Hornsea Project Three
Offshore Wind Farm

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Environmental Statement:
Chapter 3: Project Description

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Hornsea 3
Offshore Wind Farm

Ørsted

Environmental Impact Assessment

Environmental Statement

Volume 1

Chapter 3 – Project Description

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Ørsted

5 Howick Place,

London, SW1P 1WG

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

Prepared by: Orsted

Checked by: Andrew Guyton and Jennifer Brack

Accepted by: Sophie Banham

Approved by: Stuart Livesey

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Glossary

Term	Definition
Arisings	The soil that is displaced, or raised, from drilling to install foundations for offshore structures. For the purposes of this document, this soil is then considered spoil.
Array Cables (inter-array cables)	Cables which connect the wind turbines to each other and to the offshore substation(s).
Cable Circuit	A circuit is defined as a collection of conductors necessary to transmit electric power between two points. For underground cable systems, the number of conductors depends on the type of transmission technology. For HVAC transmission, there will be 3 conductors (or a multiple of 3), one for each phase. These can either take the form of three conductors bundled as one cable, or three separate cables. For HVDC transmission only two conductors (or multiple of 2) are necessary (assuming an earth return is not used). These typically are separate cables but may be attached together offshore for ease of installation. If there are multiple circuits between two points they typically will be differentiated by their ability to be isolated (by circuit breaker or disconnector) at either end. The circuit may or may not include one or more fibre optic cables for the purpose of control, monitoring, protection or general communications.
Design Envelope	A description of the range of possible elements which make up the project design options under consideration, as set out in detail in this chapter. This envelope is used to define the project 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.
Dynamic Positioning (DP)	An advanced autopilot system installed on vessels that consists of thrusters, GPS, and a control unit. The system is capable of automatically holding a vessel at location and heading specified by the operator.
Edge Weighted Layouts	A type of wind turbine layout where the spacing at all or some of the boundary of the wind farm is less than the spacing between some or all of the inter array turbines.
Offshore Export Cables	Cables that transfer power from the offshore substation(s) or the converter station(s) to shore.
Offshore Interconnector Cables	Cables that may be required to interconnect the offshore substations in order to provide redundancy in the case of cable failure elsewhere, or to connect to the offshore accommodation platforms in order to provide power for operation.
Onshore Export Cables	Cables that transfer power from the offshore export cables to the onshore substation(s).
Spoil	Waste soil or sediment that is excavated or drilled out as part of the Project's installation works.
Trenchless Techniques	Also referred to as trenchless crossing techniques or trenchless methods. These techniques include HDD, thrust boring, auger boring, and pipe ramming, which allow ducts to be installed under an obstruction without breaking open the ground and digging a trench.
Weather Downtime	Hours or days when the weather conditions, including wave, tide, current, and/or wind, prevent work.
Wind Turbine Generator	All of the components of a wind turbine, including the tower, nacelle, and rotor.

Acronyms

Unit	Description
AEZ	Archaeological Exclusion Zone
AfL	Agreement for Lease
BEIS	Department for Business, Energy and Industrial Strategy (formerly DECC)
CAA	Civil Aviation Authority
CBRA	Cable Burial Risk Assessment
CEMP	Construction Environment Management Plan
CTV	Crew Transport Vessel
DCO	Development Consent Order
DECC	Department of Energy and Climate Change (now BEIS)
DNO	Distribution Network Operator
DP	Dynamic Positioning
DPV	Dynamic Positioning Vessel
DRA	Design Risk Assessment
ECR	Export Cable Route
EIA	Environmental Impact Assessment
EMF	Electro-magnetic Field
ES	Environmental Statement
FID	Final Investment Decision
GBF	Gravity Base Foundation
GPR	Ground Penetrating Radar
HAT	Highest Astronomical Tide
HDD	Horizontal Directional Drilling
HGV	Heavy Goods Vehicle
HSE	Health, Safety and Environment
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
IALA	International Association of Lighthouse Authorities
IPC	Infrastructure Planning Commission
JB	Joint Bay

Unit	Description
JNCC	Joint Nature Conservation Committee
JUV	Jack-up Vessel
LAT	Lowest Astronomical Tide
LB	Link Box
MBES	Multi-Beam Echo Sounder
MCA	Maritime and Coastguard Agency
MFE	Mass Flow Excavation
MHWS	Mean High Water Springs
MIND	Mass Impregnated Non-Draining
MoD	Ministry of Defence
MP	Monopile
MV	Medium Voltage
NPS EN-1	Overarching National Policy Statement for Energy
NPS EN-3	National Policy Statement for Renewable Energy Infrastructure
O&M	Operations and Maintenance
OAP	Offshore Accommodation Platform
Ofgem	Office of Gas and Electricity Markets
OFTO	Offshore Transmission Operator
OREI	Offshore Renewable Energy Installations
OSS	Offshore Substations
PAX	Passengers
PEIR	Preliminary Environmental Information Report
PINS	Planning Inspectorate
PLGR	Pre-Lay Grapnel Run
PRoW	Public Rights of Way
ROV	Remotely Operated Vehicle
RPS	RPS Planning and Development Limited
SBP	Sub-bottom Profiler
SCADA	Supervisory Control and Data Acquisition
SCAR RCS	SCAR Route Clearance System

Unit	Description
SOV	Special Operations Vessel
SSS	Side Scan Sonar
SWMP	Site Waste Management Plan
TCE	The Crown Estate
TH	Trinity House Lighthouse Service
TJB	Transition Joint Bay
TJB	Transition Joint Bay
TP	Transition Piece
UXO	Unexploded Ordnance
VSC	Voltage Source Converter
WD	Water Depth
WTG	Wind Turbine Generator
XLPE	Cross Linked Polyethylene
ZDA	Zone Development Agreement
ZEA	Zone Environmental Appraisal

Units

Unit	Description
AC	Alternating Current (electricity)
DC	Direct Current (electricity)
GW	Gigawatt
kJ	Kilojoule
km	Kilometre
kV	Kilovolt
m/s	Metres Per Second
MW	Megawatt

3. Project Description

3.1 Introduction

3.1.1.1 Orsted Power (UK) Ltd. (hereafter referred to as Orsted), on behalf of Orsted Hornsea Project Three (UK) Ltd., is promoting the development of the Hornsea Project Three Offshore Wind Farm (hereafter referred to as Hornsea Three).

3.1.1.2 This chapter of the Environmental Statement provides an outline description of the potential design of Hornsea Three, based on preliminary conceptual design information and current understanding of the environment from initial survey work. It sets out the Hornsea Three 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 Three.

3.1.1.3 At this early stage in the Hornsea Three development process, the project description is indicative and the 'envelope' has been designed 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 which values are shown.

3.1.1.4 In order to avoid excessive conservatism in the assessments, the parameters assessed throughout the Environmental Impact Assessments (EIAs) are not a combination of the maximum design parameters for each component. For example, the EIA has not assessed both the maximum number of turbines and the parameters related to the largest turbine type within the envelope, as this is not a feasible scenario. Instead the maximum design scenario is chosen on a receptor by receptor and an impact by impact basis, based on a range of scenarios, whereby the physical size of the turbines is related to their number and the sizes of the associated infrastructure such as turbine foundations. These scenarios generally assume either the maximum number of turbines with parameters related to the use of the smallest turbine type, or the largest parameters in the envelope, and fewer turbines. The details of these maximum design scenarios are set out within the topic chapters, of this Environmental Statement (see volume 2: chapters 1 to 11, and volume 3: chapters 1 to 10) themselves.

3.1.1.5 It should also be noted that this project description does not refer directly to the capacity of the turbines, but rather their physical dimensions. In recent years, the capacity of the current generation of turbines has become more flexible, and may be different depending on the environmental conditions at the sites. It is also noted that the EIAs are not linked directly to the turbine capacity (but rather its physical dimensions such as tip height and rotor diameter), therefore it is not considered appropriate to constrain the envelope based on turbine capacity.

3.1.1.6 The final design will be refined after consent has been granted from within the parameters stated within this project description. Hornsea Three has already, throughout the EIA process (i.e. from Scoping to Preliminary Environmental Information Report (PEIR) to the Environmental Statement), started to refine the proposed values and to provide more detailed realistic maximum design scenarios where required.

3.2 Design Envelope approach

3.2.1.1 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 the majority of offshore wind farm applications.

3.2.1.2 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*."

3.2.1.3 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).

3.2.1.4 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".

3.2.1.5 The Design Envelope approach is widely recognised and 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*".

3.2.1.6 Throughout the Environmental Statement the Design Envelope (otherwise known as the "Rochdale Envelope") Approach has been taken to allow meaningful assessments of Hornsea Three to proceed, whilst still allowing reasonable flexibility for future project design decisions.

3.3 Hornsea Three boundary

3.3.1.1 The boundary of Hornsea Three is delineated on Figure 3.1 below and specifically consists of the:

- Hornsea Three array area: This is where the offshore wind farm 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 Three offshore 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), (see Table 3.37 below) will be located; and
- Hornsea Three onshore cable corridor : This is where the permanent onshore electrical infrastructure (onshore export cable(s), as well as the onshore HVAC booster station (if required), onshore HVDC converter/HVAC substation and connections to the National Grid) will be located.

3.4 The Agreement for Lease (AfL) area

3.4.1.1 The Agreement for Lease (AfL) from The Crown Estate (TCE) allows Orsted, as a prospective tenant of the AfL, to carry out investigations, such as survey activities, to identify the potential design within the Hornsea Three array area. It allows Hornsea Three to understand environmental sensitivities that may exist, in advance of submitting the consent application, whilst and before applying to TCE for a lease for the lifetime of the wind farm. As noted under NPS EN-3, the detailed design cannot be proposed at this stage, however further information on the site will inform the refinement of the Design Envelope post consent.

3.4.1.2 The AfL for the Hornsea Three array area covers approximately 696 km^2 and is broadly a diamond shape with a length of approximately 29 km west to east and 35 km north to south. The AfL area is where the offshore infrastructure, such as the turbines, offshore substation(s) and array cables, will be located. This area is hereafter referred to as the Hornsea Three array area throughout this chapter (see Figure 3.1).

3.4.1.3 Hornsea Three has applied to The Crown Estate for an Agreement for Lease for the offshore cable corridor.

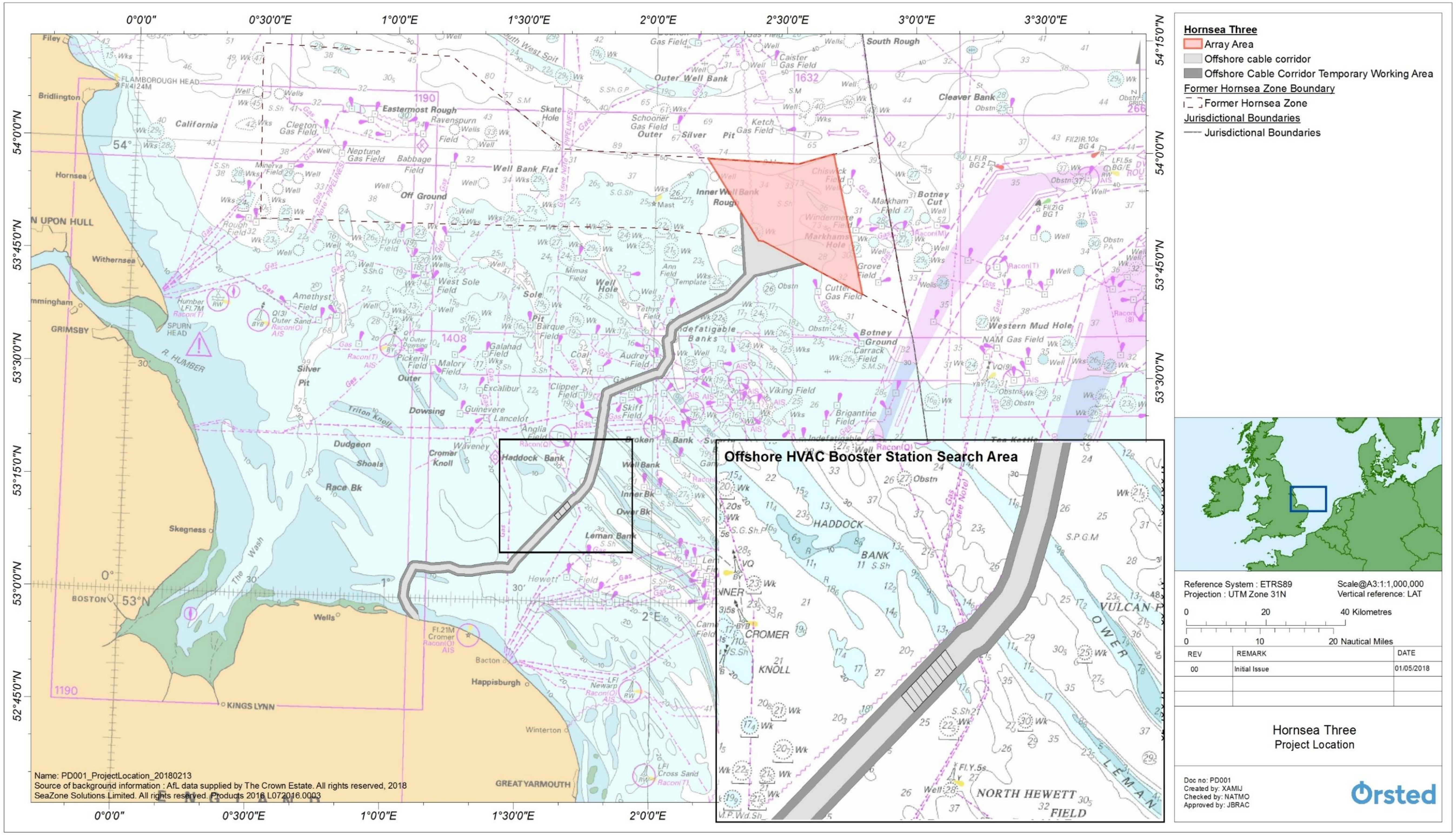


Figure 3.1: Overview of the Hornsea Three project location.

3.5 Project infrastructure overview

3.5.1.1 Hornsea Three will comprise of turbines and all infrastructure required to transmit the power generated by the turbines to the existing Norwich Main National Grid substation, which is located south of Norwich. It will also comprise of any offshore infrastructure required to operate and maintain the wind farm.

3.5.1.2 Hornsea Three will have a maximum of 300 turbines, and will have a capacity of approximately 2.4 GW. The ultimate capacity of the project will be determined based on available technology as constrained by the Design Envelope presented in this chapter. On this basis, references throughout this Environmental Statement to a capacity of up to 2.4 GW are references to an approximate capacity only.

3.5.1.3 The maximum proposed number of turbines has been reduced from the 342 proposed in the PEIR. This will reduce impacts on several receptors including, but not limited to, those associated with the following chapters;

- Marine Mammals (volume 2, chapter 4);
- Offshore Ornithology (volume 2, chapter 5);
- Commercial Fisheries (volume 2, chapter 6); and
- Shipping and Navigation (volume 2, chapter 7).

3.5.1.4 The onshore infrastructure will consist of up to 18 onshore export cables buried in up to six trenches and an onshore HVDC converter/HVAC substation to allow the power to be transferred to the National Grid via the existing Norwich Main National Grid substation. It may also include an onshore HVAC booster station.

3.5.1.5 Hornsea Three may use HVAC or HVDC transmission, or could use a combination of both technologies in separate electrical systems. Hornsea Three 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 Three 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 Environmental Statement.

3.5.1.6 The key components of Hornsea Three are likely to include (also shown in Figure 3.2):

- Offshore turbines;
- Foundations (for turbines, offshore substation platforms, and offshore accommodation platforms);
- Scour protection;
- Offshore accommodation platform(s);
- Array cables linking the individual turbines to offshore substations;
- Connection works to existing Norwich Main Substation;
- Temporary construction compounds, including storage areas;
- Permanent and temporary access roads; and
- HVAC or/and HVDC transmission system including either:
    - HVAC:
        - Offshore transformer substation(s);
        - Offshore interconnector cables(s);
        - Offshore export cable(s);
        - Offshore HVAC booster station(s) (unless specified otherwise, this refers to both Surface and Subsea designs. See paragraph 3.6.9.19 to 3.6.9.31));
        - Onshore export cable(s);
        - Onshore HVAC booster station (either instead of, or as well as, offshore HVAC booster station(s));
        - Onshore HVAC substation; and
        - Grid connection export cable(s).
    - HVDC:
        - Offshore transformer substation(s);
        - Offshore interconnector cables(s);
        - Offshore HVDC converter substation(s);
        - Offshore export cables(s);
        - Onshore export cables(s);
        - Onshore HVDC converter substation; and
        - Grid connection export cable(s).

3.5.1.7 It is likely that the Hornsea Three components will be fabricated at a number of manufacturing sites across Europe or elsewhere, to be determined as part of a competitive tendering process upon award of consent and the completion by Orsted of a Final Investment Decision (FID). A construction base (port facility) may be used to stockpile some components, such as foundations and turbines, before delivery to the Hornsea Three array area for installation. Other components, such as pre-fabricated offshore substation units, may be delivered directly to the Hornsea Three array area when required. An onshore operations and maintenance base may be provided to support the operating wind farm after construction. This onshore operations and maintenance base is not included in this application and any consent will be secured at a later date when the location and requirements for this are known.

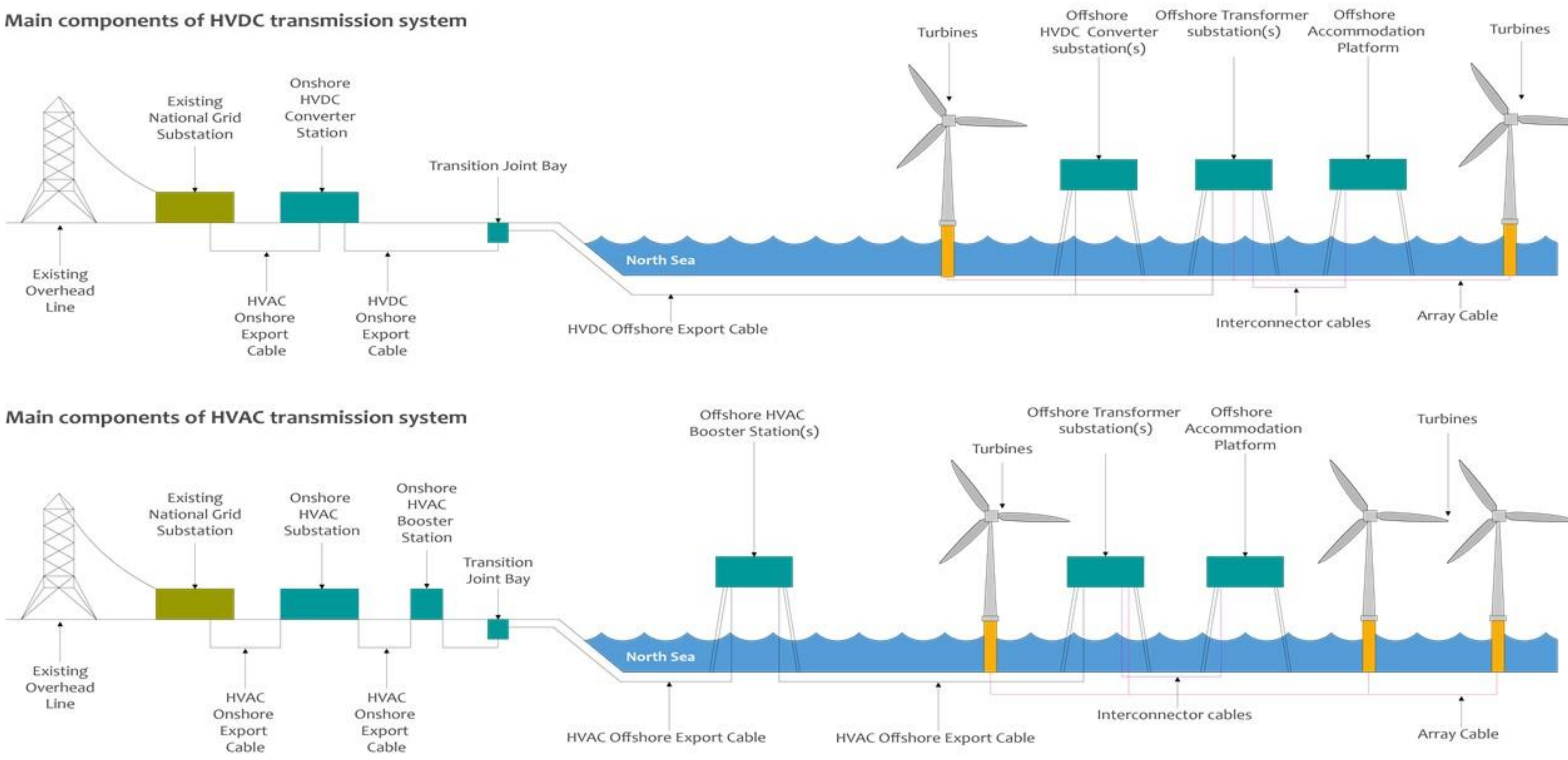


Figure 3.2: Overview of Hornsea Three infrastructure.

3.5.1.8 Hornsea Three may be constructed in a single phase or two phases. Although the total durations for each component would not exceed those stated in this document, there may be periods where work stops as one phase is completed and is initiated again for the following phase after a gap.

3.5.1.9 The maximum number of phases has been reduced from the three phases proposed in the PEIR. This will reduce impacts on a number of receptors including, but not limited to:

- Ecology and Nature Conversation (volume 3, chapter 3); and
- Land Use and Recreation, including Public Rights of Way (PRoW) (volume 3, chapter 6).

3.5.1.10 The offshore wind farm and associated grid connection components are briefly described in the following sections. Maximum design parameters (dimensions and/or numbers where appropriate) are provided to indicate the potential scale of the proposed offshore wind farm, as well as to inform the EIA. A further refined and detailed project description compared to the project description presented in the PEIR is presented here based on the findings of the consultation and EIA process.

3.6 Offshore infrastructure

3.6.1 Introduction

3.6.1.1 The following sections provide a description of the offshore components of Hornsea Three together with relevant information on construction or operation and maintainence methods and techniques where these are relevant to the EIA.

3.6.2 Site preparation activities

3.6.2.1 A number of site preparation activities will need to be undertaken in the Hornsea Three array area and offshore cable corridor (including the offshore HVAC booster station search area) prior to the commencement of construction. An overview of these activities is provided below.

Pre-Construction Surveys

3.6.2.2 A number of pre-construction surveys will be undertaken, approximately one to two years prior the start of offshore construction works, to identify, in detail, seabed conditions and morphology, and presence/absence of any potential obstructions or hazards and to verify seabed layers. These geophysical and geotechnical surveys will be conducted across the Hornsea Three array area and offshore cable corridor. They will comprise techniques such as side scan sonar (SSS), sub- bottom profiling, multibeam bathymetry and backscatter, high-density magnetometer surveys, geotechnical boreholes, CPTs and vibrocores. In addition Remotely Operated Vehicle (ROV) inspection work will be undertaken on potential items of UXO near to the cable route position lists.

3.6.2.3 Geotechnical surveys will be conducted within the footprint of the export cable corridor, turbines, offshore substations and other infrastructure.

3.6.2.4 Geophysical survey works will be carried out to provide detailed UXO, bedform and boulder mapping, bathymetry, a topographical overview of the seabed and an indication of sub-layers. These will be carried out within the whole Hornsea Three array area and offshore cable corridor boundary, utilising towed arrays and sonar, with no seabed interaction.

Unexploded Ordnance (UXO) clearance

3.6.2.5 It is common to encounter Unexploded Ordnance (UXO) originating from World War I or World War II during the construction of offshore infrastructure. 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. Due to the intensity of the surveys required to accurately identify UXO, this work cannot be conducted before detailed design work has confirmed the planned location of infrastructure. It is therefore 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. However, the detonation of UXO is a source of additional noise in the marine environment and hence may need to be considered in the assessments for certain receptors and hence some information is provided below on what could be anticipated in relation to UXO detonation.

3.6.2.6 In order to define a design scenario for consideration in the EIA a review of recent publicaly available information on UXO disposal was undertaken, including a recent study by von Benda-Beckmann *et al*. (2015) and noise modelling work carried out to inform the assessment of the potential effect of UXO clearance at the Beatrice Offshore wind farm site (BOWL 2016), along with experience from Hornsea Project One. Hornsea Project One identified 23 UXO targets that required in-situ detonation and therefore the same number could be expected for Hornsea Project Three across the Hornsea Three array area and offshore cable corridor and is considered a realistic assumption. The outputs of the study by Von Benda-Beckmann et al. (2015) and clearance at the Beatrice Offshore wind farm site (BOWL 2016) are used to inform specific assessments in relation to marine mammals (see volume 2, chapter 4: Marine Mammals).

Methodology

3.6.2.7 Targets identified during the geophysical survey that model as potential UXO (pUXO) can either be investigated to confirm their identity or avoided by a suitable distance. Indicative exclusion zones are given in Table 3.1 below.

Table 3.1: Maximum design scenario: Avoidance buffers for UXOs.

Feature	Exclusion Zone Radius (m)
Foundation	30
Cables	15
Jack-up leg	15

3.6.2.8 Inspections will be conducted using divers in the nearshore and intertidal areas. Inspections will be conducted using ROV in all other offshore areas.

3.6.2.9 Following consultation with the MMO and Ministry of Defence (MoD), any UXO found with a potential to contain live ammunition may be detonated on site and any remaining debris removed. UXO clearance for Hornsea Three will be carried out approximately one to two years prior the start of offshore construction works.

3.6.2.10 Folowing careful excavation of suspected UXO, identification of each UXO target will generally be made visually by on-board specialists monitoring camera footage (Figure 3.3). An immediate risk assessment will be carried out to enable a decision on the appropriate management required for each target.

3.6.2.11 Where a target is confirmed as non-UXO (i.e. to be inert) the device may be recovered for onshore disposal where practicable. Inert devices that cannot be practically moved will be left in-situ with Hornsea Three infrastructure to be micro-sited around the device. Non-inert devices will be managed through clearance as shown in Figure 3.4. Should an UXO be identified and clearance is required, the maximum design scenario would be an explosive detonation of the UXO in-situ to make it safe for disposal (if practicable).

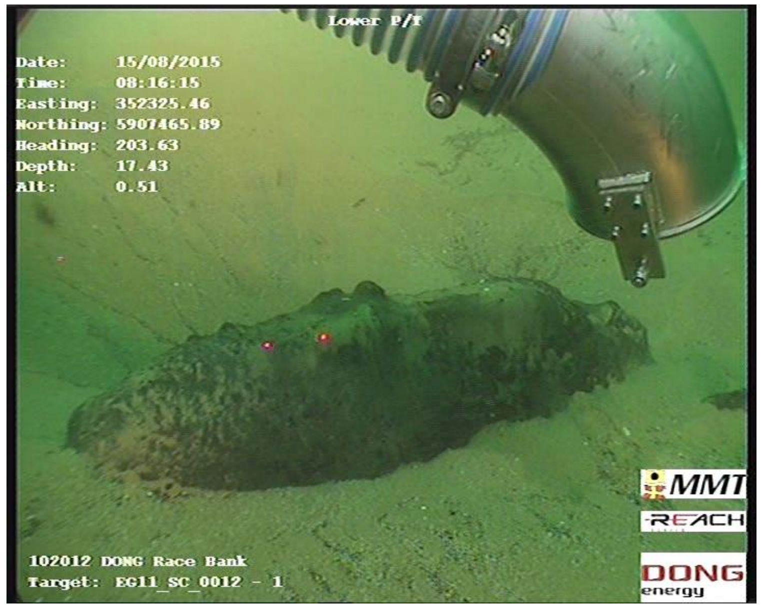


Figure 3.3: An example of a UXO following excavation.

Figure 3.4: An example of a UXO fitted with an explosive charge.

Boulder Clearance

3.6.2.12 Geophysical surveys have been undertaken within the Hornsea Three array area and offshore cable corridor and have been used to inform boulder clearance requirements for the purposes of the EIA.

3.6.2.13 From the interpretation of these data, a large number of boulders can be seen to cover the Hornsea Three array area and offshore cable corridor. The volume of boulders recorded means that micrositing of cables around these contacts would be onerous and impractical. If left *in-situ,* these boulders will pose the following risks to Hornsea Three:

- 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.

3.6.2.14 As a result of the above risks, Hornsea Three have identified that boulders over a certain size will be required to be cleared from the cable installation footprint.

3.6.2.15 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 Three offshore cable corridor, a corridor of up to 25 m 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 Three array area, a corridor of up to 15 m must be cleared as this width is sufficient for the operation of the array cable burial tools under consideration.

3.6.2.16 Boulder clearance is a common feature of offshore wind farm route clearance, taking place prior to the main construction process.

Methodology

3.6.2.17 There are two methodologies, specifically a displacement plough or a subsea grab, that may be selected for undertaking boulder clearance activities. These are presented within this section.

3.6.2.18 A displacement plough such as a SCAR RCS (shown in Figure 3.5) is a simple and robust Y-shaped design configured with a boulder board attached to the plough that scrapes along the seabed surface displacing boulders along a clearance path; a common size of this tool will clear a 15 m path. The plough will be pulled along the seabed using pulling chains. The plough will be lightly ballasted to only clear the way of boulders and not to create a deep depression in the seabed with resulting berm on each side.

3.6.2.19 For export cable sections that are densely populated by surface boulders, a displacement plough is the most likely method that will be employed to clear the export cable corridor ready for the cable trenching and burial operations.

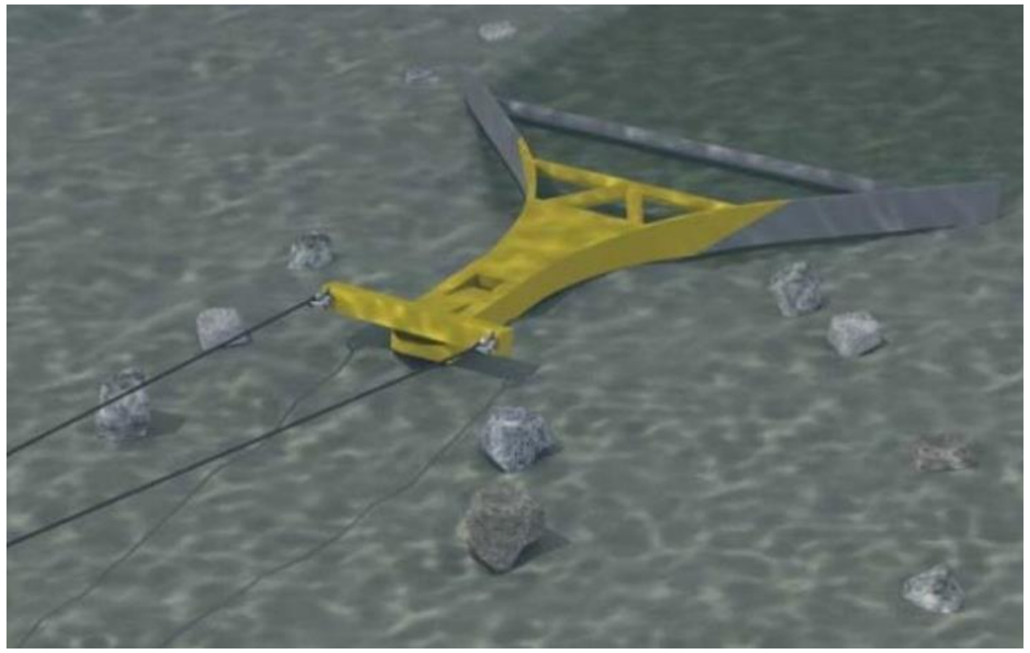


Figure 3.5: Example of a SCAR RCS.

3.6.2.20 There are two limitations of using the SCAR RCS or similar tools:

- The SCAR RCS or similar tools cannot be used in areas where slopes are present in excess of 5º; and
- If the SCAR RCS or a similar tool encounters an obstacle on the seabed such as a large boulder, that encounters a force greater than 80 Te, a rotational shift may occur in the tool resulting in potential damage to the tool and reduced effectiveness of the clearance tool in these areas.

3.6.2.21 As a result of the above limitations, this method is often used in combination with the subsea grab method (shown in Figure 3.6). Boulder clearance using a subsea grab may be conducted where boulder density is lower and where seabed slope is high (>5º). The vessel will be equipped with a survey and ROV spread to assist in subsea positioning of the grab onto the boulders and for recording their new position.

Figure 3.6: **Example of a subsea grab tool (Source: DEME Group).**

3.6.2.22 The presence, position and nature of the boulders will first be visually confirmed through ROV inspection. The subsea grab will be lowered over the confirmed boulder using the vessel crane. The engagement of the mechanical grab with the boulder will be guided by observations using the ROV. The boulder is lifted off the seabed and relocated.

3.6.2.23 Boulder relocation using a subsea grab can be a very effective way of relocating individual boulders that are found scattered in small and moderate numbers across the seabed, and gives the ability to relocate the boulders in a 'natural' scattered manner with only limited interaction with the seabed and therefore does not disturb seabed sediments.

3.6.2.24 For the Hornsea Three array area, boulder interpretation has been carried out to identify boulders that would require clearance. Assumptions on the tool required to clear these areas have been made taking the following into consideration:

- Where a high density of boulders is seen, the expectation is that the SCAR RCS or similar system will be required to clear the cable installation corridor (this is considered to present the maximum design scenario but in some scenarios a subsea grab may be used as explained in 3.6.2.20);
- Where a medium density of boulders is seen, a subsea grab is expected to be employed; and
- Where a low density of boulders is seen, a subsea grab is expected to be employed, or it is possible that installations may be microsited to avoid the requirement to clear boulders.

3.6.2.25 An indicative maximum design scenario has been calculated based on the methodology above for boulder clearance in the Hornsea Three array area and this is presented in Table 3.2 below.

Table 3.2: Maximum design parameters for boulder clearance in the Hornsea Three array area.

Parameter	Maximum value
Array cable clearance corridor width – SCAR RCS (m)	15
Export and interconnector cable clearance corridor width – SCAR RCS (m)	25
Clearance corridor width – subsea grab (m)	Size of individual boulders within 15 m corridor[a]
Clearance impact area – Markham's Triangle [a,b] (m^2)	2,122,759
Total clearance impact area – SCAR RCS [c] (m^2)	8,910,000
Total clearance impact area – subsea grab [c] (m^2)	6,814,500

a While this is the clearance corridor for the subsea grab tool, individual boulders will be grabbed within the corridor. Thus the impact is in a much smaller area.

b For the purposes of this assessment, it is assumed that a maximum of 24% of the array infrastructure (i.e. foundation and cable infrastructure) could be placed in the part of the Hornsea Three array area which coincides with the Markham's Triangle rMCZ. This assumption is based on the maximum number of structures that could be placed within this part of the Hornsea Three array area, assuming a minimum spacing of 1 km between foundations (i.e. 76 foundations for turbines, substations and accommodation platforms, of a total 319 offshore structures).

c Total impact area for SCAR RCS and subsea grab are mutually exclusive.

3.6.2.26 For the Hornsea Three offshore cable corridor, boulder interpretation has been carried out to identify potential boulders that would require clearance. Assumptions on the tool required to clear these areas have been made taking this into consideration:

- Where a high density of boulders is seen, the expectation is that the SCAR RCS or similar system will be required to clear the cable installation corridor, where the size of the boulders is sufficiently small to be cleared by the tool (this is considered to present the maximum design scenario but in some scenarios a subsea grab may be used as explained in 3.6.2.20); and
- Where medium and low densities of boulders are seen, a subsea grab is expected to be employed (note that due to the wider clearance corridor required, it is thought to be unlikely that micrositing can be successfully carried out to avoid all boulders, even in the areas currently seen to have a relatively lower density of boulders >1 m).

3.6.2.27 The maximum design scenario has been calculated based on the methodology above for boulder clearance in the Hornsea Three offshore cable corridor and this is presented in Table 3.3 below.

Table 3.3: Maximum design parameters for boulder clearance in the Hornsea Three offshore cable corridor.

Parameter	Maximum value
Clearance corridor width – SCAR RCS (m)	25
Clearance corridor width – subsea grab (m)	Size of individual boulders within 15 m corridor
Clearance impact area – Cromer Shoal Chalk Beds MCZ – subsea grab only(m^2)	176,900
Clearance impact area – North Norfolk Sandbanks and Saturn Reef SAC - subsea grab (m^2)	3,638,200
Clearance impact area The Wash and North Norfolk Coast SAC - subsea grab (m^2)	1,632,000
Clearance impact area – North Norfolk Sandbanks and Saturn Reef SAC – SCAR RCS (m^2)	3,327,900
Total clearance impact area – SCAR RCS (m^2)	16,565,100
Total clearance impact area – subsea grab (m^2)	14,017,000

Pre-lay Grapnel Run

3.6.2.28 Following the pre-construction route survey (paragraph 3.6.2.2 *et seq*.) and clearance works (paragraph 3.6.2.5 *et seq*.), it is likely that a Pre-Lay Grapnel Run (PLGR) and an associated route clearance survey of the final cable route will be undertaken. A multi-purpose vessel will be mobilised with a series of grapnels, chains, recovery winch and survey spread suitable for vessel positioning and data logging.

3.6.2.29 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 Three (see volume 5, annex 9.2: Outline Written Scheme of Investigation) .

3.6.2.30 If the final route of the offshore cables crosses any out of service cables, these will be recovered to a vessel deck, where one end will be cut, in order to pull the cable past the crossing point. The cable will then be cut, and pulled to the surface where it will be removed from site by the vessel. Any out of service cable removal will be carried out in consultation with the asset owner and in accordance with the International Cable Protection Committee (ICPC) guidelines (2011).

Sandwave Clearance

3.6.2.31 In some areas within the Hornsea Three array area and along the offshore 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 Three's project lifetime (35 years). 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.

Methodology

3.6.2.32 A sandwave clearance campaign will be completed approximately one year in advance of cable installation. If required, sandwave clearance will be completed in areas within within the Hornsea Three array area at turbine, substation and accommodation platform locations, and along the offshore cable corridor, including at the offshore HVAC booster stations.

3.6.2.33 In the Hornsea Three array area and offshore cable corridor geophysical survey data from site specific surveys were used to estimate the sandwave clearance volumes, assuming a disturbance width of 30 m per cable. However, the approach to estimating the required clearance differed between the Hornsea Three array area and the offshore cable corridor due to the certainty of encountering sandwave features. For example, sandwave features are often seen across the majority of the width of the Hornsea Three offshore cable corridor and therefore the chances of encountrering these are considered high. However, as the array and interconnector cable layout is unknown and will not be confirmed before detailed design, a different approach was taken to consider the chances of encountrering sandwaves within the Hornsea Three array area, as described in 3.6.2.35 below.

3.6.2.34 Within the Hornsea Three offshore cable corridor, sandwaves that were of sufficient height and formed with sufficient slope to be considered likely to require clearance have been identified based on the offshore export cable installation technique to be employed (see section 3.6.10) and sandwave clearance experience within Ørsted. The maximum design scenario for sandwave clearance in the Hornsea Three offshore cable corridor is summarised in Table 3.4 below.

3.6.2.35 Within the Hornsea Three array area, bathymetry data were used to identify sandwaves and it was determined that up to 60% of the array, interconnector and export cables within the Hornsea Three array area would require sandwave clearance. The maximum design scenario for sandwave clearance in the Hornsea Three array area is summarised in Table 3.5 below.

3.6.2.36 In addition to sandwave clearance, pre-trenching and pre-sweeping may be required to prepare the site for cable installation. This is described as part of cable installation in section 3.6.10 below.

Seabed preparation for foundations

Methodology

3.6.2.37 Some form of seabed preparation may be required for each foundation type. 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.

3.6.2.38 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. UXO, boulder and sandwave clearance for foundations are discussed earlier in this section.

3.6.2.39 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. Gravel volumes, where required, are provided in Table 3.10 to Table 3.15.

Table 3.4: Maximum design parameters for sandwave clearance in the Hornsea Three offshore cable corridor.

Parameter	Maximum design parameters
Sandwave clearance impact width (m)	30
Length of export cables affected by sandwaves – within Cromer Shoal Chalk Beds MCZ (km)	1
Length of export cables affected by sandwaves – within The Wash and North Norfolk Coast SAC (km)	11
Length of export cables affected by sandwaves – within North Norfolk Sandbanks and Saturn Reef SAC (km)	32
Length of export cables affected by sandwaves – outside designated sites (km)	58
Length of export cables affected by sandwaves – Total in the offshore export cable corridor (km)	102
Sandwave clearance – within Cromer Shoal Chalk Beds MCZ (m^3)	1,329
Sandwave clearance – within The Wash and North Norfolk Coast SAC (m^3)	132,737
Sandwave clearance – within North Norfolk Sandbanks and Saturn Reef SAC (m^3)	619,689
Sandwave clearance – outside designated sites (m^3)	449,202
Sandwave clearance – total (m^3)	1,202,956

Table 3.5: Maximum design parameters for sandwave clearance in the Hornsea Three array area.

Parameter	Maximum design parameters
Sandwave clearance impact width – array, interconnector and export cables (m)	30
Length of array cables affected by sandwaves (km)	498
Sand-wave clearance: Array cables (m^3)	52,031
Sand-wave clearance: Export cable (Within Array Area Only) Total (m^3)	1,755
Sand-wave clearance: Interconnector cables (m^3)	14,105
Sand-wave clearance: Foundations (m^3)	3,260
Sand-wave clearance: Total in Markham's Triangle (export cables, array cables, interconnector cables, foundations) (m^3)	7,471
Sand-wave clearance: Total in array area (export cables, array cables, interconnector cables, foundations) (m^3)	71,150

3.6.3 Turbines

Design

3.6.3.1 Hornsea Three requires flexibility in wind turbine choice to ensure that anticipated changes in available technology and project economics can be accommodated within the Hornsea Three design. The Design Envelope therefore sets maximum and, where relevant, minimum design scenario parameters against which likely significant environmental effects have been assessed. It is possible that more than one turbine type may be selected to be used within the Hornsea Three array area.

3.6.3.2 Hornsea Three may construct up to 300 turbines. A range of turbine models will be considered; however, they are likely to all follow the traditional offshore wind turbine 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. An illustration of this design can be seen in Figure 3.7 and a picture of a turbine at Walney offshore wind farm is shown in Figure 3.8 below.

3.6.3.3 The maximum design scenario for turbines describes two scenarios that represent the extents of the Design Envelope; scenario one comprising maximum number of smallest turbines, and scenario two comprising maximum number of largest turbines. The most numerous turbine scenario has a maximum of 300 turbines. The maximum size turbine has a rotor diameter of 265 m and a maximum blade tip height of 325 m relative to LAT (highest point of the structure). The minimum distance between the bottom of the blade and the water surface will be 34.97 m LAT for both the smallest and largest turbine scenario. All turbines will be marked for aviation and navigation purposes.

3.6.3.4 The maximum design scenario for the Hornsea Three turbines is shown in Table 3.6.

Access

3.6.3.5 The turbines 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.

Oils and fluids

3.6.3.6 Table 3.7 shows maximum requirements for oils and fluids in a single offshore wind turbine. Each turbine will contain components that require lubricating oils, hydraulic oils and coolants for operation (not including any other infrastructure sited on a transition piece for which values will not exceed the totals in Table 3.7 across the Hornsea Three array area).

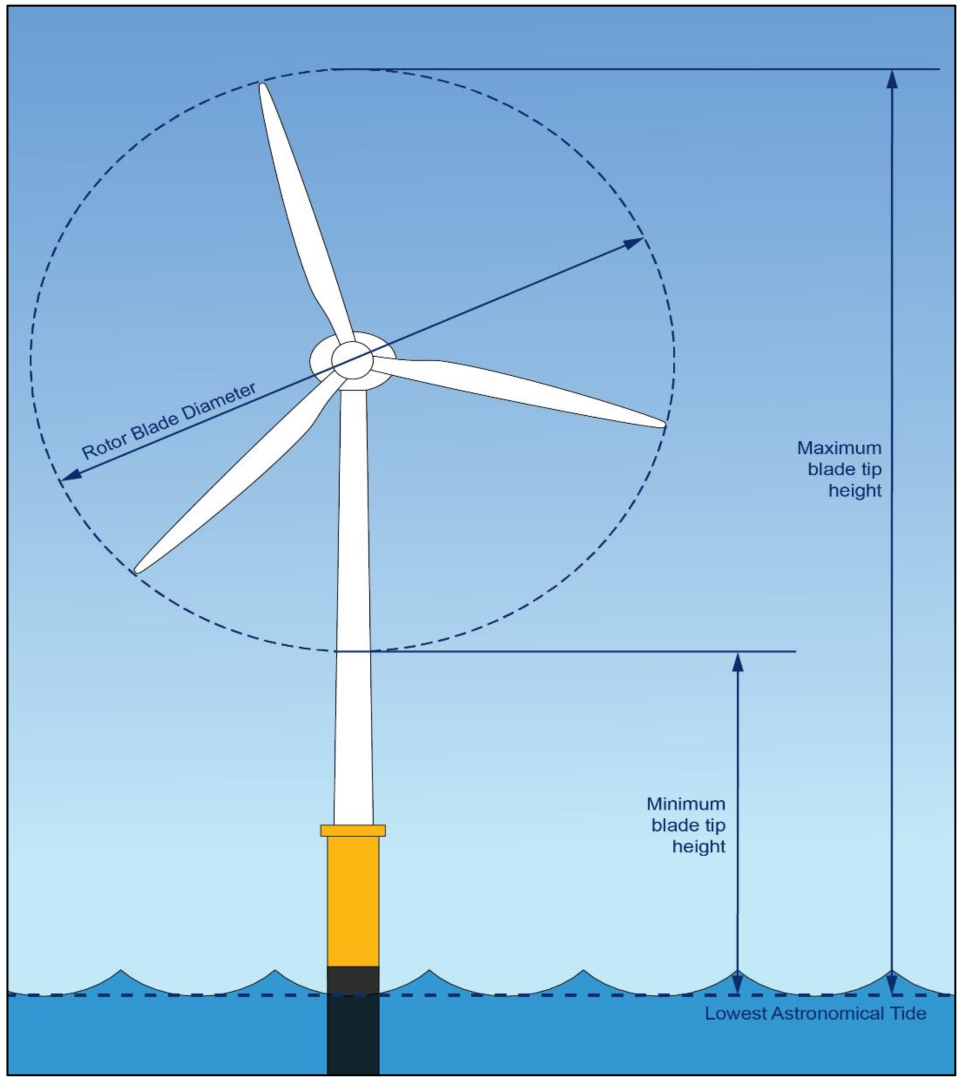


Figure 3.7: Schematic of an offshore wind turbine.

Table 3.6: Maximum design scenario: turbines.

Parameter	Maximum design scenario – Most Numerous Turbine	Maximum design scenario– Largest Turbine
Number of turbines	300	160
Minimum height of lowest blade tip above LAT (m)	34.97	34.97
Maximum blade tip height above LAT (m)	250	325
Maximum rotor blade diameter (m)	195	265

Figure 3.8: Turbines at Walney offshore wind farm.

Table 3.7: Maximum design parameters for turbine oils and fluids for a single turbine.

Parameter	Maximum design parameters
Grease (l)	1,300
Hydraulic oil (l)	20,000
Gear oil (l)	2,000
Total lubricants (l)	~25,000
Nitrogen (l)	80,000
Transformer silicon/ester oil (l/kg)	7,000
Diesel Fuel (l)	2,000
SF6 (kg)	6
Glycol / Coolants (l)	13,000

Control systems

3.6.3.7 Turbines operate within a set wind speed range. At approximately 3 m/s the wind turbine will start to generate electricity and at around 15 m/s they will reach maximum output. At around 25 m/s the turbine output starts to reduce towards zero. This enables the turbine to shut down in high wind speeds to protect the turbine and foundation, whilst enabling a gradual ramp-down of the power output to support the operation of the National Grid.

3.6.3.8 Each turbine will have its own control system to carry out functions like yaw control and ramp down in high wind speeds. All the turbines are also connected to a central Supervisory Control and Data Acquisition (SCADA) system for control of the wind farm remotely. This allows functions such as remote turbine shutdown if faults occur. The SCADA system will communicate with the wind farm via fibre optic cables, microwave, or satellite links. Individual turbines can also be controlled manually from within the turbine nacelle or tower base in order to control the turbine for commissioning or maintenance activities.

Installation

3.6.3.9 Generally, turbines are installed using the following process:

- Turbine components are picked up from a port in the UK or Northern Europe by an installation vessel. This vessel will typically be a Jack-Up Vessel (JUV) to ensure a stable platform for installation vessels when on site. JUVs are assumed to have up to six legs with an area of 170 m^2 per foot. Generally, blades, nacelles, and towers for a number of turbines are loaded separately onto the vessel;
- The installation vessel will then transit to the Hornsea Three array area and the components will be lifted onto the existing foundation or foundation and transition piece, by the crane on the installation vessel. Each turbine 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 turbine type and installation contractor, and will be defined in the pre-construction phase after grant of consent; or
- Alternatively, the turbine 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.

3.6.3.10 The total duration of the installation campaign for turbines is expected to be a maximum of 30 months.

3.6.3.11 Each installation vessel or barge may be assisted by a range of support 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 windfarm as the installation vessels they are supporting.

3.6.3.12 For the purposes of the EIA, the assumptions in Table 3.8 have been made on the maximum number of vessels and the number of return trips to the Hornsea Three array area from port that are required throughout the turbine installation campaign.

Table 3.8: Wind turbine installation assumptions.

Vessel Type	Maximum number of vessels	Maximum number of return trips per vessel type
Installation vessel	4	300
Support vessels	24	1,800
Transport vessels	12	900
Helicopter support	-	225

3.6.4 Wind turbine and surface infrastructure layouts

3.6.4.1 Designing and optimising the layout of the turbines and other offshore surface infrastructure (offshore substations and offshore accommodation platforms) is a complex, iterative process taking into account a large number of inputs and constraints including;

- Site conditions:
  - Wind speed and direction;
  - Water depth;
  - Ground conditions;
  - Environmental constraints (anthropogenic and natural);
  - Seabed obstructions (e.g. wrecks, Unexploded ordinance (UXO), existing cables); and
  - Pre-determined boundaries (AfL area).
- Design considerations:
  - Turbine type;
  - Installation set-up;
  - Foundation design;
  - Electrical design; and
  - Operation and maintenance requirements.

3.6.4.2 The Hornsea Three layouts will be designed such that they comply with a series of principles as detailed in volume 4, annex 3.7: Layout Development Principles.

3.6.4.3 In order to inform the EIA, Hornsea Three has identified two indicative layout scenarios. The indicative layout scenarios have been used within the EIA where appropriate. Layout A (Figure 3.9) includes the maximum number of structures (300 turbines and 19 platforms (offshore accommodation and substations) within the Hornsea Three array area). It includes a dense border at an approximate spacing of 1 km and a single line of orientation inside the border. 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 in order to inform the maximum design scenario for the relevant assessment.

3.6.4.4 Layout B is shown in Figure 3.10. This layout shows an indicative scenario with larger turbines in one line of orientation, and hence greater spacing between turbine locations. The total number of locations in this layout is 179 (160 turbines and 19 platforms (offshore accommodation and substations)), the border spacing is approximately 5.6 km and the internal spacing is varied.

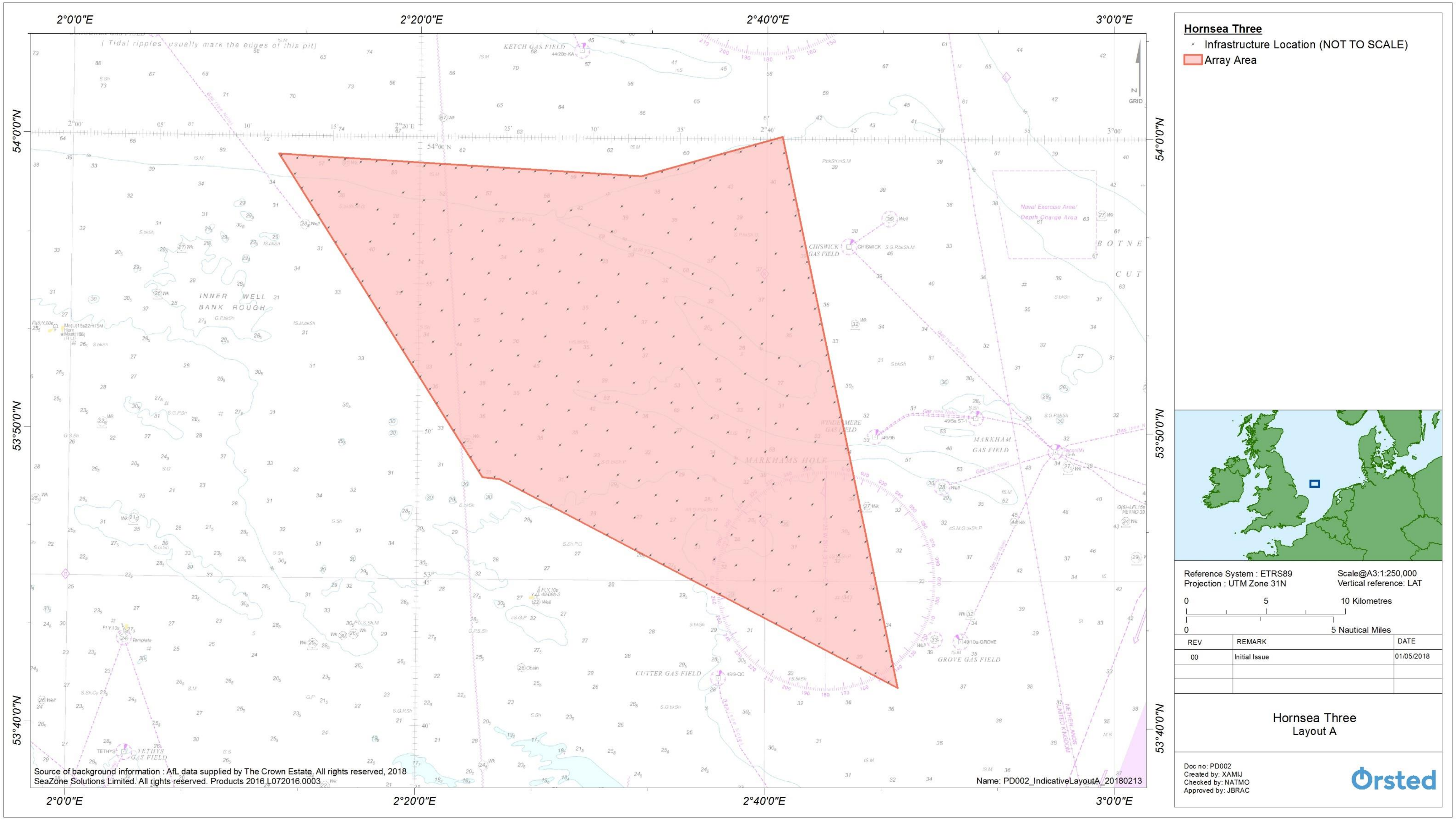


Figure 3.9: Indicative Layout A with 300 turbines and 19 platforms.

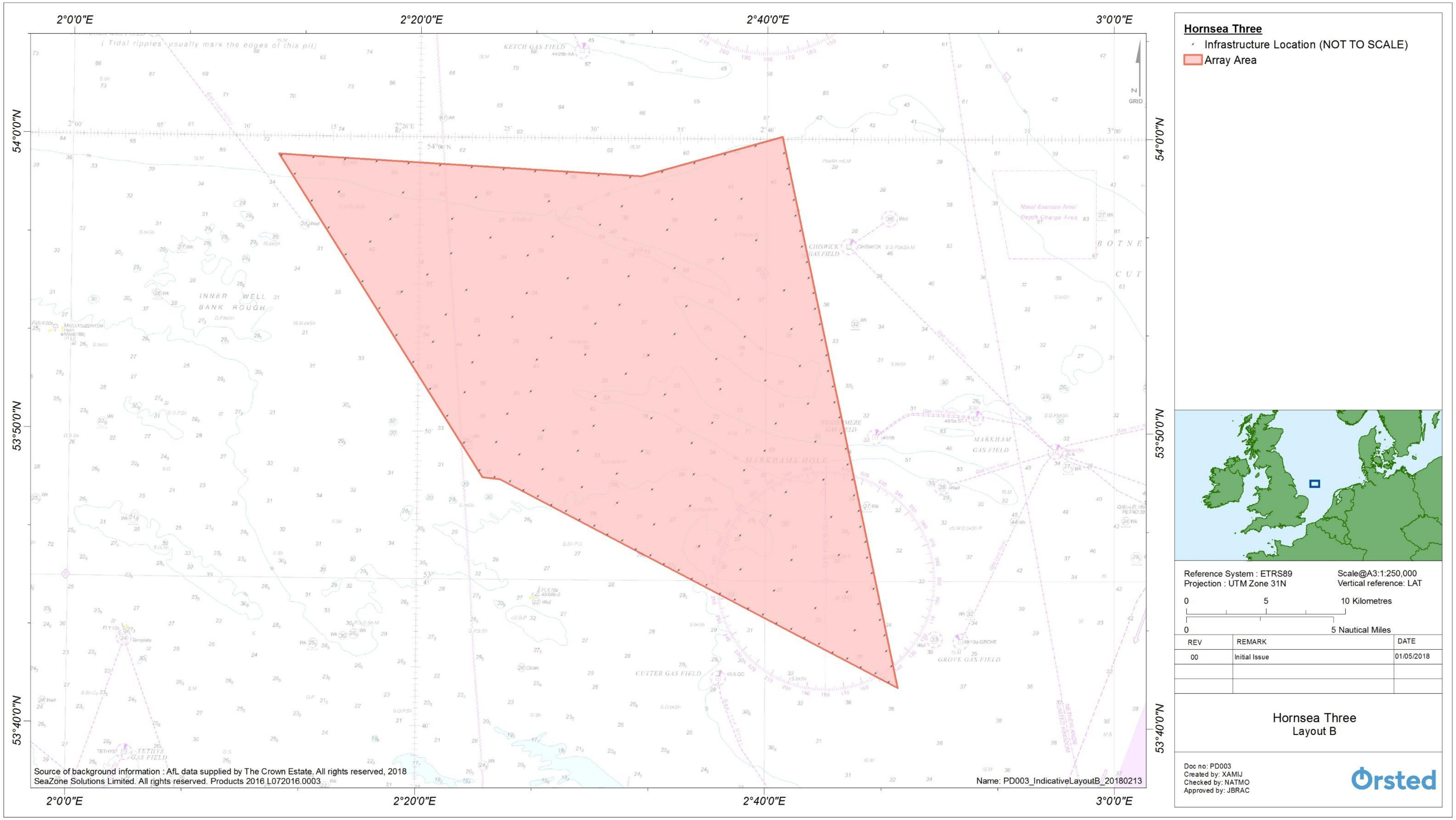


Figure 3.10: Indicative Layout B with 160 turbines and 19 platforms.

3.6.5 Foundations for turbines, offshore substations and offshore accommodation platforms

3.6.5.1 The turbines, offshore substation(s) and offshore accommodation platform(s) are attached to the seabed by foundation structures. There are several foundation types that are being considered for Hornsea Three. Hornsea Three requires flexibility in foundation choice to ensure that anticipated changes in available technology and project economics can be accommodated within the Hornsea Three design. The final selection will depend on factors including ground conditions, wave and tidal conditions, project economics and procurement approach. The range of foundation options to be used for turbines and each type of offshore substation can be seen in Table 3.9 below. As outlined in Table 3.9 below, the foundation types defined for turbines may also be used to support offshore substation structures or offshore accommodation platforms. There are also a range of foundation types that are only intended to be used for specific offshore substation types.

3.6.5.2 Each assessment within the Environmental Statement (volume 2, chapters 1 to 11 and volume 3, chapters 1 to 10) has considered the range of foundations options (including monopiles, suction bucket jacket foundations, piled jacket foundations, mono suction buckets and gravity base structures) and assessed the foundation type which presents the maximum design scenario for the relevant receptor(s).

3.6.5.3 The foundations will be fabricated offsite, stored at a suitable port facility and transported to site as needed (see paragraph 3.6.3.9 et seq.). Specialist vessels will be needed to transport and install foundations. A filter layer and/or scour protection layer (typically rock) may be needed on the seabed and will be installed before and/or after foundation installation (see paragraph 3.6.2.37 et seq.).

3.6.5.4 All floating foundation concepts proposed in the PEIR have been removed from the project envelope based on consultation responses received as part of Section 42 consultation on the PEIR. This will reduce impacts (from those presented in the PEIR) on a number of receptors including, but not limited to, those associated with the following chapters:

- Commercial Fisheries (volume 2, chapter 6: Commercial Fisheries); and
- Shipping and Navigation (volume 2, chapter 7: Shipping and Navigation).

3.6.5.5 The maximum design scenario for each of the foundation types in Table 3.9 are presented in Table 3.10 to Table 3.15 below.

3.6.5.6 Further details on the different foundation types are described in the following sections.

Table 3.9: Foundation options for turbines and offshore structures.

	Turbine	Offshore transformer substation	Offshore HVAC booster station[a]	Offshore HVDC converter substation/ Large offshore HVAC substation	Offshore accommodation platform
Maximum number of structures	300	12	4 [a] (6 subsea)	4 [b]	3
Monopile	Y	Y	Y	Y	Y
Mono suction bucket	Y	Y	Y	Y	Y
Piled jacket	Y	Y	Y	Y	Y
Suction bucket jacket	Y	Y	Y	Y	Y
Gravity base	Y	Y	Y	Y	Y
OSS suction bucket jacket	N	Y	Y	Y	Y
OSS piled jacket	N	Y	Y	Y	Y
Box-type gravity base	N	Y	Y	Y	N
Converter piled jacket	N	N	N	Y	N
Converter suction bucket jacket	N	N	N	Y	N
Pontoon GBS 1	N	N	N	Y	N
Pontoon GBS 2	N	N	N	Y	N
Table detailing maximum design parameters	Table 3.10	Table 3.11	Table 3.12 and Table 3.13	Table 3.14	Table 3.15

a Offshore HVAC booster station(s) will be placed along the Hornsea Three offshore cable corridor as described in section 3.6.9 below.

b 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 Three array area is therefore 319 (i.e. 300 turbines, three accommodation platforms, 12 offshore transformer substations and four offshore HVDC converter substations).

Table 3.10: Maximum design parameters for turbine foundations.

Turbine foundations	Maximum design parameters
Total number of structures	300
Seabed area – structure (m^2)	435,660
Seabed area – scour protection (m^2)	1,187,522
Seabed area – total (m^2)	1,623,182
Spoil volume (m^3)	1,225,692
Gravel bed volume (m^3)	919,269
Scour protection volume (m^3)	2,375,044
Pile-structure grout volume (m^3)	28,953
Structure-seabed grout volume (m^3)	217,830

Table 3.11: Maximum design parameters for offshore transformer substation foundations.

Offshore tranformer substation foundations	Maximum design parameters
Total number of structures	12
Seabed area – structure (m^2)	67,500
Seabed area – scour protection (m^2)	91,200
Seabed area – total (m^2)	158,700
Spoil volume (m^3)	735,000
Gravel bed volume (m^3)	551,250
Scour protection volume (m^3)	182,400
Pile-structure grout volume (m^3)	13,029
Structure-seabed grout volume (m^3)	33,750

Table 3.12: Maximum design parameters for surface offshore HVAC booster station foundations.

Surface offshore HVAC booster station foundations	Maximum design parameters
Total number of structures	4
Seabed area – structure (m^2)	22,500
Seabed area – scour protection (m^2)	30,400
Seabed area – total (m^2)	52,900
Spoil volume (m^3)	245,000
Gravel bed volume (m^3)	183,750
Scour protection volume (m^3)	60,800
Pile-structure grout volume (m^3)	4,343
Structure-seabed grout volume (m^3)	11,250

Table 3.13: Maximum design parameters for subsea offshore HVAC booster station foundations.

Subsea offshore HVAC booster station foundations	Maximum design parameters
Total number of structures	6
Seabed area – structure (m^2)	15,000
Seabed area – scour protection (m^2)	33,600
Seabed area – total (m^2)	48,600
Spoil volume (m^3)	11,310

Table 3.14: Maximum design parameters for offshore HVDC collector substation foundations.

Offshore HVDC collector substation foundations	Maximum design parameters
Total number of structures	4
Seabed area – structure (m²)	71,400
Seabed area – scour protection (m²)	67,858
Seabed area – total (m²)	109,200
Spoil volume (m³)	193,962
Gravel bed volume (m³)	104,664
Scour protection volume (m³)	108,800
Pile-structure grout volume (m³)	10,830
Structure-seabed grout volume (m³)	35,700

Table 3.15: Maximum design parameters for offshore accommodation platform foundations.

Offshore accommodation platform foundations	Maximum design parameters
Total number of structures	3
Seabed area – structure (m²)	8,836
Seabed area – scour protection (m²)	21,715
Seabed area – total (m²)	28,628
Spoil volume (m³)	63,335
Gravel bed volume (m³)	13,151
Scour protection volume (m³)	43,429
Pile-structure grout volume (m³)	3,257
Structure-seabed grout volume (m³)	6,185

Foundations for turbines, offshore substations and offshore accommodation platforms

Monopile foundations

Design

3.6.5.7 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 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 (Figure 3.11). 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 3.16 below.

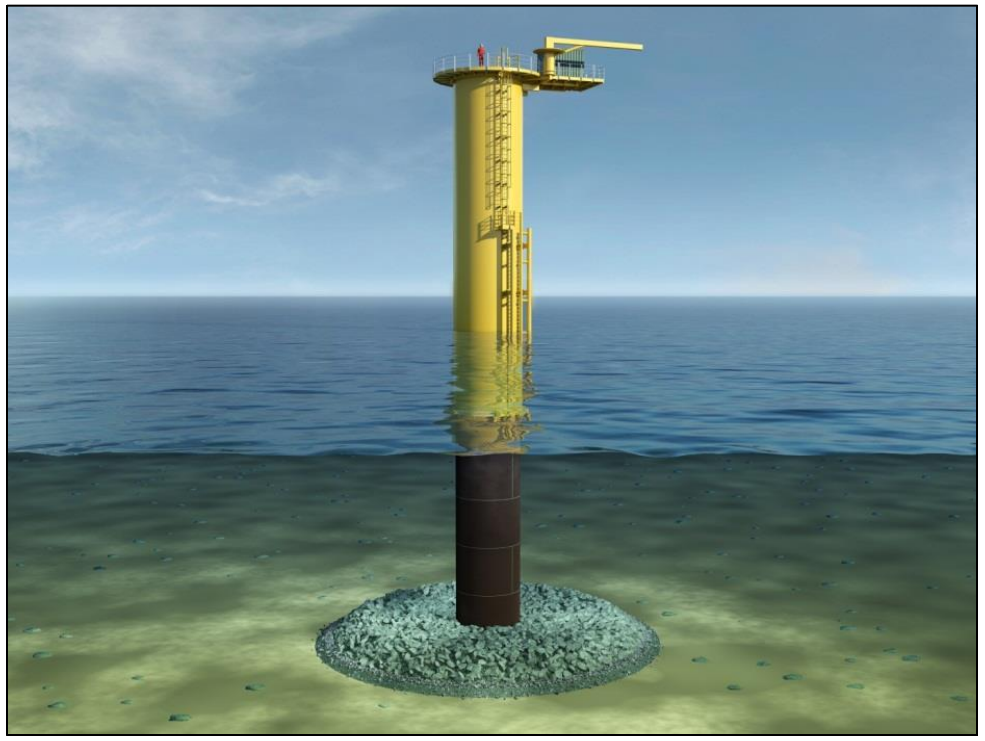


Figure 3.11: A monopile foundation and transition piece.

Table 3.16: Maximum design parameters for monopiles.

Parameter	Maximum design parameters
Diameter of monopile [a] (m)	15
Diameter of transition piece (m)	15
Typical embedment depth (below seabed) (m)	40
a	For largest proposed turbine (noting that for the maximum number of turbines, the largest maximum design monopile diameter will be smaller).

Installation

3.6.5.8 Monopiles and transition pieces will be transported to site either on the installation vessel (either JUV or Dynamic Positioning Vessel (DPV)), or on feeder barges, as described in paragraph 3.6.3.9 above. Monopiles can also be sealed and floated to site.

3.6.5.9 Once on site, the monopiles will be installed using the following process:

- 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 onto monopile using either grout or bolts.

3.6.5.10 The transition piece will either have a bolted or grouted connection 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. The grout will be pumped either from the installation vessel or a support vessel. This process is carefully controlled and monitored to ensure minimal grout is lost to the surrounding environment. The bolted solution will use bolts to connect the transition piece to the monopile in a similar manner to that used to connect the turbine and the transition piece.

3.6.5.11 Up to four installation vessels may be used, with up to two piling and two drilling simultaneously. The details for the vessels and numbers of trips required are presented in Table 3.17 below. Monopile installation may take up to 30 months in total for turbines.

3.6.5.12 Seabed preparations for monopile installation are 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 re-sited to avoid the obstruction. Site preparation activites are discussed in more detail in section 3.6.2 above.

3.6.5.13 The maximum design parameters for monopile foundations are presented in Table 3.10 above.

Table 3.17: Vessel and helicopter requirements for monopile, piled jacket, suction bucket jacket and mono suction bucket installation.

Vessel type	Maximum number of vessels	Maximum number of return trips per vessel type
Installation vessels	4	300
Support vessels	16	1,200
Transport vessels (barges)	10	150
Transport vessels (tugs)	30	450
Helicopter support	N/A	600

Piling and drilling

3.6.5.14 The modelled (noise) piling scenario (see volume 4, annex 3.1: Subsea Noise Technical Report) for monopiles and jacket pin piles assumes 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, with the longer times probably due to shorter runs and hence less opportunity for building up experience at the site. 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-finish hammer strike piling duration.

3.6.5.15 The maximum hammer energy for Hornsea Three 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 maximum hammer energy of 5,000 kJ is considered as the maximum design scenario, the actual energy used when piling will be significantly lower for the majority of the time and the driving energy will be raised to 5,000 kJ 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 (15% soft start of 750 kJ) and gradually increase to the maximum required installation energy during the piling of the final meters, which is typically significantly less than the maximum consented hammer energy.

3.6.5.16 After a review of construction logs and a preliminary analysis of ground conditions at the site, Hornsea Three currently expect the average hammer energy for monopiles across the entire construction programme to be less than 2,000 kJ (average hammer energy likely to be reached during piling) and the average maximum energy at each position (highest energy likely to be reached during piling events) to be on average less than 3,500 kJ.

3.6.5.17 The larger maximum hammer energy will not change this and indeed may allow these values to be reduced. Other reasons why larger 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 the majority 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 Three. A characteristic three hour monopile piling scenario with maximum durations for each energy level is provided in Table 3.18.

Table 3.18: Piling scenario for monopile installation using a maximum hammer energy of 5,000 kJ.

Hammer Energy	Piling Duration – Monopiles (minutes)
<750 kJ	0:45
750 – 1,500 kJ	0:45
1,500 – 2,000 kJ	0:30
2,000 – 2,500 kJ	0:20
2,500 – 3,000 kJ	0:10
3,000 – 3,500 kJ	0:10
3,500 – 4,000 kJ	0:10
4,000 – 4,500 kJ	0:05
4,500 – 5,000 kJ	0:05

3.6.5.18 If percussive piling installation is not possible due to the presence of rock or hard soils, the material inside the monopile may be drilled out before the monopile is driven to the required depth. This can either be done in advance of the driving or if the piling rate slows significantly during piling, known as refusal. If drilling is required, spoil arising from the drilling will be disposed of adjacent to the foundation location above the sea surface. Total wind farm spoil volume is given in Table 3.10 above.

3.6.5.19 It may also be possible that the piles are installed via another novel method such as vibropiling, where 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.

Piled jacket foundations

Design

3.6.5.20 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. The piles rely on the frictional and end bearing properties of the seabed for support. Unlike monopiles, there is no separate transition piece. The transition piece and ancillary structure is fabricated as an integrated part of the jacket. Pin piles will typically be narrower than monopiles.

3.6.5.21 The maximum design scenario for jacket foundations with pin piles is shown in Table 3.19 below.

Table 3.19: Maximum design parameters for jacket foundations with pin piles.

Parameter	Maximum design parameters
Number of legs per turbine	4
Separation of adjacent legs at seabed level (m)	40
Separation of adjacent legs at LAT (m)	25
Height of platform above LAT (m)	40
Leg diameter (m)	4.6
Pin pile diameter (m)	4
Embedment depth (below seabed) (m)	55
Hammer energy (kJ)	2,500

Installation

3.6.5.22 The installation of piled jackets is similar to that of monopiles, with the structures transported to site by installation vessels or barges and lowered onto the seabed by the installation vessel.

3.6.5.23 The pin piles can be installed either before or after the jacket is lowered to the seabed. If before, a piling template will be placed on the seabed to guide the pile locations. This is usually a welded steel structure. The piles will then be installed through the template, and the jacket affixed to the piles after it has been lowered into position, either welded or swaged. If piles are installed after the jacket is lowered to the seabed, the piles will be installed through the jacket feet at the seabed, or through the legs of the jacket from the top of the structure. As the there is no separate transition piece, there is no requirement for installing an additional structure offshore.

3.6.5.24 The pin piles are driven, drilled or vibrated into the seabed, in a similar way to monopiles. However, as pin piles are smaller, the maximum hammer energy to be used would be 2,500 kJ. In accordance with the discussion on monopile installation in paragraphs 3.6.5.14 and 3.6.5.15, a review of construction logs and a preliminary analysis of ground conditions at the site, Hornsea Three currently expect the average hammer energy for pinpiles across the entire construction programme to be less than 1,250 kJ (average hammer energy likely to be reached during piling) and the maximum energy at each position (i.e. for the final few meters) to be on average less than 1,750 kJ (highest energy likely to be reached during piling events). There would be no more than two piles being driven simultaneously, and eight piles being drilled simultaneously across the Hornsea Three array area. The maximum duration for turbine foundation installation across the Hornsea Three array area would be 30 months.

3.6.5.25 The vessel movements for the installation would be as for monopile foundations, as described in Table 3.17 above.

3.6.5.26 The seabed preparation would be as for the monopile foundations (paragraph 3.6.5.13). The maximum design parameters for which are presented in Table 3.10.

Suction bucket jacket foundations

Design

3.6.5.27 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 in a horizontal position underneath the legs of the jacket structure. They do not require a hammer or drill for installation. Unlike monopiles, but similarly to piled jacket foundations, there is no separate transition piece. The transition piece and ancillary structure is fabricated as an integrated part of the jacket structure and is not installed separately offshore. An example of a suction bucket jacket is shown in Figure 3.12.

3.6.5.28 The maximum design parameters for jacket foundations with suction bucketsare presented in Table 3.20.

Installation

3.6.5.29 Once at site, the jacket foundation will be lifted by the installation vessel using a crane, and lowered towards the seabed in a controlled manner (see Figure 3.12). When the steel caisson reaches the seabed, a pipe running up through the stem above each caisson will begin to suck water out of each bucket. The buckets are pressed down into the seabed by the resulting suction force. When the bucket has penetrated the seabed to the desired depth, the pump is turned off. A thin layer of grout is then injected under the bucket to fill the air gap and ensure contact between the soil within the bucket, and the top of the bucket itself. As the there is no separate transition piece, there is no requirement for installing an additional structure offshore.

3.6.5.30 The vessel movements for the installation would be as for the monopile foundations, as described in Table 3.17.

Figure 3.12: A jacket foundation with suction buckets being installed at the Borkum Riffgrund One offshore wind farm.

Table 3.20: Maximum design parameters for jacket foundations with suction buckets.

Parameter	Maximum design parameters
Number of legs per turbine	4
Suction bucket diameter (m)	20
Suction bucket penetration (m)	20
Suction bucket height above seabed (m)	5
Separation of adjacent legs at seabed level (m)	40
Separation of adjacent legs at LAT (m)	25
Height of platform above LAT (m)	40

3.6.5.31 As well as the boulder and obstruction removal that is described in the monopile section (paragraph 3.6.5.13), the suction bucket jackets may also require some seabed levelling, to ensure that all of the buckets for each structure can be placed at the same level, and that there is level ground beneath them to form a sealed chamber within the bucket once the foundation has been lowered to the seabed. The seabed levelling would likely be carried out by a dredging vessel using a suction hopper, and depositing the dredged material adjacent to the foundation location at site. Site preparation activities are described in section 3.6.2 above. The total Hornsea Three array area spoil requirements are presnted in Table 3.10 to Table 3.15 above. A Dredging and Disposal Site Characterisation for the disposal of seabed preparation material is presented in volume 4, annex 3.2.

Mono suction bucket foundations

Design

3.6.5.32 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 transition piece and ancillary structure is fabricated as an integrated part of the jacket structure and is not installed separately offshore.

3.6.5.33 The maximum design parameters for mono suction bucket foundations are presented in Table 3.21 below.

Table 3.21: Maximum design parameters for mono suction bucket.

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

Installation

3.6.5.34 The installation method is similar to that described for the suction bucket jackets in section 3.6.5.29 above, except only a single bucket needs to be installed in the seabed.

3.6.5.35 The vessel movements for the installation would be as for the monopile, as described in Table 3.17 above.

3.6.5.36 The seabed preparation would be as described for the suction bucket jacket. The total Hornsea Three array area spoil requirements are presented in Table 3.10 above.

Gravity base foundations

Design

3.6.5.37 Gravity base foundations are heavy steel, concrete, or steel and concrete structures, sometimes including additional ballast, that sit on the seabed to support the turbine tower (Figure 3.13). Gravity bases vary in shape, but are 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.

3.6.5.38 The maximum design parameters for gravity base foundations are presented in Table 3.22.

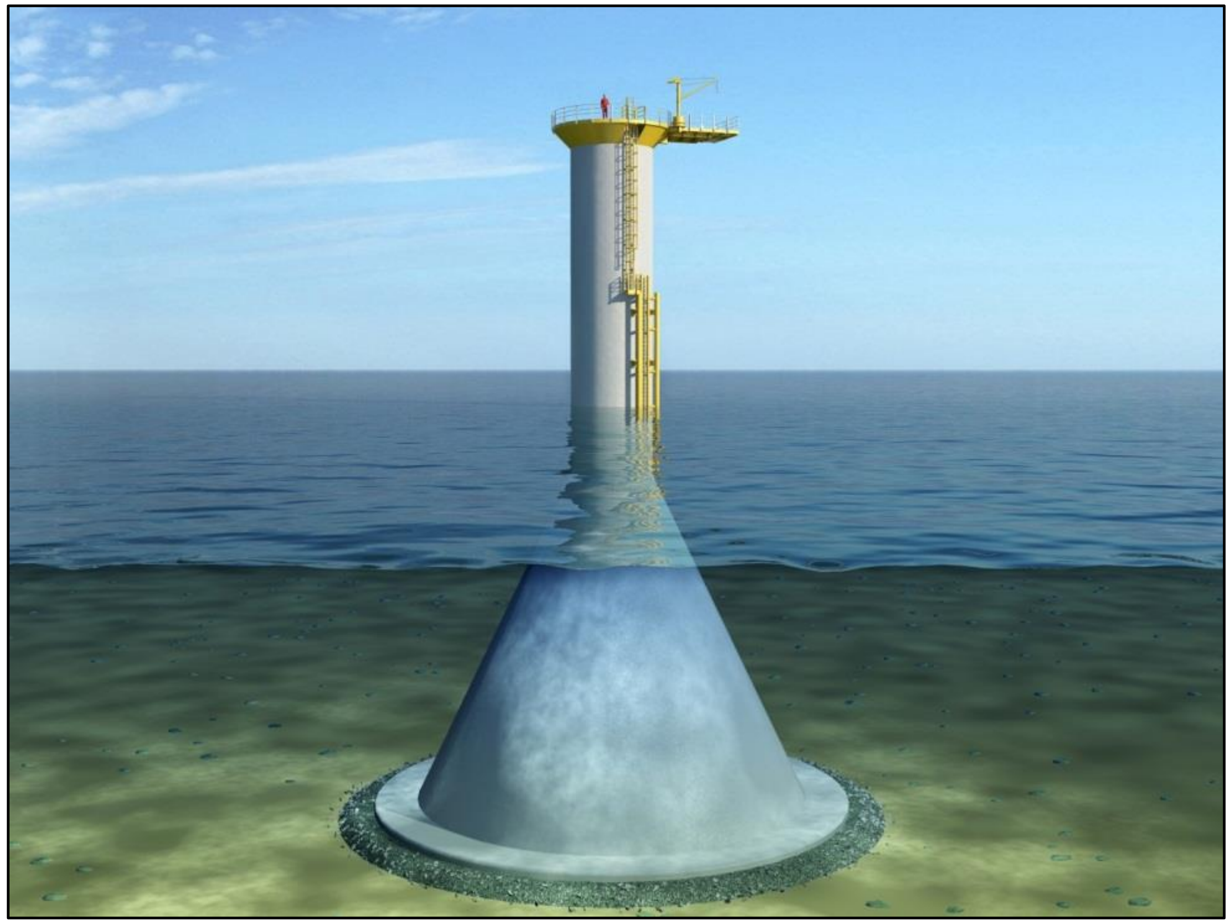


Figure 3.13: A gravity base foundation.

Table 3.22: Maximum design parameters for gravity base foundations.

Parameter	Maximum design parameters
External diameter at seabed (excluding scour protection) (m)	53
External diameter at LAT (m)	15
Seabed preparation diameter (m)	61
Scour protection diameter (m)	93

Installation

3.6.5.39 A gravity base does not require piling or drilling to remain in place. They can either be brought to site on barges or installation vessels as for the other foundation types, or alternatively they can be floated to site. This would be done by designing the structures to be buoyant, and towing them to site using tugs and support vessels. The foundations would then be lowered to the seabed in a controlled manner either by pumping in water, or installation of ballast (or both).

3.6.5.40 The vessel requirements for gravity base foundations are presented in Table 3.23 below.

Table 3.23: Vessel requirements for gravity base foundations for turbines if floated to site.

Vessel type	Maximum number of vessels	Maximum number of return trips per vessel type
Installation Vessels	3	300
Support Vessels	13	1,500
Dredging Vessels	12	1,200
Tug Vessels	4	1,200

3.6.5.41 The seabed preparation for gravity base foundations are as described for the suction bucket jacket foundations, and using the method described in paragraph 3.6.5.31. The total Hornsea Three array area spoil requirements are presented in Table 3.10.

Scour Protection

3.6.5.42 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 ('pre-installed') or afterwards ('post-installed'). 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.

3.6.5.43 The amount of scour protection required will vary for the different foundation types being considered for Hornsea Three. Flexibility in scour protection choice (rock armouring and use of mattresses) is required to ensure that anticipated changes in available technology and project economics can be accommodated within the Hornsea Three design. The final choice and detailed design of a scour protection solution for the wind farm will be made after detailed design of the foundation structure, taking into account a range of aspects including geotechnical data, meteorological and oceanographic data, water depth, foundation type, maintenance strategy and cost.

3.6.5.44 The maximum diameter of the rocks used would be 1 m and the maximum thickness of scour protection layer would be 2 m. The total Hornsea Three volume of scour protection material is presented in Table 3.10 above.

Foundation types for offshore substations and offshore accommodation platforms

3.6.5.45 Although all the foundation options available for turbines may also be used for OSS and OAP, there are some foundation designs that could be used for OSS and OAP but will not be used to support turbines. The descriptions of these foundations are outlined below.

OSS piled jacket

3.6.5.46 This foundation type is a larger variant of the piled jacket option to be used for turbines as described in section 3.6.5.20. These foundations 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 parameters for the OSS piled jacket foundation can be seen in Table 3.24 below. All other parameters are as described in section 3.6.5.20.

Table 3.24: Maximum design parameters for OSS piled jacket foundations.

Parameter	Maximum design parameters
Number of legs per jacket	6
Piles per leg	4
Separation of adjacent legs at seabed level (m)	70
Separation of adjacent legs at LAT (m)	70
Height of platform above LAT (m)	40
Leg diameter (m)	5
Pin pile diameter (m)	4
Pile height above seabed (m)	20
Mud-mats length and width [m]	10
Embedment depth (below seabed) (m)	70
Hammer energy (kJ)	2,500

OSS suction bucket jacket

3.6.5.47 This foundation type is a larger variant of the suction bucket jacket option to be used for turbines, as described in section 3.6.5.27 above. The parameters for the OSS suction bucket jacket foundation are presented in Table 3.25 below. All other parameters are as described in section 3.6.5.27 above.

Table 3.25: Maximum design parameters for OSS suction bucket jacket foundations.

Parameter	Maximum design parameters
Number of legs per platform	6
Suction bucket diameter (m)	25
Suction bucket penetration (m)	25
Separation of adjacent legs at seabed level (m)	70
Separation of adjacent legs at sea surface (m)	70
Height of platform above LAT (m)	40

Box type gravity base

3.6.5.48 This foundation type is a variant of the gravity base foundations, as described in section 3.6.5.37 above, however rather than having a circular base to support a single tower, this type of foundation has a square base that supports the steel or concrete supporting structure for the substation topsides. The parameters for the box type gravity base foundation are presented in Table 3.26 below. All other parameters are the same as for the gravity base as described in section 3.6.5.37 above. This foundation type will not be used for offshore accommodation platforms.

Table 3.26: Maximum design parameters for box type gravity base foundations.

Parameter	Maximum design parameters
Length and width at seabed level (m)	75
Length and width at LAT (m)	75
Seabed preparation buffer around base (m)	50
Seabed preparation buffer below base (m)	-1
Length & Width of seabed preparation area (m)	175

Foundation types for offshore HVDC converter stations.

3.6.5.49 Although all the foundation options available for turbines, offshore substations and offshore accommodation platforms may also be used for offshore HVDC converter substations, there are some foundation designs that could be used for offshore HVDC converter substations, but are not intended to be used for supporting other offshore infrastructure. The descriptions of these foundations are outlined below.

Converter piled jacket

3.6.5.50 This foundation type is a larger variant of the piled jacket option to be used for turbines, as described in section 3.6.5.20 above. The offshore HVDC converter stations could each be supported by four jacket structures, or a single larger jacket. The parameters for the converter piled jacket are presented in Table 3.27 below. All other parameters are as described in section 3.6.5.20 above.

Table 3.27: Maximum design parameters for converter piled jacket foundations.

Parameter	Maximum design parameters
Number of jackets per platform	4
Number of legs per platform	18
Piles per leg	4
Separation of adjacent legs at seabed level (m)	100
Separation of adjacent legs at LAT (m)	100
Pin pile diameter (m)	3.5
Pile penetration (m)	70
Mud-mats length and width (m)	20
Hammer energy (kJ)	2,500

Converter suction bucket jacket

3.6.5.51 This foundation type is a larger variant of the suction bucket jacket option to be used for turbines, as described in section 3.6.5.27 above. The parameters for the converter suction bucket jacket are presented in Table 3.28 below. All other parameters are as described in section 3.6.5.27 above.

Table 3.28: Maximum design parameters for converter suction bucket jacket foundations.

Parameter	Maximum design parameters
Number of jackets per platform	4
Number of legs (per jacket)	6
Suction bucket diameter (m)	20
Suction bucket penetration (m)	30

Pontoon gravity base – type 1

3.6.5.52 This foundation type is a variant of the gravity base foundation, as described in section 3.6.5.37 above, however rather than having a circular base to support a single tower, this type of foundation has up to three rectangular pontoons that support the steel or concrete supporting structure for the substation topside. The parameters for the pontoon gravity base – type 1 are presented in Table 3.29 below and an example of this design is shown in Figure 3.14. All other parameters are the same as for the gravity base foundations as described in section 3.6.5.37 above.

Table 3.29: Maximum design parameters for pontoon gravity base – type 1 foundations.

Parameter	Maximum design parameters
Number of pontoons per platform	3
Pontoon length (m)	170
Pontoon width (m)	35
Pontoon spacing (m)	36
Pontoon base width (m)	90

Pontoon gravity base – type 2

3.6.5.53 This foundation type is a variant of the gravity base foundations, as described in section 3.6.5.37 above, however rather than having a circular base to support a single tower, this type of foundation has a pontoon, arranged in a rectangle around an open centre, that supports the steel or concrete supporting structure for the substation topside. The parameters for the pontoon gravity base - type 2 are presented in Table 3.30 below. All other parameters are the same as for the gravity base foundations as described in section 3.6.5.37 above.

Scour protection for foundations

3.6.5.54 Scour protection is designed to prevent foundation structures for turbines, offshore substations and offshore accommodation platforms, 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 artificial seaweeds. However, the placement of large quantities of crushed rock around the base of the foundation structure is the most frequently used solution ('rock placement').

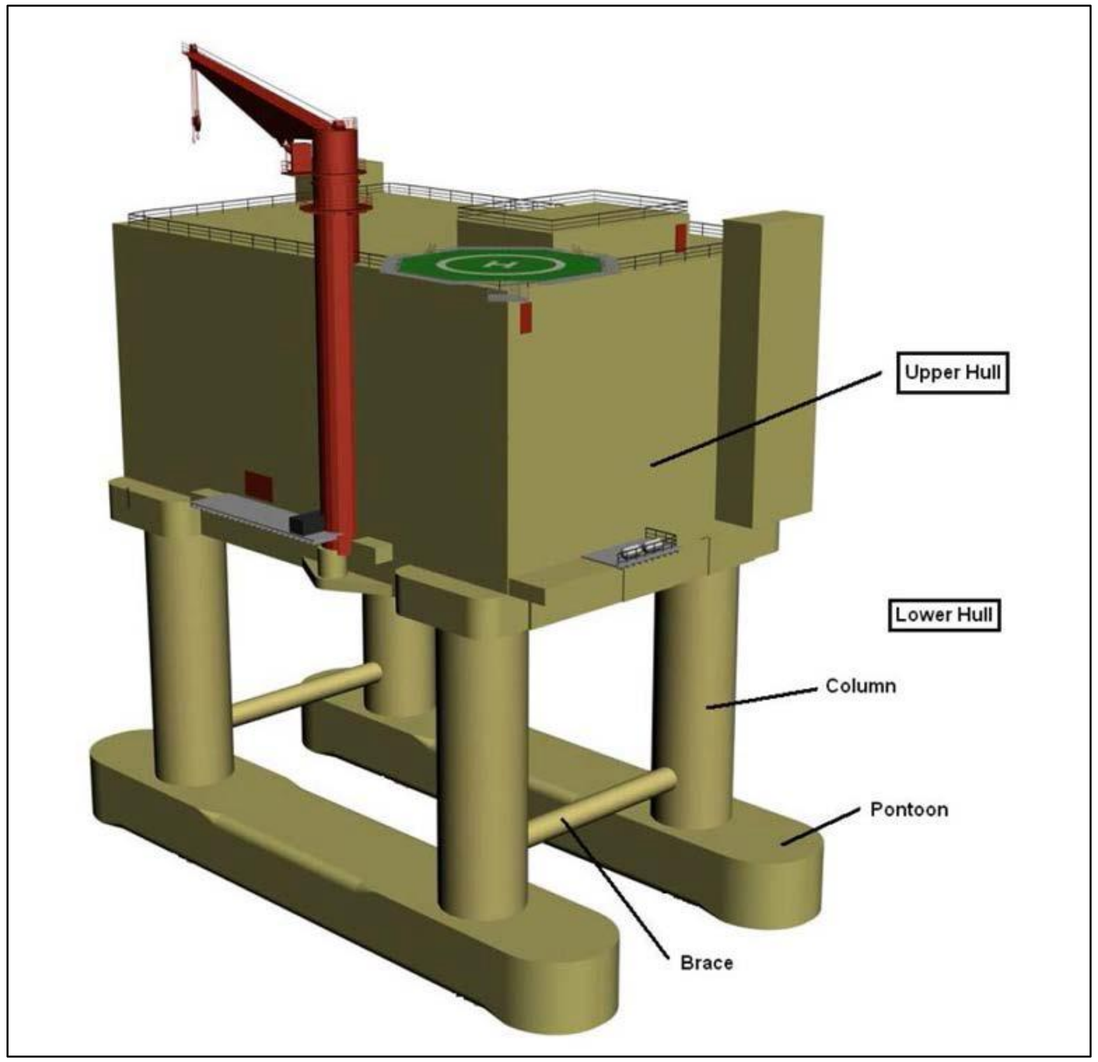


Figure 3.14: An example of a converter substation design supported by a pontoon gravity base – type 1[1] foundation.

Table 3.30: Maximum design parameters for pontoon gravity base – type 2 foundations.

Parameter	Maximum design parameters
Number of pontoons per platform	1
Pontoon length (m)	120
Pontoon width (m)	35

3.6.6 Array cables

3.6.6.1 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.

3.6.6.2 It is likely 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 or low frequency HVAC array cable system.

Design

3.6.6.3 The array cables will consist of a number of 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.

3.6.6.4 The maximum design parameters for array cables are presented in Table 3.31 below.

Table 3.31: Maximum design parameters for array cables.

Parameter	Maximum design parameters
Cable diameter (mm)	200
Total length of cable (km)	830
Voltage (kV)	170

Installation

3.6.6.5 The 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) taking into account ground conditions as well as external aggressors to the cable such as trawling and vessel anchors. This depth will likely vary across the Hornsea Three array area. 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. Figure 3.15 shows an array cable being installed.

[1] Note that this example has two pontoons, rather than the maximum three.

Figure 3.15: Array cable installation at the Gode Wind offshore wind farm.

3.6.6.6 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 Three may also need to dredge the cable route prior to installation in order to level sandwaves that may hinder installation. This is discussed in section 3.6.2 above. 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, targeted to remove the material that has partially infilled the trench.

3.6.6.7 If the array cables must cross third party infrastructure, such as existing cables, both the third-party asset and the installed cable must be protected. This protection would usually consist of a rock berm on the existing cable (separation layer), as well as a second rock berm on the cable installed for Hornsea Three (protection layer). The detailed design of the crossing would be decided in a crossing agreement developed by both parties.

3.6.6.8 Array cables will need to be made secure where the route crosses obstacles such as exposed bedrock, pre-existing cables or pipelines that mean the cable cannot be buried. This is typically achieved through some form of armouring (rock, mattress or proprietary separation layer) to maintain the integrity of the cable. Up to 10% of the total array cable length may require protection due to ground conditions (this excludes cable protection due to cable crossings). Up to 10% of the array cable within the Markham's Traingle rMCZ may include cable protection.

3.6.6.9 Cable protection will be required at cable crossings, as well as in parts of the array area where cable burial is not possible. Cable protection methods include rock placement (rock protection), concrete mattresses, fronded mattresses, rock bags, and seabed spacers among others. These are described below.

Rock Placement

3.6.6.10 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.

3.6.6.11 This rock grading generally has mean rock size in the range of 90 to 125 mm (1-3 kg) and maximum rock up to 250 mm (25 kg). The rocks generally form a trapezium shape, up to approximately 1 m above the seabed with a 3:1 gradient. 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.

3.6.6.12 Concrete mattresses will not be used as a method of cable protection in the environmentally designated sites except where required for crossing existing assets.

Mattress Placement

3.6.6.13 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 Placement

3.6.6.14 Frond mattresses are installed following the same procedure as general mattress placement operations. The fronds floating in the water column, however, can impede the correct placement of additional mattresses. The fronds are designed with the aim to form protective, localised sand berms.

Rock Bags

3.6.6.15 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

3.6.6.16 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.

3.6.6.17 The maximum design parameters for array cable installation are presented in Table 3.32 below.

Table 3.32: Maximum design parameters for array cable installation.

Parameter	Maximum design parameters
Installation methodology	Trenching, dredging, jetting, ploughing, mass flow excavation, vertical injection, rock cutting
Burial depth	Typically 1 to 2 m. Dependent on CBRA [a]
Width of seabed affected by installation (m)	15
Total seabed disturbed (km^2)	12.5
Seabed disturbance (m^2)	12,450,000
Burial spoil: ploughing/mass flow excavation (m^3)	4,980,000
Duration: per array link (days)	3
Duration: total (months)	30
a Typically the cable will be buried between 1 to 2 m, but in some areas could be buried up to 3 m. 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.	

3.6.6.18 Table 3.33 shows the details for the rock placement required for array cables and Table 3.34 shows the envelope for vessel movements associated with array cable installation.

Table 3.33: Maximum design parameters for array cable installation – rock placement.

Parameter	Maximum design parameters
Height of rock berm (m)	2
Width of rock berm (m)	7
Percentage of route requiring protection	10
Replenishment during operations (% of construction total)	25
Cable rock protection: maximum rock size (m)	1, 0.25 in the Cromer Shoal Chalk Beds MCZ
Rock protection area (m^2)	581,000
Rock protection volume (m^3)	830,000
Number of crossings (estimate)[a]	35
Cable/pipe crossings: total impacted area (m^2) [a]	87,500
Cable/pipe crossings: pre-lay rock berm volume (m^3) [a]	21,875
Cable/pipe crossings: post-lay rock berm volume (m^3) [a]	70,000
a Crossings include crossings for interconnector cables.	

Table 3.34: Maximum design parameters for array cable installation vessel and helicopter requirements.

Parameter	Maximum design parameters
Main laying vessels	3
Main burial vessels	3
Support vessels: crew boats or SOVs	4
Support vessels: service vessel for pre-rigging of towers	2
Support vessels: diver vessels	2
Support vessels: vessels for PLGR	2
Support vessels: dredging vessels	2
Main laying vessels (return trips)	315
Main burial vessels (return trips)	315
Support vessels (return trips)	1,890
Helicopter support – construction (return trips)	600

3.6.7 Offshore accommodation platforms

3.6.7.1 Hornsea Three may construct up to three offshore accommodation platforms to allow up to 150 operations staff to be housed at the Hornsea Three array area for a number of weeks at a time, and to allow spares and tools to be stored at the Hornsea Three array area. This aim being to reduce trips to the Hornsea Three array area and time spent in transit, in order to decrease down time for faults and repairs. The offshore accommodation platforms would be accessed by vessel and/or helicopter, and may have associated captive vessels to access the turbines and substations. An example of an offshore accommodation platform can be seen in Figure 3.16 below.

Figure 3.16: Offshore accommodation platform (right) at the Horns Rev 2 offshore wind farm, sited next to an offshore substation (left)[2].

3.6.7.2 Hornsea Three requires flexibility in location and foundation choice to ensure that anticipated changes in available technology and project economics can be accommodated within the Hornsea Three design, however the accommodation platforms will be located within the Hornsea Three array area.

3.6.7.3 Offshore accommodation platforms comprise of a platform with one or more decks, and helicopter platform, attached to the seabed by means of a foundation, containing accommodation, storage, workshop and logistic facilities for operating and maintaining the wind turbine generators and housing auxiliary equipment and facilities for operating, maintaining, controlling the substation and to access the substation by vessels and helicopters.

Design

3.6.7.4 The maximum design parameters for offshore accommodation platforms are presented in Table 3.35 and Table 3.36 below. The offshore accommodation platforms may also be co-sited with offshore substations, including bridge access (bridge link) between the two platforms. The offshore accommodation platforms would use the same substructure and foundation concepts as the turbines and offshore substations (excluding box type gravity base foundations) as described in section 3.6.5 above.

Table 3.35: Maximum design parameters for offshore accommodation platforms.

Parameter	Maximum design parameters
Number	3
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
Foundation type	As for turbines or offshore substations (excluding box type gravity base).
Installation	As for offshore substations in section 3.6.9

Table 3.36: Maximum design parameters for offshore accommodation platforms – chemicals.

Parameter	Maximum design parameters
Chemicals: coolant (per platform) (l)	10,000
Chemicals: hydraulic oil (per platform) (l)	10,000
Chemicals: lubricates (per platform) (kg)	3,500
Chemicals: heli fuel (across wind farm) (l)	255,000
Chemicals: vessel fuel (per platform) (l)	210,000

Installation

3.6.7.5 The installation procedure would be as described for the offshore transformer substations in paragraph 3.6.9.12 above.

[2] Note - the offshore accommodation platform is supported by a monopile foundation, and the offshore substation by a jacket foundation.

3.6.8 Transmission system

3.6.8.1 The wind farm transmission system is used to transport the power produced at the turbines and delivered by the array cables, to the UK National Grid. The system transforms the Medium Voltage (MV) power produced at the turbines to HV at the offshore transformer substations (located in the Hornsea Three array area), and transports this via export cables and a number of other offshore and onshore components (see paragraph 3.6.8.4 below). The transmission system is usually designed, paid for and constructed by the wind farm developer (Ørsted in the case of Hornsea Three), but must be purchased by an Offshore Transmission Operator (OFTO) after the wind farm is constructed in a transaction overseen by the Office of Gas and Electricity Markets (Ofgem). It is also possible that the transmission asset may be designed, procured and installed by the OFTO, however the design and installation parameters would still be as consented through this application.

Project capacity

3.6.8.2 Hornsea Three will have a capacity of approximately 2.4 GW. The total capacity of the turbines themselves may exceed 2.4 GW in order to compensate for electrical losses, as well as for turbine shut down for maintenance. However, the total number and dimensions of turbines (as well as the other maximum design parameters presented within this chapter) would not exceed that stated within this chapter. Hornsea Three may be built in one or two phases (see section 3.8 below for details). The phases may be constructed either separately or together and may be the same or different in capacity (see section 3.8 below for further details).

HVAC/HVDC transmission systems

3.6.8.3 There are a range of transmission system designs that can be used to transport the power from the Hornsea Three array area to the UK National Grid. These fall under two primary transmission types defined by how the current is delivered to the export cables; HVAC or HVDC. Both transmission types have a range of relative benefits and drawbacks. Offshore wind farms have traditionally used HVAC connections; however, HVDC connections are becoming more technically and/or economically viable in the context of far from shore projects and are used on a number of projects in Germany. Hornsea Three requires flexibility in transmission system choice to ensure that anticipated changes in available technology and project economics can be accommodated within the Hornsea Three design, and will make a decision on which transmission type to use during the detailed design phase (post consent).

3.6.8.4 An overview of the differences between the component requirements of the two technologies are outlined in Table 3.37 below.

Table 3.37: Infrastructure required for High Voltage Alternating Current (HVAC) and High Voltage Direct Current (HVDC) systems.

Component	HVAC	HVDC	Comment
Offshore transformer substation	Y	M	HVDC: may be combined with converter substation
Offshore interconnector cable	M	M	Interconnector cables may be required between offshore substations.
Offshore HVDC converter substation	N	Y	-
Offshore export cable	Y	Y	-
Offshore HVAC booster station(s)	M	N	HVAC: onshore and/or offshore HVAC booster station required.
Onshore HVAC booster station	M	N	
Onshore export cable	Y	Y	-
Onshore HVDC converter/HVAC substation	Y	Y	HVDC systems require larger onshore converter substations for conversion to HVAC.
Grid connection export cable	Y	Y	-
Table Key	*Required (Y)*	*May be required (M)*	*Not required (N)*

Circuit description

3.6.8.5 A circuit is an electrical system that allows the flow of electrons from one location to another. Typical HVAC transmission systems are three phase designs and require three conductors per electrical circuit to transport the power. Offshore these three conductors are usually combined into a single cable. Onshore these three conductors are usually housed within one cable per conductor (i.e. three cables per circuit) (Table 3.38).

Table 3.38: Cables required per circuit.[3]

	HVAC	HVDC
Offshore cables/circuit	1	2 [a]
Onshore cables/circuit	3	2

a Two HVDC offshore cables may be bundled together and installed simultaneously.

3.6.8.6 HVDC transmission systems are typically symmetrical monopoles, but they may also be Bi-Pole designs and therefore require up to two conductors per circuit to transport the power. Offshore, these are generally housed in separate cables but these cables may be installed together. Onshore these conductors are housed in separate cables (Table 3.38).

[3] Irrespective of the electrical system chosen (AC or DC) the total number of export cables will not exceed six offshore and 18 onshore.

3.6.9 Offshore substations

3.6.9.1 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. All offshore substations will be marked, as with the turbines, for aviation and navigation purposes (see paragraph 3.6.9.29 below). The exact substation locations will be determined during the design phase (typically post consent), taking account of ground conditions and the most efficient cable routing amongst other considerations. Offshore substations will not be manned but once functional will be subject to periodic operational and maintenance visits by staff by helicopter, by vessel or from a nearby accommodation platform.

3.6.9.2 Hornsea Three requires flexibility in location and foundation choice of offshore transformer substation (see 3.6.5 above) to ensure that anticipated changes in available technology and project economics can be accommodated within the Hornsea Three design.

3.6.9.3 A description of the offshore substations is provided below.

Offshore transformer substations

3.6.9.4 Offshore transformer substations are required in HVAC transmission systems and may be required in HVDC transmission systems, dependent on the system design.

3.6.9.5 These 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 to a higher voltage and to provide reactive power compensation. They may also house auxiliary equipment and facilities for operating, maintaining, controlling the substation and to access the substation by vessels and helicopters. Possible housing accommodation, storage, workshop and logistic facilities for operating and maintaining the wind turbine generators may also be included.

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

3.6.9.7 Up to 12 separate offshore transformer substations are required. All offshore transformer substations will be located in the Hornsea Three array area.

Design

3.6.9.8 The HV equipment on the offshore transformer substations is expected to be rated between 220 kV and 400 kV. The substation unit is pre-fabricated in the form of a multi-layered cube and will be mounted on a foundation (Figure 3.17) some distance above the sea surface.

Figure 3.17: Offshore substations at Gode Wind offshore wind farm.

3.6.9.9 For some HVDC transmission system designs, the equipment required in the offshore transformer substation will be incorporated into the offshore HVDC converter substation. It may also be beneficial to site multiple differing substations, or substations and offshore accommodation platforms, 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.

3.6.9.10 The last turbines in a string, normally electrically connected to a substation, might host some transmission equipment which would otherwise be placed at the substations. This equipment would be accessible without entering the wind turbine structure.

3.6.9.11 The maximum design parameters for offshore transformer substations are presented in Table 3.39 below and a schematic of an offshore transformer substation is presented in Figure 3.18.

Table 3.39: Maximum design parameters for offshore transformer substations.

Parameter	Maximum design parameters
Number of offshore transformer substations	12
Topside – main structure length and width (m)	90
Topside – ancillary structure length and width (m)	100
Topside – height (excluding helideck or lightning protection) (LAT) (m)	70

Parameter	Maximum design parameters
Height of lightning protection & ancillary structures (LAT) (m)	90
Topside - area (m^2)	8,100
Topside (including ancillaries) area (m^2)	10,000
Transformer oil - per transformer (per 200 MW capacity) (kg)	200,000
Diesel Fuel - per substation (l)	50,000
SF6 – per substation (kg)	1,500
Batteries (lead acid gel) – per substation (kg)	6,000

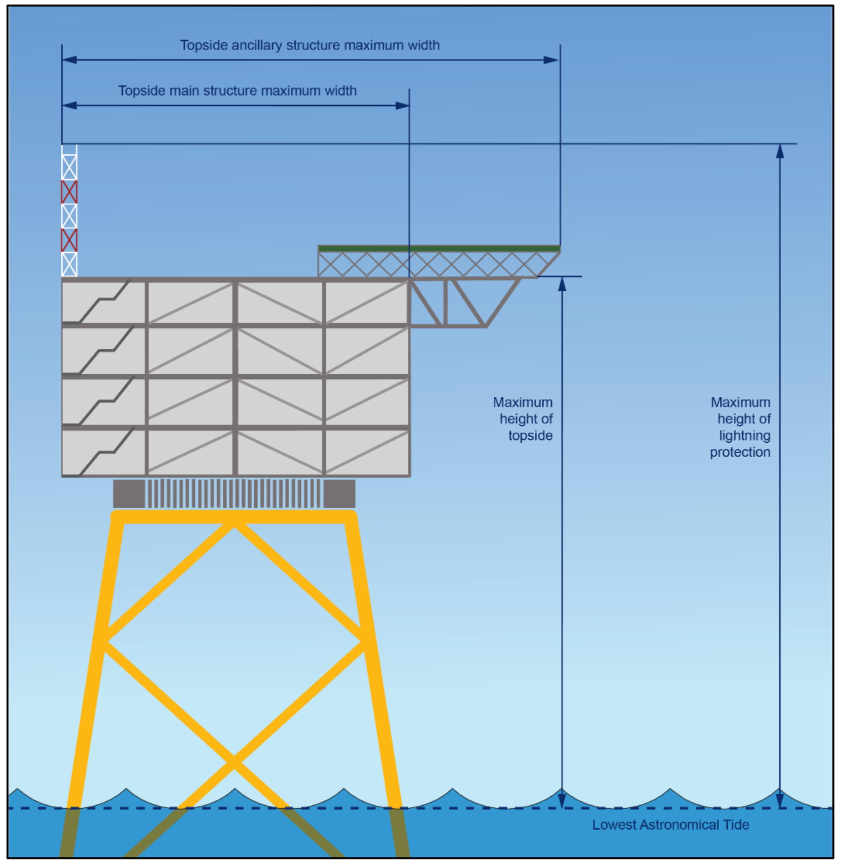


Figure 3.18: Schematic of an offshore transformer substation.

Installation

3.6.9.12 Offshore transformer substations are generally installed in two phases, the first phase will be to install the foundation for the structure using an installation vessel as described in section 3.6.5 above, secondly an installation vessel (the same as or different from the one installing the foundation) will be used to lift the topside from a transport vessel/barge, onto the pre-installed foundation structure. 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. The vessel requirements for this process are presented in Table 3.40 below. These values cover all offshore substations and accommodation platforms, not just offshore transformer substations.

Table 3.40: Maximum design parameters for offshore substation and accommodation platform installation.

Parameter	Maximum design parameters
Primary installation vessels	2
Support vessels	12
Transport vessels/barges	4
Duration (per substation) (months)	2
Installation vessels (all offshore substations and accommodation platforms) (return trips)	38
Support vessels (all offshore substations and accommodation platforms) (return trips)	228
Transport vessels (all offshore substations and accommodation platforms) (return trips)	38
Helicopter support – construction (all offshore substations and accommodation platforms)	532

Offshore HVDC converter substations

3.6.9.13 Offshore HVDC converter substations are required in HVDC transmission systems only; they are not required in HVAC transmission systems. Offshore HVDC converter substations convert the three-phase AC power generated at the turbines into DC power. This is then transmitted to the onshore HVDC converter/HVAC substation via the export cables.

3.6.9.14 In case of an HVAC transmission system, up to four large offshore HVAC substations may be built to replace the HVAC collector substations described in paragraph 3.6.9.4 onwards. The maximum design scenario of these large offshore HVAC substations would be the same as the maximum design scenario for offshore HVDC converter substations described here.

Design

3.6.9.15 As for the offshore transformer substations, the offshore HVDC converter substation unit is pre-fabricated in the form of a multi-layered cube. The offshore HVDC converter substation is expected to be larger than the offshore transformer substations, due to the differing power electronics it would contain. The structure will be mounted on a foundation some distance above the sea surface. Up to four separate offshore HVDC converter substations will be required. The maximum design parameters for offshore HVDC converter substations are presented in Table 3.41 below.

Table 3.41: Maximum design parameters for offshore HVDC converter substations.

Parameter	Maximum design parameters
Number of offshore HVDC converter substations	4
Length of topside (m)	180
Width of topside (m)	90
Topside area (m^2)	16,200
Topside - height (excluding helideck or lightning protection) (LAT)	100
Height of lightning protection above topside (LAT)	110
Diesel fuel (l)	200,000

3.6.9.16 Hornsea Three requires flexibility in location and foundation choice of the offshore HVDC convertor substations (see section 3.6.5) to ensure that anticipated changes in available technology and project economics can be accommodated within the Hornsea Three design. However all offshore HVDC convertor substations will be located in the Hornsea Three array area.

3.6.9.17 It is possible that the design approach for offshore HVDC converter substations will move towards multiple smaller units, rather than fewer large units. In this case, the maximum design parameters for the smaller offshore transformer substations (as presented in Table 3.39) would apply, however the total number of offshore transformer substations would be up to 12, with up to four offshore HVDC converter substations, not exceeding 16 in total.

Installation

3.6.9.18 Dependent on the design of the offshore HVDC converter substations, installation may be as for the offshore transformer substations (as described in paragraph 3.6.9.1 above), alternatively a 'float-over' installation may be used. This type of installation, usually used with gravity base structures, is similar to that described in paragraph 3.6.5.52 above, however it may also be advantageous to pre-assemble the topside and foundation in the fabrication yard or staging port, and float the whole substation structure to site in a single trip. The vessel requirements for installation of the offshore HVDC converter substations, as well as all other offshore substations and accommodation platforms, are presented in Table 3.40 above.

Offshore HVAC booster station(s)

3.6.9.19 Offshore HVAC booster station(s) are required in HVAC transmission systems only; they are not required in HVDC transmission systems.

3.6.9.20 Long distance, large capacity HVAC transmission systems require reactive compensation equipment to reduce the reactive power generated by the capacitance of the 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, can be located onshore, on an offshore platform, or within a subsea structure. Alternatively, a combination of these options could be used.

3.6.9.21 Hornsea Three requires flexibility in location, type and foundation choice for offshore HVAC booster station(s) (see section 3.6.5) to ensure that anticipated changes in available technology and project economics can be accommodated within the Hornsea Three design.

Location

3.6.9.22 If required offshore, this infrastructure would be located in the Hornsea Three offshore cable corridor, rather than in the Hornsea Three array area.

3.6.9.23 For the purposes of the PEIR, an area starting at approximately 40% of the total Hornsea Three cable corridor length (offshore and onshore) and continuing to approximately 60% of the total cable corridor length, was originally identified as the offshore HVAC booster station location search area. This area had initially been chosen based on preliminary electrical design studies indicating this location may be electrically optimal. This area was refined for this Environmental Statement following consultation on the PEIR (see Figure 3.1 and volume 4, annex 4.1: Offshore Export Cable Route Selection) resulting in a final offshore HVAC booster station search area that is as close as possible, taking account of other constraints, to 50% of the distance along the Hornsea Three offshore corridor (including estimated export cable route length within the Hornsea Three array area). The final location of the offshore HVAC booster station(s) will be defined in the detailed design stage, post consent. The siting will take into account final electrical design, water depth, ground conditions and other engineering and economic factors to ensure a location is chosen to minimise impact to the human and natural environment as well as minimising cost of electricity and project risk.

3.6.9.24 There may also be a requirement for an onshore HVAC booster station either instead of or as well as the offshore HVAC booster station(s). This is described in section 3.7.5 below.

Surface

Design

3.6.9.25 Although the different substations perform different functions, and contain differing internal electrical equipment, the external design of a offshore surface HVAC booster station will be very similar to the offshore transformer substations described in paragraphs 3.6.9.1 to 3.6.9.12 above. The maximum design parameters for offshore surface HVAC booster station(s) are presented in Table 3.42 below.

Table 3.42: Maximum design parameters for offshore surface HVAC booster station(s).

Parameter	Maximum design parameters
Number of surface offshore HVAC booster stations	4
Topside – main structure length and width (m)	90
Topside – ancillary structure length and width (m)	100
Topside - height (excluding helideck or lightning protection) (LAT) (m)	70
Height of lightning protection above topside (LAT) (m)	90
Transformer/reactor oil (kg)	350,000
Diesel Fuel (l)	20,000
Sulphur hexafluoride (SF6) (kg)	1,500
Batteries (lead acid gel) (kg)	6,000

3.6.9.26 Where an offshore surface platform is used for the offshore HVAC booster station(s), these will comprise a platform with one or more decks, and helicopter platform, attached to the seabed by means of a foundation. 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.

Installation

3.6.9.27 Installation will be as for the offshore transformer substations as described in paragraph 3.6.9.1 above. The vessel requirements for installation of the offshore surface HVAC booster stations, as well as all other offshore substations and accommodation platforms, are presented in Table 3.40 above.

Subsea

Design

3.6.9.28 Although this technology is known to be in the process of development by the supply chain, at the time of writing no offshore subsea HVAC booster station(s) have been constructed for HV power transfer, therefore the details of this type of structure are primarily based on knowledge of surface designs as well as an understanding of subsea structures used in the offshore oil and gas industry. The structure would likely be a sealed steel or concrete structure, similar to the topside of an offshore substation but fixed to the seabed with piles, and without any substructure required to lift it above the sea surface. It is not expected that this structure would be regularly accessed for operation and maintenance during Hornsea Three's lifetime (35 years). The maximum design parameters for offshore subsea HVAC booster station(s) are presented in Table 3.43 below, and an illustration of this type of structure is presented in Figure 3.19.

Table 3.43: Maximum design parameters for offshore subsea HVAC booster station(s).

Parameter	Maximum design parameters
Number of subsea offshore HVAC booster stations	6
Subsea structure: length (m)	50
Subsea structure: width (m)	50
Subsea structure: height above seabed (m)	15
Subsea structure: number of piles per substation	12
Piles: penetration depth (m)	50
Piles: diameter (m)	2

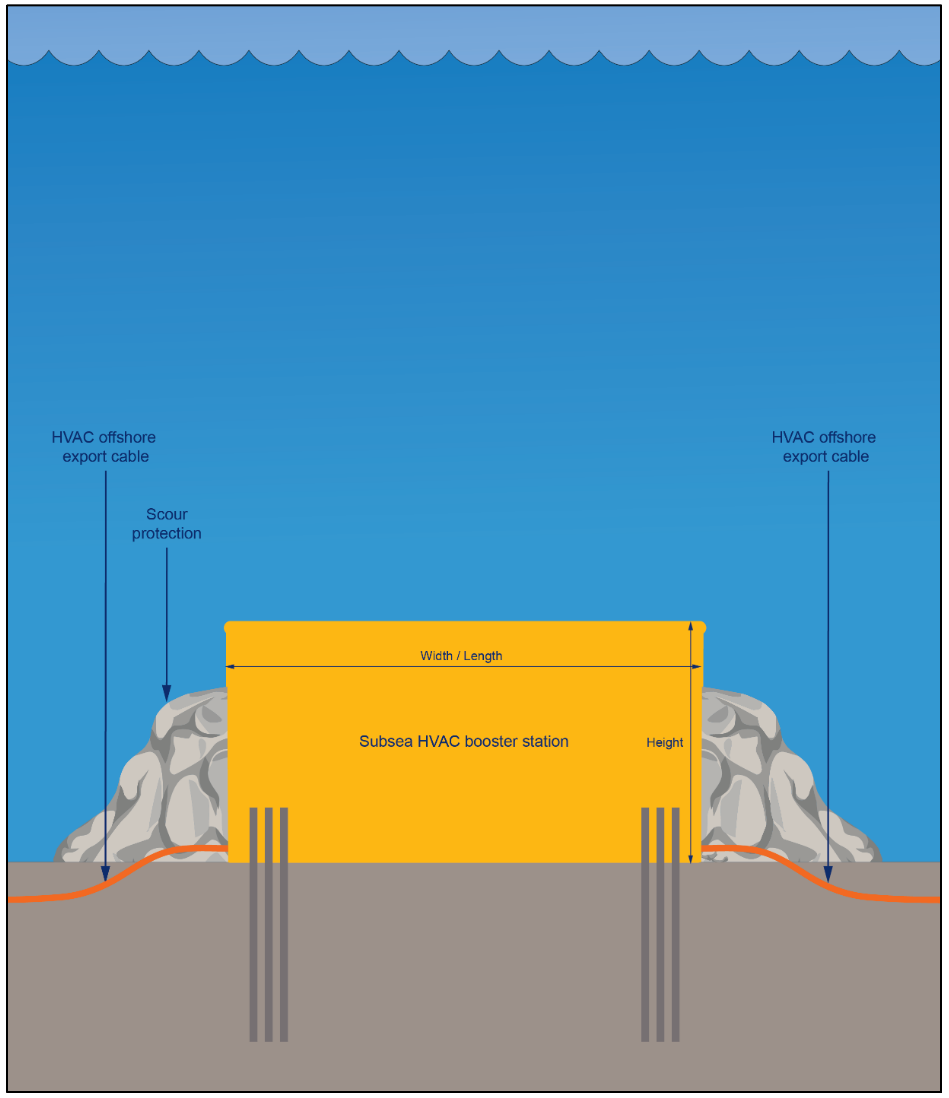


Figure 3.19: Illustration of an offshore subsea HVAC booster station.

Lighting and marking

3.6.9.29 General lighting and marking principles are outlined in section 3.6.14 below. Lighting and marking of the subsea structure (as well as all other Hornsea Three structures) will be discussed and designed in consultation with Trinity House Lighthouse Services (TH), having a statutory duty as a General Lighthouse Authority. This will be necessary to mitigate any risk to shipping that will be presented by a offshore subsea HVAC booster station(s). The marking will be based on the recommendations of the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA, 2013). The positions of the structure and export cable will be conveyed to the UK Hydrographic Office (UKHO) so that they can be incorporated into Admiralty Charts and the Notice to Mariners procedures.

Installation

3.6.9.30 The exact installation procedure for offshore subsea HVAC booster station(s) is currently unknown, however it is likely that the structure will be preassembled at the fabrication yard and brought to site either on a barge or on the installation vessel. The installation vessel will then lower the structure to the seabed and secure the structure to the seabed with piles either installed in advance or afterwards.

3.6.9.31 Installation will be as for the offshore transformer substations as described in paragraph 3.6.9.29 above. The vessel requirements for installation for installation of the offshore subsea HVAC booster stations, as well as all other offshore substations and accommodation platforms, are presented in Table 3.40 above.

3.6.10 Offshore export cables

3.6.10.1 Offshore export cables are used for the transfer of power from the offshore substations to the landfall point. For HVAC transmission systems, offshore export cables will carry electricity from the offshore transformer substations to the offshore HVAC booster station(s) and then on to the landfall. For HVDC transmission systems, offshore export cables will carry electricity from the offshore transformer substations to the offshore HVDC converter substations and then to the landfall. Up to six offshore export cables, with a voltage of up to 600 kV for an HVDC transmission system, and 400 kV for an HVAC transmission system will be required for Hornsea Three. Where possible, the cables will be buried below the seabed through to landfall.

3.6.10.2 Hornsea Three requires flexibility in type, location, depth of burial and protection measures for export cables to ensure that anticipated physical and technical constraints and changes in available technology and project economics can be accommodated within the Hornsea Three design.

Design

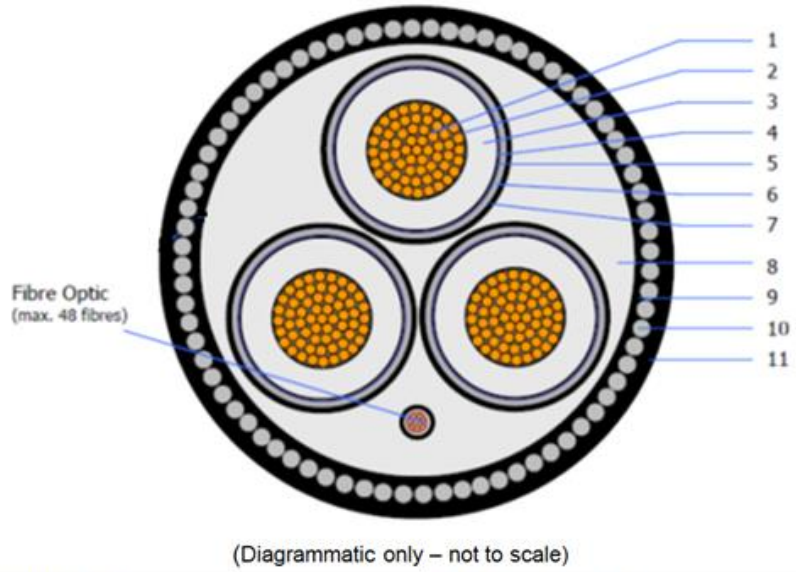
3.6.10.3 Similarily to the array cables (see section 3.6.6 above), the export cables will consist of a number of conductor cores, usually made from copper or aluminium. These will be surrounded by layers of insulating material as well as material to armour the cable for protection from extremal damage and material to keep the cable watertight. Export cables are typically larger in diameter than array cables.

3.6.10.4 The maximum design parameters for export cables are presented in Table 3.44 below and an example of an offshore export cable (HVAC 220 kV) cross section is presented in Figure 3.20 below.

Table 3.44: Maximum design parameters for offshore export cables.

Parameter	Maximum design parameters
HVAC - number of circuits	6
HVAC – voltage (kV)	400
HVDC - number of circuits	4 (plus one HVAC circuit) [a]
HVDC – voltage (kV)	600
Cable diameter (mm)	320

a Assuming a maximum of four HVDC circuits plus one HVAC circuit which may be required to supply power from the onshore HVDC converter/HVAC substation to the offshore wind farm in some HVDC system designs.



1. Plain Cu conductor	2. Conductor screen
3. XLPE Insulation	4. Insulation screen
5. Longitudinal water barrier	6. Lead sheath
7. PE semi conductive sheath	8. Fillers
9. Binder tape and string bedding	10. Galvanised wire armour
11. String serving in double layer	

Figure 3.20: Cross section through a typical offshore alternating current (AC) (220 kV) export cable (Courtesy of Prysmian).

Hornsea Three offshore cable corridor

3.6.10.5 The Hornsea Three offshore cable corridor can be seen in Figure 3.1 above, and the maximum design parameters for the offshore cable corridor are presented in Table 3.45 below.

Table 3.45: Maximum design parameters for Hornsea Three offshore cable corridor.

Parameter	Maximum design parameters
Length of Hornsea Thre offshore cable corridor (km)	163
Width of Hornsea Three offshore cable corridor (km)	1.5
Length per export cable – including export cable within the Hornsea Three array area (km)	191
Total length of export cables (km)	1,146

Installation

3.6.10.6 The export cable installation methodology, as well as the burial depth and any requirement for protection measures, will be defined by a detailed CBRA. Typically, the cable will be buried between 1 to 2 m. The CBRA will inform cable burial depth which will be dependent on ground conditions as well as external risks. This assessment will be undertaken post-consent. It is likely that the installation techniques will consist of one or a combination of trenching, dredging, jetting, ploughing, vertical injection, MFE and rock cutting.

3.6.10.7 As with the array cables, the export cables will need to be made secure where the cable crosses obstacles such as exposed bedrock, pre-existing cables or pipelines that mean the cable cannot be buried. Cable protection methods include rock placement (rock protection), concrete mattresses, fronded mattresses, rock bags, and seabed spacers among others. These are described further in paragraph 3.6.10.11 below. Up to 10% of the total export cable length may require protection due to ground conditions (this excludes cable protection due to cable crossings). Up to 10% of the export cable within the Cromer Shoal Chalk Beds MCZ, The Wash and North Norfolk Coast SAC and North Norfolk Sandbanks and Saturn Reef SAC which intersect the Hornsea Three offshore cable corridor may include cable protection.

3.6.10.8 The methodology for export cable crossings would be the same as for array cable crossings, paragraphs 3.6.6.7 to 3.6.6.18 describe this process in more detail.

3.6.10.9 The maximum design parameters for installation of up to six export cables are presented in Table 3.46 below.

Table 3.46: Maximum design parameters for export cable installation.

Parameter	Maximum design parameters
Installation methodology	Trenching, dredging, jetting, ploughing, mass flow excavation, vertical injection, rock cutting
Seabed disturbance – within Cromer Shoal Chalk Beds MCZ (m^2)	60,000
Seabed disturbance – within The Wash and North Norfolk Coast SAC (m^2)	999,000
Seabed disturbance – within North Norfolk Sandbanks and Saturn Reef SAC (m^2)	4,230,000
Seabed disturbance – outside designated sites (m^2)	9,351,000
Seabed disturbance – total (m^2)	14,640,000
Rock protection area (m^2)	802,200
Rock protection volume (m^3)	1,146,000
Burial spoil: jetting (m^3)	2,532,660
Burial spoil: ploughing/mass flow excavation (m^3)	6,876,000
Duration (months)	36

3.6.10.10 Cable installation and route preparation will be undertaken by specialist vessels, the vessel requirements for offshore export cable installation are presented in Table 3.47. Based on previous experience within Ørsted at other offshore wind farms, it is possible that a small JUV or a flat top barge will be required for export cable installation in shallow water, around HDD exit pits.

Crossings

3.6.10.11 The Hornsea Three offshore cable corridor crosses a number of existing assets, 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. The export cable will then be laid across this, at an angle close to 90 degrees. The export cable will then be covered by a second post lay berm to ensure that the export cable remains protected and in place. 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 original rock volume. The parameters for these crossings are presented in Table 3.48 below.

Table 3.47: **Maximum design parameters for export cables - vessel and helicopter requirements.**

Parameter	Maximum design parameters
Jack-up area per leg (m²)	1.2
Jack–up number of legs	4
Number of jack-ups per exit pit	5
Number of barge groundings per exit pit	1
Main laying vessels (return trips)	180
Main jointing vessels (return trips)	120
Main burial vessels (return trips)	180
Support vessels (return trips)	270
Helicopter support (return trips)	1,828

Table 3.48: **Maximum design parameters for offshore export cable crossings.**

Parameter	Maximum design parameters
Number of external assets requiring crossing in Cromer Shoal Chalk Beds MCZ	0
Number of external assets requiring crossing in North Norfolk Sandbanks and Saturn Reef SAC	20
Number of external assets requiring crossing in The Wash and North Norfolk Coast SAC	0
Number of external assets requiring crossings outside of the Cromer Shoal Chalk Beds MCZ, The Wash and North Norfolk Coast SAC and North Norfolk Sandbanks and Saturn Reef SAC	24
Replenishment during operations (% of construction total)	25
Cable/pipe crossings: total seabed area – per crossing (m^3)	2,500
Cable/pipe crossings: total seabed rock volume including operation – per crossing (m^3)	2,625
Cable/pipe crossings: total seabed area (m^2)	660,000
Cable/pipe crossings: total seabed rock volume including operation (m^3)	693,000
Rock protection area (m^2)	802,200
Rock protection volume (m^3)	1,146,000

3.6.11 Offshore interconnector cables

3.6.11.1 Hornsea Three may require power cables to interconnect the offshore substations in order to provide redundancy in the case of cable failure elsewhere, or to connect to the offshore accommodation platforms in order to provide power for operation. The cables will have a similar design and installation process to the offshore export cables and array cables. The parameters for design and installation of the offshore interconnector cables are presented in Table 3.49 and Table 3.50 below.

Table 3.49: **Maximum design parameters for offshore interconnector cables.**

Parameter	Maximum design parameters
Number of cables	15
Total cable length (km)	225
Voltage (kV)	400

Table 3.50 **Maximum design parameters for offshore interconnector cable installation.**

Parameter	Maximum design scenario
Installation methodology	Trenching, dredging, jetting, ploughing, mass flow excavation, vertical injection, rock cutting
Burial depth	Typically 1 to 2m. Dependent on CBRA [a]
Total seabed disturbance (m^2)	3,375,000
Burial spoil: jetting (m^3)	497,250
Burial spoil: ploughing/mass flow excavation (m^3)	1,350,000
Number of external assets requiring crossings	See Table 3.33
Cable/pipe crossings: total seabed area – per crossing (m^2)	
Cable/pipe crossings: total seabed rock volume including operation – per crossing (m^3)	
Cable/pipe crossings: total seabed area (m^2)	
Cable/pipe crossings: total seabed rock volume including operation (m^3)	
Rock protection area (m^2)	157,500
Rock protection volume (m^3)	225,000

a Typically the cable will be buried between 1 and 2 m. A CBRA or similar will inform cable burial depth, dependent on ground conditions as well as external risks. This assessment will be undertaken post-consent.

3.6.12 Hornsea Three intertidal area

3.6.12.1 The offshore export cables will make landfall west of Weybourne in North Norfolk. Figure 3.21 delineates the Hornsea Three intertidal area, and the onward Hornsea Three onshore cable corridor.

3.6.12.2 The works at the Hornsea Three intertidal area comprise the works required to bring the offshore export cables through the intertidal area to a location where they can be connected to the onshore export cables. The offshore cables are connected to the onshore cables at the Transition Joint Bays (TJBs), located onshore. The works at the Hornsea Three intertidal area would primarily be the same irrespective of whether HVAC or HVDC transmission is selected.

3.6.12.3 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 the wind farm, however link boxes (see paragraph 3.6.5.11) 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.

3.6.12.4 During intertidal works, a landfall construction compound is required on the onshore side of the Hornsea Three intertidal area. The location of the landfall construction compound is shown on the Works Plan - Onshore (document reference number A2.4.2). This will house the TJB works as well as any Horizontal Directional Drilling (HDD) works, including supporting equipment and facilities. The maximum design parameters for the TJBs and Hornsea Three intertidal area are presented in Table 3.51 below. Durations for activities provided in Table 3.51 below 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.

3.6.12.5 The techniques used to carry out the landfall works broadly fall in to two categories; open cut installation or trenchless techniques (i.e. HDD or thrust boring). It may be possible to carry out a HDD to beyond the Hornsea Three 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. 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.

Table 3.51: Maximum design parameters for TJBs and landfall works.

Parameter	Maximum design parameters
Number of TJBs	6
TJB depth (m)	6
Landfall construction compound (m^2)	42,000
Duration of trenching works (per cable) if open cut (weeks)	2
Duration of works for each HDD (months)	4
Duration of works (start – finish) (months)	32

Figure 3.21: Hornsea Three cable corridor in the vicinity of the intertidal area.

Trenchless techniques

Horizontal Directional Drilling (HDD)

3.6.12.6 HDD involves drilling a long parabolic borehole underneath the Hornsea Three intertidal area and shingle beach using a drilling rig located in the TJB works area on the landward side of the sea defences (Figure 3.22).

3.6.12.7 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.

3.6.12.8 Existing access roads may be upgraded or new access roads may be constructed into the landfall construction compound.

3.6.12.9 As the drill can only be carried out in a straight line, 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 pits on the landward side of the HDD would be up to 25 m long, 5 m wide and 6 m deep. The dimensions of the offshore exit pits are included in Table 3.52 below.

3.6.12.10 The process uses a drilling head controlled from the rig to drill a pilot hole along a predetermined profile based on an analysis of the ground conditions and cable installation requirements. This pilot hole is then widened using larger drilling heads until the hole is wide enough to fit the cable ducts. Bentonite is pumped to the drilling head during the drilling process to stabilise the hole and ensure that it does not collapse. Prior to the drilling taking place, an exit pit may be excavated in the nearshore area of the Hornsea Three offshore cable corridor in order for the HDD profile and ducts to stop at the required installation depth for the cable. An example of a HDD rig undertaking a HDD for an export cable landfall can be seen in Figure 3.23.

3.6.12.11 Given the small tidal range at landfall, a wet punch-out (i.e. an exit below MLWS, no closer than 200 m from MHWS) will occur. If this is the case and HDD rather than open-cut trenching is used, beach access would only be required in the event that a mud return line is dug into the beach, in order to carry recovered cuttings and drilling fluid from the hole back to shore for processing. In this case, it will be accomplished by a mini-excavator. Another option is to allow the drilling fluid and cuttings to exit into the marine environment during reaming and pipe pulling operations. Full drilling fluid losses are acceptable in some instances with the use of benign seawater based drilling fluid.

3.6.12.12 Access to the beach will be via existing tracks and the depression to the beach. In the event a mud line is dug in (rather than drilled in parallel to the HDDs) then a 'moving compound' of about 20 m^2 will be established around the excavator. A temporary beach closure may be required for pulling in the mud line over the beach in this case. This operation will be undertaken once per construction phase, as the mud return line will be moved offshore between pits.

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

3.6.12.14 A short beach closure of up to 24 hours per circuit will be required if pulling onshore welded pipes offshore.

3.6.12.15 The maximum design parameters for HDD at the landfall are presented in Table 3.52 below.

3.6.12.16 HDD exit pits will be established using one of the two following methods:

- Dredged exit pit: which has a fabricated cap to contain fluid within the dredged pit. Drilling slurry would then be pumped from below the cap back onto the lay barge for recycling before being pumped back to shore through a high density polyethylene (HDPE) mud return line. This is either drilled into position or laid on the sea bed anchored with concrete blocks (600 mm^2, 5 to 10 m spacing) before being laid across the beach as described above; or
- Sealed coffer dam, sheet piled and pumped dry which would be removed at the end of HDD works. Sheet piling and internal support frames may be required to keep the pits open during the operations and meet health and safety requirements.

3.6.12.17 The HDD exit pits will be located between 200 m and 1,500 m from MHWS mark.

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

3.6.12.19 For either method, the exit pit could be open for up to two months whilst drilling operations are underway and coffer dams may take up to 28 days to remove afterwards. Overall, exit pit operations will take up to four months:

- 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).

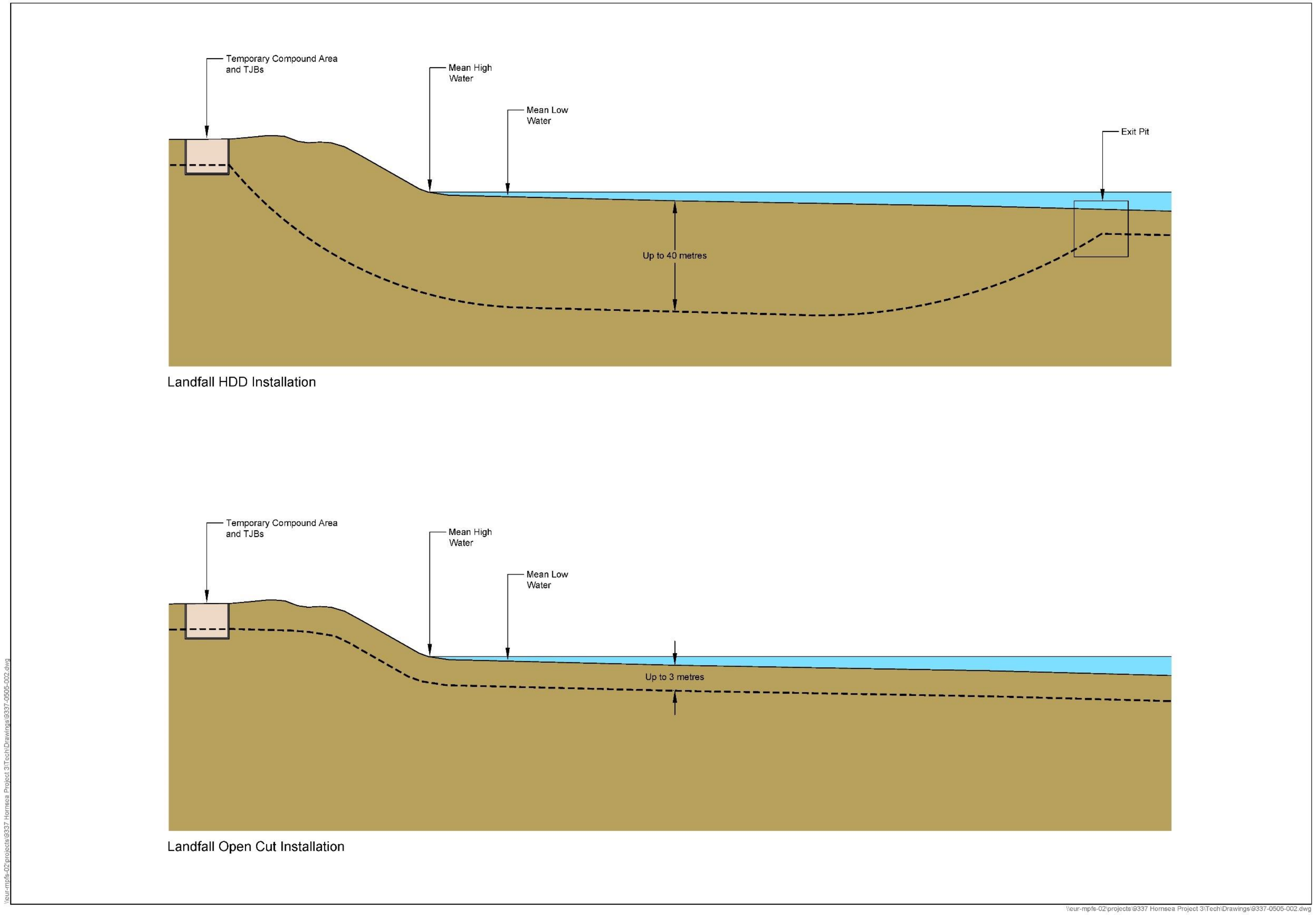


Figure 3.22: Indicative HDD and open cut arrangement.

Figure 3.23: HDD rig carrying out landfall works at the Westermost Rough offshore wind farm.

3.6.12.20 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.

3.6.12.21 If material is removed by barge to a designated disposal site in the Hornsea Three offshore cable corridor, before being recovered for backfilling, excavated material will need to be re-imported from the storage area. Some additional material (rocks) may be necessary to make up for any loss, or in case the onward plough cannot bury the cable within the exit pit. It is also possible that the excavated material is stored within the Cromer Shoal Chalk Beds MCZ. If excavated material is stored within the Cromer Shoal Chalk Beds MCZ, Hornsea Three will avoid the key features – specifically exposed chalk, and peat and clay exposures (i.e. the spoil will not be placed in these areas).

Table 3.52: Maximum design parameters for landfall HDD.

Parameter	Maximum design parameters
HDD cable ducts	8
Diameter of ducts (m)	1
Length of ducts (km)	2.5
HDD burial depth maximum (m)	40
HDD burial depth minimum (m)	5
HDD exit pits number	8
HDD exit pit area – short [a] HDD (m^2)	450
HDD exit pit area – long [a] HDD (m^2)	900
HDD exit pit excavated material volume – short [a] HDD (m^3)	1,000
HDD exit pit excavated material volume – long [a] HDD (m^3)	2,500
HDD exit pits depth (m)	3

a A short HDD length equates to an exit pit located approximately 200 m from MHWS and a long HDD length equates to an exit pit located approximately 800 m from MHWS.

Open cut installation

3.6.12.22 Open cut installation would be carried out using one of a number of 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 construction 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 cable installation are applicable to the landfall installation, excluding dredging. Figure 3.24 shows an example of this type of installation tool.

3.6.12.23 A landfall construction compound will be established approximately one to two weeks 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 will be required from mean low water (MLW) to the landfall construction compound for operational, and health and safety reasons. This would be up to one month per cable.

Figure 3.24: Example of a cable plough pulled from an installation vessel.

(source: http://www.4coffshore.com/s/about/equipmentTypes.aspx)

3.6.12.24 Prior to the vessel arrival, rollers may be placed from the MLW to the plough grade in position, if a plough is used.

3.6.12.25 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 cable would be pulled from the vessel, through the plough to the TJB in the duration of one day. Then the vessel would plough away.

3.6.12.26 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 construction compound. Public access to the beach may be restricted during this process, for up to one month per cable.

3.6.12.27 The maximum design parameters for open cut installation at the Hornsea Three intertidal area are presented in Table 3.53 below. The distance between circuits may vary depending on soil thermal characteristics and the burial depth is dependent on the beach profile. The working corridor will be reinstated as the tide returns.

Table 3.53: Maximum design parameters for open cut installation.

Parameter	Maximum design parameters
Landfall construction compound (m^2)	42,000
Distance between circuits (m)	20
Burial depth (m)	1 to 3
Intertidal burial progress rates (m/day)	100
Corridor width (m)	15
Cobble size for backfilling (mm)	250

Other methods

3.6.12.28 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 ROV type systems, controlled from and connected to the offshore installation vessel. Figure 3.25 shows this type of installation tool.

3.6.12.29 Traditional mechanical excavators, similar to those that would be used to dig TJBs and exit pits etc., can also be used for cable installation. In this process, the cable would be pulled from the offshore installation vessel through the Hornsea Three 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.

Figure 3.25: The 'sunfish' installation tool as used for cable installation at the Race Bank offshore wind farm.

3.6.13 Vessel activities

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

3.6.13.2 The total vessel numbers, vessel movements (return trips from a construction compound to site and back again) and durations are collated in Table 3.54 below. Each vessel movement represents a return trip to and from the Hornsea Three array area.

3.6.13.3 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 Three array area at any one time, rather this intensity is expected across approximately three or four 5 km^2 blocks.

Table 3.54: Total values for vessel activities during construction phase.

Vessels	Maximum design parameters
Wind Turbine Installation	
Installation vessels	4
Support vessels	24
Transport vessels	12
Installation vessels movements	300
Support vessels movements	1,800
Transport vessels movements	900
Helicopters movements	225
Monopiles (WTG) construction (standard assumptions for other foundations if not stated)	
Installation vessels	4
Support vessels	16
Transport vessels (barges and tugs)	10 + 30
Feeder barge concept - installation vessels movements	300
Feeder barge concept - support vessels movements	1,200
Feeder Barge concept - transport barge movements	150
Feeder Barge concept - transport barge tug movements	450
Helicopters movements	600
Gravity Base (WTG) – construction (mutually exclusive with Monopile values above)	
Installation vessels	3
Support vessels	13
Dredging vessels	12
Tug vessels	4
Self-installing concept - support vessels movements	1,500
Self-installing concept - dredging vessels movements	1,200
Self-installing concept - tugs movements	1,200
Substation foundations construction	
Primary installation vessels	2
Support vessels	12
Transport vessels	4
Primary installation vessels movements	38
Support vessels movements	228

Vessels	Maximum design parameters
Transport vessels movements	38
Helicopter movements	532
Inter-array cables installation	
Main laying Vessels	3
Main burial Vessels	3
Support vessels: crew boats or SOVs	4
Support vessels: service vessel for pre-rigging of towers	2
Support vessels: diver vessels	2
Support vessels: vessels for PLGR	2
Support vessels: dredging vessels	2
Main laying Vessels movements	315
Main burial Vessels movements	315
Support vessels movements	1,890
Helicopter movements	600
Export cables installation	
Main laying vessels movements	180
Main jointing vessels movements	120
Main burial vessels movements	180
Support vessels movements	270
Helicopters movements	1,828

3.6.14 Aids to navigation, colour, marking and lighting

3.6.14.1 Each turbine (including colours, marking and lighting) and any required aids to navigation will be designed in accordance with relevant guidance from Trinity House, the CAA and the MCA. The positions of all infrastructure (including turbines, substations, platforms and cables) will be conveyed to the UK Hydrographic Office (UKHO) so that they can be incorporated into Admiralty Charts and the Notice to Mariners procedures.

3.6.14.2 Lighting and marking of subsea structures will be discussed with TH, 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).

3.6.15 Safety Zones

3.6.15.1 During construction and decommissioning, Hornsea Three will apply for a 500 m safety zone around infrastructure that is under construction, including at the Hornsea Three 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 the wind farm has not yet been commissioned.

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

3.6.15.3 Further information regarding the Safety Zones which Hornsea Three intends to apply for post consent is outlined in the Safety Zone Statement (document reference number A7.1).

3.7 Onshore infrastructure

3.7.1.1 The following sections provide a description of the onshore components of Hornsea Three, together with relevant information on construction, or operation and maintainence, methods and techniques where these are relevant to the EIA.

3.7.2 Onshore site preparation activities

Pre-Construction Surveys

3.7.2.1 Prior to the commencement of the main works associated with installing the export cable and construction of the onshore substations (onshore HVAC booster station and onshore HVDC converter/HVAC substation), a number of activities may need to occur along the Hornsea Three onshore cable corridor. These include ground investigations, topographical, ground penetrating radar (GPR), UXO, ecological (see volume 3, chapter 3: Ecology and Nature Conservation) and archaeological (volume 3, chapter 5 : Historic Environment) 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 along the proposed Hornsea Three onshore cable corridor and at the onshore HVAC booster station and onshore HVDC converter/HVAC substation well in advance of the construction activities.

Ground Investigations

3.7.2.2 Ground Investigations may need to be taken at the substation sites, all HDD locations and along the Hornsea Three onshore 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.

3.7.2.3 CPTs, boreholes, window samples and exploratory/trial pits may be required for the onshore and HDD sections of the Hornsea Three onshore cable corridor. Gas monitoring may also be undertaken alongside water monitoring depending on the ground conditions.

3.7.2.4 At the Hornsea Three intertidal area, the onshore part of the works may be investigated using land based borehole rigs, JCBs (for trial pits) and tracked CPT rigs. The Hornsea Three intertidal area may require a combination of these land based borehole/CPT rigs and/or vessel based techniques depending on safety considerations for accessibility of the HDD section between tides.

3.7.2.5 Ground investigations may be dug by hand in constrained and congested areas or by using a drilling rig in more open areas. Ground investigation may also require the opening of trial pits or trenches and a range of supplementary sampling and monitoring activities (both intrusive and non-intrusive).

3.7.2.6 Any ground investigations will be undertaken in accordance with adopted industry practices and typically extend to identifying the position and the nature of any above and below ground services along the Hornsea Three onshore cable corridor. They shall be identified as accurately as possible by means of ground penetrating radar (GPR) survey techniques, opening of existing manholes, service covers, ducts and conduits and the investigation of any above ground cabinets and structures. Obvious surface features, drains, open watercourses, indentations and partially buried structures along with potential contamination sources will all be identified and factored into susbquent stages of ground investigations.

3.7.2.7 Intrusive ground investigation exploratory holes typically include inspection pits and can also encompass cable percussion boreholes (with rotary follow on), pavement coring, structural investigations, window sampling and penetration testing, trial trenches and surface water sampling.

Soil Surveys

3.7.2.8 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 Liasiaon Officer) will need to document information on existing agricultural management and soil/land conditions. This action may require soil condition surveys and intrusive soil survey trial pits, the purpose of which is to identify and describe the physical and nutrient characteristics of the existing soil profiles. The trial pits would typically be dug by hand along the Hornsea Three onshore cable corridor at approximately 100 m intervals.

3.7.2.9 Other associated preparation activies (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, assesments of yield of crops, quality of grazing land; and existing weed burden.

Drainage Managment

3.7.2.10 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.

3.7.2.11 To undertake this preconstruction drainage various tracked machinery will be used, with targeted ground clearance undertaken. An example of a tool to be used in this activity can be seen in Figure 3.26.

Figure 3.26: An example of a tracked tool used for pre-construction drainage.

Archaeological investigations

3.7.2.12 Archaeological investigations or archaeological evaluation (field testing) may need to be undertaken along the Hornsea Three onshore cable corridor at predetermined locations to ascertain if any archaeolgical items of interest are present. Typcially these occur up to two years prior to commencement of main works.

3.7.2.13 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.

3.7.2.14 Archaeological techniques that may be employed, include boreholes, archaeological trenches (as well as none intrusive geophysical investigations). Early archaeological investigations may also rely upon Watching Briefs from suitably qualified personnel.

3.7.2.15 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. A sample site can be seen in Figure 3.27.

Figure 3.27: A sample site for archaeological investigations

Watercourse Crossings

3.7.2.16 The export cable will traverse a number of drains and ditches (main river crossings are considered under HDDs). The application has prepared an Outline Watercourse Crossing Method Statement documenting the techniques that will be deployed at crossing points of watercourses (refer to the Outline Code of Construction Practice (document reference number A8.5): Appendix B - Outline Method Statement for Crossing Techniques). Watercourses will be crossed by way of HDD or Open Cut Trench. Where open cut trench, the outline method statement advises of the following pre-commencment works and activies that may be required:-

- Stage 1 – Setting out of the works and preparation of working area;
- Stage 2 – Construction of dam and culvert or pump installation;
- Stage 3 – Trench excavation;
- Stage 4 – Cable installation; and
- Stage 5 – Reinstatement.

3.7.2.17 The Outline Watercourse Crossing Method Statement also documents the provison of temporary haul road bridge and flume crossing where the open cut trench passes over drains and ditches. The provision of the haul road bridge retains access either side of the water body for construction workers. An example of flume installation at a water crossing can be seen in Figure 3.28.

Figure 3.28: A sample flume installation.

Hedge removal and vegetation clearance

3.7.2.18 Hedges and vegetation will be removed ahead of each working section. Where hedgerows and trees occur within the working area (and cable installation is not limited to HDD technicques), they will be removed. The width of hedge removed will be limited where possible – for example if Hornsea Three is delivered in two phases the construction contractor may not need to remove the full 80m temporary easement. Further details on hedgerow removal are presented in volume 3, chapter 3: Ecology and Nature Conservation and Outline Ecological Management Plan (document reference number A8.6).

3.7.2.19 Where works are required to hedgerows, these will be minimised and will be in line with the principles detailed in the Outline Landscape Management Plan and Outline Ecological Management Plan (document reference number A8.7 and A8.6 respectively). 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.

Demarcation fencing for the cable easement

3.7.2.20 Fencing will be installed along the entire export cable route to define the cable corridor and works areas. The type of fencing to be used will be dependent on the land use where the easement crosses it.

3.7.2.21 Fencing will be installed as part of the preconstruction 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.

3.7.2.22 Further details on fencing are documented in the Outline Code of Construction Practice (document reference number A8.5).

Access points off the highway

3.7.2.23 Access points will be required from the public highway onto the Hornsea Three onshore cable corridor. Temporary access points off the highway will be installed to facilitate vehicular access from the road, and into to the onshore cable corridor during construction. The access points will be constructed in line with the local authorities' requirements and in accordanace with the principles established in the Outline Traffic Management Plan (document reference number A8.2). The location of access points is shown on the Access to Works Plan (document reference number A2.5).

3.7.2.24 Access points will be required from the start of construction at that locality. Temporary access points typically comprise tarmac and stone finish. During the installation of these works traffic management arrangements may be required on the public highway. Further details on access are documented in the Outline Code of Construction Practice (document reference number A8.5) and Traffic Management measures associated with making use of an access point detailed in the Outline Construction Traffic Management Plan (document reference number A8.2).

Haul road

3.7.2.25 To provide access to the Hornsea Three onshore cable corridor and limit damage to the argricultural land, the haul road will be installed as part of the preconstruction cable works at the start of construction in that locality. The haul road, typically 6 m wide, and extending up to the full length of the Hornsea Three onshore cable corridor (except where Hornsea Three has committed to "HDD only"). The haul road provides vehicular access along the cable easement off the public highway and will be used where needed throughout the installation of the export cable. Following completion of the works being served by that access point, the haul road will be removed and the land reinstated.

3.7.2.26 The haul road will be utilised during installation and be made up of either: an average of 0.3 m of permeable gravel aggregate with a geotextile or other type of protective matting; or plastic or metal plates or grating.

3.7.3 Onshore export cables

3.7.3.1 Offshore export cables will connect to the onshore export cables at the TJBs (see section 3.6.12) and transfer the power onwards to the onshore HVDC converter/HVAC substation (potentially via an onshore HVAC booster station in the case of HVAC, see section 3.7.5). The onshore export cables will be buried for the entirety of the Hornsea Three onshore cable corridor. Overhead lines are not proposed for Hornsea Three.

Hornsea Three onshore cable corridor

3.7.3.2 The Hornsea Three onshore cable corridor consists of an 80 m (although a wider corridor is provided for in certain limited locations as shown on the Works Plans – Onshore (document reference number A2.4.2)) temporary easement, within which a 60 m permenant easement post installation is located. An overview of the Hornsea Three onshore cable corridor is presented in Figure 3.29, wth more detailed routing shown on the Works Plans – Onshore (document reference number A2.4.2).

3.7.3.3 The route refinement analysis that has informed the final corridor presented in the Hornsea Three application is detailed in volume 1, chapter 4: Site Selection and Consideration of Alternatives and has been designed in accordance with a wide range of human, biological and physical constraints as well as technical and commercial considerations.

Design

3.7.3.4 Up to six export cable circuits will be required, with each circuit consisting of up to three single cables. The cables themselves consist of copper or aluminium conductors wrapped with various materials for insulation, protection, and sealing. Table 3.55 below shows the maximum design scenario for the onshore export cables. Small fibre optic cables may also be buried alongside the export cables in order to allow for communication to the wind farm for the various control systems in place for the project.

3.7.3.5 The potential generation of electro-magnetic field (EMF) are a factor of cable current. The potential for EMF generation from the onshore export cables is considered in volume 4, annex 3.3: EMF Compliance Statement.

Table 3.55: 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 [a]	4 (plus one HVAC circuit)
HVDC – number of cables [a]	11
Approximate Hornsea Three onshore cable corridor length (km) [b]	53
Voltage (kV)	600
Diameter of cable (mm)	220
Diameter of duct (mm)	330

a Assuming a maximum of four HVDC circuits plus one HVAC circuit (with three cables) which may be required to supply power from the onshore HVDC converter/HVAC substation to the offshore wind farm in some HVDC system designs.

b For the purposes of EIA, the length of the onshore cable route length has been rounded to 55km.

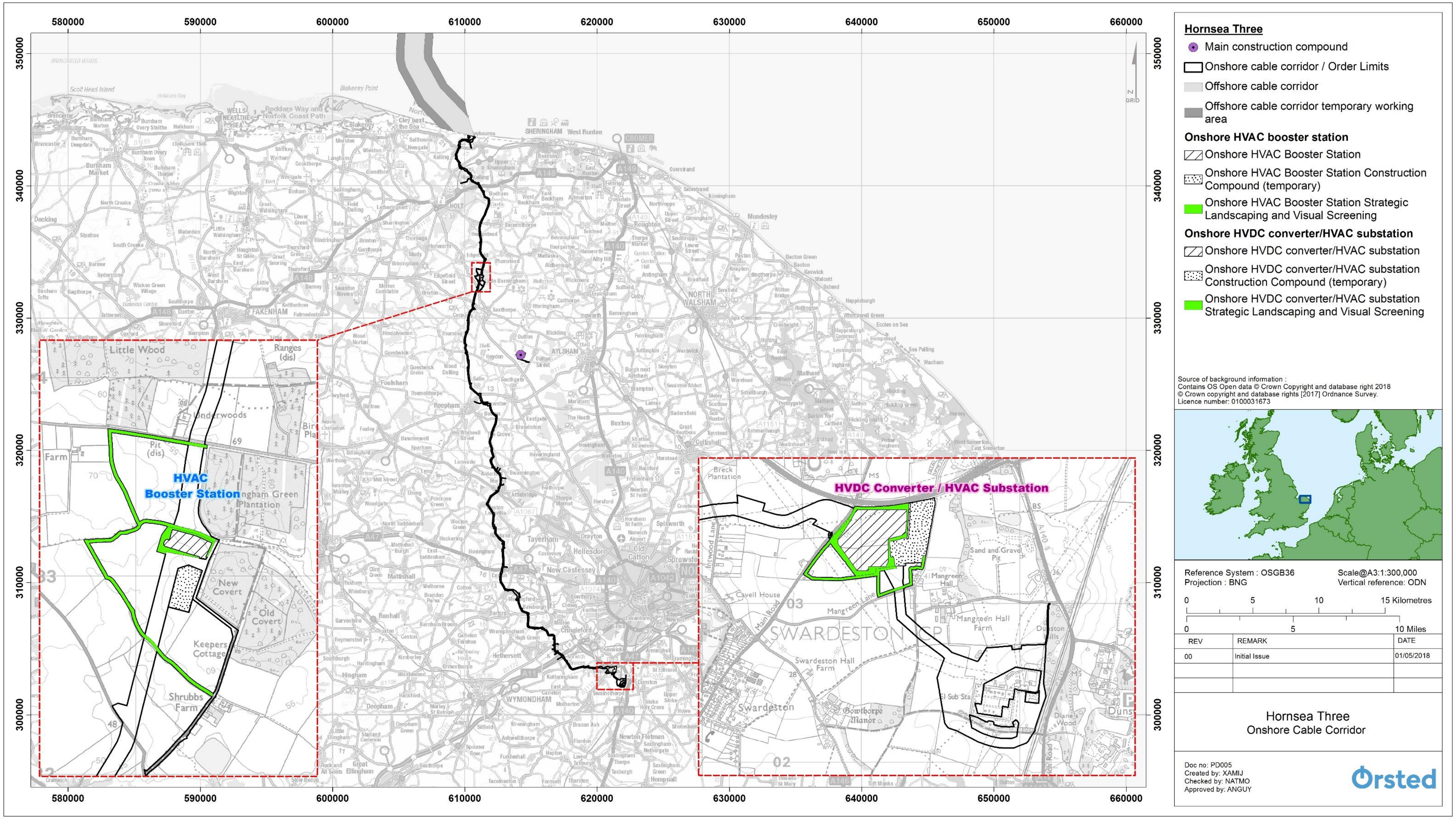


Figure 3.29: Hornsea Three onshore cable corridor and locations for onshore HVAC booster station and onshore HVDC converter/HVAC substation.

Installation

3.7.3.6 The cables will be installed within the Hornsea Three onshore 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 Three onshore cable corridor can be seen in Figure 3.32. The width of the permanent and/or temporary areas may change where obstacles are encountered.

3.7.3.7 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 3.56. The onshore export cables will typically be installed in sections of between 750 and 2,500 m at a time, with each section of cable delivered on a cable drum from which it is spooled out as it is installed. The installation of the onshore export cable is expected to take up to 30 months in total (excluding site preparation activities and reinstatement), however work is expected to progress along the export cable route with a typical works duration of three months at any particular location. Construction may be carried out by multiple teams at more than one location along the export cable route at the same time.

3.7.3.8 During construction of the cable trenches the topsoil and subsoil will be stripped and stored on site within the temporary working corridor of the Hornsea Three onshore cable corridor as construction of each linear section of the export cable route advances. The topsoil and subsoil will be stored in separate stockpiles as shown in Figure 3.27. Once the topsoil is stripped any required temporary haul roads will also be installed along the export cable route to allow trench excavation to take place. To ensure that soil is managed appropriately, the export cable route also includes a number of storage areas where additional land is provided for (see also paragraph 3.7.3.36).

3.7.3.9 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 HGV. The cables are buried in a layer of stabilised 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 3.56. However, this value is considered to be a maximum and will not be required at most locations along the export cable route. All backfill from the trenches will remain on site.

3.7.3.10 The remainder of the trench is then backfilled with the excavated material. Hard protective tiles, 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. Each trench section between joint bays (JBs) (see paragraph 3.7.3.13) is expected to be open for approximately one week.

3.7.3.11 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. This installation method, however, results in poorer thermal characteristics, can constrain the later cable deign and is slightly more expensive.

3.7.3.12 The dimensions of the export cable trenches are presented in Table 3.56 below. Within each trench or cable circuit the three cables of a HVAC circuit may either be installed in 'trefoil' or 'triangular' formation, whereby two cables sit side by side, with a third sitting above the two cables, or in flat formation where the three cables will all sit side by side at the same level in the trench. The two cables required for HVDC circuits will sit side by side in the trench. The circuits must be spaced out in order to minimise the mutual heating effect of one circuit on another, this enables the cables to effectively carry the large power volumes required without overheating and damaging the cable. The trench and cable layouts are presented in Figure 3.30 and Figure 3.31 below.

Table 3.56: 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 (m)	60
Corridor width: temporary and permanent (m)	80
Corridor area – permanent (m^2)	3,200,000
Corridor area – temporary and permanent (m^2)	4,300,000
Burial depth: target (m)	1.2
Burial depth: maximum (m)	2
Trench: depth of stabilised backfill (m)[a]	1.5
Total Installation duration (months)	30
a The average depth of stabilised backfill will be 0.6 m, with the depth going to 1.5 m in limited locations.	

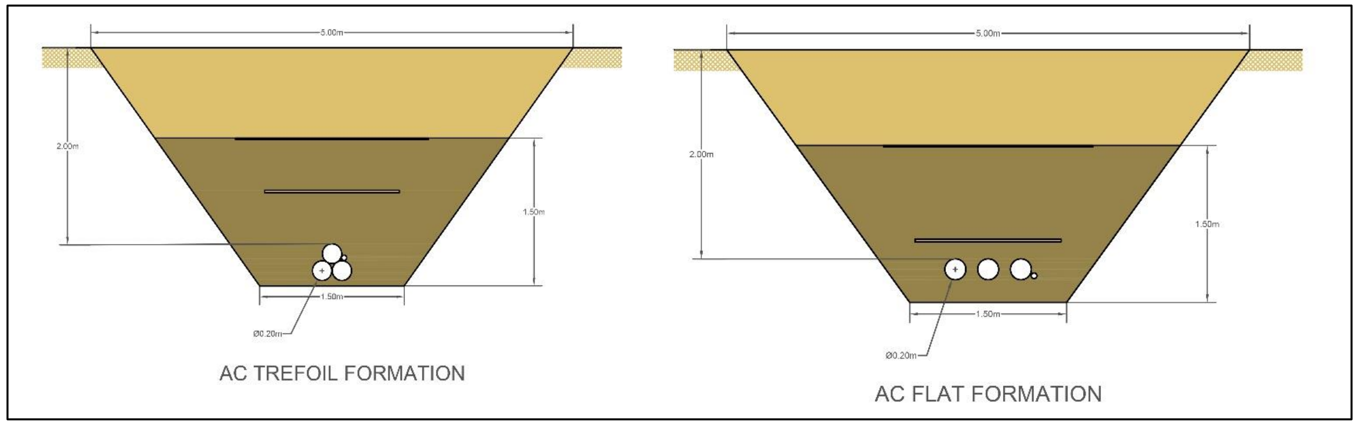


Figure 3.30: Onshore export cable HVAC trench layouts.

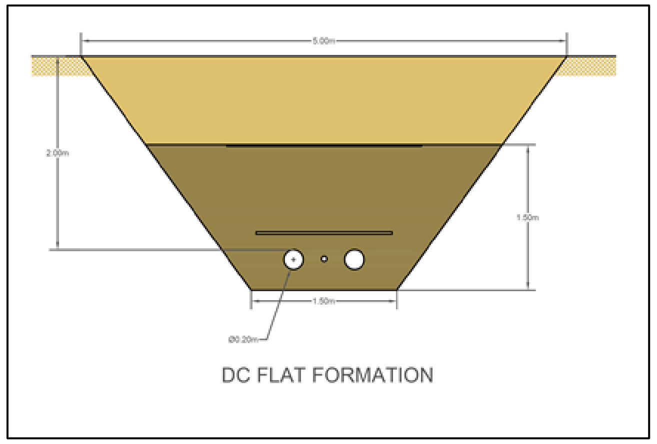


Figure 3.31: Onshore export cable HVDC trench layout.

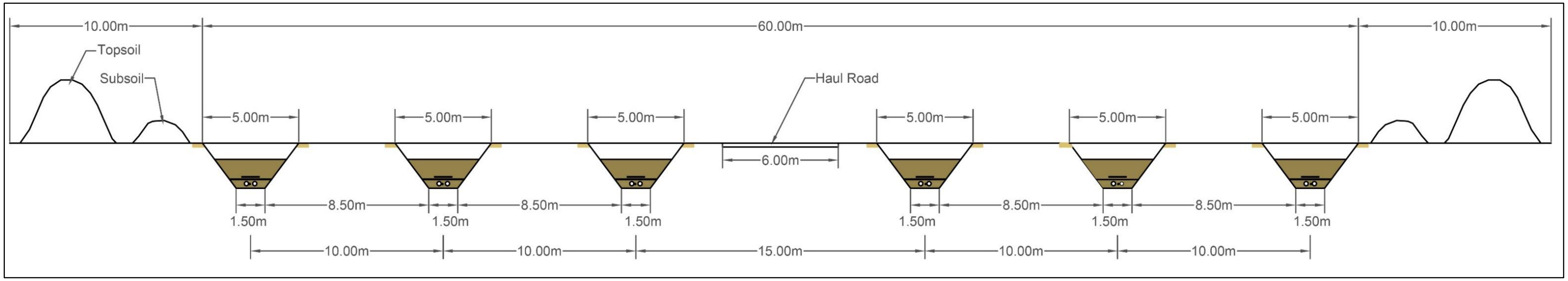


Figure 3.32: Onshore export cable corridor indicative layout showing the maximum of 6 onshore circuits.

Joint bays (JBs) and link boxes

3.7.3.13 JBs will be required along the Hornsea Three onshore 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 those described in paragraph 3.6.12.3 above, 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 3.57. JBs will only require access in the event of a cable failure requiring replacement.

Table 3.57: Maximum design parameters for joint bays (JBs).

Parameter	Maximum design parameters
Number of JBs	440
Max distance between JBs (on one circuit) (m)	2500
Min distance between JBs (on one circuit) (m) [a]	750
JB width (m)	9
JB length (m)	25
JB area (m^2)	225
JB depth (m)	2.5
JBs - Total area (m^2)	99,000
Spoil volume per JB (m^3)	563
JBs - total spoil volume (m^3)	247,500
a Excluding JBs on either side of trenchless crossings where closer spacing may be required.	

3.7.3.14 Link boxes (LBs) will also be required along the Hornsea Three onshore 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 3.58.

Table 3.58: Maximum design parameters for link boxes (LBs).

Parameter	Maximum design scenario
Number of LBs	440
Max distance between LBs (on one circuit) (m)	2500
Min distance between LBs (on one circuit) (m) [a]	750
LB dimensions (length & width) (m)	3
LB area (m^2)	9
LB depth (m)	2.0
LBs - Total area (m^2)	3,960
Spoil Volume Per LB (m^3)	18
LBs - Total Spoil Volume (m^3)	7,920
a Excluding LBs on either side of trenchless crossings where closer spacing may be required.	

Crossings

3.7.3.15 The onshore export cables will need to cross infrastructure and obstacles such as roads, railways and rivers. Hornsea Three will aim to undertake all major crossings, such as major roads, river and rail crossings using HDD or other trenchless technology. The detailed methodology for the crossings will be agreed with the relevant stakeholders such as third party asset owners, and other statutory stakeholders. Further detail on the crossing requirements along the route are provided in volume 4, annex 3.5: Onshore Crossing Schedule.

<u>HDD</u>

3.7.3.16 Hornsea Three will aim to undertake all major crossings, such as major roads, river and rail crossings using HDD or other trenchless technology. HDD involves drilling a long parabolic borehole underneath the obstacale using a drilling rig located beyond the obstacle in the Hornsea Three onshore cable corridor. The optimum design is for each drill to be carried out in a straight line, with pits 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.

3.7.3.17 The process uses a drilling head controlled from the rig to drill a pilot hole along a predetermined profile based on an analysis of the ground conditions and cable installation requirements. This pilot hole is then widened using larger drilling heads until the hole is wide enough to fit the cable ducts. Bentonite is pumped to the drilling head during the drilling process to stabilise the hole and ensure that it does not collapse. Prior to the drilling taking place, an exit pit may be excavated passed the obstacle on the export cable route in order for the HDD profile and ducts to stop at the required installation depth for the cable.

3.7.3.18 Once the HDD drilling has taken place the ducts (within which the cable will be installed) are pulled through the drilled hole. These ducts are either constructed offsite, or will be constructed onsite along the export cabel route, then pulled though the drilled hole either by the HDD rig or by separate winches.

3.7.3.19 The size of the HDD compounds is dependent on the amount of equipment that is required to construct the crossing, which in turn is primarily governed by the length of the HDD or its complexity. It is envisaged that only the major HDDs (i.e. typically greater than 200 m in length) will require a compound, which will be used to contain the drilling rig, equipment and the drill entry and exit pit. These compounds will be located within the Hornsea Three onshore cable corridor.

3.7.3.20 The HDD compounds will be provided with suitable surfacing, typically this will be constructed from stone in a similar way to the haul roads for the main cable laying activities. The compound will be secured by fencing and provided with lockable gates to control access where necessary. Appropriate drainage measures will be implemented to control surface run-off from the compound.

Open Cut

3.7.3.21 The onshore export cables will be mainly laid in open cut trenches. The trenches will be backfilled with material of adequate thermal resistivity, to dissipate the heat generated in the cables made of either native soil or stabilised material such as cement bound sand.

3.7.3.22 It may be preferable for certain crossings to be carried out as an open cut crossing, rather than a HDD. These crossings could range from smaller drains, gas and power distribution infrastructure and small roads, to high pressure gas pipelines.

3.7.3.23 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.

3.7.3.24 For smaller less sensitive infrastructure it can be quicker and less disruptive to make the crossings using open cut than undertaking the more onerous works required for HDD.

Field drainage

3.7.3.25 It may be necessary to install additional field drainage on either side of the cable trenches along the export cable route 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. Any drainage design would be agreed with landowners prior to construction. The maximum design parameters for the field drainage are presented in Table 3.59.

Table 3.59: Maximum design parameters for onshore cable route field drainage.

Parameter	Maximum design parameters
Number of drainage trenches	12
Pipe diameter (mm)	250
Trench width (mm)	500
Trench depth (mm)	1,200
Stabilised backfill depth (mm)	1,000

Access and haul roads

3.7.3.26 Access routes will be required from the public highway network at various places along the export cable route in order to access the construction works, as well as secondary construction compounds, storage locations and HDD points along the route that may be set-up in advance of the cable laying. These access routes will be up to 10 m wide, which provides space for careful storage of topsoil along the access route during construction period. Consideration has also been given to utilising existing access tracks. 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– Onshore (document reference number A2.4.2).

3.7.3.27 Access routes have also been provided to allow for monitoring of HDD operations. These access routes would only be used during the HDD operation by 4x4 vehicles and hence no physical works are required to prepare the access route. These accesses are typically 5 m wide and also make use of existing access where feasible.

3.7.3.28 Up to two temporary haul roads (being one per phase) will also be required that will run along the export cable route, in parallel to the 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. An indicative layout of the export cable route, showing the haul road, is presented in Figure 3.32. The maximum design parameters for the haul roads are presented in Table 3.60. Any sections of access road that are required to be constructed or widened would be a similar design to the temporary haul roads.

Table 3.60: Maximum design parameters for onshore cable access and haul roads.

Parameter	Maximum design parameters
Temporary haul road	2
Roadway width (m)	6
Roadway width – passing placed (m)	7
Roadway construction	Crushed aggregate on geo-textile, soil stabilisation or temporary trackway.
Aggregate depth (m)	1
Temporary culvert/bridge crossings length (m)	10

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

Temporary construction compounds

3.7.3.29 Construction compounds of various sizes will also be required along the Hornsea Three onshore cable corridor, for laydown and storage of materials, plant and staff, as well as space for small temporary offices, welfare facilities, security and parking.

3.7.3.30 Construction 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. The hierarchy of construction compounds are summarised below and detailed in the Outline Code of Construction Practice (document reference number A8.5).

Main construction compound

3.7.3.31 A main construction compound will be required to support the construction of the onshore export cables. This would operate as a central base for the onshore construction works and would house the central offices, welfare facilities, and stores, as well as acting as a staging post and secure storage for equipment and component deliveries. It may be necessary to retain part of the compound during the commissioning stages of Hornsea Three. It is envisaged that each secondary construction compound will be in place for period of up to 30 months. The main construction compound will be removed and sites restored to its original condition when construction has been completed. The main construction compound is shown in Figure 3.29.

3.7.3.32 The site identified (Oulton Airfield, off the B1149 near Oulton Street) already comprises hard standing suitable for the temporary placement of site facilities (such as offices, briefing rooms, catering facilities, storage etc. typically housed in port-a-cabins) and to allow plant and materials to be stored safely and securely. Further details on the main construction compound are documented in the Outline Code of Construction Practice (document reference number A8.5).

Secondary construction compounds

3.7.3.33 The principal contractor will also require a series of secondary construction compounds which have been located strategically along the Hornsea Three onshore cable corridor. These would 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. It is envisaged that each secondary construction compound will be in place for periods of up to three months per construction phase.

3.7.3.34 The secondary construction compound will be removed and the sites restored to their original condition when the work front in that locality has passed. The sites identified are typically currently in agricultural use. Details of surfacing required at each secondary compound will be determined by the principal contractor as it will be informed by their specific requirements and take into consideration the seasonal weather the compound will be subject to.

3.7.3.35 Each secondary construction compound will be constructed by laying a geotextile membrane or similar directly on top of the subsoil which will have stone spread over the top of it to a depth of approximately 400 mm (300 mm of 150 mm stone size c/w fine ballast and 100 mm of Type 1 clean stone) (final depth dependant on ground conditions and topography). Further details on the secondary construction compound are documented in the Outline Code of Construction Practice (document reference number A8.5).

Storage locations

3.7.3.36 The principal contractor will also require storage locations along the export cable route. These would operate as areas where some limited additional storage may be provided in addition to that land provided for along the 80 m temporary corridor. It is envisaged that each storage location will be in place for a period of one month per construction phase and the sites will be restored to their original condition when the work front has passed. The sites identified are typically currently in agricultural use and located in areas that cannot be used by the farmer during construction works because the cable installation works would temporarily restrict access. When required, topsoil will be cleared and retained onsite. Further details on the storage areas, including fencing and use are documented in the Outline Code of Construction Practice (document reference number A8.5).

General provisions

3.7.3.37 All construction 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 Three. New temporary roads or access tracks for construction traffic are likely to be required at various points along the export cable route, connecting compounds and construction sites to existing nearby roads. The maximum design parameters for construction compounds are presented in Table 3.61.

Table 3.61: Maximum design parameters for construction compounds.

Parameter	Maximum design parameters
Onshore route main compound size (m^2)	40,000
Number of major HDDs per construction phase	15
Number of total HDDs per construction phase	120

Parameter	Maximum design parameters
Major HDD compounds (length and width) (m)	70 [a]
HDD compound construction duration per compound (month)	1
JB Compounds dimensions (length and width) (m)	40[a]
JB compound construction duration per compound (months)	1
Construction compounds dimensions (length and width) (m)	90 [a]
Construction compounds: area (m^2)	33,000 [a]
Construction compound use duration per compound (months)	30 [a]
a These values should be considered realistic required dimensions for the proposed works for the purposes of this application for Development Consent, the actual dimensions will be dependent on the location and surrounding environment and may be larger than these values to optimise the use of each specific location.	

3.7.4 Site preparation activities for the onshore HVDC converter/HVAC substation and onshore HVAC booster station

3.7.4.1 For both the onshore HVAC booster station and onshore HVDC converter/HVAC substation the installation works will be relatively similar.

3.7.4.2 Preconstruction activities will entail the preparation of the site and access roads, undertaken 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.

3.7.4.3 To install the substation foundations 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.

3.7.4.4 A temporary working area will be instated adjacent to the onshore HVDC converter/HVAC substation and onshore HVAC booster station sites for the substation contractor prior to the start of the installation works and will be reinstated once all construction has been completed. 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.

3.7.4.5 Most of the larger equipment to be installed will be delivered directly to its intended installation location.

3.7.4.6 A security fence will be erected around the substation site and the contractor's areas. Site lighting will only operate when required and will be directional to avoid unnecessary illumination. Further details are documented in the Outline Code of Construction Practice (document reference number A8.5).

3.7.4.7 The civil engineering works will include:-

- 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;
- 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.

3.7.4.8 Construction management measures, including working hours, are documented in the Outline Code of Construction Practice (document reference number A8.5).

3.7.5 Onshore HVAC booster station

3.7.5.1 The onshore HVAC booster station would have the same purpose as an offshore HVAC booster station(s), as described in section 3.6.9 above, and contain similar equipment. An onshore HVAC booster station is required for HVAC transmission only; it is not required for HVDC transmission.

3.7.5.2 The onshore HVAC booster station comprises reactive compensation equipment to reduce the reactive power generated by the capacitance of the export cable in order to allow the power delivered to the National Grid to be useable.

Location

3.7.5.3 The site selection methodology for the onshore HVAC booster station is described in volume 1, chapter 4: Site Selection and Consideration of Alternatives. The location of the onshore HVAC booster station is shown in Figure 3.33 below.

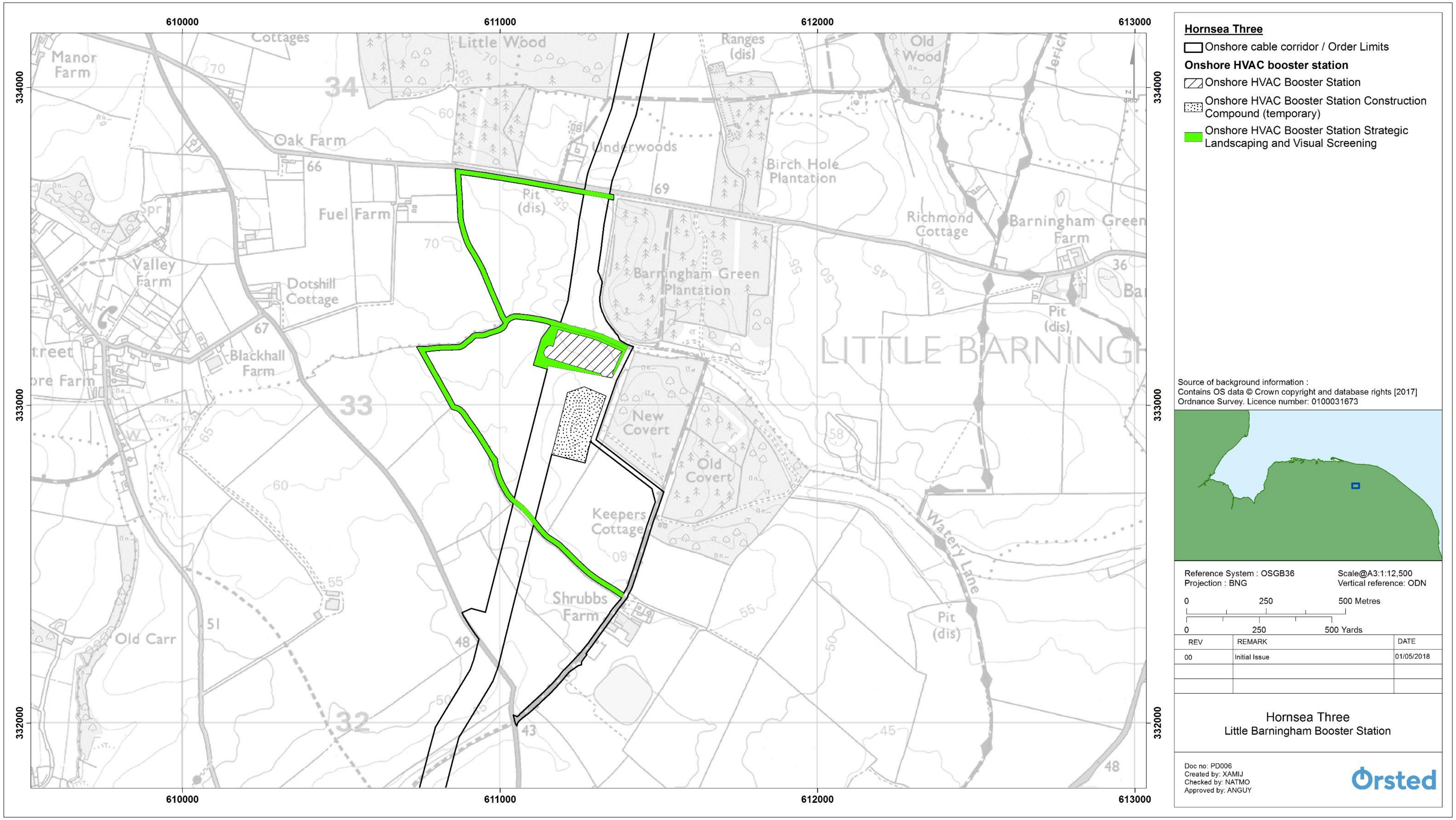


Figure 3.33: Onshore HVAC booster station location.

Design

3.7.5.4 The onshore HVAC booster station is primarily composed of high voltage electrical reactors to correct the power factor of the transmitted electricity, as well as switchgear that connect the reactors into the export cable circuits. The onshore HVAC booster station will also contain auxiliary equipment for running and controlling the onshore HVAC booster station, as well as structures to support and house the equipment. The equipment will either be housed within a single or multiple buildings, in an open yard or a combination of the above. There may also be some smaller buildings required to house components such as smaller equipment and control rooms. An underground area providing access for the export cables to enter the onshore HVAC booster station is also included in the design. An indicative layout for the onshore HVAC booster station is shown in Figure 3.34.

3.7.5.5 The maximum design parameters for the onshore HVAC booster station are presented in Table 3.62 below.

Table 3.62: Maximum design parameters for the onshore HVAC booster station.

Parameter	Maximum design parameters
Permanent area of site for all infrastructure (m^2)	30,407
Temporary area of site for construction works (m^2)	25,000
Single building [a]: length (m)	120
Single building [a]: width (m)	75
Number of buildings	6
Multiple buildings [a]: length per building (if six buildings) (m)	60
Multiple buildings [a]: width per building (if six buildings) (m)	40
Height of fire walls (m)	12.5
Building: height (m)	12.5
Maximum lightning protection height (m) (from ground level)	17.5
Underground cable access – depth (m)	5
Underground cable access – area (m^2)	6,000
Underground cable access – volume (m^3)	30,000
a The onshore HVAC booster station may comprise a single building or multiple buildings on the same site.	

Installation

3.7.5.6 The installation of the onshore HVAC booster station will require site preparation and enabling works as described in section 3.7.4 above. The final details of civil engineering works required will be identified as part of the final design of the onshore HVAC booster station.

3.7.5.7 A temporary working area will be installed adjacent to the onshore HVAC booster station which will be used to contain offices, stores, delivery and offloading areas.

3.7.6 Onshore HVDC converter/HVAC substation options

3.7.6.1 Depending on which transmission option is selected, the "onshore HVDC converter/HVAC substation" will either be an HVAC substation or a HVDC converter substation. For the remainder of this section, when "onshore HVDC converter/HVAC substation" is used, it is taken to mean the onshore HVDC converter substation or the HVAC substation unless otherwise stated.

3.7.6.2 The onshore HVDC converter/HVAC substation comprises a compound, containing equipment required to switch and transform electricity received from the windfarm to the voltage level for grid connection and to provide reactive power compensation, or containing equipment to convert HVDC electricity to HVAC electricity and housing auxiliary equipment and facilities for operating, maintaining, controlling the substation and to access the compound by vehicles and trucks.

3.7.6.3 The onshore HVDC converter/HVAC substation contains the electrical components for transforming the power supplied from the offshore 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. If a HVDC system is used it will also house equipment to convert the power from HVDC to HVAC.

Location

3.7.6.4 Hornsea Three will connect to the National Grid at the Norwich Main 400 kV substation, located between Swardeston and Stoke Holy Cross in South Norfolk. The Hornsea Three onshore HVDC converter/HVAC substation will also be located in this vicinity. The site selection methodology for the onshore HVDC converter/HVAC substation is described in volume 1, chapter 4: Site Selection and Consideration of Alternatives. The site for the onshore HVDC converter/HVAC substation is shown in Figure 3.35 below.

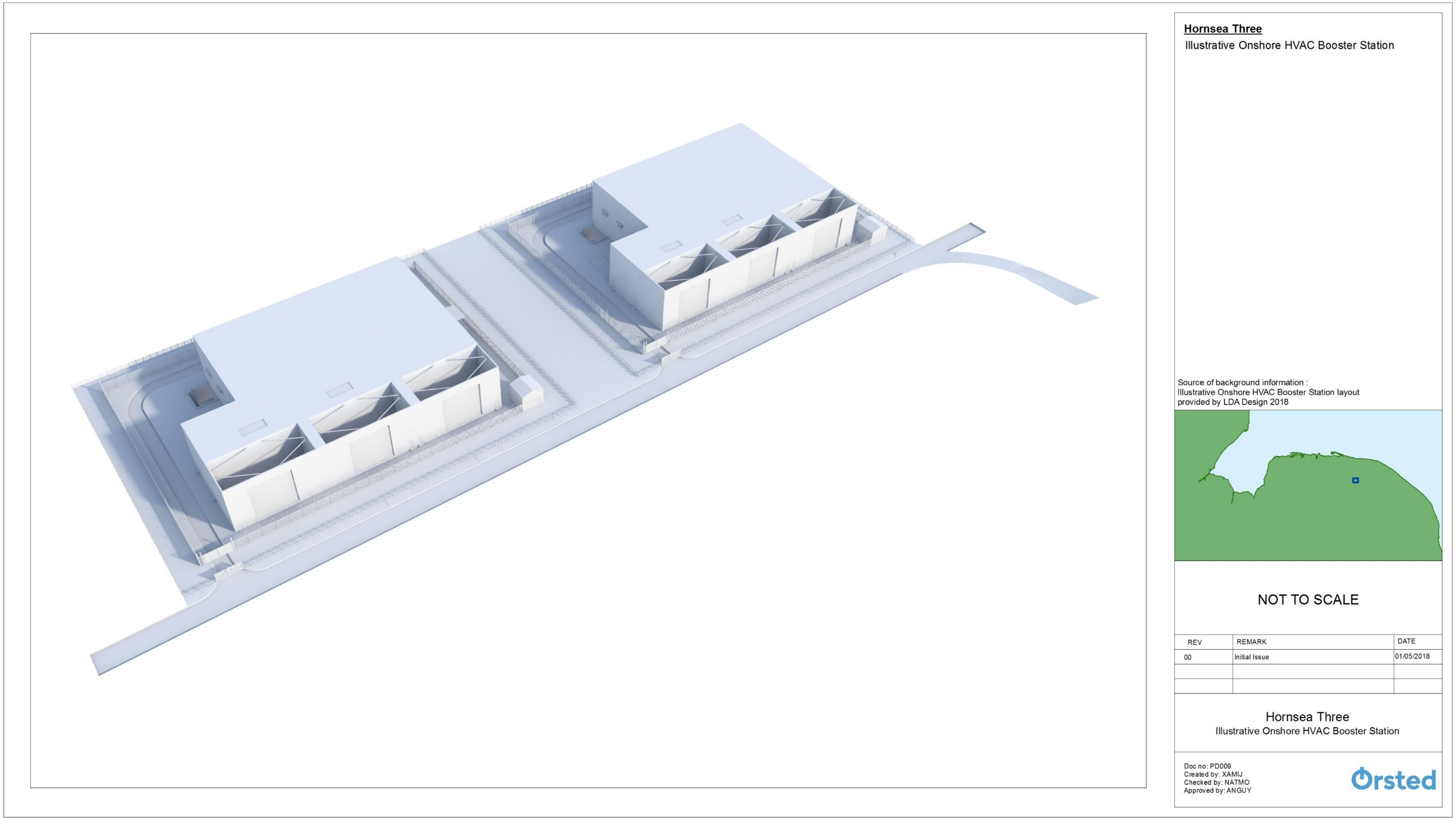


Figure 3.34: Indicative onshore HVAC booster station layout .

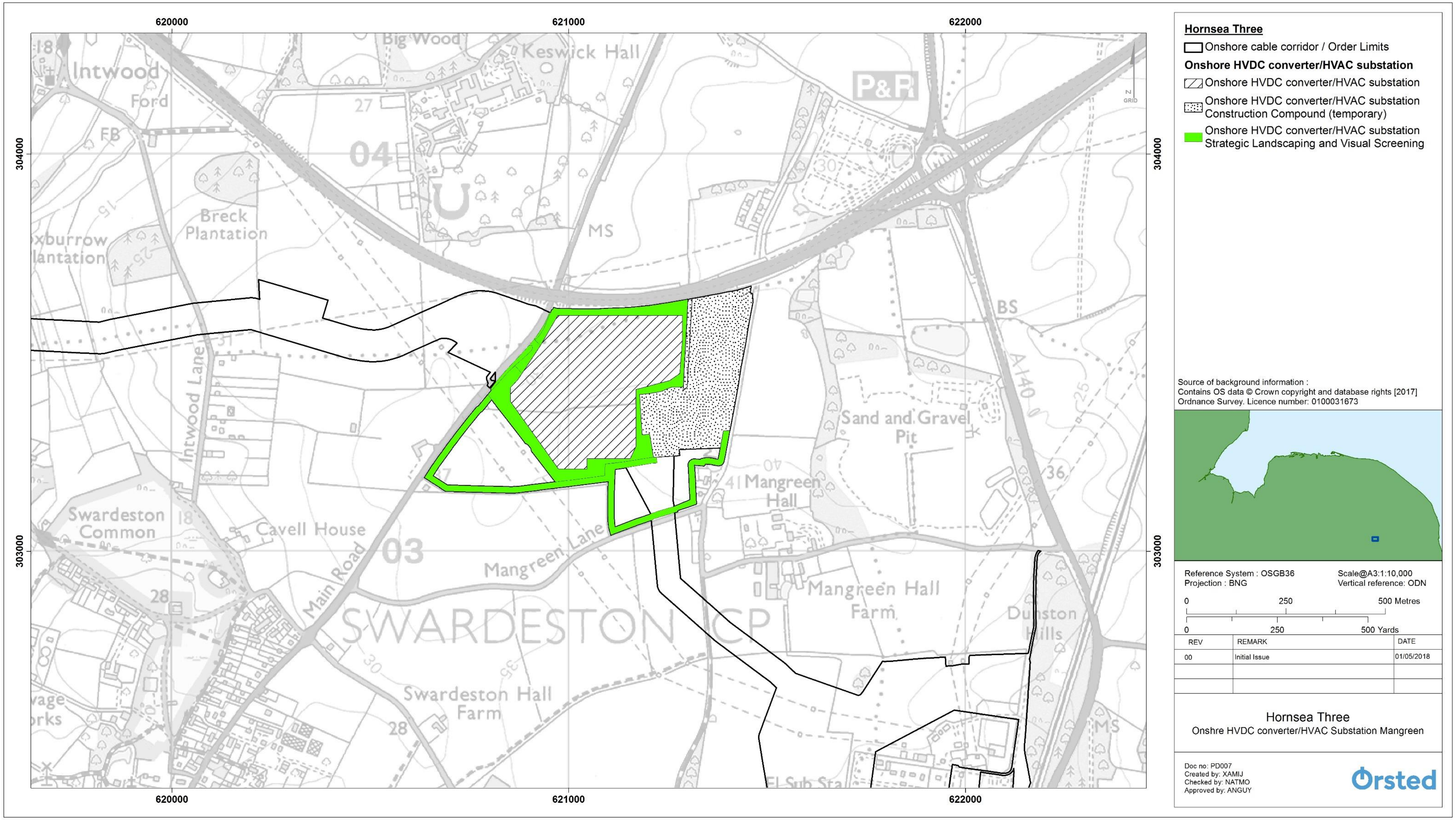


Figure 3.35: Onshore HVDC converter/HVAC substation location.

Ørsted

Design

3.7.6.5 The onshore HVDC converter/HVAC substation will consist of a range of equipment for delivery of the power to National Grid such as transformers, reactors, dynamic reactive power compensation plant (a Static Compensator (STATCOM)) filters and switchgear. It will also include a range of auxiliary and supporting equipment for the running and control of the onshore HVDC converter/HVAC substation. The main equipment will either be housed within a single or multiple buildings, 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. An indicative layout of a hybrid onshore HVDC converter/HVAC substation, developed for the purpose of informing the visulisations, is shown in Figure 3.37 below. The maximum design parameters for the onshore HVDC converter/HVAC substation for both HVAC and HVDC options are presented in Table 3.63 below.

Table 3.63: Maximum design parameters for the onshore HVDC converter/HVAC substation.

Parameter	Maximum design parameters
Permanent area of site for all infrastructure (m^2)	149,302
Temporary works area (m^2)	91,000
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
HVAC Scenario	
Maximum number of main buildings	3
Maximum length of main building (m) (if single building/if multiple buildings)	220/150
Maximum width of main building (m)	75
HVDC Scenario	
Maximum number of main buildings	2
Maximum length of main building (m)	220
Maximum width of main building (m)	75

Installation

3.7.6.6 The construction works for the onshore HVDC converter/HVAC substation are similar if using either the HVAC or HVDC solutions.

Site preparation, enabling works and civils works.

3.7.6.7 A compound will be set up that includes the permanent area required for the onshore HVDC converter/HVAC substation as well as a temporary working area required for storing and moving equipment and materials during the construction process. The topsoil of the site will be stripped and the site will be levelled as required. Civil works such as the laying of foundations and drainage, as well as the construction of buildings and supporting structures and systems will then be undertaken as required until the site is ready for the delivery of the electrical components.

Electrical component installation and reinstatement

3.7.6.8 The electrical equipment will then be installed and tested in readiness for the connection of the offshore wind farm and the National Grid substation. Once the construction of the onshore HVDC converter/HVAC 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. The construction works at the onshore HVDC converter/HVAC substation may take up to 36 months. The temporary site may include a temporary viewing platform to enable visitors and staff to safely oversee the construction without entering the construction area itself.

3.7.7 Grid connection export cable

3.7.7.1 A further section of buried onshore export cabling is required to connect the Hornsea Three onshore HVDC converter/HVAC substation with the existing National Grid substation at Norwich Main. The electrical 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 Norwich Main Substation.

3.7.7.2 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 60 m cable corridor. The remaining parameters of this section of the route are included in that described in section 3.7.3 above. The cable layout for the grid connection export cable are shown in Figure 3.36 below.

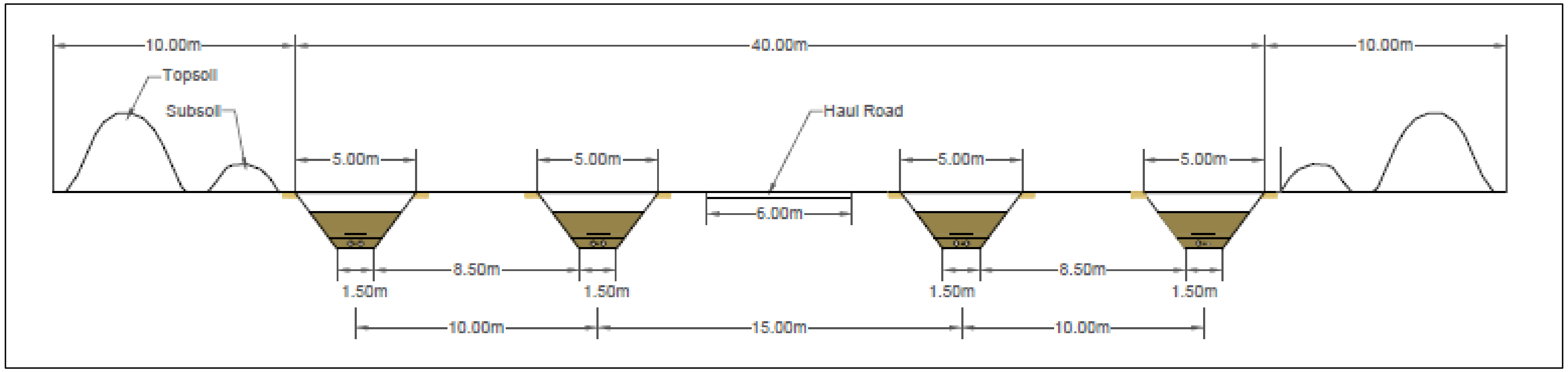


Figure 3.36: Grid connection export cable corridor indicative layout.

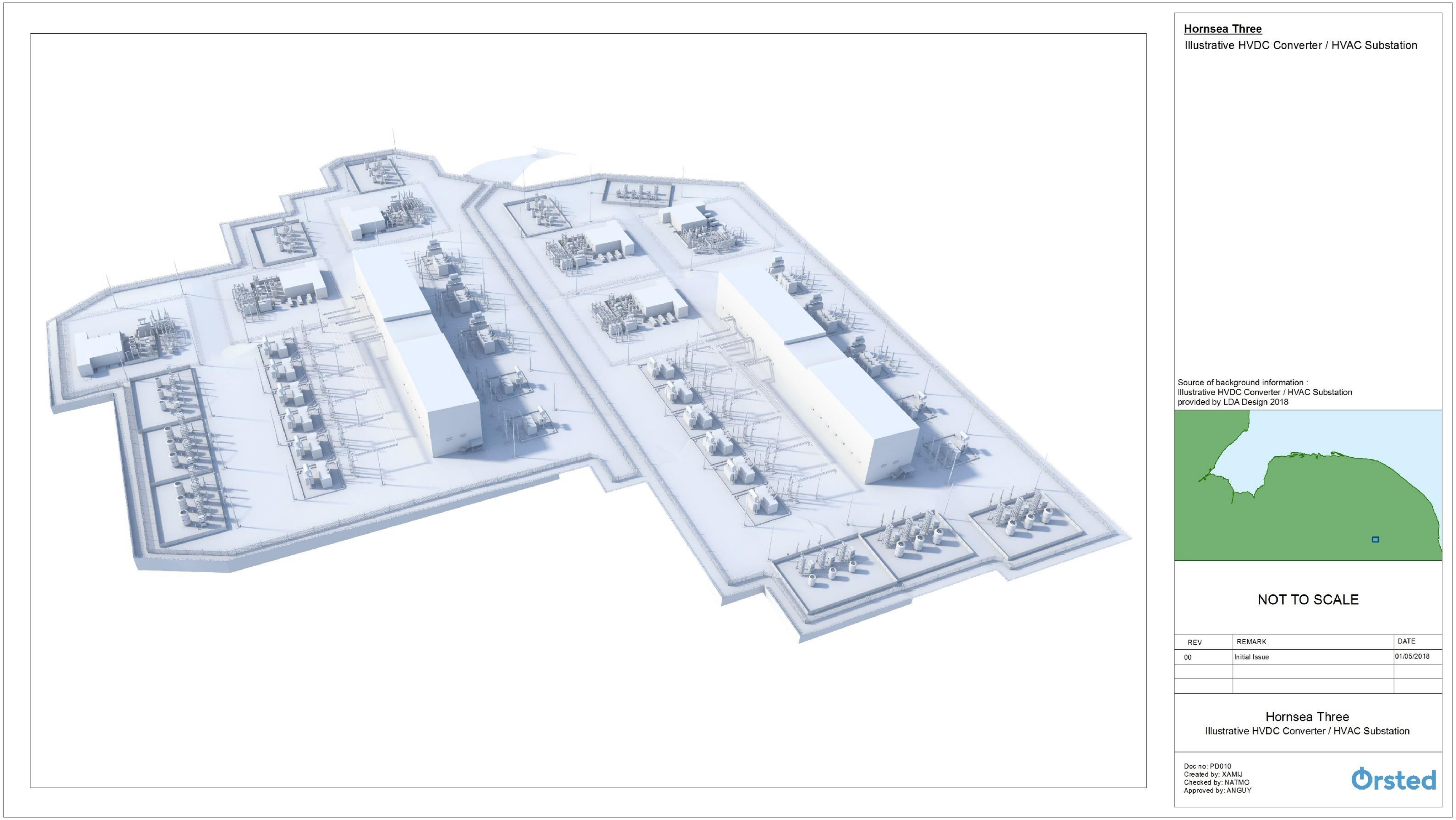


Figure 3.37: Indicative onshore HVDC converter/HVAC substation layout.

3.8 Construction Phasing

3.8.1.1 A high-level indicative construction programme where Hornsea Three is constructed in a single phase is presented in Figure 3.38 below. The programme illustrates the likely duration of the major installation elements, and how they may relate to one another if built out in a single phase construction campaign. It covers installation of the major components and does not include elements such as preliminary site preparation, and commissioning of the wind farm post-construction. Further details of where preliminary site preparation work will fit within the outline programme is discussed in sections 3.6.2 for offshore activities and 3.7.2 and 3.7.4 for onshore activities. Onshore construction is currently planned to commence in 2021 but could commence as early as 2020.

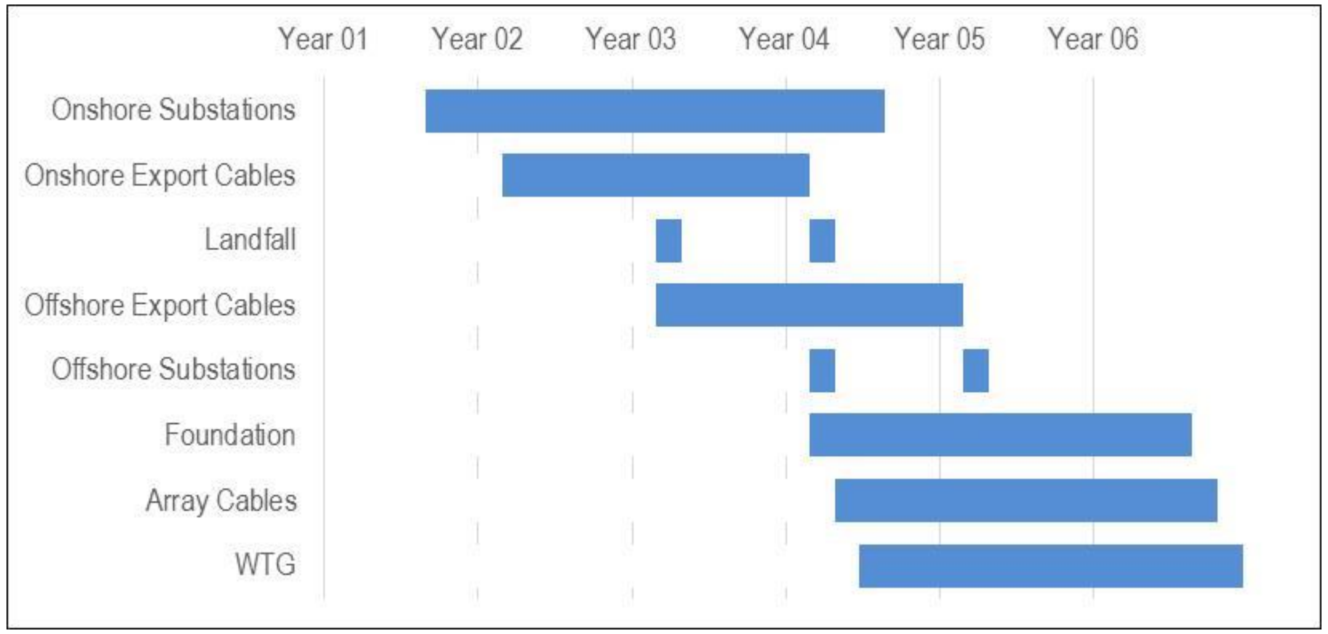


Figure 3.38: Indicative construction programme if Hornsea Three is built out in a single phase.

3.8.1.2 Hornsea Three may also be constructed in two phases, including the potential for an overlap or a gap between the completion of construction of one phase and the start of construction of another. However, if the construction activities of any phases are overlapping, the construction durations and total values for individual parameters will never exceed those stated for a single phase. For example with offshore works, no more than four monopile installation vessels would be in use at any time, and no more than two monopiles would be piled simultaneously, irrespective of any phasing described below.

3.8.1.3 It is possible that some activities may be carried out during the earlier phase for the benefit of the later one. However, any works completed for the later phase would be left in a safe state, as agreed with the relevant authorities, to await the appropriate phase for completion.

3.8.1.4 Figure 3.38 above shows an indicative programme for a single phase construction. Figure 3.39 shows an indicative construction programme where two phases are built out sequentially. These figures are provided to demonstrate indicatively how construction elements could be built out in one or two phases but still within total maximum design scenario durations presented for one phase. Phases could be sequential, fully or partially overlapping.

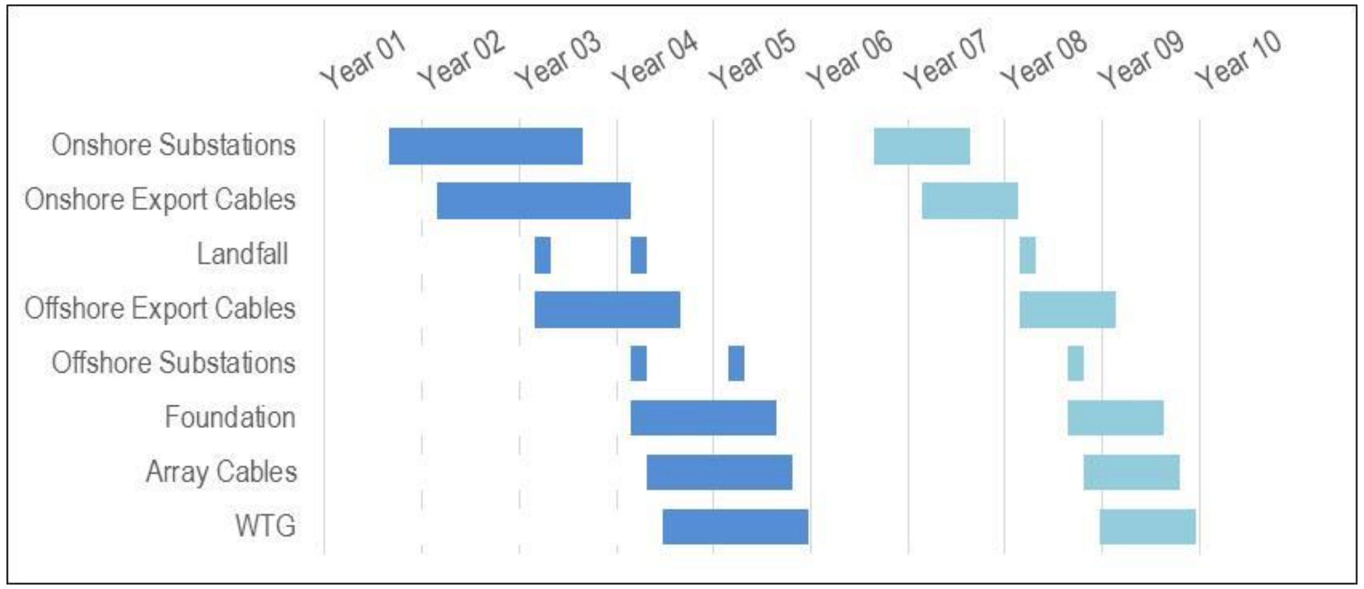


Figure 3.39: Indicative construction programme if Hornsea Three built out in two fully sequential phases.

3.8.1.5 Should Hornsea Three be built out in two phases, it is possible that these phases could be constructed directly after one another but it is also possible that there may be a gap between the construction of the phases. There are various possible reasons for this including, for example, constraints in the supply chain or the timing of auctions for the Government's Contract for Difference process which offshore wind farms currently rely on to secure a price for the electricity produced by a project. Consideration of a range of possible influences suggests a maximum gap between the same major project element in different phases (i.e. the end of piling of foundations for one phase and the start of piling of foundations on the next phase or the end of installation of onshore cables in one phase and the start of installation of onshore cables for the next) of up to approximately three years. For the onshore elements of the project, due to the maximum durations of each element of the construction works (i.e. maximum duration of construction for onshore substations is three years), this therefore means that the maximum duration over which construction of any one element (i.e. onshore HVAC booster station and onshore HVDC converter/HVAC substation) could occur would be six years, assuming a three year gap between the construction of the two phases.

3.8.1.6 The staggering of works offshore may be more complex to account for the lead in times for certain key elements. However, in a two phase scenario, all offshore works in the Hornsea Three array area would be carried out in an eight year window and all offshore works in the Hornsea Three offshore cable corridor (including the offshore HVAC booster station installation) would be carried out in an eight year window.

3.8.1.7 For the purposes of the EIA, the assessments have considered the following scenarios:

Onshore high intensity

- The maximum intensity of construction for the onshore HVAC booster station would occur if it was built in a single phase with a two-year duration;
- The maximum intensity of construction for the onshore HVDC converter/HVAC substation would occur if it was built in a single phase with a three-year duration;
- The maximum intensity of construction for the Hornsea Three onshore cable corridor would occur if it was built in a single phase within a 30 month (approximately 2.5 years) duration; and
- The maximum intensity of construction for Hornsea Three would occur if all components (onshore HVAC booster station, onshore HVDC converter/HVAC substation, export cable and intertidal works) were built simultaneously, or overlapping across multiple components. Onshore, this could result in a minimum duration of three years for all construction activities, although activities may be spatially distinct and would be preceded by pre construction activities such as borehole investigations at HDD crossing points.

Onshore long duration

- The maximum duration of construction for the onshore HVAC booster station is two years, this therefore means that the maximum duration over which construction could occur would be five years incorporating two phases (assuming a three-year gap with no active construction activity between the two phases);
- The maximum duration of construction for the onshore HVDC converter/HVAC substation is three years, this therefore means that the maximum duration over which construction could occur would be six years incorporating two phases (assuming a three-year gap with no active construction activity between the two phases);
- The maximum duration of construction for the Hornsea Three onshore cable corridor is 30 months (approximately 2.5 years), this therefore means that the maximum duration over which construction could occur would be 5.5 years incorporating two phases (assuming a three-year gap between the two phases). The work in each phase is expected to progress along the Hornsea Three onshore cable corridor with a typical active construction works duration of three months at any particular location; and
- The maximum duration of construction for all onshore elements of Hornsea Three would be eight years, which assumes construction across two phases with a three-year gap in-between, as a result of staggered construction of the components (onshore HVAC booster station, onshore HVDC converter/HVAC substation and Hornsea Three onshore cable corridor) and each phase would be preceded by pre construction activities such as borehole investigations at HDD crossing points.

Offshore high intensity

- The maximum intensity of construction in the Hornsea Three array area would occur if it was built in a single phase. In this case, the maximum durations for each activity would represent the maximum intensity (for example turbine installation would occur over 2.5 years); and
- The maximum intensity of construction for the Hornsea Three offshore cable corridor, including offshore HVAC booster station and intertidal works, would occur if it was built in a single phase. In this case, the maximum durations for each activity would represent the maximum intensity (for example export cable installation would occur over three years, preceded by pre construction activities such as sandwave clearance).

Offshore long duration

- The maximum duration of construction activities in the Hornsea Three array area would be eight years. This does not include pre-construction activities which would occur one to two years prior to construction;
- The maximum duration of construction activities in the Hornsea Three offshore cable corridor (including installation of the offshore HVAC booster stations and intertidal works) would be eight years. This does not include pre-construction activities which would occur one to two years prior to construction; and
- Within these timescales, construction of different elements is likely to be staggered as indicated in Figure 3.38 above.

3.9 Operation and maintenance

3.9.1 Description of operation and maintenance activities

3.9.1.1 The overall operation and maintenance strategy will be finalised once the operation and maintenance base location and technical specification of Hornsea Three are known, including turbine type, electrical export option and final project layout.

3.9.1.2 This section provides a description of the reasonably foreseeable planned and unplanned maintenance activities at Hornsea Three.

3.9.1.3 Maintenance activities can be categorised into two levels: preventive and corrective maintenance. Preventive maintenance will be undertaken in accordance with scheduled services whereas corrective maintenance covers unexpected repairs, component replacements, retrofit campaigns and breakdowns.

3.9.1.4 The offshore operation and maintenance will be both preventative and corrective. The operation and maintenance strategy could include either an onshore (harbour based) operation and maintenance base, or a fixed offshore operation and maintenance base (offshore accommodation platforms). Alternatively, a Special Operations Vessel (SOV), could perform the function of an offshore accommodation base and Crew Transport Vessel (CTV). The final strategy may also be a combination of the above solutions.

3.9.1.5 The general operation and maintenance strategy may rely on CTVs, 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 maximum design parameters for the operation and maintenance activities are presented in Table 3.64 below. The total operational vessel and helicopter requirements for Hornsea Three are presented in Table 3.65 below.

3.9.1.6 Preventive maintenance of subsea cables including routine inspections to ensure the cable is buried to an adequate depth and not exposed. The integrity of the cable and cable protection system (i.e. bending restrictors and bend stiffeners) will also be inspected. It is expected that on average the subsea cables will require up to two visits per year for the first three years before being reduced to yearly thereafter. Maintenance works to rebury/replace and carry out repair works on array, interconnector, accommodation and export cables, should this be required.

3.9.1.7 No substantive maintenance is expected to be required on intertidal export cables. An indicative inspection regime could consist of one annually 'scheduled' inspection, plus further 'unscheduled' inspections following extreme events, such as large storms. Scheduled and unscheduled inspection activities will require a form of geophysical survey to be undertaken over the export cable route. This is likely to require two to three persons accessing the intertidal on foot or via small 4x4 vehicle (low ground pressure vehicles will be considered such as an ARGO) for a duration of approximately two to three weeks.

Table 3.64: Maximum design parameters for offshore operation and maintenance activities.

Parameter	Maximum design parameters
Operation and maintenance vessels - CTVs:	20
Operation and maintenance vessels - SOVs	4
Operation and maintenance vessels - supply vessels	Ad hoc
Helicopters: capacity (persons)	15
JUVs	Ad hoc
Onshore facilities area - offices (m^2)	2,500
Onshore facilities area - workshop and warehouse (m^2)	2,000
Harbour facilities – quayside length (m)	100
Operational hours	24 hours, seven days a week

Table 3.65: Maximum design parameters for offshore operation and maintenance activities. A single visit comprises a return trip to and from the Hornsea Three array area.

Parameter	Maximum design parameters
Helicopter wind turbine visits (per year)	4,300
Helicopter platform visits (per year)	371
Helicopter crew shift transfer (per year)	780
Helicopter total trips (per year)	4,671
Jack-up wind turbine visits (per year)	132
Jack-up platform visits (per year)	8
Jack-up total trips (per year)	140
Crew vessels wind turbine visits (per year)	2,433
Supply vessels accommodation platform visits (per year)	312

3.9.2 Details of operation and maintenance activities

3.9.2.1 This Development Consent Order (DCO) application has been informed by a screening exercise to identify the activities to be included in relation to the offshore operation and maintenance activities. This screening exercise involved developing a generic schedule of offshore operation and maintenance activities, which identified and described typical operation and maintenance activities for offshore wind farms This process was informed by Ørsted experience from work on existing operation and maintenance projects and reference to other publicly available operation and maintenance Marine Licence applications and DCO applications. Details of those activities which require a licence and those that do not are provided in volume 4, annex 3.6: Offshore Operation and Maintenance Licensible Activities. The following section describes the processes and methods Hornsea Three 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. Maintenance due to unexpected occurences have not been described here and are not included within the application for Development Consent. In addition, some activities which could be needed in the operation and maintenance phase of Hornsea Three 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. These activities are detailed in volume 4, annex 3.6: Offshore Operation and Maintenance Licensible Activities.

3.9.2.2 During the operational life of Hornsea Three (anticipated 35 years), there can be a total of up to 16 vessels in the Hornsea Three array area on any given day. There can be up to eight vessels in the Hornsea Three array area that will operate in one 5 km by 5 km area at the same time with there being at most two 5 km by 5 km areas with this high level of vessel activity.

Offshore generation activities

Major wind turbine component replacement

3.9.2.3 This activity allows for the replacement of major wind turbine components, for example wind turbine 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 six visits for exchange events per turbine over the Hornsea Three lifetime.

3.9.2.4 The maximum design parameters for this activity are presented in Table 3.66 below.

Table 3.66: Maximum design parameters for major wind turbine component replacement.

Parameter	Maximum design quantity
Maximum number of exchange events – lifetime quantity	3,300
Footprint of seabed disturbance via jacking-up activities per exchange event (m^2)	1,020

Painting turbines

3.9.2.5 This activity includes the application of paint (e.g. Interseal) or other coatings to protect the turbine foundations 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.

3.9.2.6 There will be one full paint job per turbine every 10 years, and one touch-up paint job per turbine every three years. The maximum design parameters for painting turbines are presented in Table 3.67 below.

Table 3.67: Maximum design parameters for painting turbines.

Parameter	Maximum design quantity
Maximum number of full painting events – lifetime quantity	1,050

Bird waste removal

3.9.2.7 Marine growth and guano 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.

3.9.2.8 The maximum design parameters for bird waste removal are presented in Table 3.68 below.

Table 3.68: Maximum design parameters for bird waste removal.

Parameter	Maximum design quantity
Maximum number of cleaning events – lifetime quantity	52,500

Cable remedial burial

3.9.2.9 This activity provides remedial burial of array cables that may have become exposed via natural sediment transport processes.

3.9.2.10 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. mass-flow excavator (MFE) or similar) operated from a vessel, or diver operated injector fed from a dive platform mounted water-pump, will be powered up and manoeuvred along the exposed cable at a steady rate until the desired burial depth is achieved.

3.9.2.11 Once complete, a seabed survey will be conducted using a multibeam bathymetric survey system (or similar device) 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.

3.9.2.12 The maximum design parameters for cable remedial burial are presented in Table 3.69 below.

Table 3.69: Maximum design parameters for cable remedial burial.

Parameter	Maximum design quantity
Maximum number of remedial burial events – lifetime quantity	17
Maximum length of cable subject to jetting remediation re-burial) per remedial burial event (km)	2
Maximum width of disturbed seabed per individual jetting event (m)	10
Maximum footprint of (temporary) seabed disturbance per individual jetting exercise (for cable remediation) (m^2)	20,000

3.9.2.13 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 3.46 will be replenished.

Array cable repairs

3.9.2.14 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.

3.9.2.15 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 type of repair required. The maximum design scenario (in terms of potential environmental impact) for Hornsea Three has been calculated based on full de-burial always being required.

3.9.2.16 Alternatively, a failed cable may be rectified by replacing the entire array cable.

Cable de-burial

3.9.2.17 De-burial of cable may be undertaken if localised sediment conditions and the existing burial depth of the cable permit. This activity may take between one and five days and involves the following key steps:

- If sediment conditions and/or existing burial depth were to permit, then the cable may be gently pulled free of the seabed via the offshore substation, turbine or a cable-handling vessel;
- If sediment conditions and/or burial depth of cable do not permit the process above, then de-burial will be required, involving use of either a MFE operated from a vessel, and/or diver operated injector fed from a dive platform mounted water-pump, or the use of a grapnel to pull the cable out.

3.9.2.18 If the cable fault is located within 200 m of the offshore substation, then it is likely it will be retrieved from the seabed to the offshore substation topside via winch and pulling from a nearby JUV. If the fault is more than 200 m from the offshore substation, it is likely it will be necessary to recover a section of cable either side of the fault, sufficient to enable a repair, which would comprise of two new joints connecting a new section of cable with the ends of the original cables.

3.9.2.19 Recovery of cable more than 200 m from the offshore substation will be performed by means of dynamically positioned (DP) vessel and/or anchor barge. A dive spread/platform will also be needed for this operation.

3.9.2.20 The exact length of cable exposed and recovered to a cable handling vessel will be proportional to three times the deepest tidal water depth at the location of the fault. The total length of cable exposed and replaced in any one repair event is unlikely to exceed 200 m.

Cable repair and replacement

3.9.2.21 A new section of cable will be jointed aboard the cable-handling vessel. Upon completion of repair works and the lowering operation from a DP vessel, the resting cable will be assessed to ensure it is in the correct position. The newly repaired cable is placed on, or as close to the original cable/trench as practicably possible.

Cable re-burial

3.9.2.22 If mechanical re-burial of the cable section is required, jetting with a MFE suspended approximately 1 to 2 m above the seabed will be conducted. These techniques do not permanently add or remove any material from the seabed and take place along the existing cable route where the sediment has previously been disturbed. This operation is expected to disturb no more than 2 m width of seabed sediment (maximum 7 m if the cable cannot be reburied in the original trench from where it was recovered initially).

3.9.2.23 Where jetting by MFE is not technically feasible, trenching could be undertaken with the use of a backhoe dredger. Both jetting and trenching by these methods would occupy a similar seabed footprint.

3.9.2.24 Exact rates of re-burial will vary depending on ground conditions and the final tool used, with a range of 100 to 250 m per hour. Re-burial of the average length of cable repair (100 to 200 m) is expected to take approximately three days.

3.9.2.25 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.

3.9.2.26 The maximum design parameters for array cable repairs are presented in Table 3.70 below.

Table 3.70: Maximum design parameters for array cable repairs

Parameter	Maximum design quantity
Maximum number of cable repairs – lifetime quantity	300
Maximum cable trench width (m)	10
Maximum length of cable repair per event (km)	2
Maximum footprint of seabed disturbance per event (m^2)	25,000
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)	1,020

Access ladder replacement

3.9.2.27 This includes the replacement of access ladders to wind turbine transition pieces due to damage or corrosion.

3.9.2.28 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. The maximum design parameters for access ladder replacement are presented in Table 3.71 below.

Table 3.71: Maximum design parameters for access ladder replacement.

Parameter	Maximum design quantity
Maximum number of ladder replacement events – lifetime quantity	2,100
Footprint of seabed disturbance via jacking-up activities (m^2)	1,020

Turbine anode replacement

3.9.2.29 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 steel.

3.9.2.30 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. The maximum design parameters for turbine anode replacement are presented in Table 3.72.

Table 3.72: Maximum design parameters for wind turbine anode replacement.

Parameter	Maximum design quantity
Maximum number of anode replacement events – lifetime quantity	2,100

Offshore Transmission Activities

Offshore substation component replacement

3.9.2.31 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. The maximum design parameters for offshore substation component replacement are presented in Table 3.73 below.

Table 3.73: Maximum design parameters for offshore substation component replacement.

Parameter	Maximum design quantity
Maximum number of exchange events – lifetime quantity	32
Footprint of seabed disturbance via jacking-up activities for single exchange event (m^2)	1,020

Offshore substation painting

3.9.2.32 This includes the application of paint (e.g. Interseal) or other coatings to protect the offshore substation 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.

3.9.2.33 The maximum design parameters for offshore substation painting are presented in Table 3.74 below.

Table 3.74: Maximum design parameters for offshore substation painting.

Parameter	Maximum design quantity
Maximum number of painting events – lifetime quantity	19

Removal of organic build-up

3.9.2.34 Marine growth and guano will be physically brushed off offshore substations 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 helicopter, SOV, CTV or similar vessel.

3.9.2.35 Five cleaning events per year per substation and accomodation platform over the lifetime of Hornsea Three are planned. The maximum design parameters for removal of organic build-up are presented in Table 3.75 below.

Table 3.75: Maximum design parameters for bird waste removal.

Parameter	Maximum design quantity
Maximum number of cleaning events – lifetime quantity	3,325

Export cable remedial burial

3.9.2.36 Remedial burial of export cables that may have become exposed via natural sediment transport processes is proposed via use of water jetting tools. This is an established technique for all subsea cables and one that is used for both remediation works, and as part of planned, post-lay burial campaigns.

3.9.2.37 As-laid cable data will be reviewed to finalise the areas requiring remediation. A multibeam sonar (or similar) will be used to confirm the exact location and current cable burial depth and/or areas of exposure.

3.9.2.38 The jetting equipment (i.e. MFE operated from a vessel or diver operated injector fed from a dive platform mounted water-pump), will be powered up and manoeuvred along the exposed cable at a steady rate; nominally 1 m per minute until the desired burial depth is achieved.

3.9.2.39 A seabed survey using a multibeam bathymetric survey system (or similar device) will be used 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.

3.9.2.40 The maximum design parameters for cable remedial burial are presented in Table 3.76 below.

Table 3.76: Maximum design parameters for cable remedial burial.

Parameter	Maximum design quantity
Maximum number of remedial burial events – lifetime quantity	2.5 events per export cable
Maximum length of cable subject to jetting remediation re-burial) per remedial burial event (km)	2
Maximum width of disturbed seabed per individual jetting event (m)	The higher of 10 m or 2 x water depth x 2,000 m length of cable
Maximum footprint of (temporary) seabed disturbance per individual jetting exercise (for cable remediation) (m^2)	5 x water depth by 2 x water depth

Export cable repairs

3.9.2.41 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 onshore substation to identify the precise location of any fault along the cable length.

Cable de-burial

3.9.2.42 Where a fault is detected it may be necessary to de-bury the cable prior to recovery where testing will be conducted to establish the extent and type of repair required. The maximum design scenario is assumed to be full cable de-burial.

3.9.2.43 De-burial of cable requiring repair may be undertaken if localised sediment conditions and the existing burial depth of the cable permit. This activity may take between one and five days and involves the following key steps:

- Electrical isolation of the cable and earthing;
- If sediment conditions and/or existing burial depth permit, then the cable may be gently pulled free of the seabed via the offshore substation, turbine or a cable-handling vessel;
- If sediment conditions and/or burial depth of cable do not permit the process above, then de-burial will be required, involving one of two methods;
    - MFE operated from a vessel, with the excavator head located approximately 2 m above the seabed. This method can achieve a penetration depth of 1 to 1.5 m at a width of 2 m; and/or
    - Diver operated injector fed from a dive platform mounted water-pump.

Cable recovery

3.9.2.44 If the cable fault is located within 200 m of the offshore substation, then it is likely it will be retrieved from the seabed to the offshore substation topside via winch and pulling from a nearby JUV. If the fault is more than 200 m from the offshore substation, it is likely it will be necessary to recover a section of cable either side of the fault, sufficient to enable a repair, which would comprise of two new joints connecting a new section of cable with the ends of the original cables.

3.9.2.45 Recovery of cable more than 200 m from the offshore substation will be performed by means of DP vessel and/or anchor barge. A dive spread/platform will also be needed for this operation.

3.9.2.46 The exact length of cable exposed and recovered to a cable handling vessel will be proportional to 1.5 times the deepest tidal water depth at the location of the fault. The total length of cable exposed and replaced in any one repair event is unlikely to exceed 200 m.

3.9.2.47 No seabed intervention is planned for this part of the operation as the cable will already have been exposed via the de-burial process outlined above. Cut and exposed cable ends will be sheathed and buoyed to the surface in preparation for the repair operation. The buoyed end will then be recovered onto the cable handling vessel for jointing.

Cable repair/replacement

3.9.2.48 A new section of cable will be jointed aboard the cable-handling vessel. Upon completion of repair works and the lowering operation from a DP vessel, the resting cable will be assessed to ensure it is in the correct position. The newly repaired export cable is placed on, or as close to the original cable/trench as practicably possible.

Cable re-burial

3.9.2.49 If mechanical re-burial of the cable section is required, jetting with a MFE suspended approximately 1 to 2 m above the seabed will be conducted. These techniques do not permanently add or remove any material from the seabed and take place along the existing cable route where the sediment has previously been disturbed. This operation is expected to disturb no more than 2 m width of seabed sediment (maximum 7 m if the cable cannot be reburied in the original trench from where it was recovered initially).

3.9.2.50 Where jetting by MFE is not technically feasible, trenching could be undertaken with the use of a backhoe dredger. Both jetting and trenching by these methods would occupy a similar seabed footprint.

3.9.2.51 Exact rates of re-burial will vary depending on ground conditions and the final tool used, with a range of 100 to 250 m per hour. Re-burial of the average length of cable repair (100 to 200 m) is expected to take approximately three days.

3.9.2.52 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 export cable and 500 m around all vessels involved in the works will be notified via Notice to Mariners.

3.9.2.53 The maximum design scenario for export cable repairs are presented in Table 3.77 below.

Table 3.77: Maximum design parameters for export cable repairs.

Parameter	Maximum design quantity
Maximum number of cable repairs – lifetime quantity	21
Maximum cable trench width (m)	10
Maximum length of cable repair per event (m)	200
Maximum footprint of seabed disturbance per event (m^2)	25,000
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)	1,020

<u>Replacement of offshore substation anodes</u>

3.9.2.54 The removal and replacement of anodes, which are required for corrosion protection (internal and external to the foundation) will be required. These sacrificial anodes, usually zinc, are fastened to an external structure. The metal erodes away preferentially and so protects the erosion of the foundation. The replacement works are likely to be undertaken via a diver from a dive support vessel. The maximum design scenario for the replacement of offshore substation anodes are presented in Table 3.78 below.

Table 3.78: Maximum design parameters for replacement of offshore substation anodes.

Parameter	Maximum design quantity
Maximum number of anode replacement events – lifetime quantity	32

J-Tube repair/replacement

3.9.2.55 The offshore substation 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 either by divers from a dive support vessel or using a jack-up barge. The maximum design parameters for J-tube repair/replacement are presented in Table 3.79 below.

Table 3.79: Maximum design parameters for J-Tube repair/replacement.

Parameter	Maximum design quantity
Maximum number of J-tube replacement events – lifetime quantity	32
Footprint of seabed disturbance via jacking-up activities per J-tube replacement event (m^2)	1,020

Onshore Activities

Onshore maintenance activities

3.9.2.56 The onshore operation and mintenance requirements for the 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.

3.9.2.57 Operation and maintenance requirements for the onshore HVDC converter/HVAC substation and onshore HVAC booster station will be both preventative and corrective. The onshore infrastructure will be consistently monitored remotely, and there will be operation and maintenance staff visiting the onshore HVDC converter/HVAC substation and onshore HVAC booster station to undertake works on a regular basis, approximately every six months. These visits will occur in a small technicians' van via the established permanent access.

3.9.2.58 It is not expected that the TJBs will need to be accessed during the operation of Hornsea Three, however link boxes (see paragraph 3.6.5.10) 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.

3.10 Repowering

3.10.1.1 Although TCE lease for Hornsea Three is 50 years, the design life of Hornsea Three is likely to be 35 years. During this time, there may be a requirement for upkeep or reasonable improvement. Such maintenance is discussed in section 3.9 above, and is provided for within the DCO. If there are changes in technology, it may be desirable to 'repower' Hornsea Three at or near the end of the design life of Hornsea Three (i.e. reconstruct and replace turbines and/or foundations with those of a different specification or design.). If the specifications and designs of the new turbines and/or foundations fell outside of the maximum design scenario or the impacts of constructing, operation and maintenance, and decommissioning them were to fall outside those considered by this EIA, repowering would require further consent (and EIA) and is therefore outside of the scope of this document. At this time, it is not expected that repowering would require any removal of existing or installation of new offshore or onshore cables.

3.11 Security

3.11.1.1 Hornsea Three will be suitably secured throughout all phases of development to ensure those working on Hornsea Three can work in safety and the supply of electricity to National Grid remains secure. Any above ground onshore infrastructure such as the onshore HVDC converter/HVAC substation and onshore HVAC booster station 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.

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

3.12 Health and safety

3.12.1.1 All elements of Hornsea Three 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 Three.

3.12.1.2 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.

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

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

3.13 Waste management

3.13.1.1 Waste would be generated as a result of Hornsea Three, 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.

3.13.1.2 Procedures for handling waste materials are set out in volume 4, annex 3.4: Site Waste Management Plan (SWMP) and Outline Code of Construction Practice (document reference number A8.5).

3.13.1.3 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.

3.13.1.4 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.

3.14 Decommissioning phase

3.14.1.1 At the end of the operational lifetime of Hornsea Three, 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. TCE AfL for Hornsea Three 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 Three. The decommissioning plan and programme will be updated during Hornsea Three's lifespan to take account of changing best practice and new technologies.

3.14.2 Offshore decommissioning

Turbines

3.14.2.1 Turbines will be removed by reversing the methods used to install them.

Foundations

3.14.2.2 Piled foundations would likely be cut approximately 2 m below the seabed, with due consideration made of likely changes in seabed level, and removed. This could be achieved by inserting pile cutting devices. Once the piles are cut, the foundations could be lifted and removed from the site. At this 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.

3.14.2.3 Gravity base foundations could be removed by removing their ballast and either floating them (for self-floating designs) or lifting them off the seabed.

3.14.2.4 Any scour protection will be left in situ.

Offshore cables

3.14.2.5 Currently there is no statutory requirement for removal of decommissioned cables and removing buried cables is difficult.

3.14.2.6 Exposed cables are more likely to be removed to ensure they don't become hazards to other users of the seabed. At this time, it cannot be accurately determined which cables will be exposed at the time of decommissioning. 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.

3.14.2.7 The removal of buried cables is not an operation for which there is much precedent. Therefore, at this time, it is difficult to foresee what techniques will be used. However, it is not unlikely 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.

3.14.2.8 Once the cables are exposed, grapples 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.

3.14.2.9 Once onshore, it is likely that the cables would be deconstructed to recover and recycle the copper and/or aluminium and steel within them.

Hornsea Three intertidal area

3.14.2.10 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.

3.14.2.11 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.

3.14.3 Onshore decommissioning

Onshore export cable

3.14.3.1 To minimise the environmental disturbance during wind farm 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.

3.14.3.2 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 HVDC converter/HVAC substation and onshore HVAC booster station

3.14.3.3 The components of the onshore HVDC converter/HVAC substation and HVAC booster station 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 HVDC converter/HVAC substation and onshore HVAC booster station 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 HVDC converter/HVAC substation. If complete decommissioning is required, then all of the electrical infrastructure will be removed and any waste arising disposed of in accordance with relevant regulations.

3.14.3.4 Foundations will be broken up and the site reinstated to its original condition or for an alternative use.

3.15 References

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