work activities would move progressively through the full cable route, allowing full access to the cable route for the main construction activities to follow.

4.10.1.9 The main construction activities of HDD work, cable trenching, installation and jointing would move progressively along the corridor, optimal progress being dependent on the availability of resources, weather conditions or other engineering challenges which may arise during the works. To allow for the maximum flexibility in completing the works in a safe and efficient manner, the main activities are completed sequentially at any location prior to the next activity commencing. As such, works at any location would be intermittent, the duration being determined by the nature of the activity, until all the main construction works are completed, and all cables are installed jointed and successfully tested.

4.10.1.10 On completion of the main activities, the corridor would be prepared to be reinstated to be handed back to the landowner. Such activities would include the removal of the haul road, installation of further drainage, reinstatement of topsoil and removal of fencing and temporary access arrangements. Such reinstatement works are very much weather dependent, the works being carried out in favorable weather conditions.

4.10.1.11 As such, whilst the completion of the overall cable installation works can be expected to take up to 30 months in total, discrete works at any location would be take a considerably shorter period as would be expected of a linear project. However, to complete the works in the most time efficient and optimal manner, the entirely of the cable route corridor would be expected to be available for most of the 30 months, from the initial preparation of the route to the final reinstatement at the completion of the works.

4.10.1.12

Joint bays and link boxes

4.10.1.13 JBs will be required along the Hornsea Four onshore export cable corridor, these are typically concrete lined pits, that provide a clean and dry environment for jointing the sections of cable together. These are similar to the TJBs described in **Section 4.9.1.4**, but are typically smaller. As with the TJBs, these will likely be completely buried, with the land above reinstated. The maximum design parameters for JBs are presented in **Table 4.34**. JBs will only require access in the event of a cable failure requiring replacement.

4.10.1.14 Link boxes (LBs) will also be required along the Hornsea Four onshore export cable corridor. These are smaller pits, compared to JBs, which house connections between the cable shielding, joints for fibre optic cables and other auxiliary equipment. Land above the link boxes will also be reinstated, however, they may need manhole covers for access during the operational phase. The maximum design parameters for LBs are presented in **Table 4.34**

Table 4.34: Maximum design parameters for joint bays (JBs).

Parameter	Maximum design parameters	
	Joint bays	Link boxes
Number of JBs	240	240
Max distance between JB/LB (on one circuit) (m)	3000	3000
Min distance between JB/LB (on one circuit) (m) (most likely)	750 (1,000)	750 (1,000)
Width (m)	9	3
Length (m)	25	3
Area (m^2)	225	9
Depth (m)	2.5	2.0
Total area (m^2)	39,150	1,566
Spoil volume per JB/LB (m^3)	563	18
Total excavated volume (m^3)	135,000	3,132

Access points

4.10.1.15 A total of 31 access points will be required from the public highway to access construction works and logistics compounds for Hornsea Four (see **Figure 4.19**). Temporary access points off the highway will be installed to facilitate vehicular access from the road, and into to the Hornsea Four onshore export cable corridor during construction.

4.10.1.16 Access points will be required from the start of construction for all access points identified (see **Figure 4.19**). Temporary access points have been assessed for the effect on the road network in **Volume 3, Chapter 7: Traffic and Transport**. Detailed design of roadworks has not been fully developed and assessed at the point of PEIR. **Figure 4.19** presents the access potentially requiring detailed road junction works and traffic management arrangements in relation to the public highway. The insets labelled "archive temporary accesses" have assessed at PEIR and the inset "latest temporary accesses" have been updated to illustrate the potential locations of road works and arrangements. The nature and extent of these will be determined in consultation with ERYC and Highways England.

4.10.1.17 Further details on access will be documented in the Traffic Management Plan section of the Outline Code of Construction Practice (**Volume F2, Chapter 2: Outline Code of Construction Practice (Including Outline Construction Traffic and Travel Plan)**).

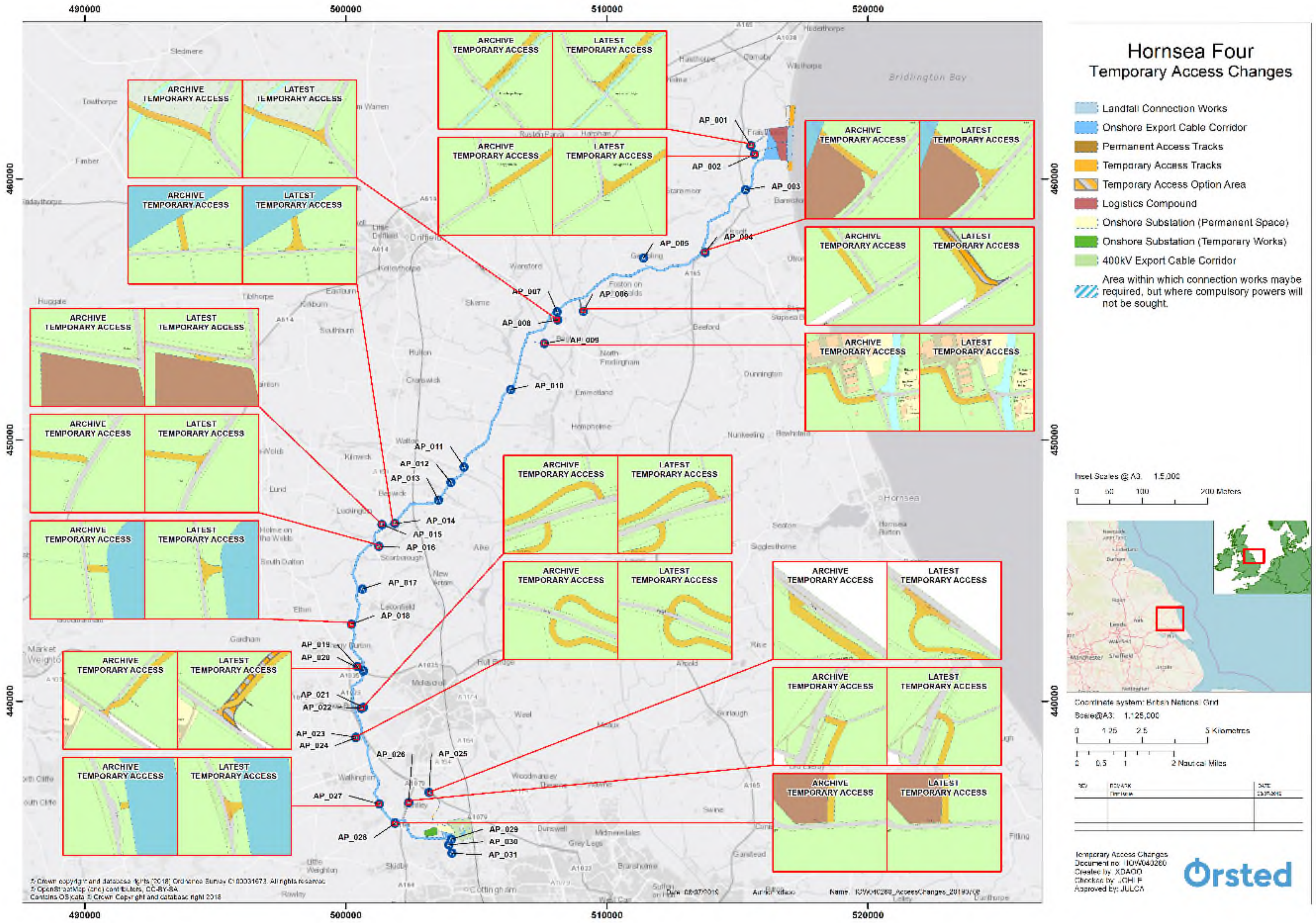

Figure 4.19: Location of potential road junction works and traffic management arrangements (not to scale).

Haul road

4.10.1.18 To provide access to the Hornsea Four onshore export cable corridor and limit damage to the agricultural land, the haul road will be installed in its entirety as part of the preconstruction cable works at the start of construction. The haul road, typically 6 m wide (**Table 4.35**) will extend the full length of the Hornsea Four onshore export cable corridor (except at gaps where Hornsea Four has committed to HDD only). The haul road provides vehicular access along the Hornsea Four onshore export cable corridor off the public highway and will be used where needed throughout the installation of the export cable and for the duration of construction activities.

4.10.1.19 In general the haul road would remain for the duration of the works, only being removed prior to final reinstatement. Where it is applicable, Hornsea Four may be able to remove sections of haul road that are not subject to further expected traffic prior to the completion of the construction works. However, it would not be possible to indicate where and when such haul road removal could be undertaken at this stage of project development.

4.10.1.20 Consideration has also been given to utilising existing access tracks, where possible. In these cases, the width of the access road may be narrower as there is no requirement to store topsoil. The route and design of these access roads where they are located outside the 80 m working width of the cable corridor are shown on the Works Plans (see **Volume 1, Annexes 4.1 and 4.2**).

4.10.1.21 One haul road will be required and will run along the export cable route, in parallel to the onshore export cables. Where there are obstacles that must be crossed by the haul roads, such as drainage ditches, temporary culverts or bridges may be installed

4.10.1.22 The haul road will be utilised during installation and will be made up of a maximum of 1m (average 0.5m) of crushed aggregate with a geotextile or other type of protective matting; or plastic or metal plates or grating. The exact specification of the road will be determined upon appointment of a principal contractor.

Table 4.35: Maximum design parameters for onshore cable access and haul roads.

Parameter	Maximum design parameters
Haul road width (m)	10 (includes hard standing, soil storage and fencing)
Haul road hardstanding width (at passing places) (m)	6 (7)
Maximum depth of haul road (m)	1.0
Average aggregate depth of haul road (m)	0.5
Roadway construction	Crushed aggregate on geo-textile, soil stabilisation or temporary trackway.

Parameter	Maximum design parameters
Temporary culvert/bridge crossings length (m)	10
Temporary culvert/bridge crossings width (m)	6

Temporary logistics compounds

4.10.1.23 Logistics compounds of various sizes will also be required along the Hornsea Four onshore export cable corridor, for laydown and storage of materials, plant and staff, as well as space for small temporary offices, welfare facilities, security and parking. Logistics compounds will also be required for crossings of other infrastructure to house operations such as drilling works. They will also be required around JB and LB construction. All logistics compounds will be removed, and sites restored to their original condition when construction has been completed, however it may be necessary to retain some compounds for slightly longer periods during the commissioning stages of Hornsea Four. The maximum design parameters for logistics compounds are presented in **Table 4.36**.

4.10.1.24 The hierarchy of logistics compounds are summarised below:

- All logistics compounds will be required to support the construction of the onshore export cables. A logistics compound would be built as a focal hub for the Contractor, sub-contractors and the client for the duration of the works and would be constructed before the cable route works commence at any location and would remain for the duration of the project. It may be necessary to retain part of the compound during the commissioning stages of Hornsea Four. The logistics compounds will be in place for period of up to 36 months and would include, but not limited to;
    - Office accommodation, including all desks, seating, office storage, welfare etc. to accommodate all staff (60+);
    - Meeting Rooms ;
    - All relevant utility services, power, water, heating, lighting telecommunications, internet and Wi-Fi connections ;
    - Printing, scanning and copying facilities;
    - Car parking for all project staff ;
    - Canteen facilities ;
    - Drying, storage and changing facilities for Personal Protective Equipment;
    - Material storage;
    - Waste storage;
    - Cable drums;
    - Security fencing; and
    - Security.
- Logistics compounds may also operate as support bases for the onshore construction works as the cable work fronts pass through an area. They may house portable

offices, welfare facilities, localised stores, as well as acting as staging posts for localised secure storage for equipment and component deliveries.

- Storage locations would also be required along the Hornsea Four onshore export cable corridor. These would operate as areas where some limited additional storage may be provided in addition to that land provided for along the onshore export cable corridor.

Table 4.36: Maximum design parameters for logistics compounds.

Parameter	Maximum design parameters
Primary logistics compound (length and width) (m) x 1	Maximum required: 140 x 140
Secondary logistics compound (length and width) (m) x 7	Maximum required: 100 x 100
Total number of logistics compounds	8
Logistics compound use (duration per compound) (months)	36
Total number of HDD locations	112 (93 actual locations and 20% contingency)
Total number of HDD compounds	224 (entry and exit at112 locations)
HDD compounds (length and width) (m)	70 x 70
HDD compound construction duration per compound (month)	1
Total number of JBs	240
JB Compounds dimensions (length and width) (m)	40 x 40 a
JB compound construction duration per compound (months)	1

Installation of the onshore export cables

Demarcation of the cable easement

4.10.1.25 Fencing will be installed along the entire export cable route to define the Hornsea Four onshore export cable corridor and works areas. The type of fencing to be used will be dependent on the land use where the easement crosses it. Discrete work areas will be fended off as required. Further details on fencing are documented in the Outline Code of Construction Practice (**Volume 2, Chapter 2**). Fencing will be installed as part of the pre-construction activities and would typically consist of:

- Post and rope for arable land;
- Post and rail for horse fields; and
- Post mesh and wire/barb for cattle and sheep.

Cable installation

4.10.1.26 During construction of the cable trenches the topsoil will be stripped and subsoil excavated. Both will be stored on site within the temporary working corridor as construction of each section of the Hornsea Four onshore export cable corridor advances. The topsoil and subsoil will be stored in separate stockpiles. Once the topsoil is stripped any required temporary haul roads will also be installed along the Hornsea Four export cable corridor to allow trench excavation to take place. Topsoil will only be stored in bunds along the cable corridor adjacent to where it is removed. .

4.10.1.27 The trenches will be excavated using a mechanical excavator, and the export cables will be installed into the open trench from a cable drum delivered to site via Heavy Goods Vehicle (HGV). The cables are buried in a layer of imported backfill material that ensures a consistent structural and thermal environment for the cables. The maximum volumes of imported stabilised backfill material (i.e. that not originating from the excavated trench) are presented in **Table 4.37**. However, this value is considered to be a maximum and will not be required at most locations along the export cable route. All excavated material from the trenches will remain on site, unless deemed unsuitable for re-use.

4.10.1.28 The remainder of the trench is then backfilled with the excavated material. Hard protective tiles or protective tape and marker tape are also installed in the cable trenches above the cables to ensure the cable is not damaged by any third party. Once the onshore export cables are installed and the trenches backfilled, the stored topsoil will be replaced and the land reinstated back to its previous use..

4.10.1.29 Alternatively, ducts can be installed in the trenches in the same manner as above, and the cables can then be pulled through the ducts from the JBs. This technique decouples the trenching from the cable installation and therefore can provide more flexibility for the installation process to optimise works and delivery of components..

4.10.1.30 The dimensions of the export cable trenches are presented in **Table 4.37**. The electrical cables must be spaced out in order to minimise the mutual heating effect of one cable on another, this enables the cables to effectively carry the large power volumes required without overheating and damaging the cable.

Table 4.37: Maximum design parameters for onshore export cable installation.

Parameter	Maximum design parameters
Trench width: at base (m)	1.5
Trench width: at surface (m)	5
Corridor width: permanent easement (m)	60
Corridor width: temporary and permanent (m)	80

Parameter	Maximum design parameters
Corridor area – permanent (m^2)	2,340,000
Corridor area – temporary and permanent (m^2)	3,120,000
Burial depth: target (m)	1.2 a
Trench: depth of stabilised backfill (m) b	1.5
Total Installation duration (months)	30

a The target depth will be 1.2m but in some areas it will be deeper dependent on the specific area for burial

b The average depth of imported backfill will be 0.6 m, with the depth going to 1.5 m in limited locations.

4.10.1.31 The onshore export cables will need to cross infrastructure and obstacles such as roads, railways and rivers. All natural watercourses including main rivers and ordinary watercourses (not artificial drainage ditches, flood defences), main roads and railways will be crossed by HDD or other trenchless technology where technically practical (see Commitment 1, **Volume 4, Annex 5.2: Commitments Register**). The HDD methodology would be as per that described for the landfall in **Section 4.9.2**.

4.10.1.32 It may be preferable, for commercial, technical, environmental reasons or a combination of all three, for certain crossings to be carried out as an open cut crossing, rather than a trenchless method. This requirement will be determined in consultation with the relevant stakeholders and/or asset owners (for details of asset owners please see **Volume 4; Annex 4.2 Onshore Crossing Schedule)**. These crossings could range from smaller drains, gas and power distribution infrastructure and small roads, to high pressure gas pipelines. For some sensitive infrastructure, such as high-pressure gas pipelines the area around the pipeline must be carefully excavated by hand and the asset supported before installation of the cables below the pipelines can take place. This is preferred by some asset owners as visual confirmation of the integrity of the asset can be maintained throughout the works. All crossings are assumed to be HDD/trenchless (which are the same) for the purpose of assessment.

4.10.1.33 The detailed methodology for all crossings will be agreed with the relevant stakeholders such as third-party asset owners, and other statutory stakeholders. Hornsea Four have prepared an Onshore Crossing Schedule which documents the techniques that will be deployed at crossing points of watercourses (see **Volume 4; Annex 4.2**).

4.10.2 Hornsea Four Onshore Substation

4.10.2.1 Hornsea Four will connect to Creyke Beck National Grid 400kV Substation, which is located near Cottingham, Humberside. See inset of **Figure 4.2**. The proposed permanent development area for the onshore substation is located North of Cottingham with the nearest Southeast corner approximately 175m west of the National Grid Energy Transmission (NGET) 400kV substation at Creyke Beck. The site is an irregular shape, following natural field boundaries.

4.10.2.2 For the project description, the maximum expected design parameters have been used for both transmission options, so references to the onshore substation encompass both options, unless otherwise stated.

4.10.2.3 As with the two transmission options mentioned in the introduction above, there are other variables which may affect the Hornsea Four capacity and the technology used. The indicative site layouts and figures included in this chapter are based on an onshore substation with two EBI Plants. The final design would be optimised to mitigate spatial, visual and noise impact and any unused land would be released back to the landowners.

Onshore Substation design

4.10.2.4 The onshore substation comprises a compound containing the electrical components for transforming the power supplied from Hornsea Four to 400 kV and to adjust the power quality and power factor, as required to meet the UK Grid Code for supply to the National Grid. If a HVDC system is used it will also house equipment to convert the power from HVDC to HVAC.

4.10.2.5 The onshore substation will consist of a range of equipment for delivery of the power to National Grid. Equipment such as transformers, shunt reactors, dynamic reactive power compensation plant, harmonic filters and various switchgear. It will also include a range of auxiliary and supporting equipment for the running and control of the onshore substation. The main equipment will either be housed within a single or multiple building(s), in an open yard or a combination of the above. If multiple buildings are used the length and width of these buildings would be reduced proportionally to the number of buildings (e.g. if two buildings were used, they would each cover half of the area required for the single larger building). There may also be some smaller buildings required to house components such as smaller equipment and control rooms.

4.10.2.6 The red line boundary (i.e. that area required for development) is similar for both a HVAC and HVDC Onshore Substation. An indicative layout has been created for the HVAC option (see **Figure 4.20**) and for the HVDC option (see **Figure 4.21**) below. The final layout may deviate from the indicative layout, but subject to the maximum design parameters. The maximum design parameters for the onshore substation for both HVAC and HVDC options are presented in **Table 4.38**. **Volume 4, Annex 4.6: Outline Design Vision Statement** provides a summary of the design aspirations for the onshore substation.

Table 4.38: Maximum design parameters for the Onshore Substation

Parameter	Maximum design parameters
Permanent area of site for all infrastructure (m^2)	155,000
Temporary works area (m^2)	130,000
Maximum main building height (m)	25
Height of fire walls (m)	25
Main building - lightning protection height (m)	30
Viewing platform height [for construction] (m)	30
Duration of construction (months)	36
Maximum number of main buildings	2
Maximum length of main building (m) (if single building / if multiple buildings)	240 / if multiple buildings then proportionately smaller
Maximum width of main building (m) (if single building / if multiple buildings)	80 / if multiple buildings then proportionately smaller
Maximum number of secondary buildings	15
Maximum height of secondary buildings (m)	15
Maximum area of secondary buildings (m^2)	7,000
Maximum number of HV equipment clusters and components	45
Maximum height of HV equipment clusters and components (m) (can be either open or closed design)	15

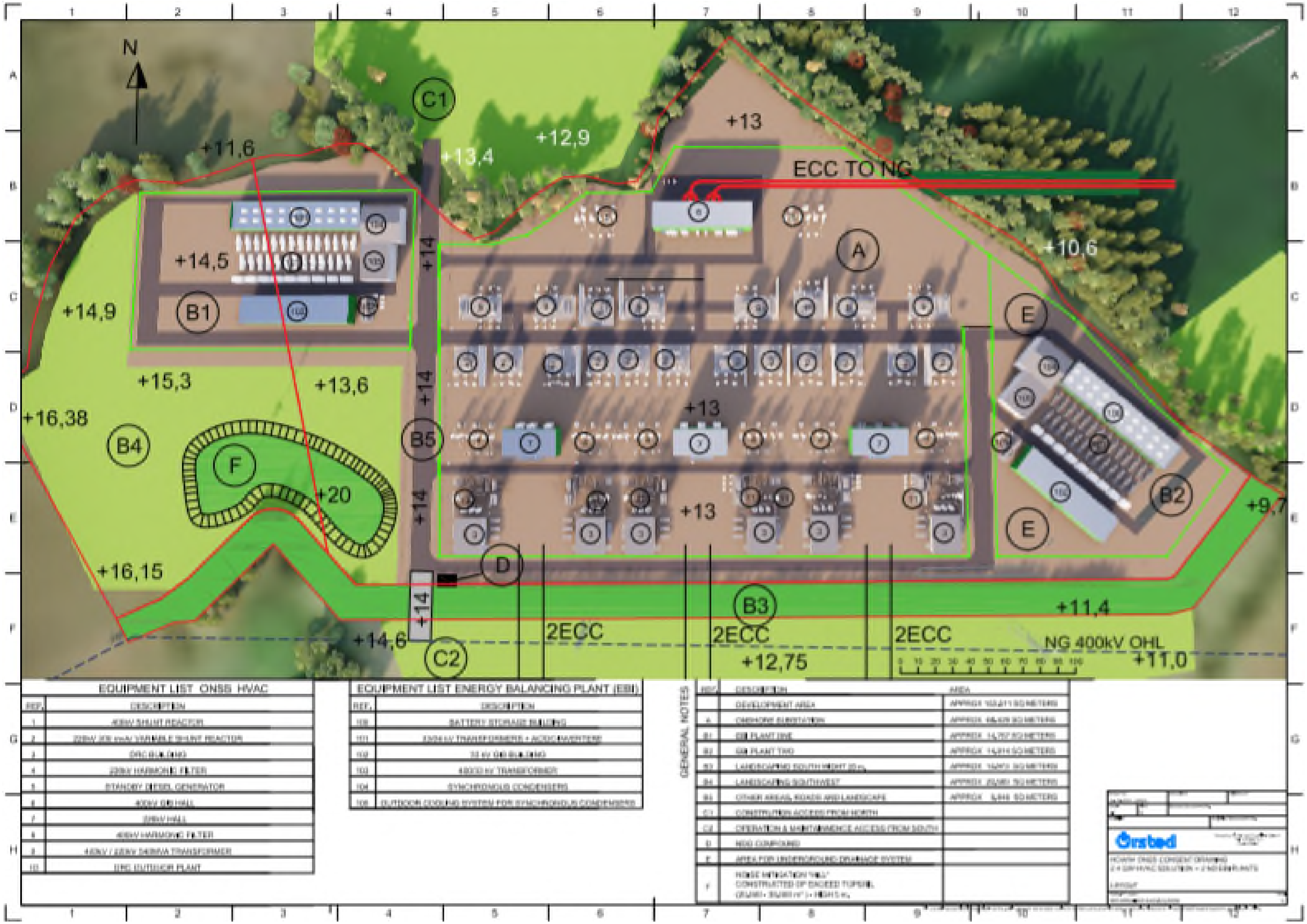

Figure 4.20: Indicative Onshore HVAC Substation layout (A). With the Energy Balancing Infrastructure(s) placed to the North-West (B1) and to the East (B2) on the figure (not to scale).

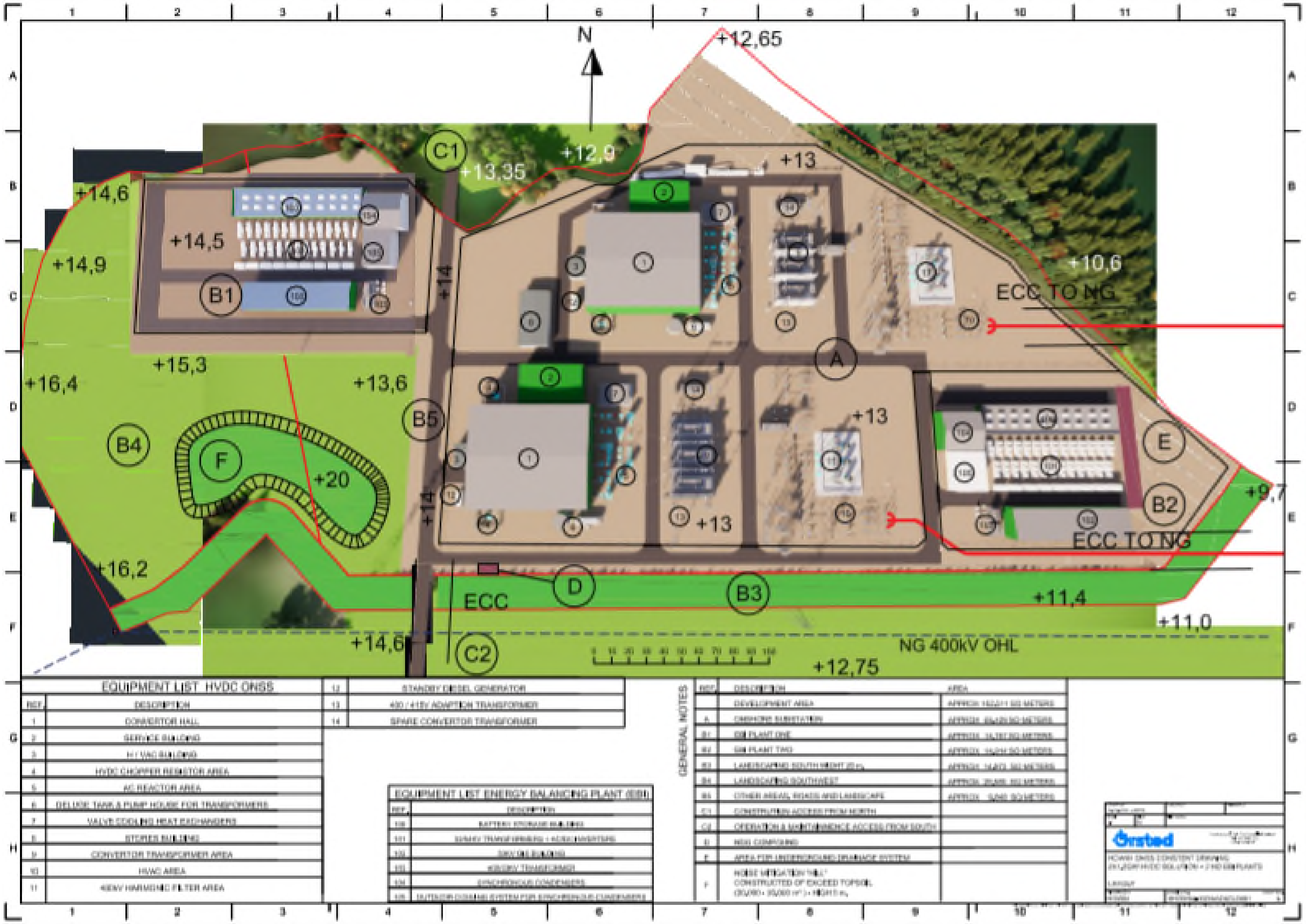

Figure 4.21: Indicative Onshore HVDC converter substation layout (A). With the Energy Balancing Infrastructure(s) placed to the North-West (B1) and to the East (B2) in the figure (not to scale).

Access

4.10.2.7 There will be temporary and permanent access to the onshore substation (see areas coloured yellow in **Figure 4.22**):

- Temporary construction access will come from the northbound carriageway of the A1079. From this new junction a temporary two-way road system to and from the site would need to be constructed, allowing construction traffic to pass in both directions. Depending on agreements with Landowners, the length of this temporary access road will be a minimum of 1.6km, and 15m wide (maximum), comprising 7m hard standing (12,800m^2) and 8m for topsoil storage and fencing (11,200m^2).
- Permanent Operation and Maintenance access shall be taken from the south, using Park Lane Road, or from the North, making the construction access road from the A1079 permanent.

4.10.2.8 The construction of the access road to the onshore substation will involve a topsoil strip, removing ~300mm topsoil from access road (4000m^3 bulk excavation). A geotextile separation membrane and geogrid will then be placed on a clay formation layer prior to the import and installation of 300mm free draining material (4,000m^3). The road will be tarmac finished to a depth of100mm (1,280m^3).

4.10.2.9 Hornsea Four are currently investigating the possibility of making the temporary construction access of the A1079 a permanent operational access. If the construction access road is not made permanent for operational access, then the road will be removed upon completion of the construction phase, in the reverse order as outlined above.

4.10.2.10 Hornsea Four are also exploring the possibility of taking limited construction access of Park Lane Road, to facilitate HDD works from the ECC to the OnSS. The requirement shall be determined via consideration of detailed design informed by engineering constraints and consulted upon with the relevant local stakeholders. Should both these options be taken forward to DCO, the assessments will be updated in the ES.

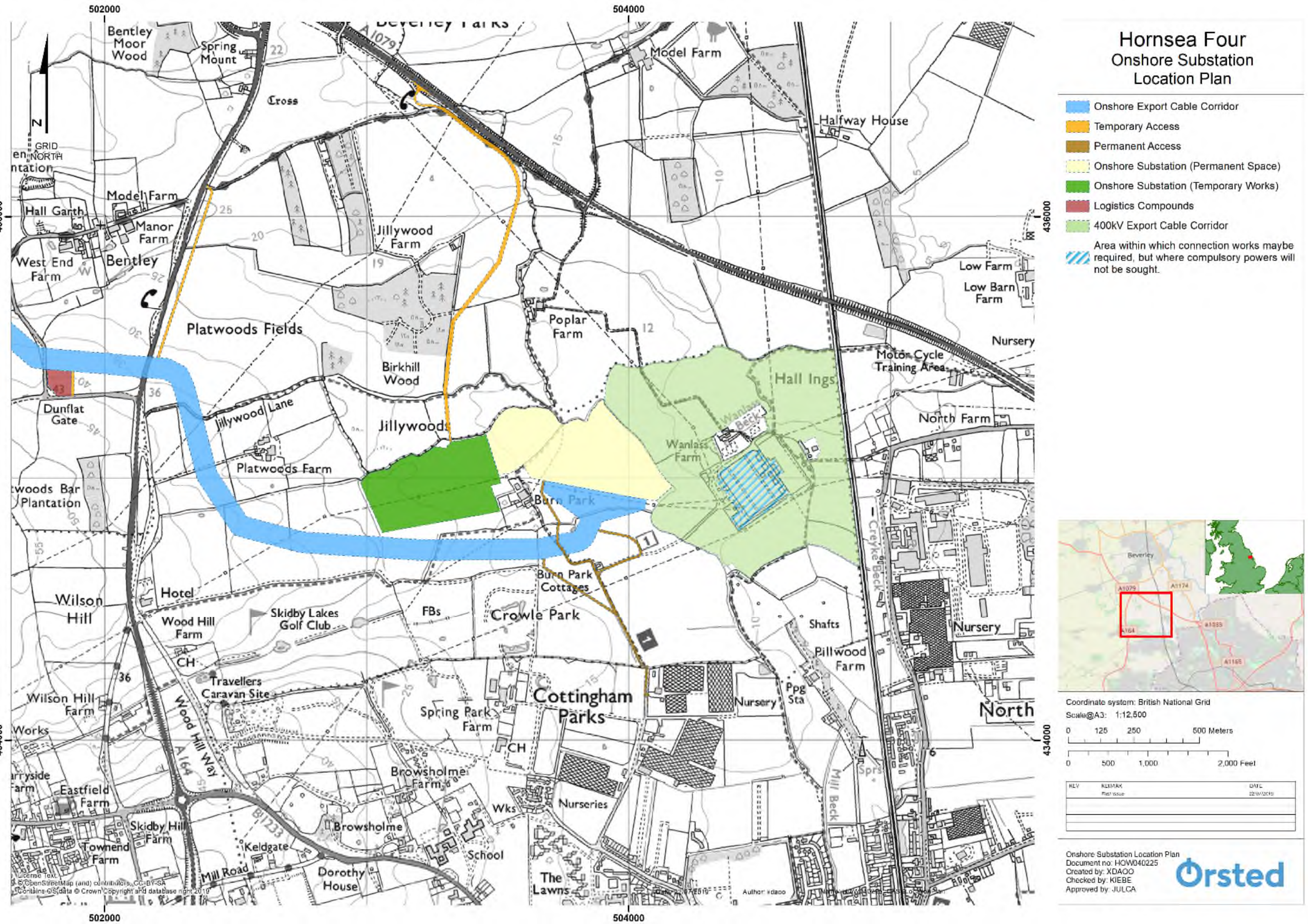

Figure 4.22: Map showing the Temporary Access Road leading to the Temporary Works Area & Permanent Access Road leading to the Onshore HCAC/HVDC Substation (not to scale).

Water connections

4.10.2.11 Based on experience from similar projects water consumption can be approx. 1,000 m^3 per year during construction. A discussion with the local utility provider will clarify and determine whether the required networks capacity is available nearby to accommodate this demand without having any impact on their existing system and significant upgrades. A permanent water connection to the site is preferred both for the construction and the operation (35 years) duration. An alternative solution during this construction period can be to transport necessary water to the logistics compound.

4.10.2.12 During operation and maintenance, the consumption of clean water will be extremely low (i.e. a few m^3 of water per annum). Typically, a connection to the public sewage system is not required for the operation and maintenance period, as the onshore substation is unmanned – there will be a dump/cess tank(s) installed for sewage.

Onshore substation construction

4.10.2.13 The construction activities will be split into two sub-phases. The first will be the enabling works, whilst the second will be the principle construction works. The total duration of the onshore substation is expected to take up to 36 months.

Enabling Works and earthworks

4.10.2.14 Pre-construction activities will include the preparation of the site by removing vegetation – including shrubs and trees and stripping top soil and sub soils before introducing a capping layer of crushed stone and further layers to formation levels (i.e. down to the clay or sand layer below topsoil). This may include the completion of geotechnical surveys. Also included within the Enabling Works will be the instatement of all below-ground drainage. All volumes of material removed and imported are presented in **Table 4.39**.

4.10.2.15 A compound will be set up that includes the permanent area required for the onshore substation as well as a Temporary Works Area required for storing and moving equipment and materials during the Principle Construction Works. The topsoil of the site will be stripped, and the site will be levelled as required. This could include two to three storey offices, viewing platform up to 30 m, communication mast for internet communication, stores, delivery and offloading areas, welfare facilities, parking areas and security accommodation. A wheel-wash station will also be instated near the temporary working area to prevent construction dirt and debris from being transferred to the public highway. A security fence will be erected around the onshore substation and the Contractor's areas. Site lighting will only operate when required and will be directional to avoid unnecessary illumination.

4.10.2.16 There will be separate drainage systems installed for different parts of the area with a total impermeable surface area of approx. of 25,000 m^2 for the onshore substation site. This will include suitably sized attenuation tank(s) below ground. The proposed location for the attenuation tank will be towards the southeast corner of the site as this area is the lowest point of the site. The exact position will be confirmed during detailed design, post-consent.

4.10.2.17 To install the substation foundation(s) a certain amount of cutting and filling of soil will be required (i.e. soil removed from the site may be used to fill in the site after foundation installation). This will be determined at the detailed design stage, post-consent. The final design will ensure that cutting and filling volumes will be aligned to avoid soil transports off-site.

Table 4.39: Maximum earthwork on onshore substation site.

Topsoil removed and stored on site	Bulk excavation (cutting)	Bulk filling	Bulk import of material (chippings and free drainage material)
30,000 m^3	20,000 m^3	30,000 m^3	40,000 m^3

Construction works

4.10.2.18 Following the enabling works, the principle construction works will include, but may not be limited to the following:

- Landscaping, including bunds, trees, and other planting, as agreed with the relevant stakeholders;
- An access road, leading from the public highway into the substation site;
- Foundations to structures and buildings;
- Buildings and Enclosures;
- Plinths for equipment;
- Bunds for oil containment;
- The construction of plant buildings;
- Internal roads;
- A parking lot for use by maintenance staff;
- Perimeter substation fences;
- Infrastructure for water drainage and attenuation;
- Internal cable duct routes;
- Viewing platforms; and
- Oil interceptor scheme.

4.10.2.19 The construction works for the onshore substation are expected to be of similar type and duration whether using HVAC or HVDC transmission solutions.

4.10.2.20 Piled foundations are not foreseen for the construction of the onshore substation. However, no geotechnical investigations have been carried out at this stage (pre-Consent) to confirm this position. Until these studies are complete (post-Consent and pre-Construction), the final design of the foundations cannot be ascertained. It is normal practice to conclude these Geotech 2 surveys post-Consent and pre-Construction due to the large financial costs (typically several million pounds). Therefore, as a precaution to ensure assessment of a maximum design scenario, an allowance of 500 pre-cast or Continuous Flight Auger (CFA) piles are assumed to be required. These would be installed over a period of 20 working days using a maximum of 2 piling rigs.

4.10.2.21 The electrical equipment will then be installed and tested in readiness for the connection Hornsea Four and the National Grid Substation. Once the construction of the onshore substation is complete the site will be secured, and the supporting infrastructure finalised in readiness for the operations phase. The temporary area will be reinstated once construction is complete.

4.10.3 Energy Balancing infrastructure

4.10.3.1 The EBI is constructed within the onshore substation site. The EBI will be connected directly to the onshore substation infrastructure or alternatively directly to the National Grid substation.

EBI design

4.10.3.2 Hornsea Four includes up to two separate EBI plants. The EBI plant layout is common for HVAC and HVDC solutions. Each plant consists of:

- Energy storage building(s)
- Transformers and converter area
- Switchgear and control room building(s)
- Energy Balancing Equipment building(s)
- DNO compound with transformer(s)
- Connection of EBI Plant to to the onshore substation or alternatively directly to National Grid Creyke Beck substation.
- Required access and internal roads, drainage systems, perimeter and internal fences.
- Required external lighting and lightning pylons

4.10.3.3 The maximum design parameters for the EBI can be seen in **Table 4.40**.

Table 4.40: Maximum design parameters for the EBI.

Parameter	Maximum design parameters
Maximum number of main buildings	4
Maximum main building height (m)	15
Maximum length of main building (m)	100
Maximum width of main building (m)	25
Height of fire walls (m)	25

Parameter	Maximum design parameters
Maximum number of secondary buildings type one	4
Maximum secondary building type one height (m)	20
Maximum secondary building type one length (m)	40
Maximum secondary building type one Width (m)	40
Maximum number of secondary buildings type two	6
Maximum secondary building type two height (m)	10
Maximum secondary building type two length (m)	14
Maximum secondary building type two Width (m)	10
Maximum area used for buildings (m2)	17,300
Lightning protection height (m)	+5m to highest building
Duration of construction (months)	36

4.10.3.4 Figure 4.20 and Figure 4.21 show indicative layouts for the EBI for HVAC and HVDC options respectively.

EBI construction

4.10.3.5 The EBI is constructed within the onshore substation site and will be constructed within the same time line and will use the same access and temporary works layouts as the onshore substation construction.

HGV movements

4.10.3.6 Table 4.41 presents the total number of HGV and Abnormal Loads during the construction of the Onshore Substation (including the EBI). There are expected to be 18 Abnormal and Indivisible Loads (AILs) over the duration of the construction phase.

Table 4.41: Maximum design parameters for HGV and Abnormal Loads during the construction.

Duration	Movements
Week 0 - 2	26
Week 3 - 18	30
Week 19 - 36	200

Duration	Movements
Week 37 - 40	50
Week 41 - 100	30
Week 101 - 142	15

4.10.4 Grid Connection Export Cable

4.10.4.1 A further section of buried onshore export cable is required to connect the onshore substation with the existing National Grid substation. The export cables will enter the substation site and connect to the substation buildings. The electrical power will pass through the buildings and into the equipment in the yard. It will exit the site via underground 400 kV HVAC cables which will connect to the UK national Grid substation.

4.10.4.2 This section of cabling will be similar in design to the onshore export cabling, but must be HVAC at 400 kV, and will have a maximum of four circuits, with a total of 12 export cables, installed within a 40 m permanent easement within a 60 m cable corridor. The cable layout for the grid connection export cable are shown in **Figure 4.23**.

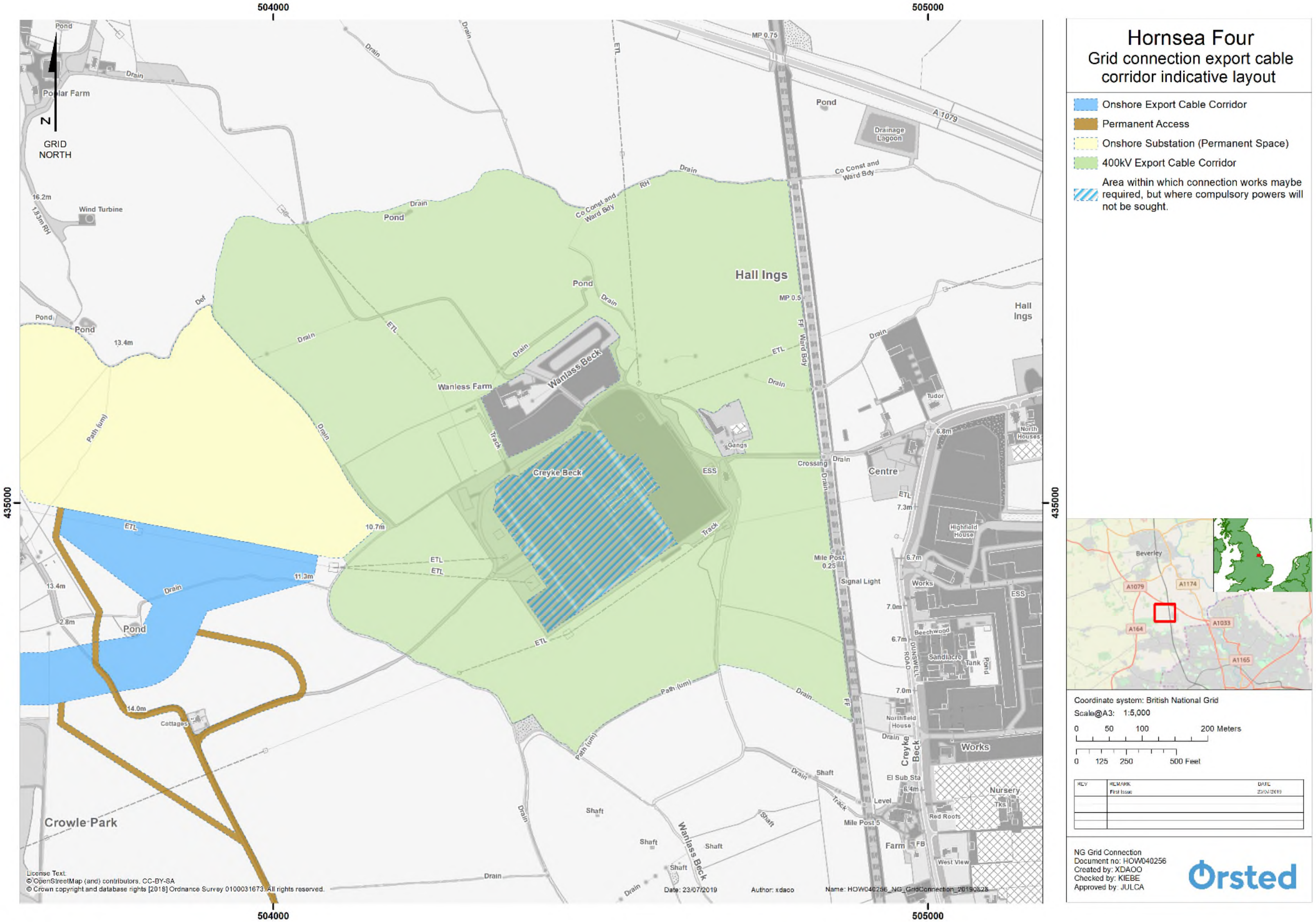

Figure 4.23: Grid connection export cable corridor indicative layout (not to scale).

4.10.5 Ancillary operations

Pre-Construction Surveys

4.10.5.1 Prior to the commencement of the main works associated with installing the onshore export cable and construction of the onshore substations, a number of activities may be needed. These include ground investigations, topographical, ground penetrating radar (GPR), UXO, ecological surveys, soil surveys, utility and private supplies surveys. These works are generally non-intrusive or, such as archaeological investigations, ground investigations and in the event a UXO is identified, targeted excavations. These are conducted to highlight specific areas of interest well in advance of the construction activities.

Ground Investigations

4.10.5.2 Ground Investigations may need to be taken at the onshore substation site, all HDD locations and along the Hornsea Four onshore export cable corridor at predetermined intervals to determine geotechnical data, water monitoring and the thermal resistivity properties of the soils to assist with the cable route design. Typically, these occur up to two years prior to commencement of main works. Boreholes or exploratory/trial pits may be required. Gas monitoring may also be undertaken alongside water monitoring depending on the ground conditions.

Soil Surveys

4.10.5.3 Engagement with landowners and tenants of agricultural land is an important part of informing the detailed design and management of the construction works. Prior to the commencement of works, the contractor (or project appointed Agricultural Liaison Officer) will need to document information on existing agricultural management and soil/land conditions. Other associated preparation activities (non-intrusive) may include: surveys of existing crop regimes, position and condition of field boundaries, condition of existing access arrangements; establishment of location of private water supplies (as far as reasonable investigations allow), review of the type of agriculture taking place, assessments of yield of crops, quality of grazing land; and existing weed burden.

Archaeological investigations

4.10.5.4 Archaeological investigations or archaeological evaluation (field testing) may need to be undertaken to ascertain if any archaeological items of interest are present. Typically, these occur up to two years prior to commencement of main works.

4.10.5.5 The aim of this evaluation is to examine a representative sample of the remains affected by development in order to generate accurate information on the heritage assets actually present. The evaluation stage generally consists of trial work that is relatively small-scale, selective and sample-based whilst still sufficient to quantify, characterise and date the full range of archaeological remains potentially affected by development works.

4.10.5.6 Archaeological techniques that may be employed, include boreholes, archaeological trenches (as well as non-intrusive geophysical investigations). Early archaeological investigations may also rely upon Watching Briefs from suitably qualified personnel.

4.10.5.7 The field testing may lead to a more extensive archaeological campaign which could include archaeological excavation (full or sample excavation), further general and targeted investigations and in some instances the potential for historic building recording – although this is expected to be minimal or not required during the construction due to the separation between onshore works and historic buildings.

Hedgerow removal and vegetation clearance

4.10.5.8 Where hedgerows and trees occur within the Order Limits and particularly the temporary working area (and cable installation is not limited to HDD techniques), their removal will be minimised and will be in line with the principles detailed in the Outline Landscape Management Plan and Outline Ecological Management Plan (see **Volume 2, Annex 3**). Prior to the commencement of any works to a hedgerow, an Ecological Clerk of Works (ECoW) will be present on site to ensure that the specified protection and mitigation measures are appropriately implemented.

Drainage management

4.10.5.9 As part of the wider excavation works it is likely that existing field drainage could be severed by the cable installation works. To manage this ahead of main works the contractor will develop a drainage strategy in consultation with the landowner. Initial works then encompass the installation of preconstruction drainage, the purpose of which is to bypass the existing drainage system to enable wider excavations whilst maintaining field drainage. Drainage requirements (see **Volume 2, Annex 6: Outline Onshore Infrastructure Drainage Strategy**) and management will feed into the flood risk assessment undertaken for Hornsea Four (**Volume 6, Annex 2.2: Onshore Infrastructure Flood Risk Assessment**).

4.10.5.10 It may be necessary to install additional field drainage on either side of the cable trenches along the Hornsea Four onshore export cable corridor to ensure the existing drainage characteristics of the land are maintained during and after construction. These drains would be installed either by small trenching machines, open cut trenching or similar.

4.11 Operation and Maintenance

4.11.1.1 This section provides a description of the reasonably foreseeable maintenance activities at Hornsea Four. This section of the Project Description will subsequently inform the Operation and Maintenance Plan for Hornsea Four which shall be developed post-Consent. Maintenance activities can be categorised into two levels: preventive and corrective maintenance:

- Preventive maintenance will be undertaken in accordance with scheduled services.
- Corrective maintenance covers unexpected repairs, component replacements, retrofit campaigns and breakdowns.

4.11.1.2 Maintain includes inspect, upkeep, repair, adjust, and alter and further includes remove, reconstruct and replace, to the extent assessed in the respective receptor chapter of the PEIR and presented in the ES.

4.11.2 Offshore

4.11.2.1 The overall operation and maintenance strategy will be finalised once the operation and maintenance base location and technical specification of Hornsea Four are known, including wind turbine generator type, electrical export option and final project layout. The offshore operation and maintenance will be both preventative and corrective. However, as more knowledge has been gained in operation and maintenance over the last years, the industry is developing and improving monitoring and preventative maintenance of operational windfarms.

4.11.2.2 The general operation and maintenance strategy may rely on an onshore (harbour based) operation and maintenance base, Crew Transport Vessels (CTVs), Special Operation Vessels (SOVs), offshore accommodation, supply vessels, cable and remedial protection vessels and helicopters for the operation and maintenance services that will be performed at the wind farm. The final operational and maintenance strategy chosen may be a combination of the above solutions.

4.11.2.3 The maximum design parameters for the operation and maintenance activities are presented in **Table 4.42**. The total operational vessel and helicopter requirements for Hornsea Four are presented in **Table 4.43**. Two scenarios for personnel visits options are currently envisaged, either Scenarios [A] (operation and maintenance from onshore helicopter base) or [B] (wind turbine generator operation and maintenance from offshore base or vessel with helicopter personnel transfer).

Table 4.42: Maximum design parameters for offshore operation and maintenance activities.

Parameter	Maximum design parameters
Operation and maintenance vessels - CTVs:	10
Operation and maintenance vessels - SOVs	2
Operation and maintenance vessels - supply vessels	Ad hoc
Helicopters: capacity (persons)	15
JUVs	Ad hoc
Onshore facilities area - offices (m2)	2,500
Onshore facilities area - workshop and warehouse (m2)	2,000
Harbour facilities – quayside length (m)	100
Operational hours	24 hours, seven days a week

4.11.2.4 Two scenarios for personnel visits options are currently envisaged, either Scenarios [A] (operation and maintenance from onshore helicopter base) or [B] (wind turbine generator operation and maintenance from offshore base or vessel with helicopter personnel transfer).

Table 4.43: Maximum design parameters for offshore operation and maintenance activities. A single visit comprises a return trip to and from the Hornsea Four array area.

Parameter	Maximum design parameters
Wind turbine Visits (included in Scenario [A] only) (per year)	2580
Wind turbine Foundation Visits (included in Scenarios [A] and [B]) (per year)	780
Platform Visits - Structural Scope (included in Scenarios [A] and [B]) (per year)	65
Platform Visits - Electrical Scope (included in Scenarios [A] and [B]) (per year)	100
Crew Shift Transfer (included in Scenarios [B] only) (per year)	260
Total Trips (worst case of Scenarios [A] or [B]) (per year)	3,525
Jack-up wind turbine visits (per year)	36
Jack-up foundation visits (per year)	82
Jack-up platform visits - Structural (per year)	5
Jack-up platform visits - Electrical (per year)	1
Jack-up total trips (per year)	124

Parameter	Maximum design parameters
Crew vessels wind turbine visits (per year)	1,205 visits/y
Supply vessels accommodation platform visits (per year)	104 visits/y

Operation and maintenance activities

4.11.2.5 The following section describes the processes and methods Hornsea Four would undertake for those activities for which a licence is required and for which consent is sought. This includes regular and scheduled operation and maintenance as well as unscheduled maintenance that is likely to occur.

4.11.2.6 Maintenance due to failures that cannot be anticipated are not described here and cannot be included within the application for Development Consent. It should be noted that the application does include typical unscheduled or reactive maintenance, i.e. the types of faults that offshore windfarms typically experience, as well as scheduled or routine maintenance. In addition, some activities which could be needed in the operation and maintenance phase of Hornsea Four have not been included in this application as it is considered that these would be best applied for at a later date, if needed, once specific details of the requirements are understood.

4.11.2.7 During the operational life of Hornsea Four (anticipated 35 years), there can be a total of up to 16 vessels in the Hornsea Four array area on any given day. Descriptions of offshore operation and maintenance activities are provided in **Table 4.44**.

Table 4.44: Offshore operation and maintenance activities.

Activity	Rationale	Parameter	Maximum design parameter
Seabed surveys	Seabed surveys will be required to ensure that cables remain buried and that the scour protection around foundations and cable crossings remains intact. Typically this will be undertaken more frequently in early years, hence the assessment is based on twice yearly for first three years; followed by yearly thereafter	Maximum number in lifetime	38
Wind turbine generator activities			
Component replacement	This activity allows for the replacement of major wind turbine components, for example blades, blade bearings, hub generators, yaw rings or nacelles (like-for-like or as within the project envelope). Works conducted under this activity would likely require a JUV supported by at least one CTV. There would be up to Seven visits on	Maximum number of exchange events – lifetime	1260
		Footprint of seabed disturbance per event (m^2)	300

Activity	Rationale	Parameter	Maximum design parameter
	average for exchange events per turbine over the Hornsea Four lifetime.		
Painting of transition pieces	This activity includes the application of paint or other coatings to protect from corrosion (internal/external). Technicians and equipment – largely hand tools - will be deployed from a CTV or similar vessel. Surface preparation is required to break down existing surface coatings and any associated corrosion. There will be one full paint job per turbine every 10 years, and one touch-up paint job per turbine every three years	Maximum number of full painting events – lifetime quantity	630
Marine growth / bird waste removal	Marine growth and bird waste will be physically brushed off turbines by hand, using a brush to break down the marine growth/organic waste (where required) followed by high-pressure jet wash (sea water only). Technicians and equipment will be deployed from a CTV or similar vessel. Up to five cleaning events per turbine per year are planned	Maximum number of cleaning events – lifetime quantity	31,500
Access ladder replacement	This includes the replacement of access ladders to wind turbine transition pieces due to damage or corrosion. Access ladder replacement is likely to require a CTV or small JUV. Technicians and equipment will be deployed from a CTV or similar vessel. One ladder replacement event is planned per turbine every five years	Maximum number of ladder replacement events – lifetime quantity	1260
		Footprint of seabed disturbance per event (m^2)	300
Foundation anode replacement	This includes the removal and replacement of anodes, which are required for corrosion protection (internal and external to the foundation). These sacrificial anodes, usually zinc, are fastened to an external structure. The metal erodes away preferentially and so protects the erosion of the turbine (foundation) steel. Anode replacement works are likely to be undertaken via divers from a dive support vessel. One turbine anode replacement event is planned per turbine every five years.	Maximum number of anode replacement events – lifetime quantity	1260
		Footprint of seabed disturbance per event (m^2)	300
J-Tube repair/ replacement	The turbine foundation J-tubes occasionally require modifications or corrective maintenance, including alterations to the bell mouth of the J-tubes during a cable repair or replacement (e.g. cutting, re-welding). This work will be undertaken	Maximum number of turbine foundation J-tube replacement events – lifetime quantity	360

Activity	Rationale	Parameter	Maximum design parameter
	either by divers from a dive support vessel or using a jack-up barge. It is expected that the frequency will be two J-tubes over the lifetime of the Offshore substation	Footprint of seabed disturbance per event (m^2)	300
Array cables			
Cable remedial burial	This activity provides remedial burial of array cables that may have become exposed via natural sediment transport processes. As-laid cable data will be reviewed to identify priority areas possibly requiring remediation. A multibeam sonar (or similar) will then be used to confirm the exact location and current cable burial depth and/or areas of exposure. Should any areas of exposed or insufficiently buried cables be identified, jetting equipment (i.e. MFE or similar) operated from a vessel, or diver operated injector, will be powered up and manoeuvred along the exposed cable at a steady rate until the desired burial depth is achieved. Once complete, a seabed survey will be conducted to determine the success of the operation. If necessary, another pass may be required to achieve the specified depth. As-buried data will be documented and only once all remedial works have been agreed will the vessel and associated equipment transit from the field to port for demobilisation.	Lifetime quantity of cable (km)	42
		Maximum length of cable subject to jetting (remediation re-burial) per event (m)	2,000
		Maximum width of disturbed seabed per event (m)	The higher of 10 m or 2 x water depth
		Maximum footprint of (temporary) seabed disturbance per event (m^2)	200,000
Cable protection replacement	Where rock protection has been employed during the construction phase, this may be replenished during operation	Up to 25% of the volume of cable protection presented in **Table 4.25** will be replenished.	
Array cable repairs	Failure of a cable system would be detected by the wind farm protection system. A cable fault would require location testing whilst off load using remote diagnostic techniques from the offshore substation or elsewhere onshore to identify the precise location of any fault along the cable length. Where a fault is detected it may be necessary to expose the cable prior to recovery where testing will be conducted to establish the extent and	Maximum number of array cable repairs – lifetime quantity	10
		Maximum cable trench width (m)	10
		Maximum length of cable repair per event (m)	200
		Maximum footprint of seabed disturbance per event (m^2)	20,000

Activity	Rationale	Parameter	Maximum design parameter
	type of repair required. The maximum design scenario (in terms of potential environmental impact) for Hornsea Four has been calculated based on full de-burial always being required. Upon completion of re-burial, a post-burial survey will be carried out to assess whether the cable is at the correct position and required burial depth. During all the works, an advisory exclusion zone of 50 m around the cable and 500 m around all vessels involved in the works will be notified via Notice to Mariners.	Predicted duration of each cable repair event	Approximately three months
		Footprint of seabed disturbance via jacking-up activities for single cable repair event (m^2)	300
		Rock-berm Area (m^2)	7,000
		Rock-berm Volume m^3	8,000
Offshore Substations and accommodation platform activities			
Offshore substation component replacement	This includes the replacement of major components, for example transformers (like-for-like or as within consented envelope). These works would likely require a JUV supported by at least one CTV. It is expected that two major components will require replacement per offshore substation over the lifetime.	Maximum number of exchange events – lifetime quantity	20
		Footprint of seabed disturbance per event (m^2)	300
Offshore substation and accommodation platform foundation painting	This includes the application of paint or other coatings to protect the offshore substation and accommodation platform foundations from corrosion (internal/external). Technicians and equipment will be deployed from a helicopter, SOV, CTV or similar vessel. Surface preparation is required to break down existing surface coatings and any associated corrosion	Maximum number of painting events – lifetime quantity	10
Marine growth / bird waste removal	As per wind turbine generators	Maximum number of cleaning events – lifetime quantity	1750
Access ladder replacement	As per wind turbine generators	Maximum number of ladder replacement events – lifetime quantity	300
Foundation anode replacement	As per wind turbine generators	Maximum number of anode replacement events – lifetime quantity	70
		Footprint of seabed disturbance per event (m^2)	300

Activity	Rationale	Parameter	Maximum design parameter
J-Tube repair/ replacement	As per wind turbine generators	Maximum number of turbine foundation J-tube replacement events – lifetime quantity	20
		Footprint of seabed disturbance per event (m^2)	300
Offshore export cable activities			
Cable remedial burial	As per array cables	Lifetime quantity of cable (km)	14
		Maximum length of cable subject to jetting (remediation re-burial) per event (m)	2,000
		Maximum width of disturbed seabed per event (m)	The higher of 10 m or 2 x water depth
		Maximum footprint of (temporary) seabed disturbance per event (m^2)	200,000
Cable protection replacement	As per array cables	Up to 25% of the volume of cable protection presented in Table 4.25 will be replenished.	
Array cable repairs	As per array cables	Maximum number of array cable repairs – lifetime quantity	35
		Maximum cable trench width (m)	10
		Maximum length of cable repair per event (m)	200
		Maximum footprint of seabed disturbance per event (m^2)	20,000
		Predicted duration of each cable repair event	Approximately three months
		Footprint of seabed disturbance via jacking-	300

Activity	Rationale	Parameter	Maximum design parameter
		up activities for single cable repair event (m^2)	
		Rock-berm Area (m^2)	7,000
		Rock-berm Volume m^3	8,000
Interconnector cable activities			
Cable remedial burial	As per array cables	Lifetime quantity of cable (km)	7
		Maximum length of cable subject to jetting (remediation re-burial) per event (m)	2,000
		Maximum width of disturbed seabed per event (m)	The higher of 100 m or 2 x water depth
		Maximum footprint of (temporary) seabed disturbance per event (m^2)	200,000
Cable protection replacement	As per array cables	Up to 25% of the volume of cable protection presented Table 4.25 will be replenished.	
Array cable repairs	As per array cables	Maximum number of array cable repairs – lifetime quantity	5
		Maximum cable trench width (m)	10
		Maximum length of cable repair per event (m)	200
		Maximum footprint of seabed disturbance per event (m^2)	20,000
		Predicted duration of each cable repair event	Approximately three months
		Footprint of seabed disturbance via jacking-up activities for single cable repair event (m^2)	300

Activity	Rationale	Parameter	Maximum design parameter
		Rock-berm Area (m^2)	7,000
		Rock-berm Volume m^3	8,000

4.11.3 Onshore

4.11.3.1 The onshore operation and maintenance requirements for the onshore export cables will be largely corrective (because there is limited requirement for preventative maintenance on the onshore cables), accompanied by infrequent on-site inspections of the onshore export cables. Onshore export cables will be consistently monitored remotely.

4.11.3.2 Operation and maintenance requirements for the onshore substation and electrical balancing infrastructure will be both preventative and corrective. The onshore infrastructure will be consistently monitored remotely, and visits will occur in a small technicians' van via the established permanent access.

4.11.3.3 Operation and maintenance staff will visit the onshore substation to undertake works on a regular basis, approximately once every six months. For the EBI, preventative maintenance 10 visits per annum with a maximum of 2 persons in attendance and 2 vehicles per day. It is anticipated that there is sufficient redundancy designed into the system that there should be no additional requirement for corrective maintenance beyond that of preventive maintenance.

4.11.3.4 Should Synchronous Condensers we used within the final EBI the O&M requirements would total 6 off-line visual inspections including testing are anticipated within the 35-year operational timeframe.

4.11.3.5 We do not expect large equipment (such as transformers) to be replaced during the lifetime of the operations. However, if it was to be done, the same operational setup as during construction should be anticipated.

4.11.3.6 It is not expected that the TJBs will need to be accessed during the operation of Hornsea Four, however link boxes will require access during the operational phase. These will have been reinstated following construction but may have manhole covers for access. These visits will occur using a 4x4 vehicle.

<u>Operational lighting and Fencing</u>

4.11.3.7 A security fence will be erected around the substation site. Permanent lighting will be reserved for essential areas only. Operational lighting will be reserved for key routes and building entrances etc. All lighting will be directional in order to minimise overspill into the surrounding countryside..

Operational Noise

4.11.3.8 The expected noise outputs from the main HV outdoor equipment within the onshore substation and EBI are shown in **Table 4.45**. The figures are for an Onshore HVAC Substation as this is the worst-case regarding noise. If it is decided to use an Onshore HVDC Substation the noise output will be reduced significantly as less HV plant will be outdoors.

Table 4.45: Sources and numbers of HV equipment and associated maximum noise levels for the onshore substation and EBI.

Component	Maximum value per unit [dB(A)]	Number
Onshore substation (HVAC option)		
Variable Shunt Reactor	97	12
Fixed Shunt Reactor	93	4
DRC	93	6
DRC Transformer	91	6
DRC Reactor	84	
Super Grid Transformer	95	6
Harmonic Filter	91	6
Harmonic Filter	91	4
EBI		
PCS Area		
MV/LV Transformers	65	<100
Power Converters	85	<100
Battery Area	84	
Central AC Units	80	2

4.12 General Practices

4.12.1 Security

4.12.1.1 Hornsea Four will be suitably secured throughout all phases of development to ensure those working on Hornsea Four can work in safety and the supply of electricity to National Grid remains secure. Any above ground onshore infrastructure such as the onshore substation will be housed in secure gated compounds, as will any ongoing construction work. The onshore export cables are buried and will not be accessible from the surface. Any accessible parts such as the link boxes will be accessible only through secure manhole covers.

4.12.1.2 The offshore infrastructure is by nature inaccessible due to being situated offshore.

4.12.2 Health and Safety

4.12.2.1 All elements of Hornsea Four will be risk assessed according to the relevant government guidance as well as Ørsted internal best practise. These risk assessments will then form the basis of the methods and safety mitigations put in place across the life of Hornsea Four.

4.12.2.2 Ørsted has a focus on employee safety. Ørsted's QHSE policy ensures that Ørsted wind farms are safe by design and that the processes and procedures are adhered to. There is a clearly defined safety culture in place in order to avoid incidents and accidents.

4.12.2.3 There will be constant controls to ensure that the safety measures are observed and followed and Hornsea Four has built a safe workplace for its employees and contractors.

4.12.2.4 The focus on QHSE is intended to ensure that everyone feels safe, in a highly controlled and safety-driven environment. This is Hornsea Four's first priority. It is done by closely monitoring all matters relating to health and safety on all Ørsted wind farms.

4.12.3 Waste management

4.12.3.1 Waste would be generated as a result of Hornsea Four, with most waste generated during the construction of the offshore and onshore elements. In accordance with Government policy contained in NPS EN-1 (DECC, 2011a), consideration will be given to the types and quantities of waste that will be generated.

4.12.3.2 Procedures for handling waste materials are set out in the Site Waste Management Plan (SWMP) section of the Outline Code of Construction Practice see. **Volume F2, Chapter 2: Outline Code of Construction Practice (Including Outline Construction Traffic and Travel Plan).**

4.12.3.3 The SWMP describes and quantifies each likely waste type and how it will be disposed of, reused, recycled or recovered in other ways during the construction stage of project. The SWMP also describes the management arrangements for the different waste types and identifies potential management facilities in the vicinity of the development. The available capacity of waste management facilities is taken into account where applicable.

4.12.3.4 Estimates for waste types and arisings from the construction of the onshore components are provided in the SWMP. These will be updated as further detailed design information becomes available prior to construction.

4.12.4 Climate change and natural disasters

4.12.4.1 The above ground/seabed components, such as the Turbines, HVAC booster station, OnSS and EBI are designed and constructed with materials considered resilient to climate change effects. The onshore and offshore electrical cables would be buried underground with a minimum depth from the top of the cables to the ground or seabed surface of 1.0m. This provides protection from climate change effects for the duration of the operational phase and resilience to flood or other extreme weather events.

4.12.4.2 The flood resilience of the project is covered within the Onshore infrastructure Flood Risk Assessment (see **Volume 6, Annex 2.2**) and **Volume 3, Chapter 2: Hydrology and Flood Risk**.

4.12.4.3 It is concluded that the project is resilient to climate change over the 35-year operational design life.

4.13 Decommissioning

4.13.1 Offshore

4.13.1.1 At the end of the operational lifetime of Hornsea Four, it is anticipated that all structures above the seabed or ground level will be completely removed. The decommissioning sequence will generally be the reverse of the construction sequence and involve similar types and numbers of vessels and equipment. The Crown Estate agreement for lease (AfL) for Hornsea Four requires that the project is decommissioned at the end of its lifetime. Additionally, the Energy Act (2004) requires that a decommissioning plan must be submitted to and approved by the Secretary of State for Business, Energy and Industrial Strategy, a draft of which would be submitted prior to the construction of Hornsea Four. The decommissioning plan and programme will be updated during Hornsea Four's lifespan to take account of changing best practice and new technologies. The approach and methodologies employed at decommissioning will be compliant with the legislation and policy requirements at the time of decommissioning.

Wind turbine generators, offshore substations and accommodation platform

4.13.1.2 Turbines will be removed by reversing the methods used to install them. Piled foundations would likely be cut approximately 1 m below the seabed, with due consideration made of likely changes in seabed level and removed. This could be achieved by inserting a pile cutting devices. Once the piles are cut, the foundations could be lifted and removed from the site. At this point in time, it is not thought to be reasonably practicable to remove entire piles from the seabed, but endeavours will be made to ensure that the sections of pile that remain in the seabed are fully buried.

4.13.1.3 The offshore substations will most likely be a reverse installation where the decommissioning most likely will be in two phases, in the first phase the topside will be lifted from the foundation to a transport vessel/barge and sailed to a suitable harbour for decommissioning. In the second phase the foundation will be decommissioned; if piled foundation they will be decommissioned as described above.

4.13.1.4 If gravity base foundations, they could possibly be removed by removing their ballast and either floating them (for self-floating designs) or lifting them off the seabed.

4.13.1.5 Any scour protection will be left in situ.

Offshore cables

4.13.1.6 Although it is expected that most array and export cables will be left in situ, for the purposes of this application for Development Consent it has been assumed that all cables will be removed during decommissioning, though any cable protection installed will be left in situ. Exposed cables are more likely to be removed to ensure they don't become hazards to other users of the seabed. At this point in time, it cannot be accurately determined whether and which cables will be exposed at the time of decommissioning

4.13.1.7 It is likely that equipment similar to that which is used to install the cables could be used to reverse the burial process and expose them. Therefore, the area of seabed impacted during the removal of the cables could be the same as the area impacted during the installation of the cables. Divers and/or ROVs may be used to support the cable removal vessels.

4.13.1.8 Once the cables are exposed, a grapnel would be used to pull the cables onto the decks of cable removal vessels. The cables would be cut into manageable lengths and returned to shore. Once onshore, it is likely that the cables would be deconstructed to recover and recycle the copper and/or aluminium and steel within them.

Intertidal area

4.13.1.9 To minimise the environmental disturbance during wind farm decommissioning the preferred option is to leave cables buried in place in the ground with the cable ends cut, sealed and securely buried as a precautionary measure. Alternatively, partial removal of the cable may be achieved by pulling the cables back out of the ducts. This may be preferred to recover and recycle the copper and/or aluminium and steel within them.

Vessel activities

4.13.1.10 Decommissioning is currently based on reverse installation and the assumptions about maximum number of vessels and helicopters and their movements is therefore the same as described for construction of the wind farm in **Section 4.8.7**.

4.13.2 Onshore

Onshore export cables

4.13.2.1 To minimise the environmental disturbance during Hornsea Four decommissioning the onshore export cables will be left in place in the ground with the cable ends cut, sealed and securely buried as a precautionary measure.

4.13.2.2 The structures of the jointing pits and link boxes will be removed only if it is feasible with minimal environmental disturbance or if their removal is required to return the land to its current agricultural use.

Onshore substation

4.13.2.3 The components of the onshore substation have varying life expectancies. Transformers typically have a useful life up to 50 years, and some components' lives can be extended beyond this period. The case for decommissioning the onshore substation in the event of the wind farm being decommissioned will be reviewed in discussion with the transmission system operator and the regulator in the light of any other existing or proposed future use of the onshore substation.

4.13.2.4 If complete decommissioning is required, then all the electrical infrastructure will be removed and any waste arising disposed of in accordance with relevant regulations. Foundations will be broken up and the site reinstated to its original condition or for an alternative use. For the EIA decommissioning of the onshore substation is assume do be similar to the construction and in reverse sequence.