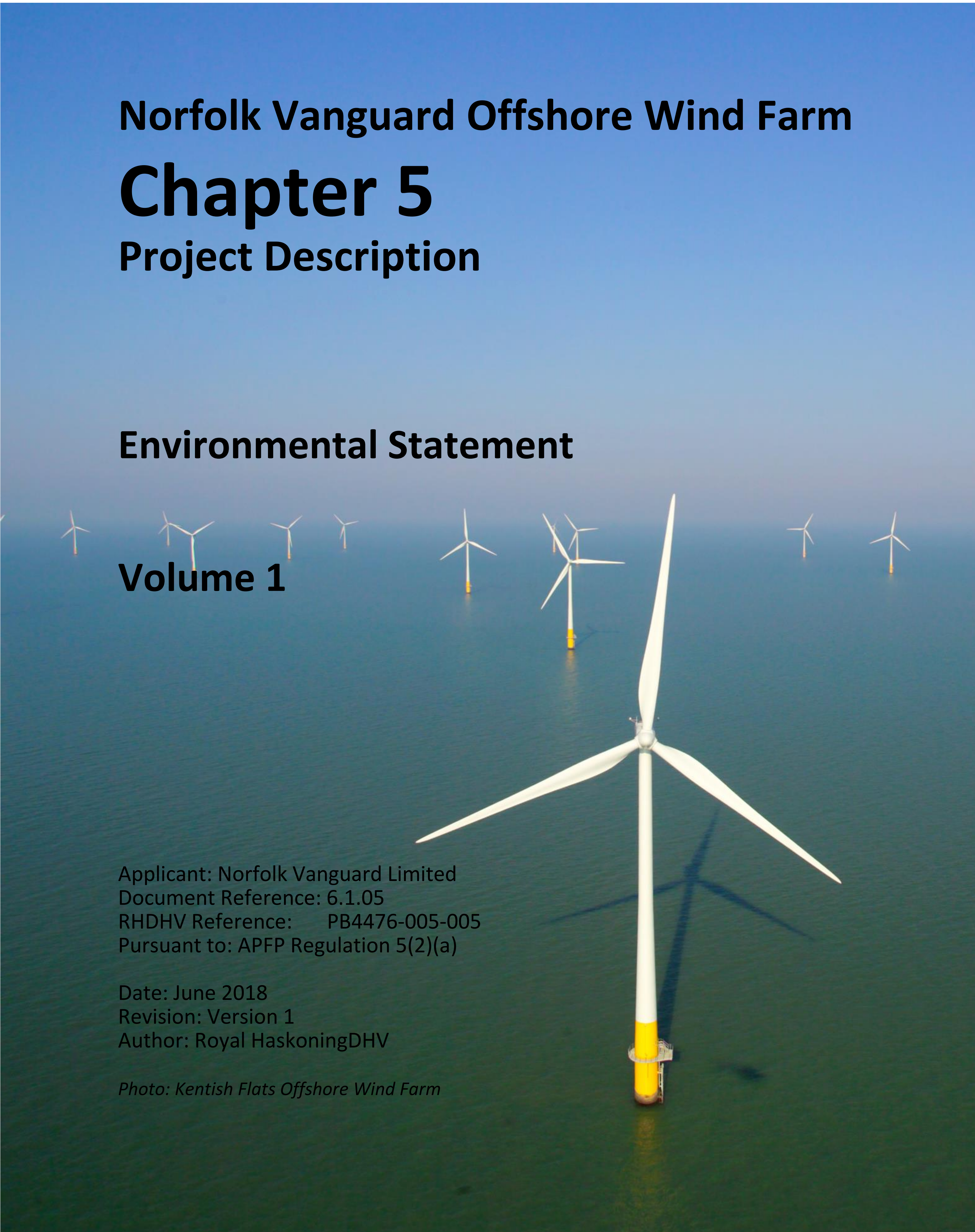
Norfolk Vanguard Offshore Wind Farm

Chapter 5

Project Description

Environmental Statement

Volume 1



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Environmental Impact Assessment
Environmental Statement

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For and on behalf of Norfolk Vanguard Limited

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Glossary

AC	Alternating Current
AIS	Air Insulation Switchgear
CAA	Civil Aviation Authority
CBS	Cement Bound Sand
CoCP	Code of Construction Practice
cSAC	candidate Special Area of Conservation
dBA	A-weighted decibel
DC	Direct Current
DCO	Development Consent Order
DML	Deemed Marine Licence
DP	Dynamic Positioning
DTS	Distributed Temperature Sensing
EIA	Environmental Impact Assessment
EMF	Electromagnetic Field
EPR	Ethylene Propylene Rubber
ES	Environmental Statement
GIS	Gas Insulated Switchgear
HAT	Highest Astronomical Tide
HDD	Horizontal Directional Drilling
HDPE	High Density Polyethylene
HGV	Heavy Goods Vehicle
HVAC	High Voltage Alternate Current
HVDC	High Voltage Direct Current
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
IDB	Internal Drainage Board
IEC	International Electrotechnical Commission
kJ	Kilojoule
LAT	Lowest Astronomical Tide
LiDAR	Light Detection and Ranging
LMP	Landscape Management Plan
MBS	Maritime Buoyage System
MCA	Maritime and Coastguard Agency
MIND	Mass Impregnated Non-Draining
MSL	Mean Sea Level
MW	Megawatt
NGET	National Grid Electricity Transmission
NOREL	Navigation and Offshore Renewable Energy Liaison
NPPF	National Planning Policy Framework
NV	Norfolk Vanguard
O&M	Operation and Maintenance
OOMP	Outline Operations and Maintenance Plan
OWF	Offshore Wind Farm
PEIR	Preliminary Environmental Information Report

RMS	Root Mean Square
ROV	Remotely Operated Vehicle
RSBL	Reference Seabed Level
SAC	Special Area of Conservation
SCADA	Supervisory Control and Data Acquisition
SF_6	Sulphur hexafluoride
SNCBs	Statutory Nature Conservation Bodies
SPL	Sound Pressure Level
SoS	Secretary of State
SSSI	Site of Special Scientific Interest
SuDS	Sustainable Drainage Systems
THLS	Trinity House Lighthouse Service
TP	Transition Piece
WTG	Wind Turbine Generator
XLPE	Cross-linked polyethylene

Terminology

Array cables	Cables which link the wind turbines and the offshore electrical platform.
Attenuation pond zone	Zone within which the attenuation pond at the onshore project substation or Necton National Grid substation will be located.
Export capacity	Maximum power transfer from the wind farm into the National Electricity Transmission System (NETS) (i.e. at the offshore transmission entry point)
Indicative mitigation planting	Areas identified for mitigation planting at the onshore project substation and Necton National Grid substation.
Interconnector cables	Buried offshore cables which link the offshore electrical platforms
Jointing pit	Underground structures constructed at regular intervals along the cable route to join sections of cable and facilitate installation of the cables into the buried ducts
Landfall	Where the offshore cables come ashore at Happisburgh South
Landfall compound	Compound at landfall within which HDD drilling would take place
Link boxes	Underground chambers or above ground cabinets next to the cable trench housing low voltage electrical earthing links.
Mobilisation area	Areas approx. 100 x 100m used as access points to the running track for duct installation. Required to store equipment and provide welfare facilities. Located adjacent to the onshore cable route, accessible from local highways network suitable for the delivery of heavy and oversized materials and equipment.
Mobilisation zone	Area within which the mobilisation area will be located.
National Grid new / replacement overhead line tower	New overhead line towers to be installed at the National Grid substation.

National Grid overhead line modifications	The works to be undertaken to complete the necessary modification to the existing 400kV overhead lines
National Grid substation extension	The permanent footprint of the National Grid substation extension
National Grid temporary works area	Land adjacent to the Necton National Grid substation which would be temporarily required during construction of the National Grid substation extension.
Necton National Grid substation	The existing 400kV substation at Necton, which will be the grid connection location for Norfolk Vanguard
Offshore accommodation platform	A fixed structure (if required) providing accommodation for offshore personnel. An accommodation vessel may be used instead
Offshore cable corridor	The corridor of seabed from the Norfolk Vanguard OWF sites to the landfall site within which the offshore export cables would be located.
Offshore electrical platform	A fixed structure located within the wind farm area, containing electrical equipment to aggregate the power from the wind turbines and convert it into a more suitable form for export to shore.
Offshore export cables	The cables which bring electricity from the offshore electrical platform to the landfall.
Offshore project area	The overall area of Norfolk Vanguard East, Norfolk Vanguard West and the offshore cable corridor
Onshore 400kV cable route	Buried high-voltage cables linking the onshore project substation to the Necton National Grid substation
Onshore cable corridor	200m wide onshore corridor within which the onshore cable route would be located as submitted for PEIR.
Onshore cable route	The 45m easement which will contain the buried export cables as well as the temporary running track, topsoil storage and excavated material during construction.
Onshore cables	The cables which take the electricity from landfall to the onshore project substation
Onshore project area	All onshore electrical infrastructure (landfall; onshore cable route, accesses, trenchless crossing technique (e.g. Horizontal Directional Drilling (HDD)) zones and mobilisation areas; onshore project substation and extension to the Necton National Grid substation and overhead line modification)
Onshore project substation	A compound containing electrical equipment to enable connection to the National Grid. The substation will convert the exported power from HVDC to HVAC, to 400kV (grid voltage). This also contains equipment to help maintain stable grid voltage.
Onshore project substation temporary construction compound	Land adjacent to the onshore project substation which would be temporarily required during construction of the onshore project substation.
Running track	The track along the onshore cable route which the construction traffic would use to access workfronts
Safety zones	A marine zone outlined for the purposes of safety around a possibly hazardous installation or works / construction area under the Energy Act 2004.
Scour protection	Protective materials to avoid sediment being eroded away from the base of the foundations as a result of the flow of water.
The Applicant	Norfolk Vanguard Limited

The OWF sites	The two distinct offshore wind farm areas, Norfolk Vanguard East and Norfolk Vanguard West
The project	Norfolk Vanguard Offshore Wind Farm, including the onshore and offshore infrastructure
Transition pit	Underground structures that house the joints between the offshore export cables and the onshore cables within the landfall
Trenchless crossing zone (e.g. HDD)	Temporary areas required for trenchless crossing works.
Workfront	The 150m length of onshore cable route within which duct installation would occur

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5 PROJECT DESCRIPTION

5.1 Introduction

1. This chapter of the Norfolk Vanguard Environmental Statement (ES) provides a full description of the components required for construction, operation, maintenance and decommissioning of Norfolk Vanguard offshore wind farm and includes a consideration of the methods used for installation, maintenance and decommissioning.

2. As outlined in Chapter 1 Introduction and detailed throughout this chapter, the offshore wind farm (OWF) comprises two distinct areas, Norfolk Vanguard East (NV East) and Norfolk Vanguard West (NV West) ('the OWF sites'). The offshore wind farm would be connected to the shore by offshore export cables installed within the offshore cable corridor from the wind farm to a landfall point at Happisburgh South, Norfolk. From there, onshore cables would transport power over approximately 60km to the onshore project substation at Necton, Norfolk.

3. Once built, Norfolk Vanguard would have an export capacity of up to 1800MW, with the offshore components comprising:

- Wind turbines;
- Offshore electrical platforms;
- Accommodation platforms;
- Met masts;
- Measuring equipment (LiDAR and wave buoys);
- Array cables;
- Interconnector cables; and
- Export cables.

4. The key onshore components of the project are as follows:

- Landfall;
- Onshore cable route, accesses, trenchless crossing technique (e.g. Horizontal Directional Drilling (HDD)) zones and mobilisation areas;
- Onshore project substation; and
- Extension to the Necton National Grid substation and overhead line modifications.

5. Vattenfall Wind Power Ltd (parent company of Norfolk Vanguard Limited), through one of its subsidiaries, is also developing Norfolk Boreas, a 'sister project' to Norfolk Vanguard. Norfolk Boreas would share a grid connection location and also much of the offshore and onshore cable corridors with Norfolk Vanguard. Therefore, in order to minimise impacts, Norfolk Vanguard Limited will include within its Development

Consent Order (DCO) application some enabling works for the Norfolk Boreas project. These are clearly defined within this chapter and are assessed in the relevant technical chapters.

5.1.1 Project Design Envelope

6. Chapter 3 Policy and Legislative Context provides a background to the 'Rochdale' or project design envelope approach.

7. The project design envelope sets out a series of design options for the project. The project design envelope has a reasoned minimum and maximum extent for a number of key parameters. The final design would lie between the minimum and the maximum extent of the consent sought, for all aspects of the project; this includes spatial and temporal elements and the proposed methodology to be employed. The project design envelope is used to establish the extent to which the project could impact on the environment. The final detailed design of the project will fall within this 'envelope', allowing for detailed design work to be undertaken post-consent without rendering the assessment inadequate or falling outside the DCO.

8. Therefore, the information presented in this chapter outlines the options required and the range of potential design and activity parameters upon which the subsequent impact assessment chapters are based.

9. Where appropriate, each impact assessment chapter contains a section detailing the worst case scenario for specific receptors and impacts. These worst case scenario sections are derived from the information provided in this chapter.

5.1.1.1 Need for flexibility

10. Detailed design work for the project will occur post-consent. The project design envelope must provide sufficient flexibility to enable Norfolk Vanguard Limited and its contractors to use the most up to date, efficient and cost effective methods and technology in order to minimise the cost to the UK consumer. In addition, post-consent/pre-construction site investigation will further inform the detailed design. Key aspects for which flexibility is required include:

- Turbine capacity and parameters due to the potential evolution of technology prior to offshore construction of Norfolk Vanguard around 2024;
- Number and capacity of offshore electrical platforms and export cables;
- Build-out scenarios/ phasing options to enable Norfolk Vanguard Limited to construct the offshore wind farm in a way which produces power to the National Grid as early as possible whilst maximising efficiencies during construction; and

- Construction and maintenance methodologies, as above, to enable competitive procurement and the most cost effective option to be adopted.

11. This chapter outlines the range of parameters for the aspects of the project where flexibility is required.

5.1.2 Project Description Terminology

12. This project description uses specific terms for different elements of the offshore and onshore project areas and infrastructure. These terms are also used within the technical chapters (Chapter 8 to Chapter 31). For clarity, these terms are summarised in Table 5.1.

Table 5.1 Project description terminology

Terminology	Description
Array cables	Cables which link the wind turbines and the offshore electrical platform.
Interconnector cables	Buried offshore cables which link the offshore electrical platforms
Jointing pit	Underground structures constructed at regular intervals along the cable route to join sections of cable and facilitate installation of the cables into the buried ducts.
Landfall	Where the offshore cables come ashore at Happisburgh South
Landfall compound	Compound at landfall within which HDD drilling would take place
Link boxes	Underground chambers or above ground cabinets next to the cable trench housing low voltage electrical earthing links.
Mobilisation area	Areas approx. 100 x 100m used as access points to the running track for duct installation. Required to store equipment and provide welfare facilities. Located adjacent to the onshore cable route, accessible from local highways network suitable for the delivery of heavy and oversized materials and equipment.
Mobilisation zone	Area within which the mobilisation area will be located.
National Grid new / replacement overhead line tower	New overhead line towers to be installed at the National Grid substation.
National Grid overhead line modifications	The works to be undertaken to complete the necessary modification to the existing 400kV overhead lines
National Grid substation extension	The permanent footprint of the National Grid substation extension
National Grid temporary works area	Land adjacent to the Necton National Grid substation which would be temporarily required during construction of the National Grid substation extension.
Necton National Grid substation	The existing 400kV substation at Necton, which will be the grid connection location for Norfolk Vanguard
Offshore accommodation platform	A fixed structure (if required) providing accommodation for offshore personnel. An accommodation vessel may be used instead
Offshore electrical platform	A fixed structure located within the wind farm area, containing electrical equipment to aggregate the power from the wind turbines and convert it into a more suitable form for export to shore.
Offshore export cables	The cables which bring electricity from the offshore electrical platform to the landfall.
Offshore project area	The overall area of Norfolk Vanguard East, Norfolk Vanguard West and the offshore cable corridor

Terminology	Description
Onshore 400kV cable route	Buried high-voltage cables linking the onshore project substation to the Necton National Grid substation
Onshore cables	The cables which take the electricity from landfall to the onshore project substation
Onshore cable route	The 45m easement which will contain the buried export cables as well as the temporary running track, topsoil storage and excavated material during construction.
Onshore infrastructure	The combined name for all onshore infrastructure associated with the project from landfall to grid connection.
Onshore project area	All onshore electrical infrastructure (landfall; onshore cable route, accesses, trenchless crossing technique (e.g. Horizontal Directional Drilling (HDD)) zones and mobilisation areas; onshore project substation and extension to the Necton National Grid substation and overhead line modification)
Onshore project substation	A compound containing electrical equipment to enable connection to the National Grid. The substation will convert the exported power from HVDC to HVAC, to 400kV (grid voltage). This also contains equipment to help maintain stable grid voltage.
Onshore project substation temporary construction compound	Land adjacent to the onshore project substation which would be temporarily required during construction of the onshore project substation.
Offshore cable corridor	The area where the offshore export cables would be located.
Running Track	The track along the onshore cable route which the construction traffic would use to access workfronts
Safety zone	A marine zone outlined for the purposes of safety around a possibly hazardous installation or works / construction area under the Energy Act 2004.
Scour protection	Protective materials to avoid sediment being eroded away from the base of the foundations as a result of the flow of water.
The Applicant	Norfolk Vanguard Limited
The OWF sites	The two distinct offshore wind farm areas, Norfolk Vanguard East and Norfolk Vanguard West.
The project	Norfolk Vanguard Offshore Wind Farm, including the onshore and offshore infrastructure
Transition pit	Underground structures that house the joints between the offshore export cables and the onshore cables within the landfall
Trenchless crossing zone (e.g. HDD)	Temporary areas required for trenchless crossing works.
Workfront	The 150m length of onshore cable route within which duct installation would occur

5.1.3 Site Description

5.1.3.1 Offshore

13. Norfolk Vanguard comprises two distinct areas, NV East and NV West, which are located in the southern North Sea, approximately, 70km and 47km from the coast of Norfolk respectively (at the nearest points). These two areas will be included in the Environmental Impact Assessment (EIA) and DCO application process as a single project.

14. The offshore site includes areas of sand ridges with associated peaks and troughs. Water depths across NV West vary between approximately 25m and 50m below Lowest Astronomical Tide (LAT). The minimum water depth is along the north-

central edge of the site and the maximum water depth is within the south-west corner of the site. The water depth within NV East varies from a maximum depth of 42m below LAT across the north-east part of the site to a minimum depth of 22m below LAT on the crest of a sand ridge in the north-east part of the site. Water depths within the offshore cable corridor, in the region of the NV West and NV East sites, are typically 40 to 50m below LAT. Progressing towards the coast, water depths decrease progressively from around 40m below LAT to 10m below LAT about 500m to 1000m from the coast.

15. NV West and NV East experience tidal velocities of up to 1.2m/s. The offshore project area substrate is relatively heterogeneous, with majority of the area characterised by medium sand.

16. The winds on the north-west coastal region blow from between 325°N and 70°N and can generate waves over fetch lengths of greater than 200km. On the south-west coastal region, such fetch lengths can only be generated over a much narrower range of wind directions of between 20°N and 60°N.

17. The southern North Sea candidate Special Area of Conservation (cSAC) encompasses Norfolk Vanguard and the offshore cable corridor also passes through the Haisborough, Hammond and Winterton Special Area of Conservation (SAC).

5.1.3.2 Landfall

18. The coast of north-east Norfolk is an almost continuous line of glacial till cliffs. The coast is exposed and therefore very dynamic. Rapid cliff erosion is occurring in places including at Happisburgh South, and severe storm events can rapidly change beach levels and the degree of exposure of the natural or defended coastline. The area surrounding the landfall area is characterised by arable farming.

19. The shoreline management plan (AECOM, 2012) states that the intended management at Happisburgh South is Managed Realignment over the next 100 years, meaning that beach and cliff erosion will be allowed to occur but in a controlled manner (i.e. minimising the rate of coastal erosion in the short term using appropriate temporary measures with a view to allowing time for measures to be introduced to allow people to adapt to the changes in the medium and long term).

20. Appendix 4.1 provides a study on coastal erosion in the area and this has informed the site selection and design of the landfall works.

5.1.3.3 Onshore

21. The onshore project area is dominated by agricultural practices. As a result of careful site selection, settlements, sensitive habitats and other physical constraints have been avoided where possible (see Chapter 4 Site Selection and Assessment of

Alternatives). Nearby towns/ villages include Happisburgh, North Walsham, Aylsham, Reepham, Dereham and Necton.

5.2 Consultation

22. Norfolk Vanguard Limited has undertaken extensive community and stakeholder consultation to inform the project design of Norfolk Vanguard, in particular the site selection. The Consultation Report (document 5.1) details all consultation undertaken on the project and Chapter 4 Site Selection and Assessment of Alternatives outlines the consultation that has been taken into account during the onshore and offshore site selection.

23. Norfolk Vanguard Limited has reviewed consultation received during informal and formal consultation and, in light of the feedback, has made a number of key decisions in relation to the project design in order to deliver an environmentally sustainable project. One of those decisions is to deploy HVDC cable technology and this removes the need for a cable relay station, reduces the onshore cable route width from 100m to 45m (see section 5.5) and reduces the number of offshore export cable trenches from six to two. Another key commitment Norfolk Vanguard Limited has made in response to consultation is to use long HDD at the landfall in order to avoid any works on the beach and any material impacts on the cliffs (see section 5.5.1).

24. Table 5.2 provides an outline of consultation in relation to the project description. However, where stakeholders have requested design changes and additional information specific to a topic, these are detailed in the relevant technical chapters.

Table 5.2 Consultation responses

Consultee	Date /Document	Comment	Response / where addressed in the PEI
Secretary of State (SoS)	November 2016 (scoping response, statutory)	The Applicant should ensure that the description of the proposed development that is being applied for is as accurate and firm as possible as this will form the basis of the EIA. It is understood that at this stage in the evolution of the scheme, the description of the proposals and even the location of the site may not be confirmed. The Applicant should be aware however, that the description of the development in the ES must be sufficiently certain to meet the requirements of paragraph 17 of Schedule 4 Part 1 of the EIA Regulations and there should therefore be more	This chapter provides a detailed and accurate description of the design envelope for the DCO application.

Consultee	Date /Document	Comment	Response / where addressed in the PEI
		certainty by the time the ES is submitted with the DCO.	
SoS	November 2016 (scoping response, statutory)	Any proposed works and/or infrastructure required as associated development, or as an ancillary matter, (whether on or off-site) should be assessed as part of an integrated approach to environmental assessment.	All works associated with the project and ancillary works are described within this chapter.
SoS	November 2016 (scoping response, statutory)	The Secretary of State recommends that the ES should include a clear description of all aspects of the proposed development, at the construction, operation and decommissioning stages, and include: Land use requirements, including the area of the offshore elements; Site preparation; Construction processes and methods; Transport routes; Operational requirements including the main characteristics of the production process and the nature and quantity of materials used, as well as waste arisings and their disposal; Maintenance activities including any potential environmental or navigation impacts; and Emissions - water, air and soil pollution, noise, vibration, light, heat, radiation.	All works associated with the project are described throughout this chapter.
SoS	November 2016 (scoping response, statutory)	The environmental effects of all wastes to be processed and removed from the site should be addressed. The ES will need to identify and describe the control processes and mitigation procedures for storing and transporting waste off site. All waste types should be quantified and classified.	Volumes of waste material are provided in Chapter 19 Ground Conditions and Contamination; Appendix 19.2 Waste Technical Assessment.
SoS	November 2016 (scoping response, statutory)	The ES should describe works [at the National Grid substation] as far as possible with the information available at the time. The ES should also identify whether there is any other consequential development, for example any upgrading of overhead lines, and consider any such works within the cumulative assessment.	All works at the National Grid substation are described within this chapter.
SoS	November	In relation to 'Offshore substation	The number of offshore

Consultee	Date /Document	Comment	Response / where addressed in the PEI
	2016 (scoping response, statutory)	platforms and accommodation platform', Table 1.1 of the Scoping Report identifies '2-6 platforms'. It is unclear how many of each type of platforms would be required. Whilst it is appreciated this detail may not be known at this stage, the number of offshore substation platforms and either shared or standalone accommodation platforms should be set out within the ES.	platforms is described in section 5.4.4.
SoS	November 2016 (scoping response, statutory)	Paragraph 114 of the Scoping Report states that "It is anticipated that the layout of WTGs will be regular in plan (i.e. turbines will be set out in rows)". If this layout is relied upon as mitigation (for example in relation to navigation), the Applicant should ensure that this principle is secured.	A description of the worst case assessed within this ES, and the rationale by which it has been chosen is presented in Chapter 15 section 15.6.2.
SoS	November 2016 (scoping response, statutory)	Paragraph 304 of the Scoping Report notes that there is rapid cliff erosion on the coast of north east Norfolk. The ES should explain how erosion rates have been taken into account in determining the depth of cable burial at the landfall, the depths of transition pits and the set-back distance of the cable relay station from the coastline.	Appendix 4.1 provides details of a coastal erosion study commissioned by Norfolk Vanguard Limited to inform the site selection regarding set-back distance of landfall works from the coastline. Initial site investigation works have been completed and will inform the final design of Horizontal Direction Drilling (HDD) at the landfall.
SoS	November 2016 (scoping response, statutory)	The ES should detail the dimensions, number and location of link boxes. It is unclear from the Scoping Report whether access will need to be maintained to the link boxes; this should be clarified.	These details are provided in section 5.5.2.6.
SoS	November 2016 (scoping response, statutory)	The Scoping Report identifies the need for jointing pits at regular intervals along the cable route (every 500-1000m) and that the precise location of the jointing pit would be determined during detailed design. The ES should identify a worst case scenario for the number of jointing pits and link boxes. The Secretary of State welcomes the proposal to locate jointing pits at the edge of field boundaries or roads	Information on jointing pits is provided in section 5.5.2.5 and link boxes is provided in section 5.5.2.6. An Outline CoCP (CoCP) (document reference 8.1) is provided with the ES.

Consultee	Date /Document	Comment	Response / where addressed in the PEI
		wherever possible. Where any such commitments are made in specific locations, these should be secured for example through a construction method statement or Code of Construction Practice (CoCP)/Construction Environmental Management Plan (CEMP).	
SoS	November 2016 (scoping response, statutory)	The cable will need to cross roads, railways, watercourses, gas, water and electrical infrastructure. The ES should identify the locations and type of all such crossings. Where commitments are made within the ES to use a specific method as mitigation (e.g. HDD below the coastal floodplain grazing marsh and the River Wensum and 'sensitive locations' as noted in paragraph 825 of the Scoping Report), the Applicant should ensure that such methodology is secured via the draft DCO. Similarly, the Scoping Report states that HDD would be used at the landfall (either by 'long' or 'short' HDD methods); therefore, its use at this location should also be secured.	Locations where trenchless crossings will be required are provided in Figure 5.3. A schedule of water crossings is provided in Appendix 20.4 of Chapter 20 Water Resources and Flood Risk. The selection of the long HDD is discussed in section 5.5.1.
SoS	November 2016 (scoping response, statutory)	The Secretary of State notes that in the absence of a detailed onshore connection route proposal, a broad indicative corridor has been identified. Such uncertainty over the physical extent of the proposed development makes a robust assessment of its potential effects difficult to undertake. The Secretary of State recommends that careful consideration should be given to how the Applicant meaningfully consults on, and properly assesses, the likely impacts arising from the proposed on-shore cable route. It is hoped that the adoption of an iterative approach will result in a more specific route corridor in order for a robust EIA to be carried out.	In line with the decision to deploy HVDC technology, a 45m wide cable route has now been defined and is shown in Figure 5.3.
SoS	November 2016 (scoping response, statutory)	The Secretary of State notes the Applicant's intention to apply a Rochdale Envelope approach to the assessment and that, where the details	Noted.

Consultee	Date /Document	Comment	Response / where addressed in the PEI
		of the scheme cannot be defined precisely for the EIA, a likely worst case scenario will be assessed. The Secretary of State welcomes the reference to Planning Inspectorate Advice Note nine 'Using the 'Rochdale Envelope' in this regard but also directs attention to the 'Flexibility' section in Appendix 1 of this Opinion which provides additional details on the recommended approach.	
SoS	November 2016 (scoping response, statutory)	The Applicant should make every attempt to narrow the range of options and explain clearly in the ES which elements of the scheme have yet to be finalised and provide the reasons. The ES must be capable of demonstrating how any changes to the development within any proposed parameters have been assessed as part of the EIA and that the proposed development would not result in significant impacts not previously considered.	Section 5.1.1 outlines the justification for maintaining a range of options. The range of options/parameters is detailed throughout this chapter and each technical chapter outlines the worst case scenario that has been assessed specific to each receptor/impact.
SoS	November 2016 (scoping response, statutory)	As the type of electrical connection (i.e. HVAC or HVDC) is to be determined post-consent of the DCO, the ES should clearly present a description of the necessary infrastructure, construction methodologies and phasing (i.e. timings) for each option. The ES should justify which option is to be considered for the assessments, noting that a defined "worst case" could vary for different technical disciplines. The Applicant should consider whether one option could result in a greater level of impact if a more intensive construction period, albeit for a shorter length of time, is adopted.	Norfolk Vanguard Limited has made the decision is to deploy High Voltage Direct Current (HVDC) cable technology to the UK's National Grid and this removes the need for a Cable Relay Station from the project. Each technical chapter outlines the worst case scenario that has been assessed specific to each receptor/impact.
SoS	November 2016 (scoping response, statutory)	Similarly, the Scoping Report has identified the overall size of the substation compound and the maximum height of buildings and notes that the appearance of the substation will depend on whether HVAC or HVDC would be used. The ES should provide details of the number and dimensions of the buildings for each option along with site layouts. The Applicant should	The onshore project substation parameters are provided in section 5.5.5. Norfolk Vanguard Limited has made the decision is to deploy High Voltage Direct Current (HVDC) cable technology to the UK's National Grid and this removes the need for a Cable

Consultee	Date /Document	Comment	Response / where addressed in the PEI
		also carefully consider how this will be assessed, particularly in terms of the landscape and visual impact aspect.	Relay Station from the project. Chapter 29 Landscape and Visual Impact Assessment details the worst case scenarios for the assessment.
SoS	November 2016 (scoping response, statutory)	The Secretary of State advises that it would be helpful to provide a table within the ES setting out the 'worst case' parameters that have been assessed for each topic area to ensure that a consistent approach has been adopted across all environmental topics in the ES. Care will be needed to ensure that by considering the environmental topics separately, this does not preclude consideration of a worst case arising from a combination of factors. The ES will need to be clear and to demonstrate how this has been assessed.	Each technical chapter outlines the worst case scenario that has been assessed specific to each receptor/impact which can differ across topics. A table of the relevant worst case scenario is provided in Chapters 8 to 31.
SoS	November 2016 (scoping response, statutory)	The Secretary of State acknowledges that at this stage of the design it is not possible to provide details of the access roads. However, it is expected that by the time the DCO application is made, these details should be known. Therefore, the ES should identify the locations, detail their construction methodology and identify those which would be temporary and those which would be permanent.	Figures 5.2 to 5.5 show onshore construction locations. Onshore construction methodology is discussed in section 5.5.
SoS	November 2016 (scoping response, statutory)	The Secretary of State considers that information on the construction phase (covering onshore and offshore activities) should be clearly indicated in the ES, including: phasing of programme including anticipated start and end dates; construction methods and activities associated with each phase; size and siting of construction compounds (including on and off site); types of machinery and construction methodology and their anticipated noise levels; lighting equipment/requirements; and	These details are provided throughout section 5.5.

Consultee	Date /Document	Comment	Response / where addressed in the PEI
		number, movements and parking of construction vehicles (both HGVs and staff). The above information should be provided for both phasing options (i.e. HVAC and HVDC).	
SoS	November 2016 (scoping response, statutory)	The Scoping Report identifies the working hours for the construction of the cable relay station and the substation as 07:00 to 19:00; however, has not provided working hours for other construction works. This information should be provided within the ES. Any need for unsocial hours of working should be detailed.	Working hours are provided in sections 5.5.5 and 5.5.6.
SoS	November 2016 (scoping response, statutory)	The Scoping Report states that a CoCP would be developed as part of the overall mitigation package. The Secretary of State welcomes that a draft CoCP will be appended to the ES and recommends that clear cross referencing is made between the two documents so it is clear how mitigation proposed in the ES is secured.	An Outline CoCP (document reference 8.1) is provided with the DCO application. A Schedule of Mitigation (document reference 6.5) is provided with the DCO application which details how mitigation proposed in the ES is secured.
SoS	November 2016 (scoping response, statutory)	The ES should identify the location and quantity of any additional cable protection required and of cable/pipeline crossings.	Cable protection is discussed in section 5.4.14. The exact locations of cable protection would be defined post consent. Maximum parameters are provided for key areas i.e. within the OWF sites, within the Haisborough, Hammond and Winterton SAC, in the nearshore (within the 10m depth contour), and in the rest of the offshore cable corridor.
SoS	November 2016 (scoping response, statutory)	The Scoping Report identifies a short and long option for HDD at the landfall. It is not clear whether the length of the HDD would be determined by the time of application. The Applicant should consider the worst case for assessment and clearly set out the parameters within the ES.	Norfolk Vanguard Limited has made the decision to deploy the long option for the HDD at the landfall, removing the options of short or long from the assessments.
SoS	November 2016 (scoping	It is noted that piling would be required to construct the turbines. The piling	Piling is discussed in sections 5.4.3.1.5, 5.4.3.2.5 and

Consultee	Date /Document	Comment	Response / where addressed in the PEI
	response, statutory)	method should be clearly described within the ES and the associated impacts assessed as part of the EIA.	5.4.4.1.3.
SoS	November 2016 (scoping response, statutory)	Paragraph 134 of the Scoping Report states that the maximum corridor width would be 50m, except for short sections at major crossings and engineering constraints where it may be wider. These locations should be identified within the ES.	The PEIR was based on the option for HVAC technology and so a 200m corridor, which has been refined to incorporate feedback from ongoing landowner consultation. The refined onshore cable route width is approximately 45m to allow for Norfolk Vanguard and Norfolk Boreas.
SoS	November 2016 (scoping response, statutory)	The Secretary of State welcomes that the location and size of the onshore temporary mobilisations areas (construction compounds) will be defined in the EIA.	These are discussed in section 5.5.4.
SoS	November 2016 (scoping response, statutory)	Information on the operation and maintenance of the proposed development should be included in the ES and should cover but not be limited to such matters as: the number of full/part-time jobs; the operational hours and if appropriate, shift patterns; and the number and types of vehicle movements generated during the operational stage (including HGVs, LGVs and staff vehicles).	Numbers of jobs are discussed in Chapter 31 Socio-economics. Working hours are provided in sections 5.5.5 and 5.5.6. Numbers of vehicle movements are discussed in Chapter 24 Traffic and Transport.
SoS	November 2016 (scoping response, statutory)	The likely maintenance requirements associated with all project cabling, including inter-array cabling, should be identified. This should be informed by the experiences at other constructed wind farm developments.	Maintenance requirements are discussed in section 5.4.18.
SoS	November 2016 (scoping response, statutory)	The Secretary of State notes that key maintenance activities associated with the onshore component would take place every summer (taking up to two months) and would potentially require 24/7 working during this period. The Secretary of State would expect to see specific consideration of any 24/7 maintenance working as part of the relevant topic chapters of the ES, and in	The indicative construction programme is discussed in section 5.5.7. Sensitive receptors are discussed in Chapters 8 to 31.

Consultee	Date /Document	Comment	Response / where addressed in the PEI
		particular potential impacts on nearby sensitive receptors (including tourism locations) and any mitigation measures proposed. This is discussed further in Section 3 of this Opinion.	
SoS	November 2016 (scoping response, statutory)	In terms of decommissioning, the Secretary of State acknowledges that the further into the future any assessment is made, the less reliance may be placed on the outcome. However, the purpose of such a long term assessment is to enable the decommissioning of the works to be taken into account in the design and use of materials such that structures can be taken down with the minimum of disruption. The process and methods of decommissioning should be considered and options presented in the ES.	Decommissioning is discussed in sections 5.4.19, 5.5.2.9, 5.5.5.8, and 5.5.6.7.
SoS	November 2016 (scoping response, statutory)	It is a condition of the Crown Estate lease for the wind farm site that the proposed development be decommissioned at the end of its operational lifetime. To this end, the Scoping Report confirms that a decommissioning plan will need to be prepared.	A decommissioning programme (Requirement 14 of the DCO) and decommissioning plan (Requirement 29) will be produced and agreed with the relevant authorities.
Bittering Parish Council	November 2016 (scoping response, non-statutory)	With regards the above consultation on the Norfolk Vanguard Offshore Wind Farm project, the concerns of Beeston with Bittering Parish Council are: 1 Where will the onshore cable lines go 2 Where will the surface equipment be located The sooner that the answers to these two questions can be answered the better and only then will this parish council be able to provide more substantive feedback on its concerns.	Figures 5.2 to 5.5 show the locations of onshore infrastructure.
Hale Parish Council	November 2016 (scoping response, non-statutory)	The HHPC are concerned about the proposals to site a new sub-station at Necton, and following an initial review of these plans it is considered that an environmental impact assessment should take into account the following: - the size and scale of the site/buildings proposed, which will have a major	The visual impact of Norfolk Vanguard is assessed in Chapter 29 Landscape and Visual Impact Assessment, taking into account the size and scale of the infrastructure including the onshore project substation,

Consultee	Date /Document	Comment	Response / where addressed in the PEI
		visual impact on the residents of Holme Hale and Necton - the extensive/intrusive light pollution that would result - public health issues, particularly as the proposed site is close to a popular local primary school - security issues, especially given the close proximity of a very active RAF base	as well as required lighting. Chapter 27 Human Health provides further information.
Necton Parish Council	November 2016 (scoping response, non-statutory)	A clear plan regarding light management during construction and operation. Many of our residents continue to be adversely affected by the shortcomings of the existing wind farm. We would want to see that energy conservation is actively practiced and not just incorporated into proposal documentation. Ideally, a robust system of penalties applied on breach of procedure actively policed by an identified independent organisation.	Requirements for site lighting are discussed in sections5.1.1.1, 5.5.5.6, 5.5.5.7, 5.5.6.4 and 5.5.6.6.
Necton Parish Council	November 2016 (scoping response, non-statutory)	Assurances that conditions applied through the planning process on Vattenfall will be transferred to any subsequent owner of any and all parts of the project. Reference is made within the scoping report that the off- and on-shore electrical infrastructure will be sold once built and commissioned.	A draft DCO is provided with the application.
Necton Parish Council	November 2016 (scoping response, non-statutory)	A detailed landscaping plan, ensuring best use of the existing land features, such as undulations and woodland copses; to include a timetable, begin at pre-construction stage and be applied alongside construction so that when the works are complete, the selected plant-life has matured.	An Outline Landscape and Ecological Management Strategy (OLEMS) (document reference 8.7) is submitted with the DCO application.
Necton Parish Council	November 2016 (scoping response, non-statutory)	A plan detailing how contractors will be selected for the groundworks associated with both the cable route and the sub-station. This plan would include expected standards relating to skills, experiences, licences, etc. of contractors and their sub-contractors. We ask for this inclusion to ensure that the experiences of some local farmers during the cabling of the Dudgeon Wind	An Outline COCP (document reference 8.1) is provided with the DCO application.

Consultee	Date /Document	Comment	Response / where addressed in the PEI
		Farm are not repeated.	
Necton Parish Council	November 2016 (scoping response, non-statutory)	A detailed report on the consideration of alternative sites for the sub-station, including sites outside the selected area.	Chapter 4 Site Selection and Assessment of Alternatives provides information on the alternative sites considered for the onshore project substation.
Necton Parish Council	November 2016 (scoping response, non-statutory)	The scoping report provides indicative parameters for the substation footprint at 300m x 250m and buildings height at 20m. We would expect these to be maximum dimensions and indeed we would wish to see a reduction in these dimensions, which we feel is possible in this fast developing sector.	The proposed dimensions of the onshore project substation are provided in section 5.5.5.1.
Cadent Gas Ltd	December 2017 PEIR Response	Provide key considerations that are required in relation to pipeline crossings.	These will be taken into account when seeking agreements with cable and pipeline operators as required. See Chapter 21 Land Use and Agriculture for detail on utilities.
Happisburgh Parish Council	December 2017 PEIR Response	The Parish Council would strongly recommend that any landfall for both wind farms is made at the same time	The worst case assessments for the ES have allowed for concurrent operation of 2 drilling rigs at landfall during installation, and a decision on whether the works would be undertaken at the same time will be made as part of detailed design.
Natural England	December 2017 PEIR Response	In relation to drill arisings it is stated that up to 50% of locations for pin piles will need drilling where they may be driven, drilled or drilled-driven. Previously it has been stated that alternative methods, i.e. drilling or vibration may be required depending on the ground conditions (para 58 page 27). Is this EIA also considering drill arisings from vibration and drilling techniques or just drilling.	An estimate of 50% of the locations requiring drilling is included in the EIA to allow a conservative assessment of drill arisings. The installation methodology used (to be determined during post consent final design) would fall within the worst case scenarios presented (e.g. maximum drill arisings and underwater noise levels).
Natural England	December 2017 PEIR Response	The worst case assumption is that excavation of up to 5m depth could be required if a sand wave is encountered during piling. What evidence is this	The Fugro (2016) geophysical survey showed that sandwaves are approximately

Consultee	Date /Document	Comment	Response / where addressed in the PEI
		based upon and why up to 5m?	5m in height.
Natural England	December 2017 PEIR Response	With regards to potentially using frond mattresses, has their effectiveness been determined elsewhere? From Natural England's perspective it may be more desirable to install a more "natural" structure, particularly if they will be left in-situ at the time of decommissioning.	A range of cable protection options are presented in order to allow the most appropriate type to be selected during final design,
Natural England	December 2017 PEIR Response	It is unclear how the pre-sweeping volumes have been calculated – was there an average sandwave height that was taken?	Pre-sweeping volumes have been analysed by CWind (2017, provided in Appendix 5.1)
Natural England	December 2017 PEIR Response	More information regarding the location and age of this "out of service" cable is needed. It may be better to leave it in situ if it is likely to break and multiple operations are needed for recovery.	Options to either leave or remove some existing cables has been considered in the total cable protection (section 5.4.14)
Natural England	December 2017 PEIR Response	The temporary disturbance width does not consider potential disturbance from anchored vessels along the cable route (when jointing cables, for example).	Vessel anchors have been added to the maximum total footprints outlined in section 5.4.1.1
Natural England	December 2017 PEIR Response	Any protection over cable crossings needs to be carefully installed to ensure that it does not exacerbate or encourage scouring to occur, particularly within the SAC. Further consultation with Natural England will be needed.	A range of cable protection options are presented in section 5.4.14, in order to allow the most appropriate type to be selected during final design. The details will be consulted on through the Scour Protection and Cable Protection Plan (Document reference 8.16, an outline plan is provided with the DCO application).
Natural England	December 2017 PEIR Response	The [offshore] construction window of 3 to 7 years has been stated. Seven years represents a large period of disturbance, and would be unfavourable in terms of impacts upon environmental elements.	Norfolk Vanguard Limited has reduced the indicative offshore construction window to 4 years.
Natural England	December 2017 PEIR Response	A full outline Operation and Maintenance Plan is to be submitted with DCO. In paragraph 250 the need for regular/periodic surveys is discussed. As recently advised for other OWFs in relation to operation and maintenance works we advise that a regulatory review (such as the 5 yearly reviews within the Aggregates industry)	An Outline Operations and Maintenance Plan (document reference 8.11) and In Principle Monitoring Plan (document reference 8.12) are submitted with the DCO application.

Consultee	Date /Document	Comment	Response / where addressed in the PEI
		should be implemented in order to ensure that the monitoring evidence will be used to inform further works	
Natural England	December 2017 PEIR Response	Given the calculation is the following sentence supposed to say per year? It has been assumed that a maximum of two locations could be visited by one jack up vessel to the OWF sites per day during operation.	A conservative estimate of visiting 2 turbines per day during operation and maintenance (O&M) has been included in the EIA.
NSAG	December 2017 PEIR Response	It was only when the PEIR document was released that we discovered that the National Grid extensions at Necton would enlarge their part of the site from 2 hectares to 9.1 hectares, that they would be adding a pylon, and that other overhead work would need to take place as well.	Section 1.4.4.3 of the Scoping Report stated that additional switchgear and electrical equipment would be required at the Necton National Grid Substation to connect Norfolk Vanguard. At that time, it was envisaged that any works required at the National Grid Substation would be consented by National Grid. Norfolk Vanguard Limited subsequently decided to take responsibility for consenting the National Grid works in order to provide a holistic assessment and management approach for the project.
National Farmers Union	December 2017 PEIR Response	The NFU requested additional information on the project design of relevance to agriculture.	Responses are detail in Table 21.3 of Chapter 21 Land Use and Agriculture.

5.3 Overview of the Project

25. The project would consist of between 90 and 200 wind turbines, each having a capacity of between 9MW and 20MW, to give an export capacity of up to 1,800MW at the point of connection to the offshore electrical platform(s). The total rated capacity of the wind turbines will be slightly higher than the export capacity, to allow for internal cable losses and potential turbine non-availability at the wind farm array. The total rated capacity of the wind turbines will be up to 1850MW. The location of the OWF sites is shown in Figure 5.1. Turbines would either all be located within NV West; all in NV East; or across both NV East and NV West.

26. The offshore cable corridor would link the OWF sites with the cable landfall location at Happisburgh South. The onshore cable route would then link the landfall with the grid connection point at Necton.

27. Norfolk Vanguard Limited has made the decision to deploy HVDC technology for the offshore and onshore export infrastructure for the project. The configuration for the HVDC solution is shown in Plate 5.1.

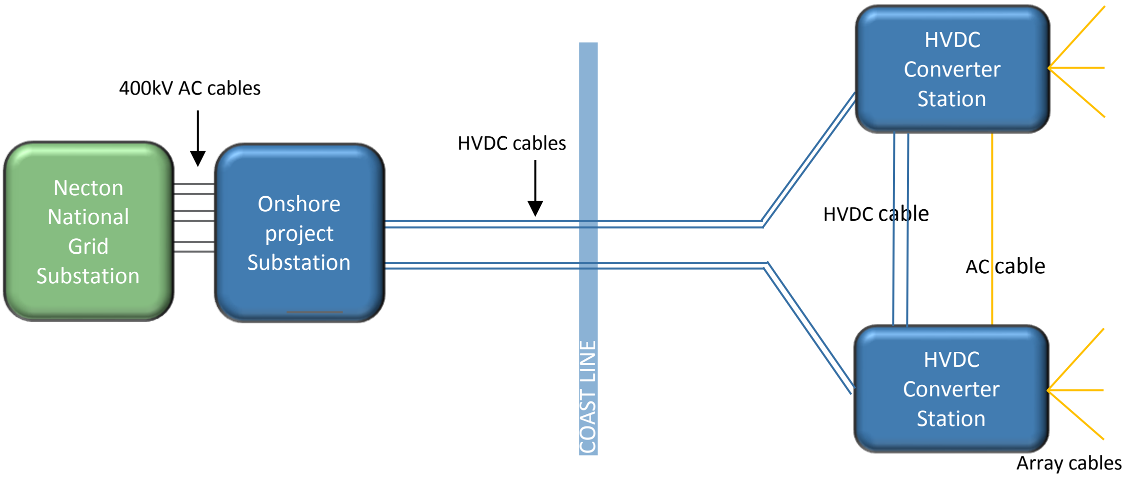

Plate 5.1 Electrical configuration

28. The DCO for the project would comprise all offshore and onshore infrastructure associated with the project, including extension to the existing Necton National Grid substation and possible laying of cable ducts for Norfolk Boreas within the onshore cable route.

29. Norfolk Vanguard Limited is currently considering constructing the project in a single phase or a two phased approach (up to a total export capacity of 1800MW).

30. Construction of the project under either approach would be anticipated to commence between 2020 and 2021 for the onshore works, and around 2024 for the offshore works. Section 5.4.15 outlines the indicative offshore construction programme scenarios for each phasing approach. Section 5.5.7 outlines the indicative onshore construction programme scenarios.

5.3.1 Key Project Characteristics

31. This section summarises the key characteristics of the offshore, landfall and onshore project design which are described further in section 5.4 and section 5.5.

32. The key offshore components of the project would comprise:

- Offshore wind turbines and their associated foundations;

- Scour protection around foundations as required;
- Offshore electrical platforms supporting required electrical equipment, and possibly incorporating offshore facilities (e.g. accommodation).
- Accommodation platforms may be installed to house workers offshore as required;
- Subsea cables;
    - Array cables: These cables connect wind turbines with each other and with the offshore electrical platforms;
    - Interconnector cables: Interconnections between the offshore electrical platforms (may be within NV West; NV West; or running from NV West to NV East depending on the location of the electrical platforms);
    - Offshore export cables: The cables that join the offshore electrical platforms with the landfall area;
    - Cable protection on subsea cables as required; and
    - Fibre optic cables which may be buried along with some or all of the electrical cables.
- Meteorological masts (met masts) and their associated foundations for monitoring wind speeds during the operational phase (additional to existing met masts within the former East Anglia Zone); and
- Monitoring equipment including Light Detection and Ranging (LiDAR) and wave buoys.

33. The landfall works would comprise:

- Up to two ducts installed under the cliff by Horizontal Directional Drilling (HDD). An additional drill is included in the impact assessment worst case scenarios where applicable, to provide a contingency in the unlikely event of a HDD failure; and
- Onshore transition pits to house the connection between the offshore cables and the onshore cables.

34. The key onshore components of the proposed project would comprise:

- Ducts installed underground through which the onshore cables would be pulled;
    - Up to two sets of ducts installed for the Norfolk Vanguard cables; and
    - Up to two sets of ducts installed for the Norfolk Boreas cables.
- Trenchless crossing points at sensitive locations such as some roads, railways and sensitive habitats (e.g. rivers of conservation importance);
- Mobilisation areas;
- An onshore project substation; and
- Extension works at the Necton National Grid substation including:

- Extension of the existing National Grid substation to accommodate grid connection for Norfolk Vanguard; and
- Modification of the existing overhead lines in the vicinity of the Necton National Grid substation for Norfolk Vanguard and Norfolk Boreas.

5.4 Offshore

5.4.1 Offshore Infrastructure Summary

35. Table 5.3 outlines the key characteristics of the offshore elements of the project. These are discussed in more detail separately within the text.

Table 5.3 Offshore project characteristics

Parameter	Characteristic
Export capacity	Up to 1,800MW
Lease period	50 years
Indicative construction window	4 years
Indicative design life	Approx. 30 years
Number of wind turbines (15MW and 20MW turbines are estimated to be the same physical size)	Range between 90 x 20MW to 200 x 9MW turbines
NV West area	295km^2
NV East area	297km^2
Offshore cable corridor area	236km^2
Water depth NV West	25m to 50m below LAT
Water depth NV East	22m to 42m below LAT
Distance from NV West to shore (closest point of site to the coast)	47km
Distance from NV East to shore (closest point of site to the coast)	70km
Maximum number of export cables	Four (laid as pairs in two trenches)
Maximum turbine rotor diameter	303m
Maximum hub height above HAT	198.5m
Maximum tip height above HAT	350m
Maximum offshore cable corridor length	90km from NV West and 100km from NV East
Maximum length of export cables	400km
Maximum total export cable trench length	200km Based on a total of 4 cables, with cables laid in pairs in approximately 100km long trenches
Maximum array cable length	600km

Parameter	Characteristic
Maximum number of interconnectors (between offshore platforms)	3
Maximum length of interconnector cable	150km
Minimum clearance above sea level	22m (Mean High Water Springs)
Indicative minimum and maximum separation between turbines	In row and inter row spacing 680m to 6060m
Wind turbine foundation type options	• Piled monopile; • Suction caisson monopile; • Piled tripod or quadropod; • Suction caisson tripod or quadropod; • Gravity Base System (GBS); and • Tension leg floating.
Maximum number of met masts	Up to two (one in NV East and one in NV West)
Maximum height of met masts above Highest Astronomical Tide (HAT)	200m
Met mast foundation type options	• Piled monopile; • Suction caisson monopile; • Piled tripod or quadropod; • Suction caisson tripod or quadropod; and • Gravity Base.
Maximum number of offshore electrical platforms	Up to two with either: Both in NV West; Both in NV East; or One in each of NV West and NV East
Maximum number of accommodation platforms	Up to two (one in NV East and one in NV West)
Topside maximum height of offshore electrical platforms above HAT	100m
Topside maximum height of accommodation platforms above HAT	100m
Offshore platform (electrical and accommodation) foundation type options	• GBS (multi-legged system); or • Six legged jacket (piled or suction caisson).
Buoys	• LiDAR, wave and guard buoys may be deployed.

5.4.1.1 Maximum total footprints of all offshore structures

36. This section collates the total footprint for offshore infrastructure discussed in further detail throughout section 5.4.

5.4.1.1.1 Temporary construction footprint

37. Table 5.4 shows the footprints associated with seabed preparation for foundation and cable installation within NV East and NV West.

Table 5.4 Total disturbance/preparation footprints in the OWF sites during construction

Infrastructure	Worst Case Scenario type	Worst Case Scenario footprint (m^2)
Seabed preparation – turbines	90 x 20MW floating tension leg platforms with gravity anchors - based on approximate 90m x 90m preparation area	729,000
Array cable pre-sweeping/pre-lay grapnel run	Average width 20m x 600,000m cable length	12,000,000
Interconnector pre-sweeping/pre-lay grapnel run	Average width 20m x 150,000m	3,000,000
Seabed preparation – offshore electrical platforms	2 platforms - based on approximate 75m x 100m preparation	15,000
Seabed preparation - accommodation platforms	2 platforms - based on approximate 75m x 100m preparation	15,000
Seabed preparation - met masts	2 met masts – based on 40m diameter preparation area	2,513
Wave buoy	No additional preparation – see infrastructure footprint	
LiDAR	No additional preparation – see infrastructure footprint	
Jack up vessel footprint - turbines	2 vessels per turbine – based on six-legged vessel with footprint of 792m^2	316,800
Jack up vessel footprint - platforms	2 vessels per platform – based on six-legged vessel with footprint of 792m^2	9,504
Vessel anchor footprint	1 vessel anchoring per turbine – based on anchor footprint of 150m^2 per vessel	30,000
Potential boulder clearance in the OWF sites	5m diameter x 53 boulders	1,041
Total disturbance footprint based on seabed preparation for foundations		**16,118,858**

5.4.1.1.2 Offshore cable corridor temporary construction footprint

38. Table 5.4 shows the temporary footprints associated with cable installation in the offshore cable corridor.

Table 5.5 Total disturbance/preparation footprints in the offshore cable corridor during construction

Infrastructure	Worst Case Scenario type	Worst Case Scenario footprint (m^2)
Export cable pre-sweeping/pre-grapnel run	360,000m^2 of pre-sweeping in the offshore cable corridor based on analysis provided in Appendix 5.1 + 600,000m^2 pre-sweeping of export cables in the OWF sites based on 30,000m length x 20m width	960,000m^2 total footprint, of which 72,000m^2 may be outside the footprint of the maximum cable installation disturbance width of 30m along the full length (200km) of export cable installation
Export cable installation	200,000m trench length x	6,000,000

Infrastructure	Worst Case Scenario type	Worst Case Scenario footprint (m^2)
	30m disturbance width (based on ploughing as a worst case scenario)	
Vessel anchor footprint during cable jointing	four cable joints in total (two per cable pair)	600
Potential boulder clearance in the OWF sites	5m diameter x 22 boulders	432
Total disturbance footprint based on seabed preparation and export cable installation in the offshore cable corridor		**6,073,032**

5.4.1.1.3 Offshore wind farm sites permanent footprint

39. Table 5.6 shows the operational footprint associated with foundations and cable protection within NV East and NV West.

Table 5.6 Total long term infrastructure footprints in the OWF sites

Infrastructure	Worst Case Scenario type	Worst Case Scenario footprint (m^2)
Worst case turbine footprint	20MW tension floating platform with gravity anchor and scour protection	11,025,000
Array cable protection	60km in the case where cables cannot be buried x 10m width; 100m cable length per turbine (x 200 turbines) x 10m width; 10m per crossing (x10 crossings) x 5m width	410,000
Interconnector cable protection	100m per offshore electrical platform x 5m width; 15km surface laid x 5m width	76,000
Offshore electrical platforms	GBS with scour protection	35,000
Accommodation platforms	GBS with scour protection	35,000
Met masts	20m diameter at seabed with scour protection (7,854m^2per foundation)	15,708
Wave buoy		300
LiDAR	2 x monopiles + scour protection	157
Total operational footprint		**11,597,165**

5.4.1.1.4 Offshore cable corridor long term footprint

40. The maximum long term footprint associated with the cable protection for offshore export cables would be 0.15km^2 (see section 5.4.14).

5.4.2 Wind Turbines

41. A range of 9MW to 20MW wind turbines is included in the project design envelope in order to future proof the DCO to accommodate foreseeable advances in wind turbine technology. For 1,800MW there could be up to 200 x 9MW turbines or 90 x 20MW turbines (or any other configuration within this range).

42. Each wind turbine would comprise a tubular steel tower atop a foundation structure, a nacelle secured at the top of the tower and a rotor with two or three blades rotating around a horizontal axis.

43. The basic turbine parameters anticipated for the project are shown in Plate 5.2 and Table 5.7.

Table 5.7 Wind turbine parameters

Item	9MW	20MW
Min lower blade tip above MHWS (m)	22	22
Min hub height above HAT (m)	107	173.5
Max hub height above HAT (m)	132.0	198.5
Max upper blade tip above HAT (m)	217	350
Maximum rotor diameter	170	303
Maximum rotor swept area per turbine (m^2)	22,698	72,107
Max blade chord (m)	7	10
Mean blade chord (m)	3	4

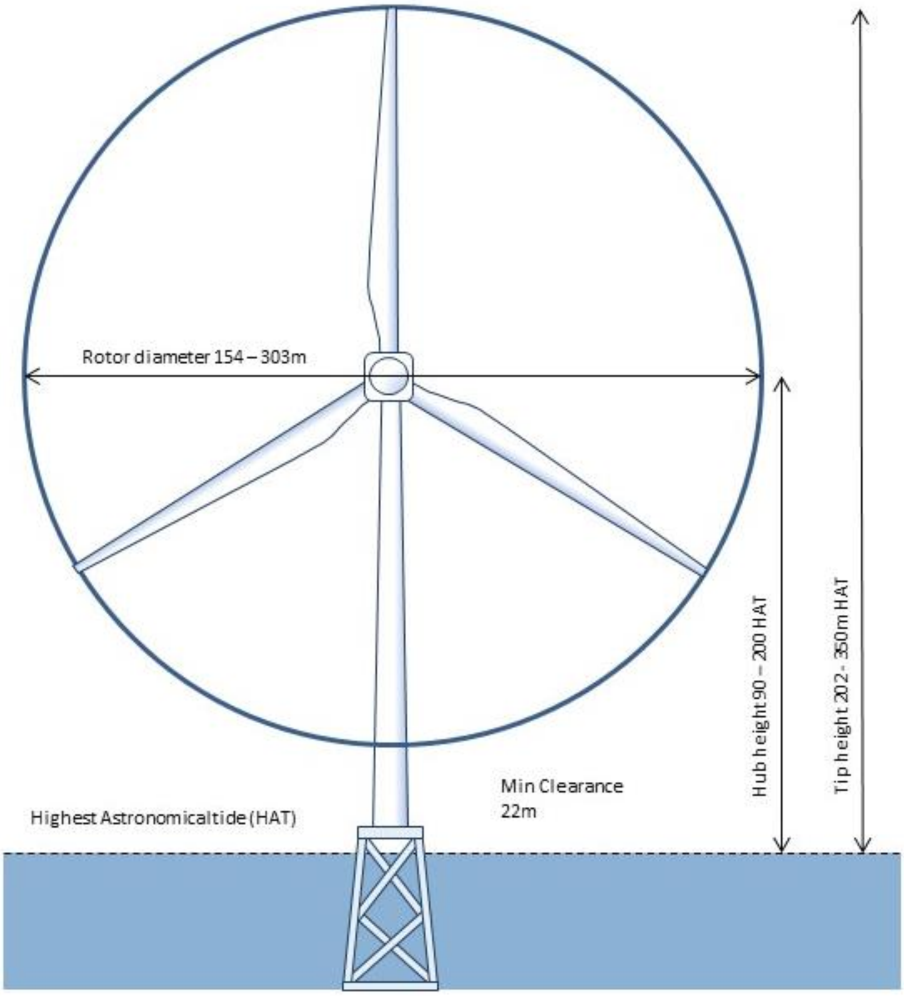

Plate 5.2 Schematic illustrating the maximum turbine dimensions

5.4.2.1 Wind turbine layout

44. A detailed design of the layout of the wind farm would be completed during the post-consent phase of the project. The final design will be informed by further wind resource, geophysical, geotechnical studies and in line with navigational requirements. Norfolk Vanguard Limited would aim to optimise the layout of the wind farm with respect to energy yield against installed capacity and installation cost, alongside safety considerations and whilst minimising environmental and human impacts.

45. To optimise energy output, detailed wake modelling would be undertaken which would consider possible layouts and different turbine models as well as wind conditions. Ideally the layout would be designed to ensure that the wind turbines would have laminar wind flow in front of the rotor disc. In the wake behind the rotor

disc, the wind flow would be turbulent with wake effects detected up to 20 rotor diameters behind turbines.

46. The wind farm layout can only be described in general terms at this stage of the project. It would have some form of regularity in plan, i.e. wind turbines will be set out in rows. However, the locations may not follow a rectangular grid system; it is more likely an offset packing arrangement would be adopted.

47. Table 5.8 provides the project design envelope for the likely distances between wind turbines; the in-row spacing is the distance separating turbines in the main rows, which would be orientated facing the prevailing wind, or as close to this as is practical and inter-row spacing is distance between the main rows. In-row spacing and inter-row spacing may vary across the wind farm sites.

48. Some areas of the offshore wind farm sites would be likely to remain undeveloped due to constraints such as ground conditions or to allow for wake recovery.

Table 5.8 Spacing between wind turbine generators (WTGs)

Item	Distance between WTGs (D = rotor diameters)	Equivalent distances (m)
In-row spacing	4D to 20D	680 to 6060
Inter-row spacing	4D to 20D	680 to 6060

49. The layout of the wind turbines will be defined post consent but would be based on the following maxima:

- 1,800MW in NV East, 0MW in NV West; or
- 0MW in NV East, 1,800MW in NV West.

50. Any other potential layouts that are considered up to a maximum of 1,800MW (e.g. 1,200MW in NV West and 600MW in NV East; 600MW in NV West and 1,200MW in NV East; or 900MW in NV West and 900MW in NV East) lie within the envelope of these scenarios.

51. The project could be constructed in either two phases (section 5.4.15) or one continuous construction phase (up to 1,800MW). Section 5.4.15 outlines the indicative offshore construction programmes, with a construction duration of up to approximately four years.

5.4.2.2 Installation process

5.4.2.2.1 Pre-installation works

Pre-construction surveys

52. Pre-construction surveys would be undertaken in advance of any foundation installation works to plan the any necessary micrositing, clearance operation and sandwave levelling.

UXO clearance

53. A pre-construction UXO survey will be undertaken and the results will inform micrositing where possible and/or identify any requirement for UXO clearance. Norfolk Vanguard Limited has reviewed the 2016 survey data and estimated up to nine clearance operations in the NV East and up to five in NV West. Ordtek (2018, provided in Appendix 5.2) provides a review of typical UXO items which may be found in the Norfolk Vanguard offshore project area.

Boulder clearance

54. Pre-construction surveys will identify any requirement for boulder clearance. Norfolk Vanguard Limited has reviewed the Fugro (2016) geophysical survey data to assess presence of boulders. Given the low proportion of boulders in the area, it is likely that micrositing around these will be possible, however an estimate of clearance of up to 37 boulders in NV West and 16 in NV East of up to 5m in diameter has been included in the assessments in order to be conservative. Boulders would be relocated within the OWF sites.

Pre-sweeping

55. Some foundation types may require sandwaves to be levelled by pre-sweeping prior to installation. The potential requirement for each foundation type is described throughout section 5.4.3.

Topside installation

<u>Transport</u>

56. The nacelle and turbine blades could both be transported to site and installed by an installation vessel or transported on a barge where they would be lifted off and installed by crane or via a separate installation vessel.

<u>Construction</u>

57. The components will be lifted into position on an already installed foundation. The installation of the wind turbines would typically involve multiple lifting operations, with up to four tower sections erected, followed by the nacelle with pre-assembled hub, and then the blades. The installation would typically take 1 day if there are no

weather delays. The installation vessel would either be of a heavy lift jack-up vessel type or anchored floating vessel type.

58. Traditional installation methods consist of tower segments lifted in place and bolted together, with the hub and nacelle conjoined in the case of single blade installation.

59. Although not current practice, it is possible that wind turbines could be fully assembled and commissioned onshore and transported to site as a single unit installation. This method is being explored by the wind industry but it is not possible to commit to this method as it is not technically proven at this stage.

Electrical connection

60. Section 5.4.13.2.5 describes the process for connecting electrical cables to the turbines.

5.4.3 Foundations

61. There are many possible foundation types currently available or under design to support offshore wind turbines and/or offshore platforms. For the project design envelope, the following have been considered:

- Quadropod and tripod (Plate 5.4)- jacket foundations with either three or four feet attached to the seabed with either 3 or 4 suction caissons or piles;
- Suction caissons (Plate 5.5)– cylindrical tubes which are installed by reducing the pressure inside the tube to draw the caisson into the seabed;
- Monopiles (Plate 5.6) – large cylinders which are hammered into the seabed;
- Gravity base structures (Plate 5.3) – which rely on the weight of the structure to anchor it to the seabed; and
- Tension leg floating foundations (Plate 5.7 and Plate 5.8) – a floating platform which is attached to the seabed by taught mooring lines to a gravity anchor or up to four suction caissons or piled anchors.

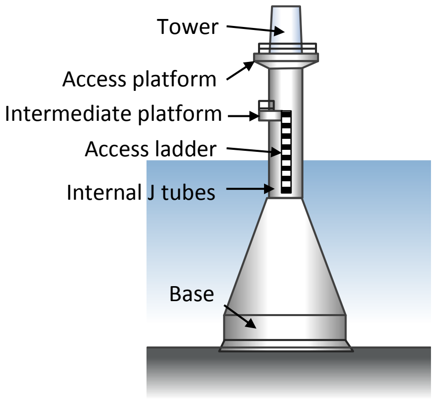

Plate 5.3 Typical gravity based structure

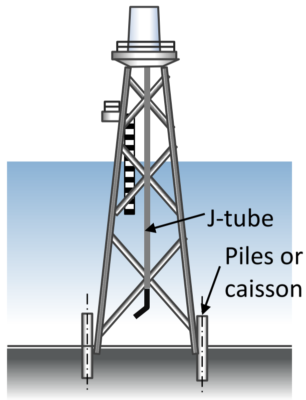

Plate 5.4 Typical jacket structure

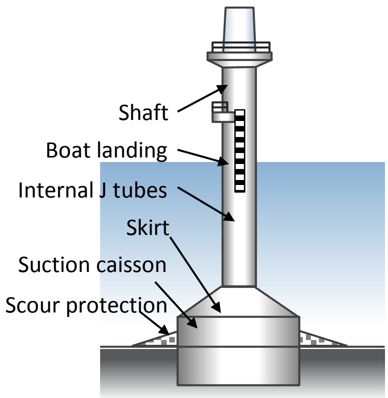

Plate 5.5 Typical suction caissons

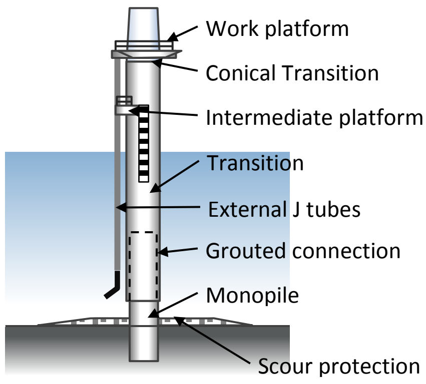

Plate 5.6 Typical monopile structure

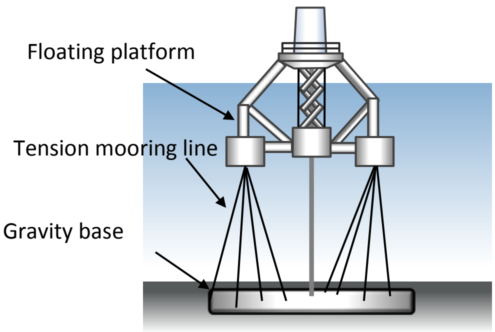

Plate 5.7 Typical tension leg floating foundation with gravity anchor

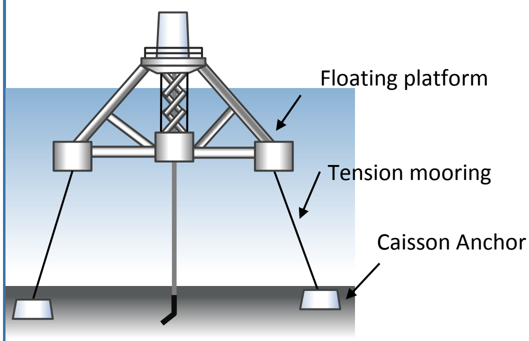

Plate 5.8 Typical tension leg floating foundation with piled or suction caisson anchors

[1] Note - these are examples of the typical foundations currently in use within the industry; nevertheless, many other different designs are possible for each type of foundation within the envelope of parameters described in this chapter.

62. There could be more than one type of foundation installed for the project. The foundation type used will be determined by a number of constraints including: ground conditions, water depths, turbine model used, wind conditions and market options.

63. The preference is to consider foundation locations within water depths of 40m or less. However, for the project it may be necessary to build at locations with greater water depths, up to 50m.

64. The foundations would be manufactured onshore and most likely delivered to site as a fully assembled unit with all ancillary structures attached. However, there are currently different logistical approaches being explored within the industry, for example, development of modular jackets in order to increase the number of vessels capable of installation.

65. Fabrication / construction methods and requirements would depend on the foundation type selected.

5.4.3.1 Quadropod and tripod foundations

66. There are many different variants of the jacket structure (Plate 5.4) but those being considered for the project are:

- Pre-piled or post-piled;
- 3-legged or 4-legged;
- Straight or battered legs; and
- Pin piled or suction caisson.

67. Potential pin pile and suction caisson dimensions are outlined in Table 5.9. All parameters provided are based on a quadropod; tripods would have the same parameters with one less pile/caisson per foundation.

68. Pile penetration depths of up to 70m depth below the seabed may be required. Piles are generally expected to be driven, however drilling may be required at up to 50% of the locations if these foundation options are chosen. Other techniques, such as pile vibration, are also being considered. Piles are usually installed vertically but concepts are being considered that install piles on a batter (angle up to 45 degrees to vertical). This will be confirmed post consent on receipt of more detailed geotechnical information. The maximum hammer energy used to install the pin piles would be 2,700 kilojoule (kJ) and the maximum volume of drill arising from one quadropod installation is discussed in section 5.4.3.1.4.

69. Suction buckets could be used to anchor the jacket foundation instead of pin piles. These would be of greater diameter than the usual jacket piles but would require no pile driving.

Table 5.9 Dimensions for pin pile foundations (based on quadropod)

Wind turbine size (MW)	Maximum seabed diameter (m)	Maximum penetration (m)	Maximum footprint on the seabed (excluding scour protection) (m^2)	Maximum area of scour protection per foundation (incl. structure footprint area) (m2)
Piles				
9	3	70	28	706.9
20	5	70	78.5	1,964
Suction caissons				
9	12	12	452	11,310
20	15	15	707	17,672

5.4.3.1.1 Material requirement for jacket foundations

70. Jacket foundations would comprise mainly steel. However, it is possible that some secondary structures, such as handrails, gratings and ladders, could be produced using other metals, such as aluminium, or composites. Concrete could also be used at the top of the jacket structure as part of a transition piece (TP) arrangement or to form the working platform and furthermore, the connection between the jacket structure and piles is often formed using cement grout.

5.4.3.1.2 Seabed preparation and penetration for jacket foundations

71. The majority of jacket foundations would not require any seabed preparation. However, depending on the jacket concept and installation method selected, there might be some requirement to carry out minor flattening at some locations; this would be to provide a more level formation for placement of a pile installation template. The template can accommodate small inclinations but some dredging should be allowed for to cover areas with steeper slopes. The volume and area impacted by seabed preparation would be significantly less than that for a gravity base foundation (see section 5.4.3.3.2). Sediment disposal is discussed in section 5.4.3.1.6.

5.4.3.1.3 Installation method of jacket foundations

72. For jacket foundations, the piles could be pre-piled or post-piled. It is anticipated that piles will generally be driven but alternative installation techniques, such as drilling or vibration, may be required depending on ground conditions. Drill arisings, should drilling be used are detailed in section 5.4.3.1.3. Should alternative techniques be incorporated (e.g. vibration), the parameters associated with the worst case scenarios (e.g. noise, duration and drill arisings), would be within those detailed for drilling and pile driving.

73. For pre-piled jackets, the overall installation methodology would typically be as follows:

- Piles and pile installation template transported to site via barge (or by installation vessel);
- Jack-up rig (alternatively floating vessel) with pile installation equipment and heavy craneage set up at pile installation;
- Pile installation template placed on seabed;
- Piles placed on seabed and driven to depth;
- Pile installation template removed and installation vessel demobilised;
- Installed pile locations surveyed and jacket dimensions adjusted;
- Delivery of jacket to site via barge (or by installation vessel);
- Lifting of jacket onto piles via floating heavy lift or jack-up vessel; and
- Levelling of jacket, grouting and/or or mechanical locking of jacket-to-pile connections.

74. For post-piled jackets, the sequence would typically be as follows:

- Jacket and piles transported to site via barge (or by installation vessel);
- Jack-up rig (alternatively floating vessel) with pile installation equipment and heavy craneage set up at jacket installation location;
- Seabed preparation carried out if required;
- Lifting of jacket from barge and lowering onto seabed;
- Lifting of piles from barge and stabbing into sleeves on jacket;
- Piles driven to depth;
- Levelling of jacket via jacking off piles; and
- Grouting and/or mechanical locking of jacket to pile connections.

5.4.3.1.4 Drill arisings

75. Pin piles may be driven, drilled or drilled-driven into the seabed. As previously discussed, it is estimated up to 50% of the locations could need drilling if these foundation options are chosen. The total quadropod drill arisings for 1,800MW would be approximately 176,715m^3, based on 45 20MW quadropod foundations with 5m drill diameter and 50m penetration. Sediment disposal for drill arisings is discussed in section 5.4.3.1.6.

5.4.3.1.5 Piling

76. A drivability assessment will be conducted at the post-consent phase when further information is available regarding the ground conditions to determine the required piling requirements (e.g. hammer energy, blow rate). At this stage it is estimated that the maximum hammer energy used for pin pile installation would be 2,700kJ. A soft start (gradual ramping up of hammer energy over consecutive blows) procedure, starting with a hammer energy of approximately 10% of the maximum energy and taking one hour to ramp up to the maximum energy would be employed using approximately 15 hammer blows per minute. Once the soft start procedure is

complete hammer blows would be a maximum of 30 per minute totalling a maximum of 8400 per foundation (average 6,000 per foundation).

77. The maximum predicted time for installation of a piled quadropod foundation is 12 hours for the largest, 5m diameter pin piles (with a six hour predicted average) or 6 hours for the 3m diameter pin pile (with a three hour predicted average).

5.4.3.1.6 Spoil removal and disposal for jacket foundations

78. If seabed preparation or drilling is required these would generate some spoil material that would require disposal. It is proposed the spoil will be disposed of within the OWF sites, with the spoil subsequently winnowed away by the natural tide and wave driven processes (see Chapter 8 Marine Geology, Oceanography and Physical Processes).

5.4.3.1.7 Scour protection for jacket foundations

79. Depending on metocean conditions scour protection may be required around the foundations to protect against currents and waves that may cause erosion of the seabed. An estimate of the total footprint of the scour protection is shown in Table 5.9.

80. Scour protection would comprise quarried rock, well graded with d_{50}=200 to 400, (i.e. half the stones will be less than a specified median (200 to 400mm diameter) and half will be greater). The quantities and extent of scour protection would be dependent on current speed, sediment type and the foundation details, however a conservative estimate of five times the foundation diameter is included within the Rochdale Envelope.

81. Alternative scour protection solutions such as ‘frond systems’ are also being considered. These comprise continuous lines of overlapping buoyant polypropylene fronds that when activated create a viscous drag barrier that significantly reduces current velocity. The frond lines are secured to a polyester webbing mesh base that is itself secured to the seabed by anchors pre-attached to the mesh base by polyester webbing lines. Grouted mattresses are also being considered.

5.4.3.2 Monopile foundations

82. Monopile foundations comprise a steel cylindrical pile and a steel cylindrical TP (Plate 5.6). Conical transitions are sometimes used to reduce the diameter of the structure at the top of the foundation.

83. The worst case dimensions considered for monopile foundations are provided in Table 5.10.

Table 5.10 Monopile dimensions

Wind turbine size (MW)	Maximum seabed diameter (m)	Maximum penetration (m)	Maximum footprint on the seabed (excluding scour protection) (m^2)	Maximum area of scour protection per foundation (incl. structure footprint area) (m2)
9	10	50	79	1,963
20	15	50	177	4,418

5.4.3.2.1 Material requirement for monopiles

84. Monopile foundations usually comprise mainly steel. However, it is possible that some secondary structures, such as handrails, gratings and ladders, could be produced using other metals, such as aluminium, or composites. Also, concrete could be used to form the working platform.

5.4.3.2.2 Seabed preparation for monopiles

85. Monopiles would be positioned in such a way to avoid or reduce seabed preparation where possible; however, where sand waves are present the seabed might need to be levelled first by excavation to the trough of the sand wave. The worst case assumption is that excavation to 5m depth could be required. The worst case excavation volumes for monopiles are predicted to be significantly less than those required for gravity base foundations which are provided in Table 5.11. Sediment disposal is discussed in section 5.4.3.2.7.

86. Dependent on the nature of the metocean conditions and final monopile design, it may be necessary to install scour protection around the base of the foundation. It is likely that if scour protection would be required for monopile foundations a filter layer would be installed first which would then be piled through. The scour protection works are likely to be installed by a dynamically positioned stone dumping vessel equipped with a fall pipe.

5.4.3.2.3 Installation method for monopiles

87. The installation of steel monopile foundations would typically consist of the following key stages:

- Prepare seabed (if necessary) prior to installation;
- Confirmation investigation of seabed to ensure no obstructions are present;
- Delivery of steel monopiles and TPs to site via barge or by installation vessel. It may also be possible to tow floated piles to site using tugs;
- Mobilisation of jack-up rig (alternatively floating vessel) with heavy craneage at installation location. It may also be necessary to mobilise a support vessel;
- Monopile upended by crane to vertical position;
- Monopile lowered to seabed;

- Locating of driving hammer onto top of pile using craneage, and monopile driven to required depth. Where ground conditions are difficult, it may also be necessary to carry out drilling using drilling equipment operated from the installation vessel before completing the driving;
- Lifting of TP on to top of monopile using craneage from installation vessel, levelling of TP and grouting of connection; and
- Installation of scour protection as appropriate.

5.4.3.2.4 Drill arisings

88. Monopiles may be driven, drilled or drilled-driven into the seabed. As previously discussed, it is estimated up to 50% of the locations could need drilling if these foundation options are chosen. The maximum amount of monopile drill arisings for 1,800MW would be approximately 397,608m^3, based on 45 x 20MW monopile foundations with 15m drill diameter and 50m penetration. Sediment disposal for drill arisings is discussed in section 5.4.3.2.7.

5.4.3.2.5 Piling

89. A drivability assessment will be conducted at the post-consent phase when further information is available regarding the ground conditions to determine the required piling requirements (e.g. hammer energy, blow rate). At this stage it is estimated that the maximum hammer energy used for monopile installation would be 5,000kJ for the largest 15m diameter monopiles. A soft start (gradual ramping up of hammer energy over consecutive blows) procedure, starting with a hammer energy of approximately 10% of the maximum energy and taking one hour to ramp up to the maximum energy would be employed using approximately 15 hammer blows per minute. Once the soft start procedure is complete hammer blows would be a maximum of 30 per minute totalling a maximum of 7,200 per foundation (average 6,000 per foundation). The maximum predicted time for installation of a monopile foundation is 6 hours (with a three hour predicted average).

5.4.3.2.6 Spoil removal and disposal for monopile foundations

90. If seabed preparation or drilling is required these would generate some spoil material that would require disposal. It is proposed the spoil will be disposed of within the OWF sites, with the spoil subsequently winnowed away by the natural tide and wave driven processes (see Chapter 8 Marine Geology, Oceanography and Physical Processes).

5.4.3.2.7 Scour protection for monopile foundations

91. Dependent on the specific conditions and design, the total extent of the scour protection is estimated to be approximately five times the pile diameter. The maximum area that would be occupied by this material is provided in Table 5.10.

92. The types of scour protection being considered for monopile foundations would be the same as those considered for jacket foundations as described in section 5.4.3.1.7. The predicted area of scour protection is provided in Table 5.10.

5.4.3.3 Gravity base structures

93. There are many possible shapes and sizes of gravity base foundations currently on the market or in design. A typical foundation comprises a base, a conical section and a cylindrical section. One of the main factors affecting size is whether the structure would be transported on a barge or vessel and lifted into place or whether it would be floated or semi-floated with the assistance of a barge/pontoon to site. The buoyant structures are significantly larger in size.

94. The base would be hexagonal, octagonal or circular. Bases with a cruciform plan shape are also being considered, occupying a similar footprint.

95. The base would be between one and 12m high, depending on the design. It is likely that the shaft would be cone shaped at the bottom, tapering to a cylinder at the top (Plate 5.3) with an outer diameter of approximately 5 to 9m.

96. Some alternative gravity base concepts do not have a cone transition, just a cylindrical shaft, with an outer diameter of approximately 5 to 9m. The bases of these flat base gravity structures are much higher, typically up to 20m, but the footprint sizes are similar and within the same project design envelope.

97. Gravity base structures might also use a skirt at their base which penetrates the seabed giving more stability to the structure. The penetration could vary from around 0.1 to 5m. Under base grouting may also be used to strengthen the soil beneath the foundation and fill small voids.

98. Estimation of footprint sizes at the seabed for Norfolk Vanguard gravity base foundations are outlined in Table 5.11.

Table 5.11 Gravity base structure and seabed preparation dimensions

Wind turbine size (MW)	Maximum gravity base diameter (m)	Maximum seabed preparation diameter (m)	Maximum footprint per base (m^2)	Maximum seabed preparation area (m^2)	Maximum volume of excavation (m^3)
9	40	50	1,257	1,963.5	9,817
20	50	60	1,963.5	2,827	14,137

5.4.3.3.1 Material requirement for gravity base structures

99. Gravity base structures are generally concrete with steel reinforcement. They are produced in a large range of sizes, depending on design, water depths and whether the structure is intended to be buoyant during installation.

100. There are also hybrid concepts that include a steel tower.

101. Secondary structures, such as handrails, gratings, fenders and ladders, would be produced using steel (or possibly another metal or composite material). The working platform could also be made from steel.

102. The ballast material commonly used is sand. Other materials may be considered as an alternative, such as olivine, dolerite, basalt or pig iron. However, it is most likely to be sand dredged local to the site depending on the suitability of the material.

103. Some gravity base structure solutions require an injection of a cement grout mix under the foundation to strengthen the soil and/or fill voids. If underbase grouting is used, it is estimated up to 75m^3 of cement grout could be required per foundation.

5.4.3.3.2 Seabed preparation and penetration for gravity base structures

104. Gravity base structures may require seabed preparation to level the seabed, provide a base with adequate bearing capacity and to ensure adequate contact between the foundation base and seabed.

105. Sand waves are known to be present across the offshore project area of varying magnitude. Gravity base structures are not suitable in areas of very large and mobile sand waves but they could be used in areas where smaller sand waves are present. At these locations the seabed may need to be excavated to the trough of the sand wave and the underside of the base would be placed at this level on a bedding layer.

106. At some locations, excavation of upper sediments may be required to reach a competent formation level.

107. Seabed preparation would consist of dredging works and the installation of a bedding and levelling layer. The dredging works are likely to be carried out using a trailer suction hopper dredger. The bedding and levelling layer installation would be undertaken by a fall pipe vessel. Sediment disposal is discussed in section 5.4.3.3.4.

108. Gravity base structure foundations would likely be installed where no, or little ground preparation is required and micro-siting would be used to minimise any dredging requirements. However, the worst case scenario envisaged is an excavation to level an area of sand waves up to 5m in depth, with estimated volumes as provided in Table 5.11.

5.4.3.3.3 Installation method of gravity base structures

109. Gravity base structures would be delivered to site via one of two methods, depending on the foundation design:

- Floating, towed to site and sunk via ballasting; or

- Traditional, transported to site by barge and installed by heavy lift crane.

110. For the floating structures, it is possible that a bespoke barge would be used to support the foundation during its journey to site. For the traditional solution, it is likely that a heavy lift vessel would be required to perform the installation. This could be a jack-up or floating vessel.

111. The installation of gravity base structures is heavily dependent on design and fabrication methods and definitive methodology for installation.

112. The overall installation methodology would typically be as follows:

- Prepare seabed (if necessary, see section 5.4.3.3.2);
- Gravity base structure transported to site via barge or floated to site, hauled by tugs;
- Mobilise heavy lift floating crane (if foundation is non-buoyant solution);
- Lift foundation from barge and lower to prepared area of seabed, or adjust buoyancy of floating foundation and sink to prepared area of seabed;
- Install backfill as necessary; and
- Install scour protection (likely to be rock dumping).

113. Backfilling works, if required, could be undertaken by a trailer suction hopper dredger. The scour protection works are likely to be installed by a dynamically positioned stone dumping vessel equipped with a fall pipe. The scour materials will be placed in one or multiple layers.

5.4.3.3.4 Spoil removal and disposal for gravity base structures

114. For gravity base structures, it is possible that greater seabed preparation will be required. Again, this is dependent on the nature of the ground conditions present underneath the bases (for example, if sand waves are present).

115. Examples of amount of materials requiring excavation are given in sections above. In these examples it would be preferable to use some of this material as backfill but in an extreme case all of it may need to be removed if it is unsuitable for backfilling.

116. The dredged sand would be deposited within the OWF sites. It is possible that some of this dredged material would be used later for infill works, and as ballast material.

5.4.3.3.5 Scour protection for gravity base structures

117. As with jacket foundations, scour protection might be required, that would typically consist of quarried rock. An estimate of the total footprint of the scour protection and is shown in Table 5.12.

118. More scour protection will be needed when the base is buried at depth due to sand waves and scour protection could extend to cover 5 times the diameter of the base.

The maximum estimated area of scour protection required per foundation is provided in Table 5.12.

Table 5.12 Wind turbine gravity base structure and scour protection footprints

Wind turbine size (MW)	Gravity base diameter (m)	Total area of scour protection (m^2)*	Rationale for scour protection
9	40	31,416	5 × diameter (40m) around foundation
20	50	49,087	5 × diameter (50m) around foundation
Total maximum across the wind farm site		6,283,200	200 (9MW) × 31,416m^2 = 6,283,200m^2 or 90 (20MW) × 49,087m^2 = 4,417,830m^2

* This includes the area which would be occupied by the foundation as well as the scour protection.

119. The scour protection works are likely to be installed by a dynamically positioned stone dumping vessel equipped with a fall pipe. The scour materials will be placed in one or multiple layers.

120. Alternative methods of installing scour protection, such as grouted mattresses, are also under consideration.

121. If this foundation type is adopted, further work would be undertaken post consent to determine the extent of scour protection required.

5.4.3.4 Suction caisson foundations

122. The use of suction caisson foundations in the offshore wind industry is a relatively new concept and has only previously been used in a prototype for offshore wind turbines. The technology is however well advanced in the oil and gas industry as an alternative to piles.

123. Suction caissons comprise a steel cylindrical tower (the shaft) with cylindrical skirt, which penetrates into the seabed (Plate 5.5). A single caisson monopole could be used or a jacket with three (tripod) or four (quadropod) suction caissons.

124. The base height of the skirt above seabed is typically 5m or more, although it may be possible to install it below seabed to reduce scour effects.

125. Table 5.13 shows the dimensions for monopole suction caissons and scour protection footprints (see Table 5.9 for suction caisson quadropods).

Table 5.13 Suction caisson monopole dimensions footprints

Wind turbine size (MW)	Suction bucket diameter	Penetration depth (m)	Total area of scour protection (m^2)*	Rationale for scour protection
9	25m	15	12,272	5 × diameter (25m)
20	35m	30	24,053	5 × diameter (35m)

* This includes the area which would be occupied by the foundation as well as the scour protection.

5.4.3.4.1 Material requirement for suction caisson foundations

126. Suction caisson foundations would comprise a mainly steel structure with some secondary structures, such as handrails, gratings and ladders, made of metals, such as aluminium, or composites. Also, concrete could be used to form the working platform.

5.4.3.4.2 Seabed preparation and penetration for suction caisson foundations

127. In areas where the seabed is level, the suction caisson foundation may not require significant seabed preparation. However, measures may be required in areas in which sand waves are present to provide a level formation for the installation and to allow scour protection to be later placed around the foundation. It is possible that excavation to the trough of the sand wave would be necessary before installing the suction caisson. Based on the assumption that the skirt is buried, a worst case excavation volume (5m in depth) has been estimated. The worst case excavation volumes for suction caissons are predicted to be significantly less than those required for gravity base foundations which are provided in Table 5.11. It is proposed the spoil will be disposed of within the OWF sites.

5.4.3.4.3 Installation method for suction caisson foundations

128. Suction caisson foundations are most likely to be towed to site by tugs as they are designed to be buoyant. The caisson skirt and shaft are generally delivered and installed as a single part.

129. The overall basic installation methodology would typically be as follows:

- Prepare seabed (if necessary) prior to installation;
- Confirmation investigation of seabed to ensure no obstructions are present;
- Suction caisson foundation towed to site via barges;
- Suction caisson foundation is ballasted and lowered to seabed;
- Initial penetration occurs under foundation self-weight;
- Pumps are attached to caisson and water evacuated. Typically, there are a number of chambers within the caisson in order to implement a controlled installation and to control levels. Sometimes water jetting is used at the tip of the skirt to facilitate penetration;

- Install backfill as necessary;
- Install scour protection (likely to be rock dumping).

5.4.3.4.4 Scour protection for suction caisson foundations

130. The types of scour protection being considered for suction caisson foundations would be the same as those considered for jacket foundations, as described in section 5.4.3.1.7. The predicted area of scour protection is provided in Table 5.10.

5.4.3.5 Floating tension leg foundations

131. Floating tension leg foundations are being considered for the project as they have some significant advantages over traditional foundation types. They comprise a floating steel structure and a steel cylindrical TP. The structure would be constructed on the quayside in a suitable harbour and once fully assembled the structure and the wind turbine floated out to site for full installation. The structure would be held to the seabed under tensioned mooring cables anchoring the structure to the seabed (Plate 5.7 and Plate 5.8). Anchors would be either:

- Pin piles;
- Caissons; or
- A single gravity base.

132. The dimensions of the anchor piles, caissons and gravity base options are provided in Table 5.14.

Table 5.14 Floating tension leg foundation anchor dimensions

Parameter	9MW	20MW
Floating structure and mooring lines		
Diameter of floating structure(m)	45	70
Maximum water penetration (m)	35	35
Maximum number of anchor lines	12	12
Maximum movement of platform at the surface (m)	10	10
Anchor line length (m)	20	20
Anchor line angle	Vertical (0^o) for gravity base Up to 30^o for piled or caisson anchors	
Gravity base anchor		
Gravity base dimensions (m)	45 × 45	70 × 70
Gravity base area (m^2)	2,025	4,900
Gravity base foundation and scour protection area (m^2)	50,625	122,500
Total area for 1800MW	10,125,000m^2 (10.13km^2)	11,025,000m^2 (11.03km^2)
Pin pile anchor		
Maximum number of piled anchors	4	4
Pin pile maximum diameter (m)	3	3
Pin pile area per foundation (m^2)	28.3	28.3

Parameter	9MW	20MW
Pin pile and scour protection area per foundation (m^2)	707	707
Hammer energy pin pile (kJ)	2,700	2,700
Suction caisson anchor		
Maximum number of caissons	4	4
Suction caisson diameter (m^2)	20	30
Suction caisson area per foundation (m^2)	1,256.6	2,827.4
Suction caisson and scour protection area per foundation (m^2)	31,416	70,686

5.4.3.5.1 Material requirements for floating tension leg foundations

133. While floating platforms would comprise mainly steel, some secondary structures such as handrails, gratings and ladders, could be produced using other metals such as aluminium or composites. Concrete could also be used to form the working platform.

5.4.3.5.2 Seabed preparation for floating tension leg foundations

134. Anchors would be positioned in such a way to avoid seabed preparation where possible, however if sand waves are present (particularly for the gravity anchors), the seabed might need to be levelled first by excavation to the trough of the sand wave. The worst case assumption is that excavation to 5m depth is required. The volume and area impacted by seabed preparation is estimated to be similar to that required for gravity base foundation (see section 5.4.3.3.2). It is proposed the spoil will be disposed of within the OWF sites.

5.4.3.5.3 Installation method for floating tension leg foundations

135. The installation of tension leg floating foundations would typically consist of the following key stages:

- Prepare seabed (if necessary) prior to installation of piles/caissons/gravity bases;
- Confirmation investigation of seabed to ensure no obstructions are present;
- Delivery of foundation components to site via barge or by installation vessel. It may also be possible to tow floated piles to site using tugs;
- Mobilisation of jack-up rig (alternatively floating vessel) with heavy craneage at installation location. It may also be necessary to mobilise a support vessel;
- Seabed installation of piles/caissons/gravity bases by vessel crane and auxiliary equipment to required position;
- Installation of scour protection;
- Possible locating of driving hammer onto top of pile using craneage, and pile driven to required depth (estimated maximum pile energy is provided in Table 5.14);

- Assembly onshore of floating platform and wind turbine together including testing and commissioning of wind turbine;
- Float out of foundation and wind turbine assembly using tug barges;
- Attaching tension cables to the floating foundation and to the piles/caissons/gravity bases;
- Partly flooding the foundation in order to tension the foundation cables followed by expelling the water using compressed air in order to increase the tension in the cables; and
- Installation of array cabling.

5.4.3.5.4 Scour protection for floating tension leg foundations

136. The types of scour protection being considered for floating tension leg foundations would be the same as those considered for jacket foundations as described in section 5.4.3.1.7. The predicted area of scour protection is provided in Table 5.14.

5.4.4 Offshore Platforms

5.4.4.1 Offshore electrical platforms

137. The offshore substations will be located within the OWF sites. At this stage of the project it is not possible to provide precise locations, since the final location will depend upon many factors such as wind turbine layout design.

138. The maximum number of platforms would be two, with either both in NV West or NV East, or one located in each OWF site.

139. The offshore electrical platforms would consist of a topside structure configured in a multiple deck arrangement. Decks would either be open with modular equipment or the structure could be fully clad. All weather sensitive equipment will be placed in environmentally controlled areas.

5.4.4.1.1 Offshore electrical platform: foundation type and construction method

140. The substations would require bespoke foundations on which to place the topsides that contain the equipment outlined in Table 5.17. The following options for substation foundation are being considered:

- GBS; or
- Up to six legged jackets (piled or suction caisson).

141. An alternative solution which is being considered is a self-installing structure, which is towed to site and then floods or fills its legs to sit on the prepared seabed. Piles may be used to minimise future movement. The footprint of this type of solution would be within the parameters described in Table 5.15.

142. Table 5.15 provides the worst case parameters for offshore electrical platform foundations.

Table 5.15 Offshore electrical platform foundation dimensions

Parameter	Six-legged pin pile	GBS (multi-legged)
Maximum footprint per platform (m^2)	42 (based on 6 legs of 3m diameter)	7,500 (based on approximately 75 x 100m)
Maximum penetration depth (m)	20	N/A
Maximum drill arisings per platform* (m^3)	848	N/A
Maximum area of scour protection per platform (m^2)	1,060 (based on 5 x pile diameter)	17,500
Maximum area of scour protection for two platforms(m^2)	2,120	35,000
Maximum seabed preparation area per foundation (m^2)	Less than GBS	7,500

* should drilling be required

The construction methods used to install substation foundations would be similar those described for the wind turbine foundations described in section 5.4.2.2.

5.4.4.1.2 Installation method

143. The foundation installation process for the offshore electrical platform options would be as described in sections 5.4.3.1, 5.4.3.2, and 5.4.3.4.

144. The topsides could be installed using the following options:

- By a suitable crane vessel (or vessels working together) in a single lift;
- By a suitable crane vessel (or vessels working together) in separate lifts of deck and sub-modules;
- Using a rail-skid transfer from a large jack-up; or
- Self-installing.

5.4.4.1.3 Piling

145. Piling for offshore electrical platforms would be as described in section 5.4.3.1.5 with the following key parameters (Table 5.16):

Table 5.16 Offshore electrical platform piling parameters

Parameter	Pin pile (six legged worst case)
Maximum diameter (m)	3
Maximum hammer energy (kJ)	2,700
Maximum seabed penetration (m)	70
Soft start hammer energy (kJ)	270
Ramp up	20mins at starting energy followed by 40min ramp up to maximum energy
Max number of blows per pile	300
Average number of blows per pile	200

Parameter	Pin pile (six legged worst case)
Max piling time per foundation (assuming issues such as low blow rate, refusal, etc) (hr)	9
Average 'active piling time' per foundation (hr)	1.5

5.4.4.1.4 Offshore electrical platform equipment

146. Table 5.17 includes a list of equipment which would be housed within the offshore electrical platforms.

Table 5.17 Indicative equipment of HVDC offshore electrical platform

Equipment
Power transformers
Switchgear: Low Voltage, Medium Voltage and High Voltage
Instrumentation, protection and control systems
Neutral earthing resistor
Standby generators
Fuel supplies
Auxiliary and uninterruptible power supply systems and transformers
Emergency shelter
Craneage
Metering stations
Meteorological equipment
Helipad (optional)
Messing facilities
Cooling system
AC equipment such as phase reactors and AC filters
AC/DC converter with switching devices: valves (typically IGBT's)
DC equipment, such as DC capacitors and DC filters and associated equipment

5.4.4.1.5 Oils and fluids in the offshore electrical platforms

147. Some of the equipment at the offshore electrical platforms will contain fluids. The following list covers the key types of fluids that would be required:

- Diesel for the emergency diesel generators (in diesel storage tanks);
- Oil for the transformers;
- Deionised water for the valves cooling system;
- Glycol;
- Sewage and grey water;
- Lead acid for UPS and batteries;
- Engine oil; and
- Sulphur hexafluoride (SF_6)

148. To avoid discharge of oils to the environment, the electrical platforms would be designed with a self-contained bund to collect any possible oil spill. Any transfer of

oil/fuel between the substations and service vessel would follow best practice procedures. Procedures would also be put in place should there be a spill to the marine environment. To avoid discharge/spillage of oils it is anticipated that the transformers would be filled for their life and would not need interim oil changes.

149. Any oil spillage from the diesel tank or from the transformer would be collected in a separate oil waste tank. Both oil waste and other wastes (waste water etc.) would be brought to shore in a secure container and disposed according to industry best practice procedures.

150. All waste would be processed on the electrical platforms or transferred as required.

5.4.4.2 Accommodation platform

151. Two accommodation platforms may be required (one in NV West and one in NV East) to house construction and operation and maintenance personnel and equipment. This would require a foundation structure likely to be similar to that of the offshore electrical platforms (section 5.4.4.1.1). Therefore, the maximum dimensions are as provided in Table 5.15. The maximum predicted footprint of the foundation including scour protection would be 17,500m^2 and the maximum hammer energy used if piled foundations were used would be 2,700kJ.

5.4.5 Meteorological Masts

152. Up to two operational meteorological masts (met masts) may be installed within the OWF sites, neither of which would exceed the hub height of a wind turbine generator (Table 5.7). The foundations used may be jacket, gravity base or monopile. The information provided in Table 5.18 illustrates the different size of foundation required to support met masts.

Table 5.18 Meteorological mast foundation dimensions

Parameter	Number/type
Number of met masts across the project	2
Maximum number in NV West	1
Maximum number in NV East	1
Type of foundation being considered	Jacket, Gravity Base, Monopile
Maximum diameter at seabed (m)	20
Total maximum footprint (m^2)	628
Total maximum footprint plus scour protection (m^2)	15,708
Maximum seabed preparation area per foundation	2,827

5.4.6 Buoys

153. It is anticipated that up to two LiDAR and two wave buoys may be installed across the Norfolk Vanguard site. These devices will be anchored to the seabed. The

dimensions for wave and LiDAR buoys are provided in Table 5.19. There would also be the requirement for a number of guard buoys around the OWF sites which will be determined in consultation with the Maritime and Coastguard Agency (MCA) and Trinity House Lighthouse Service (THLS).

Table 5.19 Wave and LiDAR buoy dimensions

Parameter	Wave buoy	LiDAR
Maximum Number installed across the project.	2	2
Max Elevation (m HAT)	5	25
Seabed attachment types	Floating with anchors	Floating with anchors, Monopile
Seabed footprint (per buoy)	Anchor footprint approximately 150m^2	5m diameter with scour protection 1,963.5m^2

5.4.7 Ancillary Structures

154. Ancillary structures are likely to form part of the final design of the wind farm; however, the requirement and nature of these would be determined at the detailed design phase. Ancillary structures may include: temporary landing places, moorings or other means of accommodating vessels in the construction and / or maintenance of the authorised development; buoys, beacons, fenders and other navigational warning or ship impact protection works; and temporary works for the benefit or protection of land or structures affected by the authorised development.

5.4.8 Underwater Noise

155. An assessment of the underwater noise levels that could be generated by the project is provided in Appendix 5.3 and Appendix 5.4.

5.4.9 Airborne Noise

5.4.9.1 Installation and construction noise

156. Any noise stemming from the construction activities associated with turbine installation is likely to be temporary and local to the OWF site.

5.4.9.2 Operational noise

157. Noise emissions which occur from the flow of air around the turbine blades are related to a combination of blade profile, rotor diameter, rotor speed and maximum tip speed. The noise level of the turbine varies between manufacturer and model, but is estimated to typically range between 105dBA (A-weighted decibel) and 115dBA at 10m/s wind speed, measured according to International Electrotechnical Commission (IEC) 61400-11 Measurement Standard.

5.4.10 Oils, Fluids and Effluents

158. Oils in the wind turbines shall be biodegradable where possible. All wind turbines will have provision to retain all spilt fluids within nacelle/tower. The volume of oil and fluids will vary depending on wind turbine design, i.e. conventional design or gearless, whether one or two or more rotor bearings are used in the design and the amount of redundancy designed into the system.

159. All chemicals used will be certified to the relevant standard. A brief summary of usual oils and fluids in the systems of a typical WTG is provided in Table 5.20.

Table 5.20 Peak quantities for normal turbine operation

Parameter	9MW	20MW
Grease (litres)	1000	2000
Synthetic Oil / Hydraulic Oil (litres)	1000	2000
Nitrogen (litres)	100	200
Water/Glycerol (litres)	1000	2000
Silicone Oil - transformer option (kg)	1500	2000
SF6 gas - MV breaker option (kg)	50	100

5.4.11 Navigation Lighting Requirements and Colour Scheme

160. The wind farm will be designed and constructed to satisfy the requirements of the Civil Aviation Authority (CAA), Maritime and Coastguard Agency (MCA) and THLS in respect of lighting and marking. The following guidance and regulations will be considered (or as updated):

- International Association of Lighthouse Authorities (IALA) Recommendations 0-139 – The Marking of Man-Made Offshore Structures (IALA, 2013).
- Department of Energy & Climate Change (DECC) Standard Marking Schedule for Offshore Installations (DECC, 2011).
- Maritime and Coastguard Agency (MCA) Marine Guidance Notice (MGN) 543 and Annexes – Offshore Renewable Energy Installations (OREIs) – Guidance on UK Navigational Practice, Safety and Emergency Response (MCA, 2016).
- Civil Aviation Authority (CAA) CAP 393 Air Navigation: The Order and Regulations Article 222 (CAA, 2016).
- CAA CAP 764 – Policy and Guidelines on Wind Turbines (CAA, 2016).
- CAA Policy Statement November 2012 – The lighting and marking of WTGs and meteorological masts in UK territorial waters (CAA, 2012b).

161. The colour scheme for nacelles, blades and towers is generally RAL 7035 (light grey). Foundation steelwork is generally in RAL 1023 (traffic yellow) from HAT up to a minimum of 15m. The Aids to Navigation shall be located within the traffic yellow area.

5.4.11.1 Construction

162. During the construction phase, working areas will be established and marked in accordance with the IALA Maritime Buoyage System (MBS) and THLS consultation. Such areas and markings will be promulgated by appropriate means in advance. Temporary lighting may be required at the request of THLS.

5.4.11.2 Operation

163. During operation, lighting and marking will be as per the above guidance in consultation with CAA, MCA and THLS.

5.4.12 Electrical Infrastructure

5.4.12.1 Offshore cable corridor

164. Export cables transmit power from the offshore electrical platforms to the onshore project substation. These cables operate at a higher voltage than is used for the array cables. The offshore section of the export cable route extends from the offshore electrical platforms up to the landfall at Happisburgh South; the onshore section goes from the landfall to the onshore project substation at Necton.

165. The design of the offshore cable corridor facilitates cables connecting the offshore electrical platforms located in the NV East and NV West. The branch of the offshore cable corridor linking to the south-eastern corner of NV West is included specifically for this purpose.

166. The main spine of the corridor extends westwards from NV East to the landfall site at Happisburgh South. It runs adjacent to, and to the south of, existing gas pipelines over much of this distance. In general, this main part of the corridor is 2km wide. However, a wider section has been included at the kink in the corridor where it crosses the Bacton to Zeebrugge gas pipeline.

5.4.12.1.1 Export cables

167. Cross-linked polyethylene (XLPE) or Mass Impregnated Non-Draining (MIND) HVDC cables of approximately 150mm diameter would be used to transmit power from the offshore electrical platforms to the landfall location. Similar cables may also be used to provide connection between the offshore electrical platforms. The nominal operating voltage of these cables would be approximately +/-320kV.

168. Communications facilities will be provided either by installing a separate fibre-optic cable or by integrating a fibre bundle in the armouring of the HVDC cables.

169. HVDC cables are screened so that the electric stresses are contained within the insulation layer. The magnetic fields caused by the electric currents in the conductors cannot be contained in this way. However, it is normal practice to bundle together the flow and return cables of a DC system and install them in a single

trench. As the net current in the two cables is zero, the resultant magnetic fields are limited to a small spatial extent.

170. At full load, total heat loss per metre for a pair of large HVDC cables is roughly 100W/m.

5.4.12.1.2 Export and interconnection cables: minimum cable spacing, number and width of cable trenches

171. A minimum separation distance for the subsea cables would be employed primarily to reduce the risk of damaging the adjacent cable during any cable repairs/replacement in the operation and maintenance (O&M) phase.

172. A practical cable corridor width has to allow for:

- Clearance for installation;
- Long-term operation and maintenance capability, including space to effect cable recovery and repairs;
- Potential of third parties requiring the seabed adjacent to the cables; and
- Seabed lease requirements from The Crown Estate and associated costs.

173. Indicative cable spacing arrangements for the offshore export cables is displayed in Plate 5.9. The separation between cables is determined by the potential space required to undertake a cable repair based on the bight length to lift a section of cable, which is a factor of the water depth. Depth throughout the majority of the offshore cable corridor is less than 48m and therefore this represents a conservative worst case scenario

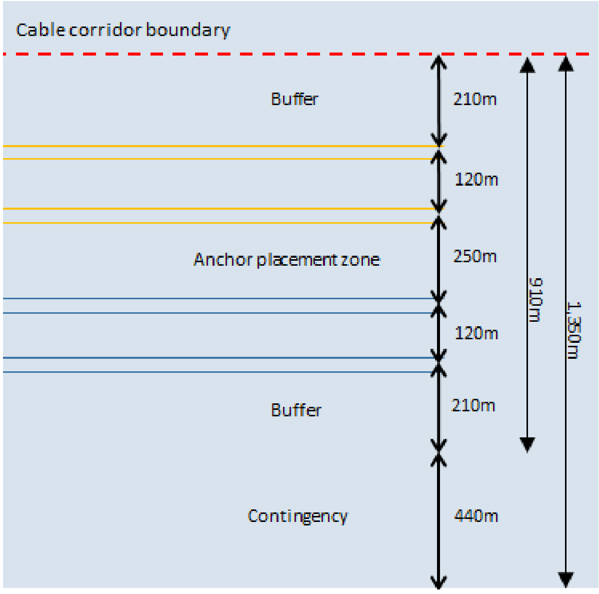

Plate 5.9 Indicative export cable layout (two pairs of cables for Norfolk Vanguard (yellow) and two pairs of cables for Norfolk Boreas (blue)) based on 48m water depth

174. A central anchor placement zone with a width of 250m has been identified to accommodate any vessels needing to set anchors to hold position whilst installing or maintaining the cables. The width of the anchor placement zone is based on previous experience of exclusion zones for anchors which are dependent on the direction the anchor will be recovered. When recovering away from an adjacent cable a 50m safety zone is commonly requested. When recovering towards an adjacent cable the zone increases to 100m.

175. The individual cables have been grouped into pairs which will be laid in one trench with separation distances of 120m allowing for a repair bight.

5.4.12.2 Interconnector cables

176. Interconnector cables allow for transmission of power between the offshore electrical platforms. Such interconnection may be needed to provide redundancy in the system, in case of failure of one of the export cable systems. Some interconnection cables may operate at the same voltage as the array cables; others may operate at the same voltage as the export cables.

5.4.12.3 Array cables

177. The cables between adjacent wind turbines will be relatively short, typically 1 to 3km. However, some of the cables between the offshore substation(s) and the wind turbine strings will be longer, and could be up to 15km in length. A maximum distance of 600km of array cable is predicted over the entire project.

178. The nominal operating voltage of the array cables will be less than 100kV (Root Mean Square (RMS), phase-to-phase). The nominal voltage is likely to be 66kV.

179. Two or three different conductor sizes will be used in the array network. The size of each individual cable will be chosen according to the electrical load that the cable is required to carry. The array cables would be approximately 100-150mm in diameter, three conductor packages enclosed in a protective sheath. The conductors would be stranded copper or aluminium, and would be encased in solid polymeric insulation with metallic screens. The insulation would be XLPE or Ethylene Propylene Rubber (EPR). All cables will contain optical fibres embedded between the cores for communication purposes.

180. The intensity of EMF emitted by subsea cable is very low due to the design and operation of the cable. The screening of the individual conductors means that the electric stresses are contained within the insulation layer. The magnetic fields caused by the electric currents in the conductors cannot be contained in this way. However, as the three conductors form part of a balanced three-phase system, the net current in the cable is always zero; as a result, the magnetic fields are limited to a small spatial envelope close to the cable.

181. At full load, total heat loss per meter for a large 66kV 3-core cable is 150W/m.

5.4.13 Cable Installation Methods

5.4.13.1 Pre-lay works

5.4.13.1.1 Pre-installation works

Pre-construction surveys

182. A pre-construction survey would be undertaken in advance of cable installation works. The results of this survey would be used to plan the routing of all Norfolk Vanguard cables including micrositing where possible.

UXO clearance

183. A pre-construction UXO survey will be undertaken and the results will inform micrositing where possible and/or identify any requirement for UXO clearance. Norfolk Vanguard Limited has reviewed the 2016 survey data and estimated 28 clearance operations in the offshore cable corridor. Appendix 5.2 provides a review of typical UXO items which may be found in the Norfolk Vanguard offshore project area.

Boulder clearance

184. Pre-construction surveys will identify any requirement for boulder clearance. Norfolk Vanguard Limited has reviewed the Fugro (2016) geophysical survey data for the presence of boulders. Given the low proportion of boulders in the area, it is likely that micrositing around boulders will be possible, however an allowance for clearing 22 boulders of up to 5m in diameter has been included in the assessments in order to be conservative. Boulders would be relocated within the offshore project area, outside the route of the cable installation.

Pre-lay grapnel run

185. Before cable-laying operations commence, it would be necessary to ensure that the route is free from obstructions such as discarded trawling gear or abandoned cables identified as part of the pre-construction survey. A survey vessel would be used to clear all such identified debris, in a 'pre-lay grapnel run'.

186. The maximum width of seabed disturbance along the pre-grapnel run would be 20m. This is encompassed by the maximum footprint of cable installation works associated with ploughing (30m disturbance width).

Pre-sweeping

187. Mobile sand waves could result in exposure and scouring of the cable or the cable being held in suspension over time. To prevent this, the cable could be placed in the troughs of sand waves to a reference seabed level that would minimise the potential

for cables becoming unburied, as required. If this is not possible, an alternative is to dredge the top of the sand waves prior to installation. This process is termed the pre-sweep and would be completed as required before the cable could be laid on the seabed.

Pre-sweeping in the offshore cable corridor

188. A detailed export cable installation study (Appendix 5.1) was commissioned by Norfolk Vanguard Limited to assess the project geophysical survey data (Fugro, 2016) and confirm the potential for cable burial. This study provided:

- A review of site geology and available installation tools which showed that the sediments are conducive to cable burial;
- The calculation of a non-mobile reference seabed level (RSBL) below which the seabed will not fall during the lifetime of the wind farm;
- Calculations of sediment volumes which would require dredging during pre-sweeping works to enable cables to be buried below the RSBL, both inside and outside the Haisborough, Hammond and Winterton SAC. These volumes are likely to decrease as the route and installation tools are further refined.
- Identification of potential disposal areas within the Haisborough, Hammond and Winterton SAC for material removed from the SAC during pre-sweeping.
- Explanation of how offshore export cable route adjustments/micrositing can be undertaken due to contingency in the offshore cable corridor width.

189. Indicative pre-sweeping areas and volumes for the offshore cable corridor provided in Appendix 5.1) are outlined in Table 5.21. The maximum width of pre-sweeping in the offshore cable corridor would be approximately 37m depending on the depth of sand waves. The 37m pre-sweeping width is based on sand wave depth of approximately 5m with a slope gradient of 1:3 and a width of 7m at the base of the dredged area. This would be in discrete areas and not along the full length of the corridor.

Table 5.21 Parameters for pre-sweeping activity within the offshore cable corridor

Parameter	Max. quantity for the entire export cable corridor (m^3)	Max. quantity for the section of export corridor within the Haisborough, Hammond and Winterton SAC (m^3
Volume of material to be moved		
Per trench (pair of export cables)	325,000	250,000
Total for two trenches	600,000	500,000
Area of seabed affected by pre-sweeping		
Per trench (pair of export cables)	180,000	125,000
Total for two trenches	360,000	250,000

Pre-sweeping in the OWF sites

190. Pre-sweeping in the OWF sites may be required for the 600km length of array cables, resulting in an area of temporary disturbance of up to 12km^2 based on a disturbance width of 20m.

Sediment disposal

191. Any dredged material would be disposed of within the offshore cable corridor and/or within the OWF sites. Material originating within the Haisborough, Hammond and Winterton SAC will be placed in a disposal site within the section of the offshore cable corridor that overlaps with the SAC (Figure 5.2).

Removal of existing disused cables

192. Where the offshore cable corridor crosses an 'out of service' cable, these may be recovered from the seabed before the start of installation. The removal would be dependent on depth of burial, and if it breaks during recovery a number of grappling operations may be required.

5.4.13.2 Cable burial methods

5.4.13.2.1 Ploughing

193. In this method, a forward blade cuts through the seabed, while laying the cable behind. Ploughs used for cable burial can either be used as post lay burial tools or as simultaneous lay and burial tool. Post lay burial using ploughs is not usual for a number of reasons including danger of damage to cable. Simultaneous laying and burial using cable plough is effective for export cables but has a number of difficulties for array cables.

194. If the cables are bundled, it can be technically challenging due to the bigger cross section area of bundled cable having to pass through the plough, therefore simultaneous laying and burial has been substituted by post lay burial on some projects.

195. Even if the primary method adopted for laying the export cables is ploughing, there could be locations where other methods to bury and protect the cable are required, i.e. for any jointing loops, corner areas and where ploughing will be unable to negotiate obstacles, cable crossings, etc.

196. Ploughing tools can be pulled directly by a surface vessel or can be mounted onto self-propelled caterpillar tracked vehicles which run along the seabed taking power from a surface vessel. The plough inserts the cable as it passes through the ground.

197. Typical dimensions for a plough are 15m x 6.5m x 7m, with a dry weight of 41 tonnes. This particular example has a burial potential of 3m depth.

198. The rate of the burial progress using ploughing will depend on a number of factors (e.g. seabed conditions and nominal tow tension). An installation rate of approximately 150-300 m/h is expected.

5.4.13.2.2 Trenching or cutting

199. This method consists of three operations. First a trench is excavated or cut while placing the sediment and fill next to the trench. The cable is subsequently laid in the trench and lastly the sediment or fill is returned to the trench. Trenching can be a challenging method to use compared with other methods listed here; however, this technique may be required for sections of cable runs where it is most practical.

200. Trenching or cutting would only be used as the last option on areas where other methods for protecting the cable are not economically and/or technically feasible.

201. Pre-lay cutting of trenches (or ‘pre-trenching’) has become more popular in recent years. This is an option where a large trench is cut in one or multiple passes to the correct depth before the cable is laid back in the trench at a later date. The trench can be backfilled naturally or if required with a backfill plough or other method of material replacement. The use of backfill ploughs is normally not favoured due to the danger of damaging the cable.

202. An installation rate of approximately 30-80m/h is expected.

5.4.13.2.3 Jetting

203. Two methods of water jetting are typically available:

- Lay the cable and jet at a later date:
    - The cable is laid on the seabed first and afterwards a jetting machine is positioned above the cable. Jets flush water beneath the cable fluidising the sediment whereby the cable, by its own weight, or by a depressor, sinks to the depth set by the operator. As the sediment is fluidised a minor amount of sediment spill is expected. The sledge can be pulled directly by a surface vessel or can be mounted onto self-propelled caterpillar tracked vehicles which run along the seabed taking power from a surface vessel; or
- Lay the cable and jet at the same time:
    - In this method water jets are used to jet out a trench and the cable is placed into the trench behind the jetting lance. Concurrent cable lay and jet is suitable for export cables but presents difficulties with array cables.

204. Jetting tools can be pulled directly by a surface vessel or can be mounted onto a Remotely Operated Vehicle (ROV) e.g. self-propelled caterpillar tracked vehicles which run along the seabed taking their power from a surface vessel.

205. Typical dimensions for an ROV jetting system are 5m x 4.2m x 3m, with a dry weight of 13 tonnes. A machine of this type is capable of operating submerged for up to 10 days.

206. In shallow waters a vertical injector could be used. This is a large jetting/cutting share which is strapped to the side of a barge and the cable is laid in the foot of the trench. This technique can provide deeper burial than traditional methods, which may be useful in areas of high seabed mobility or whilst crossing areas of high risk.

207. An installation rate of approximately 150-450m/h is expected.

5.4.13.2.4 Offshore export cable trench sizes

208. The export cables would be buried where possible, with typical target depths of between 1m and 3m (with potentially greater overall burial depths where pre-sweeping is used). The final burial depth will be decided when a detailed study has been completed pre-construction to assess the relevant factors for each part of the cable route.

209. The trench shape and width would be determined by the installation method. In addition, its design and size is influenced by a number of factors including safety, soil characteristics, outer cable diameter, trench depth, minimum available width of excavator bucket, type of crossings, and any special purpose requirements for the above mentioned scenarios.

210. Depending on the burial method used, a sloped trench (“V” shape) may be created. The methods that don’t result in a side slope are:

- Simultaneous lay and bury methods with a cable plough cut a vertical slot (sometimes with water jet assistance) and lay the cable into the bottom of the slot. This slot will close very shortly after cable lay due to the natural tides.
- Post-lay burial with seabed tractor or ROV-based jetting tools just liquefy a slot of soil and depress the cable into the liquefied soil. This method could result in a 10m width trench for 5m deep.
- Post-lay mass flow burial, or lowering, of the cable blasts a hole in the seabed into which the cable drops. Side slope of the hole will be dependent on the tool arrangement and the soil type.

211. However, the most conservative case in terms of trench slope (and therefore width) would be the ploughing method. In this case the range of the side slope angle varies usually between 30^{o} and 10^{o}. A trench width of 10m could be achieved if a 45^{o} tool would be used, although this slope would only be suitable in cohesive and stable soil conditions.

212. However, taking into account the type of seabed expected in an offshore cable corridor, with ripples and sand waves, 45^{o} would incur too greater risk, due to the fact that, in sands, side slopes of approx. 45^{o} are unlikely to be sustainable for more than a few tidal cycles. Therefore, relatively stable trenches in sand will require side slopes of approx. 30^{o}.

213. The following picture explains how a submarine trench would look if ploughing were to be used for trenching.

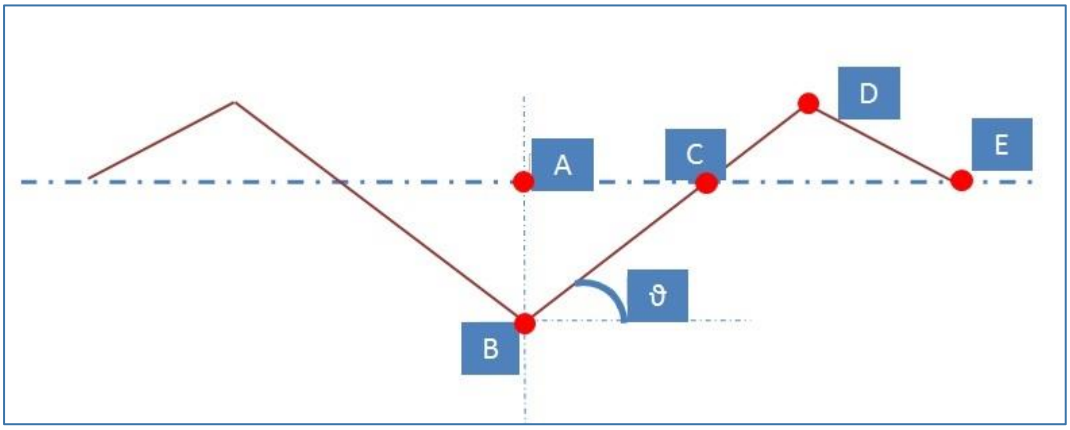

Plate 5.10 Ploughed trench cross section

214. In the above picture, **ϑ** represents the blade angle of the plough, which drives the angle of the trench side slope.

215. The following values of trench width would be obtained for different trench depths based on Plate 5.10.

Table 5.22 Expected trench width for specific depths

AB* length (m)	AC* length (m)	ϑ (º)	Trench width (2 x AC*) (m)	Spoil width at each side (CE*) (m)
1	1.7	30	3.4	3
1.5	2.6	30	5.2	4.5
2	3.5	30	6.9	6
2.5	4.3	30	8.6	7.5
3	5.2	30	10.0	9

*Dimensions as shown in Plate 5.10

216. Taking 3m depth as the maximum case, the width resulting for a ploughed trench of 30^{o} would be 10m. Should the subsequent spoil be taken into account, the total disturbance width would be 10 + 9 + 9 = 28m. A conservative 30m temporary

disturbance width is assessed for the export cables in this ES which would encompass the pre-grapnel run, pre-sweeping and trenching works.

217. In principle, no material is expected to be permanently displaced during cable burial as the trench would be backfilled with its own material.

5.4.13.2.5 Array cable installation

218. The array cables will be surface laid with cable protection within 50m of each wind turbine and then buried using a mix of the following methods described in sections 5.4.13.2.1 to 5.4.13.2.3:

- Ploughing;
- Pre-trenching or cutting; and/or
- Jetting.

219. The maximum temporary disturbance width for array cable installation would be 20m, encompassing the pre-grapnel run, pre-sweeping and trenching works.

220. Each section of cable is laid from the cable lay vessel either from a static coil or a revolving turn carousel, turntable or drum depending upon the characteristics of the cable. The cable is led via a cable pick-up arrangement and an associated cable track way through linear cable engines and is led over board through a cable chute/stinger usually mounted at the stern of the vessel. For smaller array cable sizes, it is possible to use barges to lay the cable and these are generally at multiple short lengths.

221. Divers would not be used for cable installation. The hook up would be done by the support of ROVs. The cable will be pulled into the turbine via a J-tube (or alternative cable entry system), and later connected to the turbine. A typical methodology for installing the cable into a J-tube is as follows, although alternative cable entry details and installation methods are being considered:

- A cable barge or a specialist cable installation vessel would be mobilised to the site. The cables would be supplied either on cable reels or as a continuous length;
- The vessel would transit to site and take up station adjacent to a wind turbine structure and either holds station on dynamic positioning (DP) or sets out a mooring pattern using anchors. A cable end would be floated off from the cable reel on the vessel towards the wind turbine structure and connected to a pre-installed messenger wire in the J-tube. The messenger wire would then allow the cable to be pulled up the J-tube;
- The cable would be pulled up the J–tube in a controlled manner with careful monitoring. When the cable reaches the cable temporary hang-off (at a later date a cable jointer would terminate the cable and install the permanent hang-

off), the pulling operation ceases and the cable joint is made. The cable would be laid away from the J-tube on the first wind turbine towards the J-tube on the second wind turbine.

- When the cable installation vessel nears the J-tube on the second wind turbine structure, the cable end would be taken from the reel, ready for pulling up the J-tube; and
- The cable end would then be attached to the messenger wire from the bell mouth of the second J-tube. A tow wire would then be taken from the cable installation vessel and connected to the messenger line at the top of the J–tube and the pulling operation is repeated in the same manner as was employed at the first J-tube.

5.4.13.3 Jointing of offshore cables

222. The jointing of subsea cables offshore requires a window of good weather time as the cables would be hanging down from the vessel posing a risk to the crew should the vessel be moving. Typically, jointing can take between one and ten days after both cable ends are secured on-board the jointing vessel. Additional time is needed to recover the cables pre-jointing and to re-bury the cable post-jointing.

5.4.14 Cable Protection

223. There may be some locations where array, export or interconnector cables cannot be buried due to cable crossings or cables become unburied overtime due to mobile sediments, and so the use alternative methods of protection may be required.

5.4.14.1 Types of cable protection

224. Cable protection options include:

- Rock placement - the laying of rocks on top of the cable;
- Concrete mattresses, which are prefabricated flexible concrete coverings that are laid on top of the cable. The placement of mattresses is slow and as such is only used for short sections of cable;
- Grout or sand bags could be placed over the cable; this method is also generally applied on smaller scale applications;
- Frond mattresses can be used to provide protection by stimulating the settlement of sediment over the cable. This method develops a sandbank over time protecting the cable but is only suitable in certain water conditions. This method may be used in close proximity to offshore structures. An example of a typical frond mattress is shown in Plate 5.11; and
- Uraduct or similar, is a protective shell which can be fixed around the cable to provide mechanical protection. Uraduct is generally used for short spans at crossings or near offshore structures where there is a high risk from falling

objects. Uraduct does not provide protection from damage due to fishing trawls or anchor drags.

Plate 5.11 Concrete mattress (Source: www.archiexpo.com)

Plate 5.12 Frond concrete mattress (Source: www.pipeshield.com)

5.4.14.2 Unburied cable

225. The maximum width and height of cable protection for unburied cable would be 5m and 0.5m, respectively. It is not anticipated that there would be any unburied cable due to ground conditions during the construction phase. However, cable protection for cables which become unburied during the life of the project has been estimated. The following cable lengths for cable protection over unburied cables are assumed:

- Export cables - estimated 14km per cable pair;
  - 28km length;
  - 0.14km^2 area;
- Interconnector cables - estimated 10% of length plus 100m approaching each electrical platform;
  - 15km length plus 100m x two platforms;

  - $0.076km^2$ area;
- Array cables – estimated 10% of length plus 100m at turbines.
  - 60km length plus 100m x 200 turbines;
  - $0.4km^2$ area.

226. Norfolk Vanguard Limited is committed to minimising the placement of cable protection within the Haisborough, Hammond and Winterton SAC and is confident that burial will be possible throughout the SAC. However, to allow for the unlikely event that hard substrate is encountered in the SAC, placement of cable protection for up to 4km per cable pair (8km in total within the SAC) over the life of the project has been assessed in the ES. This is included within the total for the export cables, described above.

5.4.14.3 Cable crossings

227. Where the offshore cable is required to cross an obstacle such as an existing pipeline or cable, protection would be installed to protect the obstacle being crossed. At the crossing, the power cable would be laid on top of this protection rather than being buried. Each crossing would require a carefully agreed procedure between the cable owners.

228. The maximum width and length of cable protection for cable crossings would be 10m and 100m, respectively. The maximum height of cable crossings is 0.9m.

229. Nine cable crossings and two pipeline crossings per cable pair (six of which are within the Haisborough Hammond and Winterton SAC) are anticipated within the offshore cable corridor resulting in an area of up to $0.022m^2$ in total for the two export cable pairs.

230. Up to 10 crossings are estimated for the array cables which would have an area of $0.01km^2$.

5.4.14.4 Landfall cable protection

231. Cable protection may be required at each of the landfall HDD exit points. This could entail one mattress (6m length x 3m width x 0.3m height) plus rock dumping (5m length x 5m width x 0.5m height) at each exit point (up to two cable pairs), with a total footprint of $36m^2$.

5.4.14.5 Summary of potential cable protection requirements

232. The total areas which could be occupied by cable protection are provided in Table 5.23.

Table 5.23 Estimation of area occupied by and volume of cable protection

	Length (m)	Width (m)	Height (m)	Total area (m2)	Total volume (m3)
Array cable protection - unburied (10% of total length)	60,000	5	0.5	300,000	150,000
Array cable protection - approaching turbines	20,000	5	0.5	100,000	50,000
Array cable protection - crossings (based on 10 crossings on 250m3 per crossing)	1000	10	0.9m in total, including existing cable	10,000	9,000
Interconnector cable protection - approaching electrical platforms	200	5	0.5	1,000	500
Interconnector cable protection - unburied	15,000	5	0.5	75,000	37,500
Export cable protection - unburied (20km length per pair of cables)	40,000	5	0.5	200,000	100,000
Export cable protection - crossings (based on 22 crossings on 250m3 per crossing)	2,200	10	0.9m in total, including existing cable	22,000	19,800
Protection at the landfall HDD exit locations - mattress	12	3	0.3	36	11
Protection at the landfall HDD exit locations – rock dumping	10	5	0.5	50	25
Total				708,086 (0.71km^2)	366,836

5.4.15 Indicative Offshore Construction Programmes

233. Project construction in the UK is currently dependent on funding mechanisms to drive financial investment decisions and construction periods could be elongated or shortened by the requirements within any funding contract. The final design (e.g.

number of turbines, platform, cables, etc.) will also affect the construction programme as well as weather conditions during construction. An indicative offshore construction window of four years is estimated. Offshore working hours during construction are anticipated to be 24/7.

234. Indicative programmes based on single and two phase buildout scenarios are provided below. As shown in Table 5.24 and Table 5.25, if a multi-phase construction approach was taken, the overall duration of the construction works could last longer.

Table 5.24 Indicative Norfolk Vanguard construction programme – single phase

		2024				2025				2026				2027				2028			
Indicative Programme	**Approximate duration**	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Foundation installation	20 months																				
Array & interconnector cable installation	19 months																				
Export cable installation	6 months																				
Wind turbine installation	20 months																				
Total construction works	23 months																				

Table 5.25 Indicative Norfolk Vanguard construction programme – two phase

		2024				2025				2026				2027				2028			
Indicative Programme	**Approximate duration**	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Foundation installation	2 x 8 months																				
Array & interconnector cable installation	2 x 7 months																				
Export cable installation	2 x 3 months																				
Wind turbine installation	2 x 8 months																				
Total construction works	2 x 12 months																				

5.4.16 Construction Vessels

235. The number and specification of vessels employed during the construction of the Norfolk Vanguard project would be determined by the marine contractor and the final construction strategy. It is anticipated that several types of construction vessel could work in parallel during the construction of the project.

236. The final selection of the port facilities required to construct and operate the project has not yet been determined, however local options include Hull, Great Yarmouth or Lowestoft.

237. The following list intends to show examples of the type and number of vessels required for key construction activities. Approximately 1180 vessel movements are estimated during construction.

Table 5.26 Examples of vessels for construction

Activity type	Vessel type	Indicative number of vessels
Seabed preparation	Dredging vessel	5
Foundation Installation	Tugs and barges storage and transport	5
Foundation Installation	Jack-up vessel	2
Foundation Installation	Dynamic Position Heavy Lift Vessel	2
Foundation Installation	Support vessels	10
Foundation Installation	Scour Vessel	5
Wind turbine installation	Jack-up vessel	2
Wind turbine installation	Dynamic Position Heavy Lift Vessel	2
Wind turbine installation	Accommodation vessel	2
Wind turbine installation	Wind farm service vessel	10
Wind turbine installation	Support vessels	5
Offshore electrical platform installation	Substation Installation Vessels	5
Offshore electrical platform installation	Tug with accommodation barge	2
Offshore electrical platform installation	Supply vessel	1
Offshore electrical platform installation	Support vessels	5
Cable installation	IA Cable Vessels	5
Cable installation	Accommodation vessel	2
Cable installation	Export Cable Vessels	5
Cable installation	Export cable support vessel	5
Cable installation	Landfall Cable Installation Vessels	2
Cable installation	Pre-trenching/backfilling vessel	2
Cable installation	Cable jetting and survey vessel	5
Cable installation	Filter Layer Vessel	2

Activity type	Vessel type	Indicative number of vessels
Commissioning	Commissioning Vessels	10
Other vessels	Accommodation Vessels	2
Other vessels	Crew transfer	10
Total		**113**

5.4.16.1 Vessel footprints

238. The footprint associated with jack up barges and anchored vessels during foundation construction are shown in Table 5.27.

Table 5.27 Construction vessel footprints

	Jack up	Anchors
Maximum number of legs/anchors	6	6
Footprint area per placement (m^2)	792	150.0
Estimated operations per turbine	2	1
Number of turbine (and platform) locations	200 (+6 platforms)	200
Total footprint (m^2)	**326,304**	**30,000**

5.4.17 Safety Zones

239. The safety zones that could be applied for the project construction are presented in Table 5.28 below. These would be determined on the basis of a detailed safety case.

Table 5.28 Potential safety zones during construction, operation and decommissioning

Type of safety zone	Area covered
Construction*	Up to 500m around each foundation or renewable energy installation whilst under construction
Commissioning**	Up to 50m around each renewable energy installation where construction has finished but some work is ongoing, e.g. wind turbine incomplete or in the process of being tested before commissioning.
Operations**	50m around each renewable energy installation during operation.
Major Maintenance*	Up to 500m when major maintenance is in progress (use of jack-up vessel or similar).
Decommissioning	Up to 500m at the end of the working life of a renewable energy installation when it is being removed from site
* The Construction, Major Maintenance and Decommissioning safety zones are required to ensure a safe distance is maintained from vessels engaged in high risk activities such as jacking operations and heavy lifts.	
**The Commissioning and Operations safety zones are required to ensure small vessels are not adversely affected by propeller or thruster wash from vessels used for transfer whilst also ensuring no additional risk is created for personnel during access and egress. This zone also reduces risk of injury to third parties from items dropped from aloft.	

5.4.18 Offshore Operation and Maintenance

240. This section provides an overview of maintenance activities. An outline Operations and Maintenance Plan (document reference 8.11) is provided with the DCO application.

5.4.18.1 Maintenance activities

241. All offshore infrastructure including wind turbines, foundations, cables and offshore substations would be monitored and maintained during this period in order to maximise operational efficiency and safety for other sea users.

242. The operation and control of the wind farm would be managed by a Supervisory Control and Data Acquisition (SCADA) system, connecting each turbine to the onshore control room. The SCADA system would enable the remote control of individual turbines, the wind farm in general, as well as remote interrogation, information transfer, storage and the shutdown or restart of any wind turbine if required.

243. During the life of the project, there should be no need for scheduled repair or replacement of the subsea cables, however, reactive repairs and periodic inspection may be required. Periodic surveys would also be required to ensure the cables remain buried and if they do become exposed, re-burial works would be undertaken.

244. Typical maintenance activities would include:

- General wind turbine service;
- Oil sampling / change;

- UPS (uninterruptible power supply) battery change;
- Service and inspections of wind turbine safety equipment, nacelle crane, service lift, high voltage system, blades;
- Cable burial inspection;
- Cable repair and replacement;
- Foundation inspection and repair; and
- Cable crossing inspection and repair.

5.4.18.1.1 Wind turbines

245. There are a number of potential maintenance strategies for the wind farm. The wind farm could be maintained from shore using a number of varying O&M vessels (e.g. crew transfer vessels) possibly supported by helicopters. Alternatively the wind farm could be maintained primarily using crew transfer vessels operated on a daily basis from an offshore accommodation vessel (Service Offshore Vessel) or platform. Helicopter operations may still be utilised with this option. For all options, a maximum of 14 helicopter round trips per week is anticipated.

246. Although it is not anticipated that large components (e.g. wind turbine blades or substation transformers) would frequently require replacement during the operational phase, the failure of one of these components is possible. Should this be required, large jack-up vessels may need to operate continuously for significant periods to carry out these major maintenance activities.

247. It has been assumed that a maximum of two locations could be visited by one jack-up vessel to the OWF sites per day during operation. Assuming a jack up vessel with a seabed footprint of 792m^2, this would lead to a total area of up to 0.52km^2 per year.

5.4.18.2 Vessel and helicopter operations

248. A number of vessel and / or helicopter visits to each turbine would be required each year to allow for scheduled and unscheduled maintenance.

249. If the crew are based onshore, this would mean crew vessels sailing to and from the wind farm on a daily basis from shore, possibly supported by helicopters. If the crew are based on an offshore accommodation platform or vessel, the majority of small crew vessels would be operated on a daily basis from the offshore accommodation vessel or platform, although further support vessels are also still likely to transit to and from shore each day and helicopter operations may still be utilised. Collector and converter stations would typically require an average of 1 visit/week, although as a result of an unscheduled maintenance there will be several visits until reparation is finished. Table 5.29 provides a breakdown of the maximum anticipated trips per year to the wind farm during operation.

Table 5.29 Anticipated trips per year to the wind farm during operation

Vessel type	Vessel movements
Large O&M Vessel	40
Accommodation O&M	40
Small O&M Vessel	300
Lift Vessel	5
Cable Maintenance Vessel	5
Auxiliary Vessels	90
Total	**480**
Helicopter Trips to Site per week	14

250. During O&M activities Norfolk Vanguard Limited would seek to agree appropriate safety zones around wind turbines and work areas. Safety zones are described above in Table 5.28.

5.4.18.3 Cable failures

251. During the life of the project, repairs may be required and periodic inspection will be undertaken. Periodic surveys would also be required to ensure the cables remain buried and if they do become exposed, re-burial works would be undertaken.

252. Based on statistical analysis and experience from existing wind farms, the estimated rate of cable failure would be approximately:

2.86 failures / 1,000 km / year

253. This figure is based on existing and previous technology and does not allow for advances in cable technology in the future. Based on this, the following unplanned cable repairs are estimated per year:

- One export cable repair;
- Two array cable repairs; and
- One interconnector repair.

254. In most cases a failure would lead to the following series of operations: taking out the damaged part of the cable, cutting the cable, inserting a joint, bringing a new segment of cable and jointing the new segment with the old cable.

255. The cable would be unburied using jetting (or removal of mattress/rock protection) and then once the repair is done the opposite (reinstalling the mattress, rock dumping, jetting or other methods of cable burial or protection). However, in a number of cables the fault might be very close to the substation or wind turbine and if there is sufficient slack it could be directly pulled in, making this operation much easier, although more rare.

256. When export cables need to be repaired, it is not cost effective to replace the whole length. Instead, usually the fault should be identified and localized, and therefore only few hundred metres would need to be subject to the repair. The replacement section will be deployed by the installation vessel in a bight, laid to one side of the original cable route. The cable repair bight length will be dependent on the water parameters of the cable laying vessel.

257. For array cables, the entire length of a cable (likely to be between 0.68km and 6km subject to turbine spacing) could require replacement and therefore 6km has been assumed as the worst case.

5.4.18.4 Cable re-burials

258. As previously discussed, cables could become exposed due to moving sand waves but also sometimes due to erosion of other soft/mobile sediment (not just sand waves). During the life of the project, periodic surveys would be required to ensure the cables remain buried and if they do become exposed, re-burial works would be undertaken.

259. The operator would need to be aware of whether the cables are exposed (and so pose a risk). This would require bathymetric surveys to be performed. A proportionate risk-based approach would be to use those early years of operation to build up a picture of sand wave mobility and erosion/deposition rates and find the area with the most variation, thus the surveys could then be made to cables in those areas.

260. In order to detect the exposure of cables, there are many techniques which can be used. Some operators have been testing the use of Distributed Temperature Sensing (DTS), which uses strain in the fibre optic as a measure of cable temperature, given that an exposed cable is cooler since the water conducts the heat better than soil. The use of this system is common for export cables but not for array cables.

261. The following reburial requirements have been estimated based on the worst case scenario that no pre-sweeping is undertaken (pre-sweeping would minimise the need for reburial):

- Estimated export cable reburial at 5 year intervals:
    - Up to 10km per cable pair within the Haisborough, Hammond and Winterton SAC; and
    - Outside the SAC: up to 10km per cable pair.
- Reburial of 25% of the array cable is estimated every 5 years; and
- One interconnector repair per year is estimated.

262. An In Principle Monitoring Plan (document reference 8.12) is submitted with the DCO application which outlines the proposed monitoring, the details of which would be agreed post consent with the relevant Regulators and SNCBs. Post-construction surveys are a requirement of the DMLs.

5.4.18.5 O&M port

263. The O&M facility is to be located in a service port (yet to be chosen). It is envisaged that O&M needs, in terms of laydown areas and facilities would be minimal compared to requirements during the construction phase.

264. An office, storage or warehouse facility and quayside loading area would be needed. During the first operational years of the project, operations might be coordinated and implemented from the onshore facility. As more turbines are installed it is the expectation that the majority of accommodation needs are to be offshore.

265. It is expected that an O&M strategy would be based on a concept of large service vessels operating for long durations at the offshore site, however this would not be confirmed until a wind turbine provider is selected. After more wind turbines are installed, these may be supplemented with offshore accommodation vessels or fixed accommodation platforms, with helicopter support.

5.4.19 Offshore Decommissioning

266. The scope of the decommissioning works would be determined by the relevant legislation and guidance at the time of decommissioning and would most likely involve the accessible installed components. Offshore, this is likely to include removal of all of the wind turbine components, part of the foundations (those above seabed level), removal of some or all of the array cables, interconnector cables, and offshore export cables. Scour and cable protection would likely be left *in situ*.

267. The process for removal of foundations is generally the reverse of the installation process. The anticipated techniques for the various foundation types are as described below.

268. It is anticipated that decommissioning will be undertaken in the same phased approach as used for construction. Based on previous estimates and experience it is anticipated that decommissioning of each phase would take approximately 1 year.

269. As an alternative to decommissioning, the owners may wish to consider re-powering the wind farm. Should the owners choose to pursue this option, this would be subject to a new application for consent.

5.4.19.1 Quadropod and tripod foundations

270. The overall removal methodology for pin pile foundations would typically be as follows:

- Removal of turbine, mast, switchgear and ancillaries, and cutting of cables (leaving buried array cables *in-situ*);
- Local jetting and/or suction around legs of jacket to a depth of approximately 1-2m;
- Deployment of underwater remote abrasive cutting equipment from service vessel;
- Mobilisation of heavy lift DP vessel or jack-up rig and attachment of crane slings to jacket;
- Abrasive cutting of pile legs at a depth of approximately 1-2m below the seabed;
- Lifting of jacket by crane on DP vessel or jack-up rig onto barge; and
- Transportation of jacket to port and dry dock for dismantling and reuse/recycling where possible.

271. Note that it would not be intended to reinstate the local excavations remaining at the pile leg locations as it is anticipated that this would refill naturally over time.

5.4.19.2 Gravity base structures

272. The overall removal methodology for gravity base structures would typically be as follows:

- Removal of turbine, mast, switchgear and ancillaries, and cutting of cables (leaving buried array cables *in-situ*);
- Mobilisation of heavy lift DP vessel or fleet of tugs (dependent on whether foundation design is buoyant or requires heavy lift);
- Removal of marine growth and sediment from base and jetting under base plate to remove adhesive effects of grout (if present) or cohesive bearing material. If a deep skirt has been used, the skirt may require cutting;
- It may also be necessary to locally remove scour protection via dredging;
- For buoyant design: controlled de-ballasting of foundation using remote pumping equipment and/or installation of buoyancy aids. Careful consideration will need to be given for the disposal of the ballasting material (i.e. whether it is disposed of locally or requires to be transported to a particular offshore disposal area);
- For design requiring heavy lift: lifting of foundation from seabed onto barge (as per installation, a bespoke transportation barge may be required dependent on the design);
- For buoyant design: foundation will become buoyant on de-ballasting;

- Transportation of foundation to port and dry dock (via towing or on barge dependent on foundation type) for deconstruction and reuse/recycling of materials where possible.

5.4.19.3 Suction caisson foundations

273. The overall removal methodology for suction caisson foundations would typically be as follows:

- Removal of turbine, mast, switchgear and ancillaries, and cutting of cables (leaving buried array cables in-situ);
- Mobilisation of service vessel with pumping equipment and ROV, and mobilisation of tugs. It may also be necessary to mobilise a DP vessel with craneage to facilitate with the refloating and subsequent manipulation of the foundation;
- Removal of sediment and marine growth from suction caisson lid, and jetting of pump connections on lid. It may also be necessary to locally remove scour protection via dredging;
- De-ballasting or adding of buoyancy aids to foundation as required by design;
- Connection of pumping equipment to suction caisson valves;
- Controlled pumping of water into caisson chambers. The caisson will rise from its installed position to the surface as the internal pressure overcomes the side wall friction. Some manipulation from craneage on a DP vessel may also be required;
- Towing of foundation to port and dry dock for dismantling and reuse/recycling where possible.

5.4.19.4 Monopile foundations

274. The overall removal methodology for steel monopile foundations would typically be as follows:

- Removal of turbine, mast, switchgear and ancillaries, and cutting of cables (leaving buried array cables in situ);
- Mobilisation of service vessel;
- Local jetting and/or suction around base of monopile to a depth of approximately 1-2m;
- Deployment of underwater remote abrasive cutting equipment from service vessel;
- Mobilisation of heavy lift DP vessel or jack-up rig and attachment of crane slings to top of monopile and TP;
- Abrasive cutting of monopile at a depth of approximately 1-2m below the seabed;

- Lifting of combined monopile/TP by crane on DP vessel or jack-up rig onto barge;
- Transportation of monopile/TP to port and dry dock for dismantling and reuse/recycling where possible.

275. Note that it would not be intended to reinstate the local excavations remaining at the monopile locations as it is anticipated that this would refill naturally over time.

276. It should be noted that other reuse / disposal options are potentially available once the foundation is removed – for example, consideration could be given to sinking the foundation in a deeper offshore location with the intention of developing an artificial reef. This could be applicable for any of the foundation types but careful site planning would need to be undertaken to ensure that hazards to navigation are not introduced.

5.4.19.5 Tension leg floating foundations

277. The overall removal methodology for floating tension leg foundations would typically be as follows:

- Removal of and cutting of cables into the wind turbine (leaving buried inter array cables *in-situ*);
- Mobilisation of service vessel with pumping equipment and ROV, and mobilisation of tugs. It may also be necessary to mobilise a DP vessel with craneage to facilitate with the refloating and subsequent manipulation of the floating foundation and the fixed seabed foundations (piles/caissons/gravity bases);
- De-ballasting or adding of buoyancy aids to foundation as required by design;
- Controlled pumping of water into chambers in order to release tension in holding wires. Wires will be cut or released and then stored on board the vessel. Compressed air will be used to add buoyancy until the foundation is in the correct configuration to be towed back to a dismantling harbour. Some manipulation from craneage on a DP vessel may also be required in order to add stability during this process;
- Removal of sediment and marine growth from suction caisson lid/piles/gravity bases. It may also be necessary to locally remove scour protection via dredging;
- Connection of pumping equipment to suction caisson valves/cutting of piles 1m below seabed or leaving the gravity base on the seabed – dependent on requirements at the time;
- Controlled pumping of water into caisson chambers. The caisson will rise from its installed position to the surface as the internal pressure overcomes the side wall friction. Some manipulation from craneage on a DP vessel may also be required; and

- Towing of foundation/ wind turbine components to port and dry dock for dismantling and reuse/recycling where possible.

5.4.19.6 Removal of scour protection

278. Where scour protection materials have been used, it is likely that they would be left in place. There would be some disturbance of the scour protection materials during the removal of the foundations but they would simply fall to the seabed and flatten over time.

5.4.19.7 Removal of cabling

279. General UK practice will be followed, i.e. buried cables would simply be cut at the ends and left *in-situ*.

5.5 Onshore

280. Norfolk Vanguard Limited is seeking consent for the following onshore elements of the project:

- Landfall;
- Onshore cable route, trenchless crossing (e.g. Horizontal Directional Drilling (HDD)) zones and mobilisation areas;
- Landscaping and surface water management;
- Onshore project substation; and
- Extension to the Necton National Grid substation and overhead line modifications.

281. As part of the DCO application Norfolk Vanguard Limited is also be seeking to obtain consent to undertake some works for the Norfolk Boreas project, these include:

- Installation of ducts to house the Norfolk Boreas cables along the entirety of the onshore cable route from the landward side of the transition pit at the landfall to the onshore project substation; and
- Overhead line modifications at the Necton National Grid substation for both projects.

5.5.1 Landfall

5.5.1.1 Cable landfall location

282. The landfall location at Happisburgh South (Figure 5.3) was chosen as the result of a detailed site selection process which is described in Chapter 4 Site Selection and Assessment of Alternatives.

283. The landfall comprises a stretch of coastline approximately 0.25km from Beach Road in the north to Upton Way in the south.

284. The landfall zone extends approximately 500m inland to allow the transition pits to be located outwith any areas at high risk of natural coastal erosion (shown in Figure 5.3).

285. The landfall (including transition pits) encompasses agricultural land (See Chapter 21 Land Use and Agriculture for further information on land use at the landfall).

5.5.1.2 Cable landfall construction method

286. The offshore export cable will come to land using long HDD and duct installation under the cliff. The landfall ducts will exit in the subtidal zone beyond 5.5m LAT and approximately 1km from the onshore drilling location, to avoid impacts on the intertidal zone. Ducts, and subsequent cables, would be buried at sufficient depth below the coastal shore platform and cliff base to have no effect on coastal erosion. Chapter 8 Marine Geology, Oceanography and Physical Processes explains that erosion would continue to be driven by natural processes which would not be affected by Norfolk Vanguard. Natural coastal erosion throughout the lifetime of the project has been allowed for within the project design by ensuring appropriate set back distances from the coast for the HDD entry point (see Chapter 4 Site Selection and Assessment of Alternatives).

287. Two HDD drills and ducts are required for Norfolk Vanguard (with a third drill considered for the purposes of the worst case assessment, providing a contingency in the unlikely event of a drill failure). The underground landfall ducts would be located within the zone displayed in Figure 5.3.

288. The offshore cables would then be installed in the ducts and jointed to the onshore cables at the transition pits on the landward side of the landfall.

289. By using the HDD method, High Density Polyethylene (HDPE) ducts (through which cables are pulled) would be installed below ground using a surface to surface drilling profile. The enabling works for HDD installation would include:

- Instatement of temporary landfall compound to accommodate the drilling rigs, ducting and associated materials and welfare facilities. The temporary landfall compound would be located within the landfall compound zone shown in Figure 5.3 and would be 60m long by 50m wide.
- The land would be levelled, topsoil removed and stored within the landfall compound and, if necessary, dependant on ground conditions, bog mats or geotextile and hard standing may be laid to protect the subsoil during the drilling operations.
- The landfall compound would be securely fenced and access from the local road network, suitable for haulage equipment, would be instated along the onshore

cable route to the drilling site. An indicative site layout for the HDD works is shown in Plate 5.14.

290. The works for HDD installation per duct would include:

- A pilot hole would be drilled from the entry pit and advanced in stages until the required length is reached and the boring head emerges at the exit point. The drill head would be guided by sensors, potentially tracking a wire placed above ground. Drilling fluid (a combination of water and natural clays such as bentonite) would be employed to lubricate the drilling process and cool the drill head. Fluid pressures would be monitored throughout the process to minimise the potential for breakout of the drilling fluid. An action plan would be developed and procedures adopted during the drilling activity to respond to any drilling fluid breakout.
- Once the pilot hole is completed, it would be enlarged through several passes with reamers until the necessary diameter for duct installation is achieved.
- The HDD would exit at an offshore location, classified as a 'long HDD'. The long HDD option does not require any restrictions or closures to the beach for public access.
- The ducts would be typically floated into position at the offshore exit point via barges. The ducts would then be flooded with water and pulled into the reamed drill hole from the entry pit. Alternatively the ducts could be welded in sections onshore and pulled from the offshore side.

291. Upon completion of the duct installation, the drilling rigs would be removed and drilling fluids/other wastes cleared from the site with the land reinstated. During the cable pull phase of works, the appropriate transition pits would be excavated and exposed allowing cables to be pulled through the pre-installed ducts and jointed. The joint bays would then be reinstated.

292. An example HDD rig is shown in Plate 5.13 with indicative compound dimensions and equipment shown in Plate 5.14.

Plate 5.13 Example HDD rig[1]

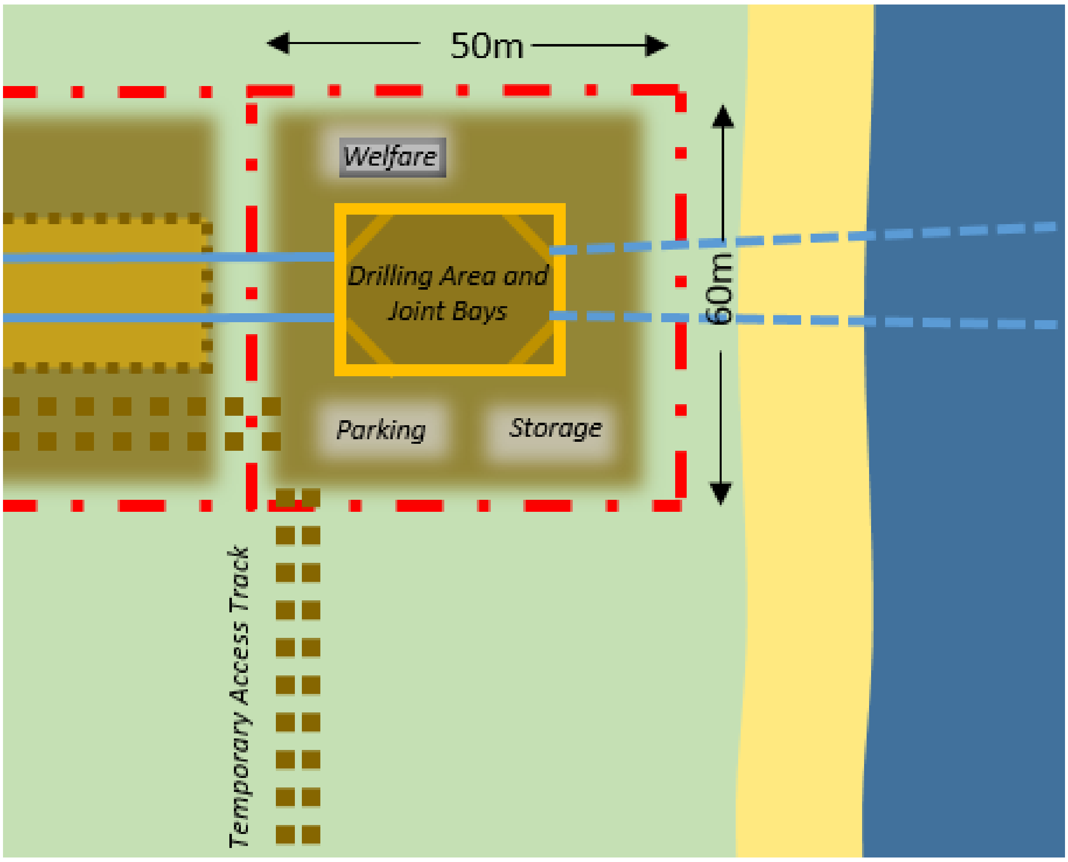

Plate 5.14 Indicative landfall compound

[1] Source: Vattenfall Wind Power Ltd.

293. Once the ducts have been installed, the offshore cables could then be installed at the optimum time (taking into account weather, tide and the offshore works schedule) by positioning the cables at the offshore exit point and pulling through the ducts to the transition pit.

294. Noise generated from construction at HDD sites is detailed in Chapter 25 Noise and Vibration.

295. The Rochdale Envelope for Norfolk Vanguard, includes the option of concurrent drilling with two parallel drilling rigs.

5.5.1.3 Transition pit and link boxes

296. Each cable circuit would require a separate transition pit to connect the offshore and onshore cables at the landfall. Therefore, two transition pits may be required at landfall. The transition pits would be accommodated within the landfall compound (Figure 5.3). Each transition pit would comprise an excavated area of 15m x 10m x 5m, per circuit, with a reinforced concrete floor to allow winching during cable pulling and a stable surface to allow jointing.

297. A temporary enclosure would be provided to allow a controlled environment to be maintained during jointing activities. A small generator could be required to provide the necessary electrical power for the enclosure, any powered jointing equipment and any pumps to manage groundwater.

298. Following cable pulling and jointing activities, the joints would be buried to a depth of 1.2m using stabilised backfill, pre-excavated material or a concrete box. The remainder of the transition pit will be backfilled with the pre-excavated material and returned to the pre-construction condition, so far as is reasonably possible.

299. Link boxes for each of the required transition pits may be utilised. See section 5.5.2.6 for further details.

5.5.1.4 Landfall key parameters

300. Table 5.30 summarises the landfall key parameters.

Table 5.30 Summary of key parameters at landfall

Parameter	Minimum	Maximum	Additional information
Number of Drills	2	3	Maximum considers allowance for a failed drill
Number of Cable Ducts	2	2	Duct would not be installed in a failed drill.
Diameter of Drill (mm)	500	750	

Parameter	Minimum	Maximum	Additional information
Approximate length of Drill (m)	700	-	Indicative length of 1000m
Number of Transition Pits	2	2	Pit per circuit (offshore export cable pair).
Depth per Pit (m)	-	5.0	Below ground level.
Width per Pit (m)	-	10.0	
Length per Pit (m)	-	15.0	
Area of landfall compound (m^2)		6000	Considers the option of two works areas operating in parallel, each 60m x 50m.
Amount of material to be excavated (m^3)	-	1,325.4m^3	Volume of HDD excavated material (based on 750mm diameter bore, 1,000m drill and three drills.

5.5.1.5 Cable pull through at landfall

301. The following sequence of events for the cable pull through at landfall is expected:

- The cable would be floated from a cable laying vessel or barge to the HDD exit location;
- The free end of the cable (or cables) would be attached to a pull-wire that passes through the HDD duct;
- An onshore winch would then be used to pull the end of the cable through the duct and into the transition pit. The end of the cable would then be mechanically terminated at this location; and
- Once the cable is terminated, the buoyancy would be released to allow the cable to sink to the seabed.

5.5.2 Onshore Cable Route

5.5.2.1 Location

302. The location of the 45m wide onshore cable route is presented in Figure 5.4. From Happisburgh South, the onshore cable route travels north-west, past Ridlington and Witton, towards the northern edge of North Walsham. From North Walsham the onshore cable route heads south-west passing to the north of Aylsham (Figure 5.4 Map 4) and Reepham (Figure 5.4 Map 5) before crossing the River Wensum (Figure 5.4 Map 7). From this point the onshore cable route passes to the north of Dereham before crossing the A47 and entering the onshore project substation near Necton (Figure 5.4 Map 9).

303. The onshore cable route would contain the main HVDC onshore export cables within ducts for Norfolk Vanguard and the ducts for Norfolk Boreas. The onshore cable route is approximately 45m wide and has been refined from the 200m onshore cable

corridor presented in the Preliminary Environmental Information Report (PEIR). The onshore cable route has been refined and routed in such a way to minimise potential impacts, and taking account of landowner preferences and to avoid sensitive features, such as mature trees and archaeological features.

5.5.2.2 Onshore cable route requirements and dimensions

304. The onshore cable route would require trenches (within which ducts would be installed to house the cable circuits); a running track to deliver equipment to the installation site from mobilisation areas; and storage areas for topsoil and subsoil.

305. The working area required to install the ducts and cables for the project, as well as ducts for the Norfolk Boreas project are provided in Plate 5.15 below. Throughout the onshore cable route, the total temporary strip (total land requirement to install the cables), permanent strip (total ongoing land requirement of the installed cables) and ongoing right of access strip (temporary area required to be reserved for access for future repair or maintenance activities) are illustrated.

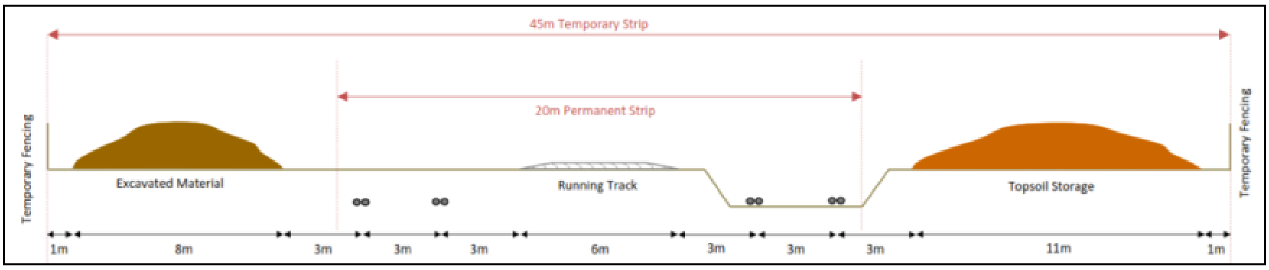

Plate 5.15 Indicative Norfolk Vanguard and Norfolk Boreas onshore cable route

5.5.2.3 Duct and cable installation

306. The main duct and cable installation method would be through the use of open cut trenching. HDPE ducts would be installed within the trenches and the soil backfilled. Cables would then be pulled though the pre-laid ducts at a later stage in the construction programme.

307. Trenches would be approximately 1m in width and the ducts would be buried to a minimum depth of 1.05m (from top of duct to surface). The cable circuits would be installed in a flat formation (each cable core installed alongside another). This minimum depth is equivalent to the electricity distribution provider in the UK's standard depth (Engineering Construction Standard ECS 02-0019).

308. Where the onshore cable route crosses major transport routes or waterways the standard open cut trenching installation technique would not be suitable. Further details of alternative crossing methodologies are provided in section 5.5.2.8. To

minimise impacts of crossing sensitive features such as hedgerows, the working width could be reduced to the running track and cable trenching areas only (e.g. 20m for Norfolk Vanguard and Norfolk Boreas) with soil storage areas retained immediately before and after the feature crossing.

5.5.2.3.1 Duct installation process

309. The onshore cable duct installation strategy is proposed to be conducted in a sectionalised approach in order to minimise impacts. Construction teams would work on a short length (approximately 150m section) and once the cable ducts have been installed, the section would be back filled and the top soil replaced before moving onto the next section. This would minimise the amount of land being worked on at any one time.

310. Topsoil would be stripped from sections of the onshore cable route for the length of route to be worked on at any one time and stored and capped to minimise wind and water erosion within the easement as shown in Plate 5.15.

311. The profile of the soil would be carefully maintained during the storage process, further detail of which is provided in Chapter 19 Ground Conditions and Contamination. The cable trenches would then be excavated, typically utilising tracked excavators. The excavated subsoil would be stored separately from the topsoil, capped and the profile of the soil maintained during the storage process.

312. The trench could require shoring with wooden battens or other edge protection to enhance integrity and mitigate trench collapse risks. This requirement would be dependent on appropriate risk assessments considering the soil and prevailing weather conditions.

313. A Surface Water and Drainage Plan (Requirement 19) would be developed and implemented to minimise water within the trench and ensure ongoing drainage of surrounding land. Where water enters the trenches during installation, this would be pumped via settling tanks or ponds to remove sediment, before being discharged into local ditches or drains via temporary interceptor drains (further detail is provided in Chapter 20 Water Resources and Flood Risk).

314. A stabilised backfill such as Cement Bound Sand (CBS) would be installed at the base of the trench. A duct for each cable core and a separate duct for a fibre optic bundle would be laid on the CBS base and backfilled with CBS to a covering depth of 100mm. This approach would ensure a consistent homogeneous medium for the dissipation of heat generated by the cables during operation. The CBS backfill would be covered with high voltage cable warning tiles with integrated warning tape and the trench backfilled with subsoil material excavated from the trench. The stored

topsoil would be replaced upon the backfilled subsoil to reinstate the trench to pre-construction condition, so far as reasonably possible.

315. The plant required for trench excavation is summarised in Chapter 25 Noise and Vibration. The trench arrangement for duct and cable installation is shown in Plate 5.16.

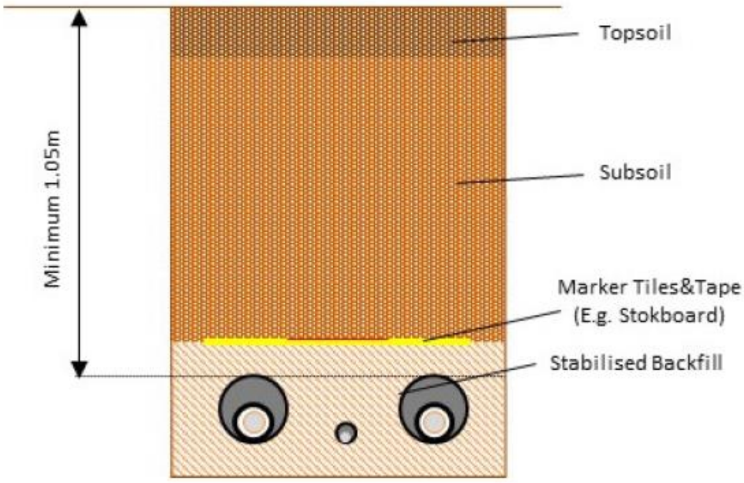

Plate 5.16 Trench arrangement

5.5.2.4 Running track

316. The running track would provide safe access for construction vehicles along the onshore cable route, from mobilisation areas to duct installation sites. The running track could be up to 6m wide and may ultimately extend the full length of the onshore cable route. A separation of 2m is maintained from the edge of the running track and the cable trench for safety, drainage and duct storage prior to pulling (if this is required). Speed limits on the running track will typically be limited to 20mph.

317. Following topsoil stripping, the running track would be established in stages. It will be formed of protective matting, temporary metal road or permeable gravel aggregate dependant on the ground conditions, vehicle requirements and any necessary protection for underground services.

318. At drain crossings the running track would be installed over a pre-installed culvert pipe to allow continued access to the cable route. The pipe would be installed in the drain bed so as to avoid upstream impoundment, and would be sized to accommodate reasonable 'worst-case' water volumes and flows. These culverts may remain in place for up to two years.

319. At larger crossings, temporary bridges may be employed to allow continuation of the running track. At sensitive locations such as some rail and river crossings (Mid-Norfolk railway, North Walsham railway, River Wensum, River Bure, King's Beck, Wendling Beck (upstream), and North Walsham & Dilham Canal), the running track would terminate and continue on the far side. These locations would be defined as 'stop ends' to the construction work fronts to mitigate any direct impacts to the features and therefore divide up the various construction areas.

320. During the duct installation process, each work team would use the running track to travel from the mobilisation area (section 5.1.1.1) or appropriate running track access point to the work front. The running track would also be used for transport of plant and materials between the mobilisation area and the work front. The running track would be extended piece-wise as the work front moves outward from the mobilisation area.

321. When duct installation is completed, the running track would be taken up and the topsoil replaced. All recovered stone and other materials would be removed from site via the mobilisation area.

5.5.2.4.1 Cable pulling process

322. Cables would be pulled through the installed ducts later in the construction programme in a phased approach. This approach would allow the main civil works to be completed in advance of cable delivery, preventing the requirement to reopen the land.

323. Cable pulling would not require the trenches to be reopened, with the cables pulled through the pre-installed ducts from jointing pits located along the onshore cable route. Access to and from the jointing pits would be required to facilitate the works during this phase of the project.

324. This would be achieved through access to the onshore cable route directly from the highways network (at crossing locations) or existing local access routes where possible. In some locations, isolated sections of the running track would be left in place from the duct installation works or be reinstated to allow access to more remote joint locations. It is estimated that running track would be required for 20% of the total onshore cable route length for the cable pull and jointing works. An estimated breakdown of running track required per cable section is provided in Table 5.31.

Table 5.31 Estimated retained or reinstated running track for cable pull and joint

Route section	Total section length [km]	Estimated running track requirement [km]	Estimated running track requirement [%]
MA1-East	6	0.95	16
MA2-West	5.3	1.92	36

Route section	Total section length [km]	Estimated running track requirement [km]	Estimated running track requirement [%]
MA2-East	6	0.26	4
MA3-West	3	0.67	22
MA3-East	6	2.60	43
MA4-West	3	0.00	0
MA4-East	5	0.00	0
MA4A-West	5	1.74	35
MA5-West	0.8	0.42	52
MA5-East	6	0.45	8
MA6-West	1.7	1.40	82
MA6-East	5.1	0.27	5
MA7-West	4.4	0.75	17
MA7-East	3.6	0.40	11
TOTAL	**60.9**	**11.83**	**19.4**

325. During the cable installation phase, each section of running track would be used to bring in plant, cable reels and other materials to the joint bays from the nearest appropriate public highway location (as discussed in Chapter 24 Traffic and Transport). This usage would be repeated for each of the Norfolk Vanguard cable installation phases (i.e. up to two phases in total).

326. To facilitate the cable pull and joint, the joint pit would be excavated and cable drums delivered by HGV low loader to the open joint pit locations (see section 5.5.2.5). The cable drum would be located adjacent to the joint pit on a temporary hard standing and a winch attached to the cable, pulling the cable off the drum from one joint pit to another, through the buried ducts. Cable jointing would be conducted once both lengths of cable that terminate within it have been installed.

327. The cable pulling and jointing process would take approximately five weeks per 800m length of cable, including installing and removing any temporary hard standing and delivering the cables to the joint pits. However, any one joint pit could be open for up to 10 weeks to allow its neighbouring joint pit to be opened and the cables pulled from one pit to the next, dependant on the level of parallel work being conducted.

5.5.2.5 Joint pits

328. Joint pits would be required along the onshore cable route to allow cable pulling and jointing of two sections of cable. The joint pits would typically be located at approximately 800m intervals, although site specific constraints may result in shorter intervals where necessary. The joint pits would be of a similar design and installed using the same approach as transition pits which are described in section 295.

329. All excavation and reinstatement activities for the joint pits would be conducted as per the cable trenching activities, detailed in section 5.5.2.3.

330. Joint pits for Norfolk Vanguard are included in this assessment and will be part of the consented project. Joint pits for Norfolk Boreas will be considered as part of the Norfolk Boreas assessment.

5.5.2.6 Link boxes

331. Link boxes are required in close proximity (within 10m) to a subset of jointing pit locations to allow the HVDC cable sheaths to be bonded to earth to maximise cable ratings. Link boxes would not be required at all jointing locations and can typically be placed at 5km intervals. The number and placement of the link boxes would be determined as part of the detailed design.

332. The link boxes would require periodic access by technicians for inspection and testing. Where possible, the link boxes would be located close to field boundaries and in accessible locations.

333. The link boxes, with dimensions 1.5m x 1.5m, per circuit, would be buried to ground level within an excavated pit, providing access via a secured access panel. Alternatively, above ground link box cabinets (1.2m x 0.8m x 1.8m) may be utilised which are typically sited on a 0.15m deep concrete slab.

334. Link boxes for Norfolk Vanguard are included in this assessment and will be part of the consented project. Link boxes for Norfolk Boreas will be considered as part of the Norfolk Boreas EIA and DCO application.

Plate 5.17 Example below ground link box following reinstatement (Source: Rey Wind Farm, Vattenfall Wind Power Ltd.)

5.5.2.7 Key parameters

335. Table 5.32 summarises the onshore cable route key parameters with Table 5.33 summarising the joint pit key parameters.

Table 5.32 Summary of onshore cable route key parameters

Element	Minimum	Maximum	Additional information
Number of cable trenches	2	4	Norfolk Vanguard and Norfolk Boreas duct installation
Width of cable trench (m)	1	5	Maximum considers two adjacent trenches are excavated as a single trench rather than as two separate trenches of 1m
Length of cable Route (km)		60	Approximate
Cable Diameter (mm)	100	150	
Type of cable	XLPE or MIND electrical cables, plus fibre optics		
Voltage (kV)	320	500	
Temporary strip width (m)	35	45	Duct installation would cover up to 45m in width to facilitate future installation of onshore cables for Norfolk Boreas (see Plate 5.15)
Permanent strip width (m)	13	20	Permanent strip would cover up to 20m in width to accommodate Norfolk Vanguard and Norfolk Boreas.
Burial depth (m)	1.05	-	1.05m 'normal' agricultural, 1.2m 'deep ploughing' agricultural to top of duct target. Up to 20m at trenchless crossings.

Table 5.33 Summary of joint pit key parameters

Element	Minimum	Maximum	Comments
Number of cable circuits	2	2	Separate jointing pits are required for each cable circuit (Norfolk Boreas joint pits not included in Norfolk Vanguard DCO).
Width (m)	3	6	
Length (m)	10	15	
Depth (m)	1.5	2	
Nominal distance between jointing pits (m)	500	1000	Actual distance dependant on existing infrastructure along the cable route, cable specification and cable delivery limitations. Typically 800m.

5.5.2.8 Operations and Maintenance

336. There is no ongoing requirement for regular maintenance of the onshore cables following installation, however access to the onshore cable route would be required to conduct emergency repairs, if necessary. Access to each field parcel along the

cable route is available from the identified operational side accesses using existing field entry points where possible or accessing the cable route from road crossings.

5.5.2.9 Decommissioning

337. No decision has been made regarding the final decommissioning policy for the onshore cables, as it is recognised that industry best practice, rules and legislation change over time. It is likely the cables would be removed from the ducts and recycled, with the transition pits and ducts capped and sealed then left in situ.

5.5.3 Crossing Installation Methods

338. When crossing some features along the onshore cable route, alternative or amended installation approaches would be required to minimise the impact on the feature being crossed as much as reasonably practicable. The following sections detail the crossing installation methods available with the type proposed at each crossing provided in Chapter 20 Water Resources and Flood Risk Appendix 20.4.

5.5.3.1 Hedgerows

339. When crossing hedgerows, the width of the onshore cable route would be reduced to the running track and cable trenches only (as the DCO for Norfolk Vanguard will be seeking to install ducts for Norfolk Boreas at the same time, this would result in a width of up to 20m for both projects) to minimise the amount of hedgerow removal (see Plate 5.15). Hedgerow removal would be conducted before the nesting season or hedgerows would be netted prior to removal to discourage nesting birds. Any hedgerow removed would be replanted with hedgerow types matching the existing where possible as part of reinstatement works, with the following limitations.

340. After completion of duct installation, ongoing construction access into certain fields along the onshore cable route will be required to facilitate the phased delivery, installation and jointing of cables. (For the majority of joint locations, field accesses will be maintained at nearby points where public roads cross the onshore cable route. In a minority of cases, where there are no nearby crossing points or where the roads are unsuitable for construction traffic, it will be necessary to maintain access along the onshore cable route from a suitable road some distance away).

341. To facilitate these access arrangements during the cable installation phase of the project, it will be necessary to retain suitable openings in a certain number of hedgerows for a further two years after the duct installation phase (for Norfolk Vanguard only). These openings would be replanted at the end of this further period, with hedgerow types matching the existing. Only hedge plants such as quick thorn and blackthorn may be planted directly above the onshore cables where a hedge is necessary either for screening purposes or to indicate a field boundary. For reference, the following trees must not be planted within 6m of the cables and

should only be planted as individual specimens or in a single row in the area between 6 to 10m of the cables. Dense mass planting should only be carried out greater than 10m from the cables:

- Ash, cedar, larch, beech, elm, horse chestnut, sweet chestnut, London plane, hornbeam, lime, lime alder, scots pine, black pine, oak, sycamore, apple, plum, cherry, pear, and most conifers.

342. The following trees must not be planted within 10m of the cables:

- Poplar and willow.

343. The number and location of hedgerow openings required for ongoing access during cable installation will not be known until the detailed design of the cable system is completed. The total number of openings is not expected to exceed 200. No opening would be greater than 6m wide.

5.5.3.2 Manual excavation for underground services

344. Information on the type and location of underground services has been collected (see Chapter 21 Land Use and Agriculture and a full crossing schedule in Chapter 20 Water Resources and Flood Risk Appendix 20.4) and would be updated and verified as part of the pre-construction activities. Where these services are identified, manual trench excavation would be employed within 1m (or the stipulated distance requirement of the asset owner if applicable) of these locations to uncover the services in a controlled and safe manner.

345. The exposed services would be supported as necessary to prevent damage and the cable ducts installed at a suitable depth below the asset. Crossing of the services would be made at a perpendicular angle where possible to minimise crossing length and any potential interference impacts.

346. The works would be conducted within the onshore cable route with no additional land requirements. The running track could require reinforcement in these locations to minimise services damage. Soil storage and re-instatement of the trench would be conducted in line with the main cable route installation.

5.5.3.3 Traffic management

347. Where the onshore cable route crosses roads, tracks and public rights of way, traffic management would be employed to allow construction activities to continue safely. Where appropriate, single lane operation of roads would be utilised during installation with signal controls to allow movements to continue. Where the width of the road (<7.2m kerb to kerb) does not permit single lane operation, alternative methods such as temporary road closure or diversion could be required. To minimise the impact of closures or diversions, night working could be employed.

The detailed installation method for each crossing utilising traffic management would be agreed with the relevant highways authority or landowner prior to works beginning. It should be noted that trenchless crossing methods (refer to section 5.5.3.6) may be required at locations where standard traffic management techniques are not deemed to be suitable.

348. Temporary closures or diversions would be in place for the period of time required for the duct installation (e.g. approximately one week for 150m with a maximum worst case of two weeks). Temporary crossings of the onshore cable route could then be installed to allow public access to continue where the running track is required to remain in service. The crossings would be managed to allow safe operation.

349. For installation, the ducts may be encased in concrete to a minimum depth of 0.9m under the road surface to ensure protection of the onshore cables from traffic movements.

350. The works would be conducted within the onshore cable route with no additional land requirements. Soil storage and re-instatement of the trench would be conducted in line with the main cable route installation and the road surface would be reinstated to its pre-excavation condition, so far as reasonably possible.

5.5.3.4 Temporary dam and divert

351. Where small scale watercourses such as field drains, which are shallower than 1.5m are to be crossed, temporary damming and diverting of the watercourse would be employed. The suitability of this method would be agreed at detailed design following consent from the relevant land owners as part of the agricultural design process; larger water courses may also require consent from internal drainage boards and flood management agencies.

352. The watercourse would be dammed at either side of the onshore cable route using sandbags or straw bales and ditching clay with water flow pumped/piped across the dammed section. The cable trenches would then be excavated within the dammed section and ducts installed to a suitable level below the drainage depth (e.g. 2m of cover below the bed level for Internal Drainage Board (IDB) drains). Reinstatement of the trench would be conducted to the pre-construction depth of the watercourse and the dams removed.

353. The works would be conducted within the onshore cable route with no additional land requirements. The running track could also require culverting or temporary bridging in these locations to allow continued cable route access and removed once cable installation is complete. Soil storage and re-instatement of the trench would be conducted in line with the main cable route installation.

5.5.3.5 Culverting

354. Where larger watercourses such as field drains are deeper than 1.5m, culverting could also be implemented; however, the suitability of this method would be agreed with the relevant authorities at detailed design stage following consent from the relevant internal drainage boards and flood management agencies. It is noted that the Environment Agency deem this technique to be least desirable river crossing method due to the potential for adverse effect on the environment.

355. A culvert duct would be installed in the current watercourse, suitably sized for necessary water volumes and flows. The culvert duct would be backfilled or encased in concrete to a depth of 2m, the cable ducts would subsequently be laid perpendicular and backfilled to ground level creating a culverted watercourse.

356. The works would be conducted within the cable route with no additional land requirements. The running track would be included within the culverting exercise in these locations to allow continued cable route access. Excess excavated material from other areas of the cable route could be used for backfill of the trench.

357. Culverting may be required temporarily for a width of 6m to allow the running track to cross watercourses during duct installation works (up to 2 years dependant on location along the route section being worked) and for ‘inaccessible’ sections of the running track relating to the cable pulling works period (approximately 3 months per location). This method will be employed at all watercourses with exception to those designated as ‘stop ends’ where the running track will not cross the watercourse.

5.5.3.6 Trenchless crossing methods

358. Trenchless installation methods such as HDD, micro tunnelling or auger boring would be used where open cut trenching is not suitable due to the width and, or type of feature being crossed. The locations where trenchless methods would be employed are illustrated in Figure 5.4 (trenchless crossing zones).

359. With trenchless methods, the depth at which the ducts are installed depends on the topology and geology at the crossing site. Typically, for a river crossing, HDD ducts would be installed 5m below the floodplain, and at least 2m below the river bed. A Flood Risk Activity permit under the Environmental Permitting Regulations 2010 will be applied for where required.

5.5.3.6.1 HDD

360. See section 5.5.1 for further details regarding HDD installation methods.

5.5.3.6.2 Auger boring / micro-tunnelling

361. In both cases a circular or rectangular pit (shaft or cofferdam) is constructed each side of the feature to be crossed. These are typically 1m below the invert level of

the conduit (pipe or duct) to be installed. The conduit is driven through the side wall from the launch pit to a reception pit. The method of driving varies to suit prevailing ground conditions.

362. Auger boring is suitable in most cases with the exception of sands or obstructions such as cobbles or boulders. First a pilot pipe is jacked through the ground from the launch shaft to the reception shaft. An auger is attached to the end which clears the opening of soil and is itself followed by the permanent lining.

363. Micro-tunnelling involves remote control tunnel boring machines tunnelling themselves from the launch to reception shaft conveying spoil to the launch shaft via conveyors. The permanent conduit immediately follows the machine, installed by jacking from the launch pit. This method can be used in most ground as the drilling head can be configured to prevailing ground conditions.

5.5.3.6.3 Associated temporary works areas

364. Where trenchless drilling activities are to be conducted, a temporary work area would be required to store drilling equipment, welfare facilities, ducting and water[2] for the drilling process. The trenchless drilling compounds would typically be of dimensions 100m x 50m for the reception site and 150m x 50m on the launch site and would be located adjacent to the onshore cable route and inclusive of a stop end, as displayed in Figure 5.4.

365. The exact dimensions would be fully determined by site specific constraints and drilling requirements such as cable segregation and drilling depth. A temporary bridge may be included to allow continuation of the running track and allow access to both sides of the crossing at Wendling Carr. At all other locations, a stop end would be employed, requiring the inclusion of a turning area for vehicles within the temporary work area. Plate 5.18 to Plate 5.22 provide indicative plan layouts and example aerial photography of trenchless installation techniques for crossing significant features such as major roads, major rivers and railways.

366. The trenchless installation would occur prior to or parallel to the main cable installation works and the drilling rig would be located within the onshore cable route for duct installation with the temporary compound adjacent. The precise location and sizing of the drilling site can only be derived through detailed analysis of the ground conditions and derivation of proposed drill profile (angle and depth).

367. A series of desk top studies and site visits have been used to identify the likely proposed locations for trenchless installation and these are shown in Figure 5.4.

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[2] It is assumed that water is required to be transported and stored on site in water bowsers during the trenchless drilling activities and cannot be sourced from local watercourses.

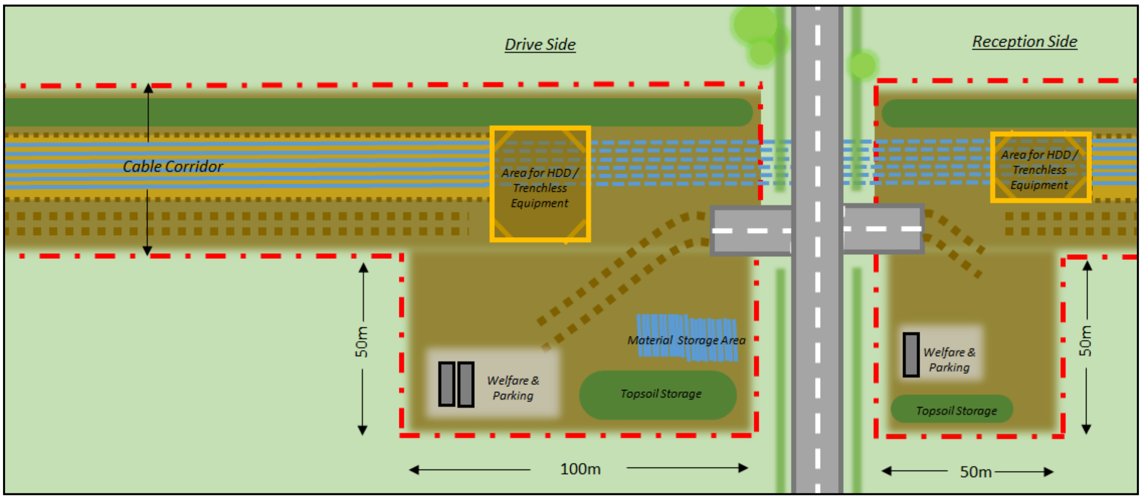

Plate 5.18 Indicative trenchless road crossing

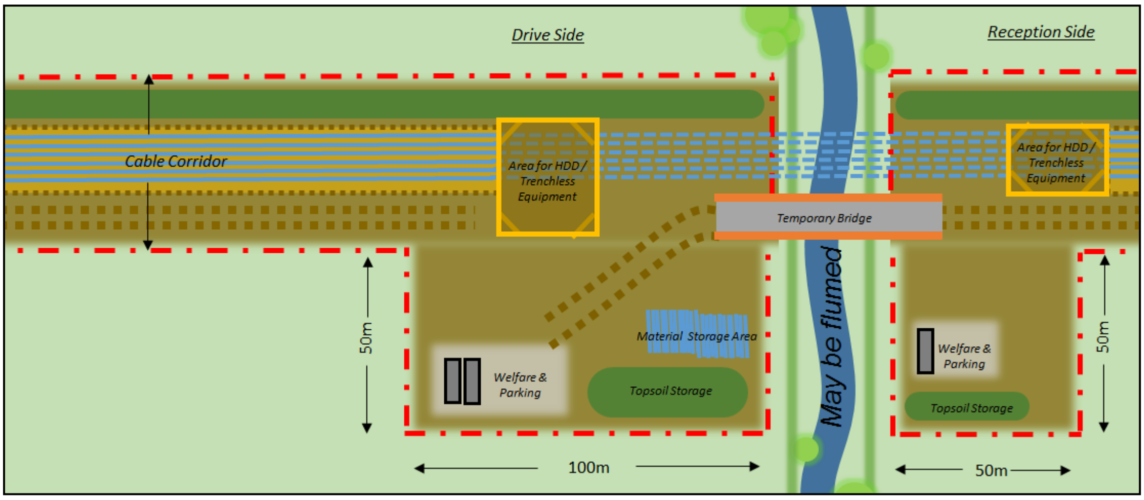

Plate 5.19 Indicative trenchless river crossing with temporary bridge

Plate 5.20 Aerial image of example trenchless river crossing with temporary bridge (Source: Courtesy of the J Murphy & Sons Ltd)

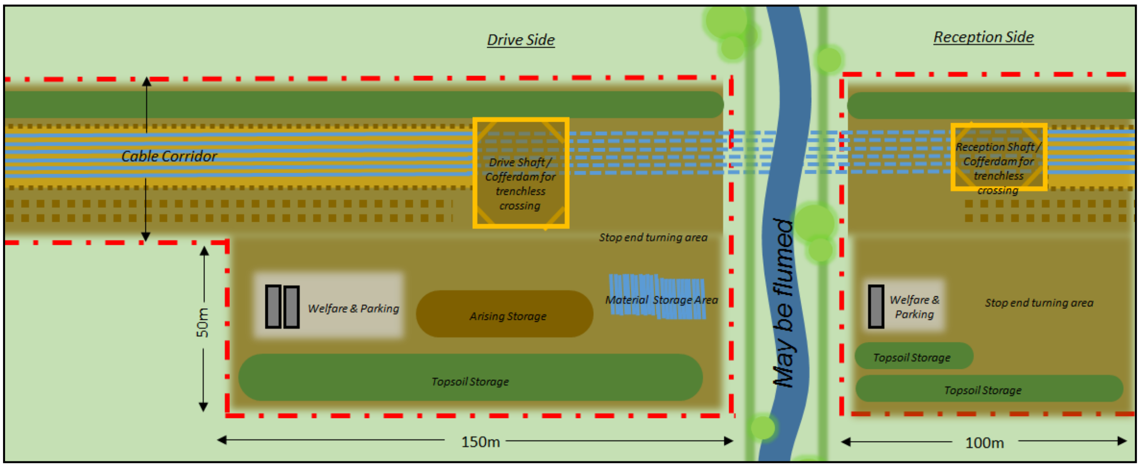

Plate 5.21 Indicative trenchless river crossing with stop end

Plate 5.22 Aerial image of example trenchless river crossing with stop end (Source: Courtesy of the J Murphy & Sons Ltd)

5.5.4 Mobilisation Areas

368. To enable construction, mobilisation areas would be required to store equipment and provide welfare facilities. These mobilisation areas would be located adjacent to the onshore cable route, accessible from the local highways network and suitable for the delivery of materials and equipment. Each mobilisation area would serve one or two work fronts and are evenly distributed along the onshore cable route length as far as possible. A series of desk based studies and site visits have been used to identify the likely locations for mobilisation areas and these are shown in Figure 5.4, termed mobilisation zones.

369. The mobilisation areas would be a maximum of 100m x 100m dimensions (or 150m x 100m if combined with a trenchless drilling compound) with specific sizing and dimensions for each location based on site constraints and land boundaries.

370. Hardstanding would comprise of permeable gravel aggregate to a depth of 0.3m underlain by geotextile or other suitable material and would be laid to allow safe storage and movement of vehicles within the area and maintain required drainage. Site lighting and secure fencing around the perimeter of the mobilisation area would be utilised for safety and security purposes. Where possible, the mobilisation areas would be supplied by existing water, sewerage and electrical services although the use of bowsers, septic tanks and generators could be employed if necessary.

371. The mobilisation areas will remain in place for the duration of the onshore duct installation activities, proposed as two years (see section 5.5.7). Following installation of the ducts, the mobilisation areas would be removed and the land reinstated. During cable pull phase, materials will be delivered directly to the joint locations, or through the use of a cable logistics area (existing hardstanding near Oulton) (Figure 5.4 map 5).

5.5.4.1 Trenchless crossing zones

372. Full details of trenchless crossing zones and associated temporary works areas are provided in section 5.5.3.6.

5.5.4.2 Onshore cable route access

373. Small temporary works areas could be required to facilitate the safe ingress and egress from the public highways to the onshore cable route or mobilisation areas through temporary slip roads. Traffic and transport assessments have identified where these additional accesses may be required and further assessment will be undertaken post consent based on the final design of the project. An Outline Design and Access Statement (document reference 8.3) is submitted with the DCO application. Accesses are expected to be located at each mobilisation area and intersections between the public highway and cable route, where suitable, to facilitate side access to the onshore cable route.

5.5.5 Onshore Project Substation

5.5.5.1 General specification

374. The onshore project substation will consist of an HVDC substation.

375. The onshore project substation converts the HVDC electrical power from the Norfolk Vanguard export cables to the HVAC format and appropriate voltage required for connection to the National Grid system. Filtering, switchgear and associated protection and control equipment is also located at the onshore project substation

to provide compliance with the technical requirements of the National Grid and allow safe operation of the Norfolk Vanguard connection.

376. The onshore project substation will consist of two similar converter stations, each having a power transfer capability of between 800MW and 1000MW. As such, in the worst case scenario the onshore project substation will consist of:

- 2x converter buildings - housing DC filter equipment and power electronics to convert HVDC to HVAC power for connection to National Grid;
- 2x outdoor HVAC compounds – each compound will contain one or more 400kV transformers, plus HVAC filters, busbars and cable sealing ends;
- Control building – housing SCADA and protection equipment;
- Access roads – for operation and maintenance access to equipment; and
- Associated connections between equipment via overhead busbar and cabling, including buried earthing system.

377. The largest equipment within the onshore project substation will be the converter halls with an approximate height of 19m. The tallest structure at the onshore project substation site will be the lightning protection masts at a height of 25m. All other equipment will not exceed a height of 13m. The total land requirement for the onshore project substation to the perimeter fence is 250m x 300m.

378. Table 5.34 summarises the onshore project substation key parameters.

Table 5.34 Onshore project substation key parameters summary

Element	Maximum	Comments
Length of site (m)	300	
Width of site (m)	250	
Tallest Structure (m)	25	Lightening protection masts
Tallest building (m)	19	Converter hall
Fence Height (m)	2.4 + 1.0	Palisade fence + electrical pulse fencing

5.5.5.2 Location

379. The onshore project substation is proposed to be located within the footprint illustrated in Figure 5.5. A detailed site selection process (described in Chapter 4 Site Selection and Assessment of Alternatives) has been undertaken to determine a suitable location. Siting of the onshore project substation has had due consideration to avoid existing watercourses, hedgerows and other known infrastructure/ constraints to minimise impacts. Consideration has also been given to the potential siting of equivalent onshore project substation for Norfolk Boreas for cumulative assessment purposes.

5.5.5.3 Onshore project substation temporary construction compound

380. During construction of the onshore project substation, a temporary construction compound would be established to support the works. The compound would be formed of hard standing (refer to section 5.5.4) with appropriate access to the A47 to allow the delivery and storage of large and heavy materials and assets required for construction of the onshore project substation.

381. The compound would be of dimensions 200m x 100m and accommodate construction management offices, welfare facilities, car parking, workshops and storage areas. Water, sewerage and electricity services would be required at the site and supplied either via mains connection or mobile supplies such as bowsers, septic tanks and generators. This compound could also serve as a mobilisation area (section 5.1.1.1) for cable installation works.

382. The location of the onshore project substation temporary construction compound would be sited within the zone identified in Figure 5.5, in close proximity to the onshore cable route and onshore project substation with due consideration for avoiding existing watercourses, hedgerows and other known infrastructure/ constraints to minimise impacts.

5.5.5.4 Pre-construction works

383. Prior to the construction works beginning, a number of surveys and studies would be undertaken to inform the final detailed design including ecological surveys, archaeological surveys, geotechnical investigations, noise modelling and mitigation requirements such as landscaping and drainage assessments (see Chapter 22 Onshore Ecology and Chapter 28 Onshore Archaeology and Cultural Heritage for further information).

384. Surface water drainage requirements would be dictated by the final drainage study and would be designed to meet the requirements of the NPPF[3] with run-off limited, where feasible, through the use of infiltration techniques which can be accommodated within the area of development.

385. High level studies have indicated than an attenuation pond with volume 4,050m^3 (approximate dimensions of 58m x 58m x 1.2m) should be employed to allow a sufficient attenuation to greenfield runoff rates into the closest watercourse or sewer connection. The full specification for the attenuation pond and drainage strategy would be addressed as part of detailed design post-consent.

[3] Limit post development off site run-off to the existing greenfield rate and providing sufficient on site attenuation for rainfall events up to 1 in 100 year rainfall event, plus a 30% allowance for climate change over the lifetime of the development.

386. Foul drainage would be collected through a mains connection to an existing local authority sewer system if available or septic tank located within the development boundary. The specific approach would be determined during the detailed design phase with consideration for the availability of mains connection and the number of visiting hours for site attendees during operation.

387. The onshore project substation would be enclosed by a temporary perimeter fence for the duration of the construction period with a permanent fence installed as part of the construction works.

5.5.5.5 Screening

388. The onshore project substation site benefits from some substantial existing hedgerows and woodland blocks within the local area. However Norfolk Vanguard Limited has committed to additional planting to further screen the Norfolk Vanguard onshore project substation. The location of this proposed additional planting is provided in Figure 5.6. Further information on the proposed screening is provided in Chapter 29 Landscape and Visual Impact Assessment.

389. The mitigation planting would be designed to comprise a mix of faster growing ‘nurse’ species and slower growing ‘core’ species. The core species would comprise a mix of preferred native, canopy species that would outlive the nurse species and characterise the woodland structure over the longer term. It is anticipated that the growth rate of these species would be on average 250mm per annum. It is anticipated that 5m to 7m growth would take 20 years and the nurse species would be sufficiently fast growing to provide substantial screening of the onshore project substation after 20 years.

390. It is anticipated that the construction of the project, including mitigation planting, would commence in 2020. In locations where it is possible to achieve advanced planting this would already have had a minimum of three years of growth prior to completion of construction and commencement of operation, which equates to approximately 1.2m in height on top of a base height of approximately 1m (for the faster growing nurse species).

5.5.5.6 Construction

391. The site would be stripped and graded as required by the final design. Stripped material would be reused on site where possible as part of bunding and shielding as allowed for in the final design. Any excess material would be disposed of at a licenced disposal site. Excavations and laying of foundations, trenches and drainage would commence after grading is complete.

392. At this stage it is not known whether the foundations would either be ground-bearing or piled based on the prevailing ground conditions.

393. The control buildings and converter hall would likely be constructed from a steel frame with cladding panels. The structural steelwork and cladding would be fabricated and prepared off site and delivered for erection. The frame would be erected with the use of cranes and the cladding fitted through a variety of means, dependant on the cladding selected i.e. brick or blockwork, sheet cladding etc.

394. The specialist electrical equipment would then be delivered to site, installed and commissioned. Due to the size and weight of assets such as the transformers, specialist delivery methods would be employed and assets would be offloaded at site with the use of a mobile gantry crane.

395. The onshore 400kV cables from the onshore project substation to the Necton National Grid substation would be installed in a direct bury method. This method will require a trench to be excavated between the onshore project substation and the Necton National Grid substation (~1,750m) for the cables to be laid directly and jointed before being reinstated.

396. The route for the Norfolk Vanguard onshore 400kV cables will be as shown in Figure 5.5. Up to four trenches would be required to accommodate two circuits with two cores per phase, a total of 12 cables for Norfolk Vanguard.

397. Only the Norfolk Vanguard onshore 400kV cables will be installed under the Norfolk Vanguard DCO application. An equivalent cable route for the onshore 400kV cables for the Norfolk Boreas connection will be included under the Norfolk Boreas DCO application.

398. Construction activities would normally be conducted during working hours of 7am-7pm. Evening or weekend working could be required to maintain programme progress and for specific time critical activities such as transformer oil filling and processing; however, these would be kept to a minimum. Perimeter and site lighting would be required during working hours in the winter months and a lower level of lighting would remain overnight for security purposes.

399. The construction programme for the onshore project substation would be expected to be approximately 24 to 30 months.

5.5.5.7 Operations and maintenance

400. The onshore project substation would not be manned; however, access would be required periodically for routine maintenance activities, estimated at an average of one visit per week. Normal operating conditions would not require lighting at the onshore project substation, although low level movement detecting security lighting may be utilised for health and safety purposes. Temporary lighting during working hours will be provided during maintenance activities only.

401. Peak operational noise levels will be produced by transformers and harmonic filter reactors, further details are provided in Chapter 25 Noise and Vibration.

402. Noise mitigation measures are provided in Chapter 25 Noise and Vibration.

5.5.5.8 Decommissioning

403. No decision has been made regarding the final decommissioning plan for the onshore project substation, as it is recognised that industry best practice, rules and legislation change over time.

404. A full EIA will be carried out ahead of any decommissioning works being undertaken. The programme for decommissioning is expected to be similar in duration to the construction phase of 24-30 months. The detailed activities and methodology for decommissioning will be determined later within the project lifetime, in line with relevant policies at that time, but would be expected to include:

- Dismantling and removal of electrical equipment;
- Removal of cabling from site;
- Removal of any building services equipment;
- Demolition of the buildings and removal of fences; and
- Landscaping and reinstatement of the site.

405. The decommissioning methodology cannot be finalised until immediately prior to decommissioning, but would be in line with relevant policy at that time.

5.5.6 National Grid Substation Extension and Overhead Line Modifications

406. The existing Necton National Grid substation would require an extension to accommodate the Norfolk Vanguard connection points. The Necton National Grid substation would need to accommodate circuit breakers and associated busbar (metal bar that conducts electricity within a substation) structures which allow connection onto the existing 400kV overhead line for generation to be transmitted onto the wider National Grid system. In addition to the Necton National Grid substation itself, modifications to the existing overhead line structures adjacent to the substation would be required to provide a double turn-in arrangement[4].

5.5.6.1 General specification

407. The Necton National Grid substation outdoor busbar will be extended in a westerly direction to a total length of 340m (inclusive of existing Necton National Grid substation), with seven new AIS bays installed along the busbar extension for Norfolk Vanguard. For cumulative assessment purposes, five further AIS bays installed to the

[4] Each overhead line tower carries two 400kV circuits. In this arrangement, both circuits are turned into the substation busbar structure.

east will be required for Norfolk Boreas extension works with a total busbar length (Norfolk Vanguard extension, Norfolk Boreas extension and existing substation) of 470m.

408. The maximum height of the outdoor busbar and bays at the substation is estimated to be 15m.

409. Extension works are to be completed to facilitate only Norfolk Vanguard, including any temporary land requirements.

410. Two new overhead line towers will be required to accommodate Norfolk Vanguard and Norfolk Boreas in close proximity to the existing corner tower (to the north east of the existing Necton National Grid substation) with a maximum height of 55m. The existing corner tower will be demolished such that the net new number of towers is one. The design approach taken would be confirmed at detailed design phase, post consent.

411. The National Grid substation extension and overhead line modification works will be conducted within the areas identified within Figure 5.5.

412. Table 5.35 summarises the Necton National Grid substation key parameters.

Table 5.35 Necton National Grid substation key parameters summary

Element	Maximum	Comments
Length of site (m)	340	Including existing operational site
Width of site (m)	150	
Tallest structure (m)	15	Outdoor AIS busbar and landing gantries
Tallest new tower (m)	55	Two new terminal towers, one of which would replace the existing corner tower

5.5.6.2 National Grid temporary works area

413. During construction of the Necton National Grid substation modification for Norfolk Vanguard, a single temporary works area will be established to support the works. Given project duration, the compound will likely be tarmacked with some concrete hard standing for heavier plant and equipment. Access to the A47 will be provided utilising the existing access road to the site to permit safe delivery of plant and equipment required for construction, with a 'no right turn' traffic management scheme employed for safety.

414. The compound will accommodate construction management offices, welfare facilities, car parking, workshops and storage areas. Water, sewerage and electricity

services would be required at the site and supplied either via mains connection or mobile supplies such as bowsers, septic tanks and generators.

415. The location of the Necton National Grid substation temporary mobilisation area will be sited within the zone identified in Figure 5.5, in close proximity to the existing Necton National Grid substation with due consideration for avoiding existing watercourses, hedgerows and other known infrastructure/constraints to minimise impacts.

5.5.6.3 Pre-construction works

416. Prior to the construction works beginning, a number of surveys and studies would be undertaken to inform the final detailed design including ecological surveys, archaeological surveys, geotechnical investigations and mitigation requirements such as landscaping and drainage assessments (see Chapter 22 Onshore Ecology and Chapter 28 Onshore Archaeology and Cultural Heritage for further information).

417. Surface water drainage requirements would be dictated by the final drainage study and would be designed to meet the requirements of the NPPF[5]. The SuDS philosophy would be employed to limit run-off, where feasible, through the use of infiltration techniques which can be accommodated within the area of development. Allowance for the extension of the existing attenuation pond at the Necton National Grid substation has been included to accommodate additional impermeable ground associated with the substation extension for Norfolk Vanguard. A total volume of 4,200m^3 is to be assumed, which considers both the existing Necton National Grid substation and the National Grid substation extension for Norfolk Vanguard.

418. Foul drainage would be collected through a mains connection to existing local authority sewer system if available or septic tank located within the development boundary. The specific approach would be determined during detailed design with consideration for the availability of mains connection and the number of visiting hours for site attendees during operation.

419. The Necton National Grid substation would be enclosed by a temporary perimeter fence for the duration of the construction period with a permanent fence installed as part of the construction works.

5.5.6.4 Screening

420. In locations where it is possible to achieve advanced mitigation planting this could be implemented at the start of the construction phase. This would mean these areas would already have had a minimum of approximately three years of growth prior to

[5] Limit post development off site run-off to the existing greenfield rate and providing sufficient on site attenuation for rainfall events up to 1 in 100 year rainfall event, plus a 30% allowance for climate change over the lifetime of the development.

completion of construction and commencement of operation which equates to approximately 1.2m in height on top of a base height of approximately 1m, for the faster growing nurse species (see Chapter 29 Landscape and Visual Impact Assessment).

421. The mitigation planting would be designed to comprise a mix of faster growing 'nurse' species and slower growing 'core' species. The core species would comprise a mix of preferred native, canopy species that would outlive the nurse species and characterise the woodland structure over the longer term. It is anticipated that the growth rate of these species would be on average 250mm per annum. It is anticipated that 5m to 7m growth would take 20 years and the nurse species would be sufficiently fast growing to provide substantial screening of the National Grid substation extension after 20 years.

5.5.6.5 Construction

422. The site would be stripped and graded. Stripped material would be reused on site where possible as part of bunding and shielding as allowed for in the detailed design. Any excess material would be disposed of at a licenced disposal site. Excavations and laying of foundations, trenches and drainage would commence after grading is complete.

423. The design and construction of foundations at the Necton National Grid substation will be subject to the outcome of geo-technical site investigations, post-consent. It is possible that some piled foundations will be required, but this is considered unlikely. Upon completion of the foundations, the specialist electrical equipment would then be delivered to site and installed and commissioned.

424. For the overhead line modifications, temporary towers would be constructed in close proximity to the existing towers and the existing circuits transferred over to the temporary towers (within the area identified in Figure 5.5). One existing tower would be removed and replaced with new towers; of which there would be up to two each a maximum of 55m in height and the circuits transferred from the temporary towers. The temporary towers and foundations would then be removed. The tower foundations may be piled or excavated and cast, dependant on the ground conditions and structural requirements. It is anticipated that the footprint of the towers would be larger than that of the existing towers; the orientation and design of the new towers would be selected to allow for the double turn in arrangement.

425. Construction activities would normally be conducted during working hours of 7am to 7pm. Evening or weekend working may be required to maintain programme

progress. Perimeter and site lighting would be required during working hours and a lower level of lighting would remain overnight for security purposes.

426. The construction programme for the Necton National Grid substation extension and overhead line modification works is expected to be approximately 24-30 months. However, the timing of the overhead line works will be subject to securing the necessary circuit outages.

5.5.6.6 Operations and maintenance

427. The Necton National Grid substation would be unmanned. Maintenance of the substation would be undertaken approximately every three years, involving electrical isolation of equipment before it is worked on. Visual checks would be undertaken on a monthly inspection visit to the site. If the substation requires refurbishment or replacement works, vehicles would be used to carry workers in and out of the site and suitable vehicles would be used to bring new materials and equipment to site and to remove old equipment. During operation, the Necton National Grid substation would not normally be illuminated. However, lighting would be used when conducting inspection and maintenance activities (during working hours only).

428. Operational noise levels are not anticipated to change from existing levels due to the nature of the extension works. A standby generator will be at the site for emergency use only. Details of the noise emissions are provided in Chapter 25 Noise and Vibration.

5.5.6.7 Decommissioning

429. No decision has been made regarding the final decommissioning plan for the Necton National Grid substation, as it is recognised that industry best practice, rules and legislation change over time.

430. An appropriate impact assessment will be carried out ahead of any decommissioning works being undertaken. The programme for decommissioning is expected to be similar in duration to the construction phase of approximately 24 to 30 months. The detailed activities and methodology for decommissioning would be determined prior to end of the lifetime of the project, in line with relevant policies at that time, but would be expected to include:

- Dismantling and removal of electrical equipment;
- Removal of any building services equipment;
- Demolition of the buildings and removal of fences; and
- Landscaping and reinstatement of the site.

5.5.7 Use of Natural Resources

431. Norfolk Vanguard Limited has sought to minimise the use of, and effect on natural resources through its careful site selection process (outlined in Chapter 4 Site Selection and Assessment of Alternatives) as well as its choice of technology and the specific installation methods proposed. Early site surveys, including for water resources, ecology and archaeology, have enabled a good understanding of the natural resources of the area to ensure that effects on key features can be avoided. Where the project has the potential to directly affect a resource, installation methods such as the use of trenchless techniques have either removed or considerably reduced any impacts.

432. The decision to adopt HVDC technology has provided a much reduced project footprint as a cable relay station is no longer required and the number of cables, and therefore the width of the cable corridors on and offshore, is significantly reduced. This reduces direct impacts on the natural environment and the additional resources to build the project.

433. Further information on natural resources and the avoidance of key features can be found in Chapter 4 Site Selection and Assessment of Alternatives, Chapter 21 Land Use and Agriculture, Chapter 22 Onshore Ecology, Chapter 23 Onshore Ornithology and Chapter 28 Onshore Archaeology and Cultural Heritage.

5.5.8 Indicative Onshore Construction Programme

434. This section summarises the main construction activities and sequence associated with installation of the Norfolk Vanguard onshore infrastructure.

5.5.8.1 Pre-construction works (2020 to 2021)

435. Pre-construction works would be conducted to maximise the efficiency of the main construction works and mitigate potential programme delays. Pre-construction works would take place before the 'main installation works' and are scheduled to begin from 2020.

436. The pre-construction works would consider the requirements of Norfolk Boreas to minimise future disruption and would therefore cover a cable route width of up to 45m.

437. The main pre-construction activities are noted below and would be applicable to the onshore project substation and onshore cable works:

- Road Modifications – New junctions off existing highways would be required and are subject to planning. Installing these ahead of the main works provides immediate access to the mobilisation areas and provides float should any planning issues arise.

- Hedge and Tree Netting / Removal – Hedge and tree removal is seasonal and can be influenced by ecological factors. Removing these ahead of the main works mitigates potential programme delays and provides access along the route from the outset.
- Ecological preparations – pre-construction activities agreed with Natural England and local authorities.
- Archaeological preparations – pre-construction activities agreed with Historic England and local authorities.
- Pre-construction Drainage – Modifications to existing agricultural drainage would be required. This is often complex meaning it is time consuming and difficult to modify. Pre-construction drainage works allow the existing drainage to be understood and provisions installed to allow easy modification during construction. This is best done at least a season before main construction starts in order to let the drainage establish in the landscape. This significantly improves the productivity of construction, especially in fields with significant water management.

5.5.8.2 Landfall

438. For a drill length of 1000m, it is anticipated that site establishment, there will be three drills and two ducts (allowing for failure of one drill at 1000m for worst case assessments) and demobilisation will take approximately 20 weeks when considering 12 hour (7am to 7pm), 7 day shifts. 24 hour operation can be employed for drilling activities, subject to planning and environmental restrictions, and could reduce the installation to approximately 14 weeks. Cable pulling will be undertaken subsequent to the main duct installation.

5.5.8.3 Main duct installation works (2022 to 2023)

439. The main duct installation works would be broadly broken into the following work packages:

- Enabling works;
- Duct installation and
- Reinstatement works.

440. Plate 5.23 to Plate 5.25 provide an indicative overview of the duct installation works programme (approximately two years), with focus on the enabling works and reinstatement sequences. Full details of the processes involved in these installation works is provided in section 5.5.1.

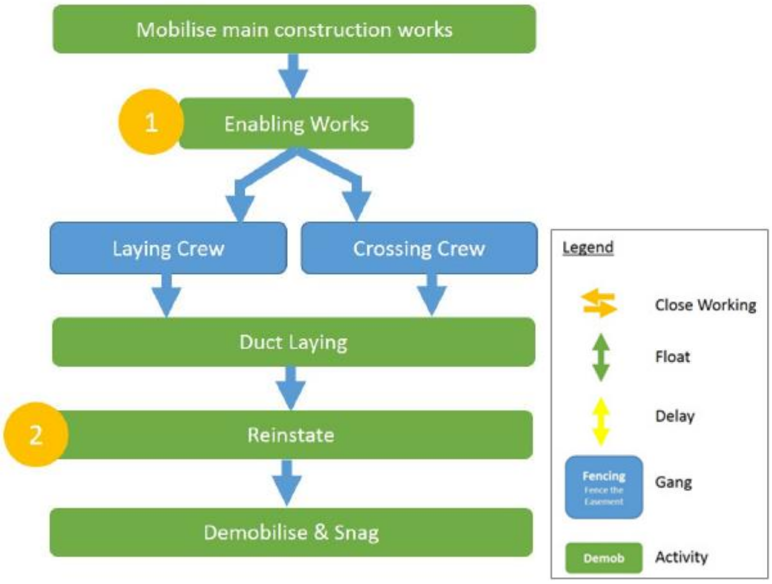

Plate 5.23 Overview of main duct installation works process

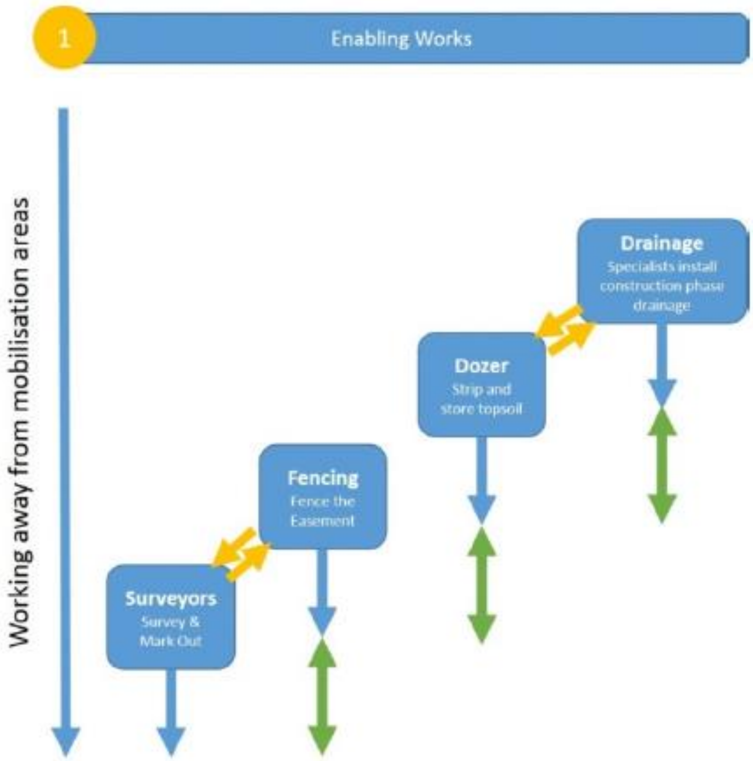

Plate 5.24 Enabling works details

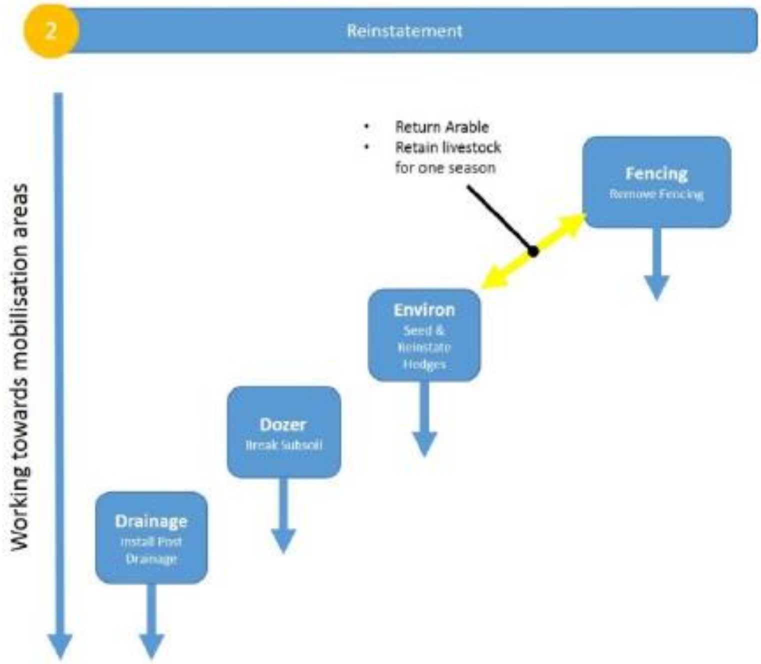

Plate 5.25 Reinstatement works detail

5.5.8.4 Workforce

441. It is estimated that the required resource, across the route length, would peak to 300 to 350 operatives during the two year duct installation works. It is proposed that a five day working week limited to the hours of 7am to 7pm would be employed with an average installation productivity of approximately 150m per week.

442. Seven day working could be required during specific periods of the installation, such as following periods of poor weather, but would be reserved where programme acceleration is required. Seven day and 24 hour working would be employed for any trenchless crossings, subject to specific requirements.

5.5.8.5 Cable installation (2024 to 2025)

443. For details of cable installation activities and process, refer to section 5.5.2.3. The cables would be supplied and installed in up to two phases in parallel with the commissioning of up to two phases of offshore wind turbine planting.

5.5.8.6 Onshore project substation construction (2022 to 2025)

444. Full details of the onshore project substation construction activities are provided in section 5.5.5. The main works for the final substation infrastructure, such as drainage, foundations and buildings would be constructed within a 24 to 30 month period, in parallel with the duct installation programme. Onshore project substation plant (such as transformers and switchgear) would subsequently be supplied and

installed in up to two phases of 2024 and 2025 in parallel with the commissioning of the two phases of offshore wind turbine planting.

5.5.8.7 Indicative construction programme

445. Table 5.36 below presents a high level indicative construction programme associated with the landfall and onshore infrastructure for the project with respect to a two phase development programme.

Table 5.36 Indicative project construction programme

Activity	Year					
	2020	2021	2022	2023	2024	2025
Landfall						
Duct Installation						
Cable Pull, Joint and Commission						
Phase 1						
Phase 2						
Onshore cable route						
Preconstruction works						
Duct installation works						
Cable pull, joint and commission						
Phase 1						
Phase 2						
Onshore project substation						
Preconstruction works						
Primary works						
Electrical plant installation and commission						
Phase 1						
Phase 2						

5.6 Response to Potential Major Accidents and Disasters

446. The Infrastructure Planning (Environmental Impact Assessment) Regulations 2017 (the EIA Regulations 2017) require significant risks to the receiving communities and environment, for example through major accidents or disasters, to be considered. Similarly, significant effects arising from the vulnerability of the proposed development to major accidents or disasters should be considered. Relevant risks are covered in the topic chapters within this ES.

447. A major accident, as defined in the Control of Major Accident Hazards (COMAH) Regulations 2015 (as amended), means "an occurrence (including in particular, a major emission, fire or explosion) resulting from uncontrolled developments in the course of the operation of any establishment and leading to serious danger to human health or the environment, immediate or delayed, inside or outside the establishment and involving one or more dangerous substances".

448. Offshore wind developments have an intrinsically low risk of causing major accidents. The turbines, blades towers and foundation bases of offshore wind farms have an excellent safety record with a very low failure rate and are positioned many kilometres offshore away from populated areas and the public. On the rare occasion that offshore turbine blades have been lost into the sea or damage has been caused to a turbine by a fire within the nacelle, this has resulted without injury. The performance of each turbine is constantly monitored through the SCADA system sending performance data through to a central, partly automated monitoring and control centre. As a result a problem can be quickly detected and pre-prepared safety management action plans rapidly enacted.

449. Whilst exposed power cables on the seabed can pose a snagging risk to shipping and fishing vessels, the projects export and array cables will be buried where possible to protect the cables and remove the snagging risk. This is discussed in detail in Chapter 15 Shipping and Navigation, which also discusses the risk that the increased vessel movement to and from the site may pose to navigational safety during construction and operational phases.

450. The buried cables onshore and offshore pose very little risk to the public as they are designed to 'trip out' automatically should any failure in insulation along the cable be detected.

451. The risk of substation fires is historically low; however, substation fires can impact the supply of electricity and create a localised fire hazard. The highest appropriate levels of fire protection and resilience will be specified for the onshore project substation to minimise fire risks. The onshore project substation is also located away from populated areas.

452. The small quantities of lubricants, fuel and cleaning equipment required within the project will be stored in suitable facilities designed to the relevant regulations and policy design guidance.

453. The offshore wind industry strives for the highest possible health and safety standards across the supply chain. However, there have been incidents including a small number of worker fatalities during the construction and operation of offshore wind farms. Risks to the public onshore and sea users offshore during construction

have been minimised through the use of controlled construction sites onshore and vessel safety zones offshore.

454. Safety zones are temporary exclusion areas enacted during construction, allowing Norfolk Vanguard Limited and its contractors to control vessel movements to enable safe construction works to proceed.

455. Onshore, controlled or closed construction sites will be operated where construction works are undertaken, in sections where access is strictly controlled during periods when the works are ongoing.

456. Norfolk Vanguard Limited recognises the importance of the highest performance levels of health and safety to be incorporated into the project. There is a commitment to adhere to a high level of process safety, from design to operations and for all staff, contractors and suppliers to have a high level of safety awareness and knowledge of safety and safe behaviour. Norfolk Vanguard Limited will enact a Code of Conduct for suppliers, contractors and subcontractors. They must all comply with the Code as well as health and safety legislation. Norfolk Vanguard Limited will ensure that employees that are going to work for Norfolk Vanguard Limited have undergone necessary health and safety training.

457. With a commitment to the highest health and safety standards in design and working practices enacted, none of the anticipated construction works or operational procedures is expected to pose an appreciable risk of major accidents or disasters.

458. In conclusion, the risk of ‘major accidents and/or disasters’ occurring associated with any aspect of the project, during the construction, operation and decommissioning phases is negligible.

5.7 References

AECOM (2012). Kelling to Lowestoft Ness Shoreline Management Plan
Fugro (2016). Norfolk Vanguard Offshore Wind Farm Geophysical Investigation

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