FIVE ESTUARIES OFFSHORE WIND FARM

PRELIMINARY ENVIRONMENTAL INFORMATION REPORT

VOLUME 2, CHAPTER 1: OFFSHORE PROJECT DESCRIPTION

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FIGURES

DEFINITION OF ACRONYMS

Term	Definition
AIS	Automatic Identification System
CAA	Civil Aviation Authority
CBRA	Cable Burial Risk Assessment
CPS	Cable Protection Systems
CTVs	crew transfer vessels
DCO	Development Consent Order
DP	Dynamic Positioning
ECC	Export Cable Corridor
EIA	Environmental Impact Assessment
ES	Environmental Statement
GBS	Gravity Based Structure
HAT	Highest Astronomical Tide
HDD	Horizontal Directional Drilling
JUVs	Jack-up vessels
MCA	Maritime and Coastguard Agency
MCAA	Marine and Coastal Access Act 2009
MDS	Maximum Design Scenario
MFE	Mass flow excavator
MW	megawatts
NPS	National Policy Statement
NtMs	Notices to Mariners
O&M	Operation and Maintenance
OSPs	offshore substation platforms
OWF	Offshore Wind Farm
PEIR	Preliminary Environmental Information Report
PINS	Planning Inspectorate
PLGR	Pre-Lay Grapnel Run
PVMs	Permanent vessel moorings
SCADA	Supervisory Control and Data Acquisition
SOVs	Service Operation Vessels

Term	Definition
THLS	Trinity House Lighthouse Service
TJBs	Transition Joint Bays
TP	Transition Piece
UXO	Unexploded Ordnance
VE	Five Estuaries Offshore Wind Farm
VE OWFL	Five Estuaries Offshore Wind Farm Limited
WTGs	Wind turbine generators

1 OFFSHORE PROJECT DESCRIPTION

1.1 INTRODUCTION

1.1.1 This chapter of the Preliminary Environmental Information Report (PEIR) describes the offshore elements of the proposed Five Estuaries Offshore Wind Farm (VE). It sets out the VE design and components for the offshore infrastructure, as well as the main activities associated with the construction, Operation and Maintenance (O&M) and decommissioning of the project.

1.1.2 This chapter has been drafted by GoBe Consultants on behalf of Five Estuaries Offshore Wind Farm Limited (VE OWFL) ('the Applicant'), and sets out:

- The design envelope approach;
- Consultation relating to the offshore project design undertaken to date;
- An overview of the project location and proposed offshore site boundaries;
- The design envelope of the offshore project components and the techniques used to build, operate, maintain and decommission VE; and
- The project programme.

1.1.3 This chapter details the above insofar as related to the offshore components of the proposed scheme up to and including the landfall where the offshore export cables (below MHWS) will meet the onshore export cables (above MLWS) – see Figure 1.1: Five Estuaries Project Schematic. Full details of the onshore elements of the proposed development are provided in Volume 3, Chapter 1: Onshore Project Description.

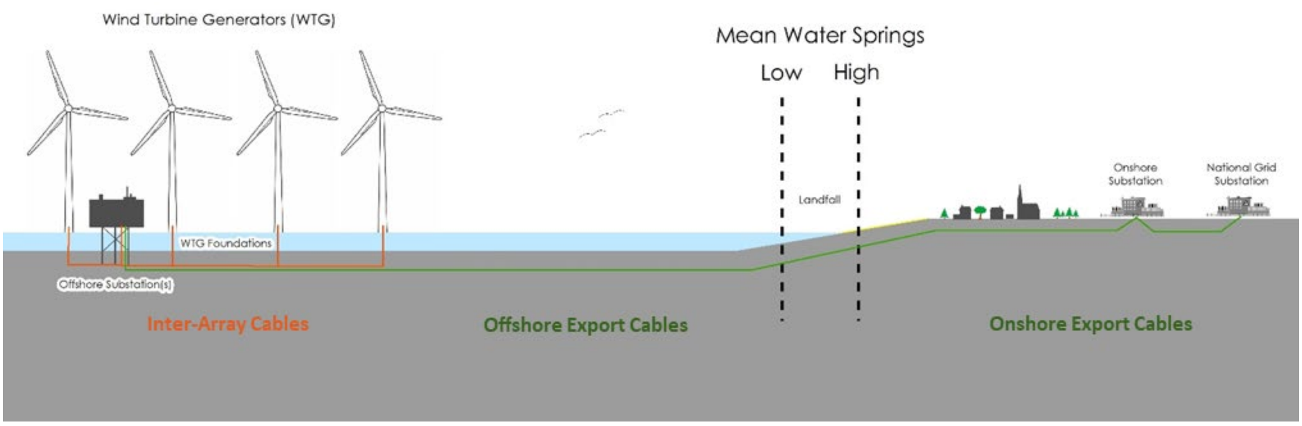


Figure 1.1: Five Estuaries Project Schematic

1.1.4 A detailed description of the site selection process that has resulted in the selection of the locations of project infrastructure and final routing is also provided in Volume 1, Chapter 4: Site Selection and Consideration of Alternatives.

1.1.5 Details of embedded mitigation, proposed to avoid or reduce environmental effects, are contained within the environmental assessments presented in Volumes 2 and 3. The description of the Proposed Development is inclusive of embedded mitigation, which have been directly incorporated into the design. Volume 1, Chapter 3: EIA Methodology explains the approach to embedded mitigation that has been applied in the PEIR.

1.1.6 A detailed description of the project envelope is provided in Volume 4, Annex 1-1.

1.2 PROJECT OVERVIEW

1.2.1 All offshore elements will be installed within the offshore Red Line Boundary (RLB) (Figure 1.2). The key offshore elements of VE will be as follows:

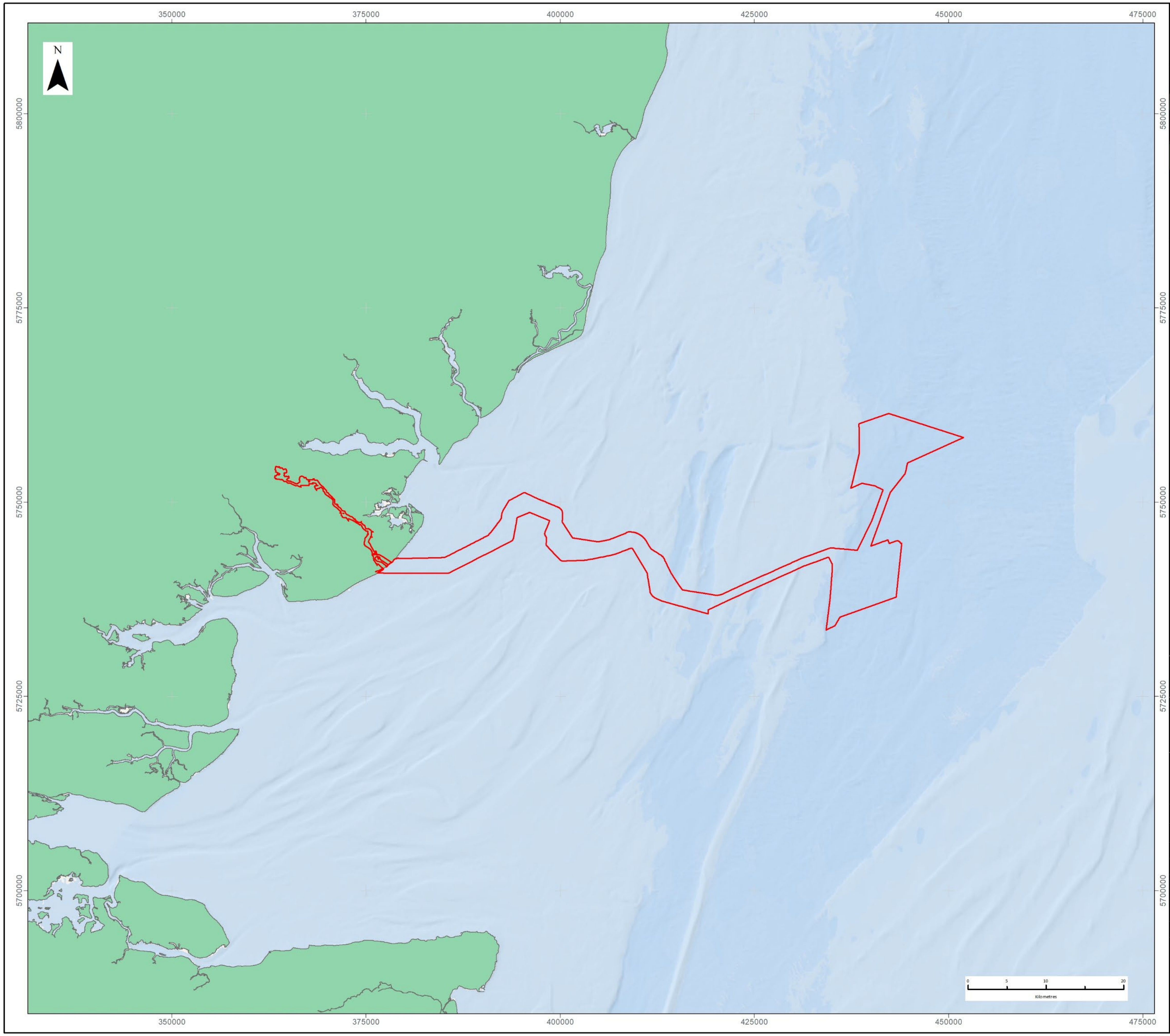
- Up to 79 offshore wind turbine generators (WTGs), associated foundations;
- Up to 200 km of Inter- array cables;
- Up to 2 offshore substation platforms (OSPs); and
- Up to 370 km offshore export cables, each in its own trench within the overall cable corridor.

GRID CONNECTION SCENARIOS

1.2.2 Each of the MDSs presented below in Table 1.24, which describe the construction and maintenance of the export cables are associated with the radial connection approach scenario.

1.2.3 Following VE's involvement with the Offshore Transmission Network Review (OTNR) and the feedback from our last stage of consultation, VE has identified the opportunity to coordinate with the North Falls Offshore Wind Farm project (NF). The primary goal of this coordination is to reduce the potential impact of building the onshore connection to the national electricity transmission network for the two projects.

1.2.4 VE is also considering submitting an application for a DCO that would allow for flexibility to accommodate a coordinated offshore connection at a later date, provided there is greater certainty on the commercial, regulatory and technical environment. The viability of any coordinated connection is dependent on the progress made by the OTNR process and associated regulatory and commercial policy changes and the individual offshore connector projects involved.



LEGEND

Project PEIR Red Line Boundary

Data Source:
Basemap: Esri, Garmin, GEBCO, NOAA NGDC, and other contributors

PROJECT TITLE:

FIVE ESTUARIES OFFSHORE WINDFARM

DRAWING TITLE:

The Five Estuaries Red Line Boundary

VER	DATE	REMARKS	Drawn	Checked
1	21/02/2023	For Issue	SM	MB

DRAWING NUMBER:

1.2

SCALE:	PLOT SIZE:	DATUM:	PROJECTION:
1:500,000	A3	WGS84	UTM31N

FIVE ESTUARIES
OFFSHORE WIND FARM

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1.3 DESIGN ENVELOPE APPROACH

OVERVIEW

1.3.1 At this stage in the VE development process, decisions on exact locations of infrastructure and the precise technologies and construction methods employed cannot be made. Therefore, the project description at this stage is indicative and the design envelope approach (often referred to as the 'Rochdale Envelope') has been used to provide certainty that the final project as built will not exceed these parameters, whilst providing the necessary flexibility to accommodate further project refinement during the detailed design phase post-consent (PINS, 2018). It should be noted that the ECC has been assessed at a width to allow for micro siting around obstacles and other constraints that may be identified in pre-construction surveys, as well as, allowing room for export cables from a proposed third party windfarm project - North Falls.

1.3.2 This flexibility is required in terms of options for foundation types, WTG size, siting of infrastructure and construction methods etc. to ensure that anticipated changes in available technologies between now and the detailed design phase can be accommodated within the design, whilst retaining an Environmental Impact Assessment (EIA) that considers all options, with conclusions that are robust regardless of the final design eventually built out.

1.3.3 The description of the Proposed Development will be refined as the design continues to evolve through the key subsequent stages of the design, consultation and EIA process culminating in the Environmental Statement (ES) that will accompany the DCO Application.

1.3.4 The final project design will depend on factors including ground and environmental conditions that will be subject to detailed pre-construction surveys, project economics and the approach to procurement of resources. This chapter therefore sets out a series of options, all of which are encompassed within the overall design envelope and have been assessed.

POLICY AND LEGISLATIVE CONTEXT

1.3.5 The design envelope approach is recognised in the Overarching National Policy Statement (NPS) for Energy (EN-1) (DECC, 2011a) and the NPS for Renewable Energy Infrastructure (EN-3) (DECC, 2011b). This approach has been used in the majority of offshore wind applications.

1.3.6 In the case of offshore wind, NPS EN-3 (paragraph 2.6.42) recognises that:

'Owing to the complex nature of offshore wind farm development, many details of a proposed scheme may be unknown to the applicant at the time of application, possibly including:

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

1.3.7 NPS EN-3 continues:

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

1.3.8 NPS EN-3 also states that:

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

1.3.9 The design envelope approach is widely recognised and is consistent with the Planning Inspectorate (PINS) Advice Note Nine: Rochdale Envelope (PINS, 2018). Page 11 of that note states that:

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

1.3.10 Throughout the EIA, the design envelope approach has been taken to allow meaningful assessments of VE to proceed, whilst still allowing reasonable flexibility for future project design decisions.

1.3.11 Draft NPS' have also been reviewed and relevant parts incorporated in to the PEIR:

- Draft overarching National Policy Statement for energy (EN-1) (BEIS, 2021a)
- Draft National Policy Statement for renewable energy infrastructure (EN 3) (BEIS, 2021b)
- Draft National Policy Statement for electricity networks infrastructure (EN-5) (BEIS, 2021c)

RELATIONSHIP TO THE MAXIMUM DESIGN SCENARIO

1.3.12 This chapter sets out the full offshore design envelope for VE, however individual impact assessments do not consider all options. Instead, for each impact, the assessment is based upon the scenario which results in the greatest potential for change, sometimes referred to as the 'worst-case' scenario. In the context of VE, this is referred to as the Maximum Design Scenario (MDS) approach.

1.3.13 For example, for the impact of long-term benthic habitat loss the MDS is defined by the scenario resulting in the largest physical interaction with the seabed, which would result from Gravity Based Structure (GBS) foundations. However, for underwater noise impacts on fish and marine mammals, the scenario that would result in the greatest propagation of underwater noise would be from piled foundations. Adopting this approach ensures that the 'worst-case' scenario for each impact is robustly considered, and therefore any other scenario as built would not result in impacts of greater significance of effect than those assessed in the EIA. It also reduces the volume of assessment documentation required to allow a proportionate but robust EIA.

1.3.14 To avoid excessive conservatism in the EIA, the parameters assessed throughout the EIA are not necessarily a combination of the MDS for each component, hence the MDS is chosen on an impact-receptor basis, on a range of eventual build-out scenarios. The details of the MDS for each impact assessed are described in detail within the topic-specific chapters of the PEIR.

1.4 PRE-CONSTRUCTION WORKS

PRE-CONSTRUCTION SURVEYS

1.4.1 Geophysical and geotechnical surveys would be carried out before works commence and the information from those surveys would allow the following to be determined:

- Route debris;
- Boulders;
- Archaeological features;
- Unexploded Ordnance (UXO) presence;
- Seabed features;
- Sediment depth; and
- The specific nature of the seabed to be determined.

1.4.2 Geotechnical and geophysical surveys may comprise survey methods including but not limited to, multibeam sonar, sidescan sonar and sub-bottom profiling. Where required, seabed sediments may be subject to grab sampling for physical and biological analyses. In addition, buoys may be deployed to survey local meteorological conditions.

1.4.3 An analysis of these factors would then inform the final locations of WTGs, the requirement for foundation drilling, installation methods for the final cable route taken, the target cable burial depth, and what (if any) additional cable protection would be required. Additionally, micrositing will be undertaken prior to installation to make minor adjustments to the project layouts to accommodate unexpected on-site conditions encountered in the pre-construction surveys. If identified and required to facilitate the most appropriate final layouts of infrastructure, then any out of service cables will be removed where necessary and possible.

BOULDER CLEARANCE

1.4.4 As described above, geophysical surveys will be undertaken post-consent to inform the need for boulder clearance requirements. Where large volumes of boulders are present, micrositing of cables around these may not be possible. If left in situ, boulders would present the following risks to VE:

- Exposure of cables and/ or not achieving target burial depth for cables;
- Obstruction risk to the cable installation equipment leading to damage and/or delays; and
- Risk of damage to the cable assets themselves.

1.4.5 Boulders may be cleared using a number of methods, depending on the density of boulders encountered. Where boulders are present in high density, a boulder clearance tool, for example, SCAR plough or similar may be employed. In areas of low density, it may be more efficient to use a grab to target and re-locate individual boulders. Typical grab tools may be used such as the Utility Remotely Operated Vehicle (UTROV) tine grab or a clamshell grab. Whilst unlikely, there is the potential that boulders may be removed by the use of a boulder clearance tool and/ or a grab tool at any location in the offshore RLB.

1.4.6 For the purpose of determining a design envelope for boulder clearance, it is assumed 100% of the array cable and offshore export cable lengths will require boulder clearance. The design envelope for boulder clearance is described within the array cable and offshore export cable sections in Table 1.1. The total area of seabed which may be disturbed by boulder clearance is 10,260,000 m^2 (10.26 km^2), however this is expected to be greatly reduced once the results of pre-construction surveys are known.

1.4.7 The overall Construction Programme under Section 1.13, presents the expected timings for construction. This activity is expected to be completed within weeks to months. However, as highlighted under Section 1.13, there are several variables that may affect this. Consequently, it is possible the activity may not be carried out in one single campaign.

Table 1.1: MDS for boulder clearance

Parameter	Design envelope for export cables	Design envelope of inter-array cables	Total
Length of cable route requiring boulder clearance	100%	100%	N/A
Length of cable route requiring boulder clearance (km)	370	200	570
Width of boulder plough/ clearance tool (m)	18	18	N/A
Total area of seabed disturbed by boulder plough/ clearance (m^2)	6,660,000	3,600,000	10,260,000
Total area of seabed disturbed by boulder clearance (km^2)	6.66	3.60	10.26

PRE-LAY GRAPNEL RUN

1.4.8 Following the pre-construction route survey and boulder clearance works, a Pre-Lay Grapnel Run (PLGR) may be undertaken prior to cable installation. A vessel will be mobilised with a series of grapnels, chains, recovery winch and suitable survey spread.

1.4.9 These works will take place within the seabed preparation footprint for subsea cables (Table 1.2). The total area of seabed which may be disturbed by a PLGR is 8.5 km^2.

1.4.10 The overall Construction Programme under Section 1.13, presents the expected timings for construction. This activity is expected to be completed within a few weeks. However, as highlighted under Section 1.13, there are several variables that may affect this. Consequently, it is possible the activity may not be carried out in one single campaign.

Table 1.2: MDS for the use of a PLGR

Parameter	Design envelope for export cables	Design envelope of inter-array cables	Total
Length of cable route requiring PLGR	100%	100%	N/A
Length of cable route requiring PLGR (km)	370	200	570
Width of PLGR (m)	15	15	N/A
Total area of seabed disturbed by PLGR (m^2)	5,550,000	3,000,000	8,550,000
Total area of seabed disturbed by PLGR (km^2)	5.55	3.00	8.55

UNEXPLODED ORDNANCE CLEARANCE

1.4.11 In the offshore wind industry, it is common to encounter UXO originating from World War I and World War II during pre-construction surveys. This poses a health and safety risk where it coincides with the planned locations of infrastructure and vessel activity, and therefore it is necessary to survey for and carefully manage any items of UXO that are discovered.

1.4.12 If found, a risk assessment will be undertaken and items of UXO are either avoided, removed or detonated *in situ*. The methods of UXO clearance considered for VE may include:

- High-order detonation;
- Low-order detonation (deflagration); and
- Removal/ relocation.

1.4.13 As explained above, detailed pre-construction surveys will be completed post-consent to determine the precise nature of the seabed. As the detailed pre-construction surveys have not yet been completed, it is not possible at this time to determine how many items of UXO will require clearance. As a result, a separate Marine Licence will be applied for post-consent for the clearance (if required) of any UXO identified. In order to define the design envelope for consideration of UXO within the EIA, a review of recent information has been undertaken, in conjunction with experience from nearby offshore wind farms (including Galloper and Greater Gabbard).

1.4.14 The overall Construction Programme under Section 1.13, presents the expected timings for construction. This activity is expected to be completed within a few weeks to months. However, as highlighted under Section 1.13, there are several variables that may affect this. Consequently, it is possible the activity may not be carried out in one single campaign.

Table 1.3: MDS for UXO clearance

Parameter	Design Envelope
Expected total number of potential UXO targets	2,000
Expected number of UXO requiring clearance in the pre-construction phase	60
Maximum number of clearance events within 24 hours	2

TRIAL TRENCHING

1.4.15 If required, trial trenching may be undertaken up to two years prior to the commencement of the offshore construction phase. The trial trenching will utilise the same methodology as the installation of export and inter-array cables (see Sections 1.8 and 0 respectively). During trial trenching cables may or may not be installed. Table 1.4 presents the MDS for the proposed trial trenching.

Table 1.4: MDS for trial trenching

Parameter	Design Envelope		
	Export cables	Inter-array cables	Total
Total length of trial trenching (km)	5	5	10
Maximum burial depth (m)	3.5	3.5	N/A
Maximum installation tool seabed disturbance width (jetting) (m)	18	18	N/A
Total area of seabed disturbed by cable installation (m^2)	90,000	90,000	180,000
Total area of seabed disturbed by cable installation (km^2)	0.09	0.09	0.18
Total volume of sediment disturbed by cable installation[1] (m^3)	78,750	78,750	157,500

[1]Assuming a V-shaped trench in which 50% of sediment is fluidised and the remaining 50% re-suspended in the water column

SANDWAVE CLEARANCE

1.4.16 In some areas within the VE array areas and offshore ECC, existing sandwaves and similar bedforms may be required to be cleared or levelled before array and offshore export cables are installed. This is done for two reasons:

- Many of the cable installation tools require a relatively flat surface in order to achieve cable burial to the target depth. It may not be possible to successfully bury a cable on a slope above a critical gradient; and
- The cable must be buried to a depth where it is expected to stay buried throughout the lifetime of the project. Sandwaves are generally mobile features that migrate naturally. Over time, sandwave migration can cause cables to become exposed if they are not sufficiently cleared before cable installation.

1.4.17 Sandwave clearance may be undertaken using the following methodologies:

- Mass flow excavator;
- Boulder clearance plough; and/ or
- Dredging:
  - Water injection dredging;
  - Trailer hopper suction dredger; and/ or
  - Backhoe dredging.

1.4.18 If seabed material is dredged, it will be disposed of in a licensed disposal area within the array areas and/or offshore ECC (see Section 1.9).

1.4.19 The requirements for sandwave clearance will vary along the cable routes. The determination of depths and locations will be made post-consent and be informed by the cable burial risk assessment. However, based on initial geophysical analysis it is predicted the depth of sandwave clearance will vary along the routes between 1 – 10 m. In addition, the width of clearance will vary between 25 m to 700 m based on the features present. However, the maximum areas and volumes will not exceed those presented in Table 1.5.

1.4.20 The overall Construction Programme under Section 1.13, presents the expected timings for construction. There are several variables that may affect this. Consequently, it is possible the activity may not be carried out in one single campaign.

Table 1.5: MDS for sandwave clearance

Parameter	Design envelope for export cables	Design envelope of inter-array cables	Total
Length of cable route requiring sandwave clearance	50%	50%	N/A
Length of cable route requiring sandwave clearance (km)	185	100	285
Illustrative width of sandwave clearance disturbance corridor (m)	70	70	N/A
Indicative depth of sandwave clearance dredging (m)	5	5	N/A
Total area of seabed disturbed by sandwave clearance (m^2)	12,950,000	7,000,000	19,950,000
Total area of seabed disturbed by sandwave clearance (km^2)	13.0	7.0	19.95
Total volume of sediment disturbed by sandwave clearance (m^3)	64,750,000	35,000,000	99,750,000
Maximum volume of material cleared from sandwaves requiring disposal (m^3)	64,750,000	35,000,000	99,750,000

SEABED PREPARATION FOR FOUNDATIONS

1.4.21 Depending on the foundation types chosen for WTGs and OSPs (see Section 0), some form of seabed preparation may be required to provide a clear and level surface for foundation installation, which may include seabed levelling and removing debris.

1.4.22 Some foundations, in particular larger GBS foundations, need to be placed on prepared areas of seabed due to their size. Seabed preparation involves levelling and/or dredging of soft mobile sediments as required, as well as boulder and obstacle removal. It is likely that dredging would be required in the case of GBS foundations. If required, this would be carried out by dredging vessels and the spoil would be deposited on the seabed within a licensed disposal area within the array areas. In some cases, it may be required to place a layer of gravel on the seabed prior to the installation of GBS foundations to provide a clear, level surface.

1.4.23 Table 1.6 presented the maximum design scenario for the greatest area and spoil volume for each of the foundation types considered for VE. Volume 4, Annex 2.1: Physical Processes Technical Assessment provides the equivalent details for each of the foundation types within the full design envelope.

1.4.24 The overall Construction Programme under Section 1.13, presents the expected timings for construction. However, as highlighted under Section 1.13, there are several variables that may affect this. Consequently, it is possible the activity may not be carried out in one single campaign.

Table 1.6: MDS for seabed preparation

Parameter	WTG foundations	OSP foundations	Total
Foundation type	79 x gravity base jacket foundations	2 x gravity base monopile foundation	N/A
Seabed preparation area per foundation (m^2)	3,600	7,000	N/A
Seabed preparation area for all foundations (m^2)	284,400	14,000	298,400
Seabed preparation depth (m)	4	4	N/A
Seabed preparation spoil volume per foundation (m^3)	14,400	28,000	N/A
Seabed preparation spoil volume for all foundations (m3)	1,137,600	56,000	1,193,600
Volume of gravel bed (m^3)[2]	284,400	14,000	298,400

[2] Assuming a gravel bed is required at all foundation locations

1.5 CONSTRUCTION OF STRUCTURES IN THE ARRAY AREAS

1.5.1 The proposed structures in the northern and southern arrays include:

- WTGs; and
- OSPs.

LAYOUTS

1.5.2 Designing and optimising the layout of WTGs and OSPs is a complex, iterative process considering a large number of inputs and constraints, including:

- Site conditions:
  - Wind speed and direction;
  - Water depth;
  - Ground conditions;
  - Environmental constraints (anthropogenic and natural); and
  - Seabed obstructions (wrecks, UXO, existing infrastructure).
- Design considerations:
  - WTG model;
  - WTG wake losses;
  - Regulatory requirements;
  - Installation set-up;
  - Foundation design;
  - Electrical design; and
  - O&M requirements.

1.5.3 The VE layout will have spacing between adjacent structures as presented in Table 1.7. The same minimum spacing will be applied in both the northern and southern arrays. The final layout may use dense borders (perimeter weighed) but will not breach the minimum spacing distance. In order to inform the EIA process, the Applicant has identified MDS layouts on a topic-specific basis where required (for example for Seascape, Landscape and Visual Impact Assessment). Further information on the guiding principles governing the wind farm layout is provided within Volume 7, Report 6: Navigation Risk Assessment.

1.5.4 It is important to note that **these layouts are indicative for the purposes of assessment and do not represent the final layout design**, which is subject to the considerations in the bullets above. The final positions of WTGs could be located anywhere within the consented array boundaries (Figure 1.2), but the layout will follow a series of principles and will be subject to agreement with the relevant stakeholders. The final WTG and OSP locations will be confirmed post-consent in the detailed design phase.

1.5.5 The minimum spacing of structures within the array boundaries is presented in Table 1.7.

1.5.6 As per statutory guidance requirements, a setback of at least one nautical mile (measured tip-to-tip) will be maintained from the neighbouring Galloper OWF for both array areas, assuming the array layouts do not align. This will allow a search and rescue asset to safely exit one array without entering the other.

Table 1.7: Minimum spacing for structures in the northern and southern arrays

Structure	Minimum spacing (m)
WTGs	830
OSPs	450

WIND TURBINE GENERATORS

OVERVIEW

1.5.7 The WTGs convert wind energy to electricity. Key components include rotor blades, gearboxes (in some cases), transformers, power electronics and control equipment. Offshore turbine models are continuously evolving and improving; therefore the exact wind turbine model will be selected post-consent from the range of models available at the point of procurement. The wind turbines will be permanently attached to the seabed with foundation structures (see Section 0). The WTGs will be distributed between both the northern and southern arrays (see Figure 1.2).

1.5.8 Up to 41 large, or up to 79 smaller WTGs are planned for VE. A range of WTG models will be considered; however, they are all likely to follow the traditional WTG design with three blades and a horizontal rotor axis.

1.5.9 The blades are connected to a central hub, forming a rotor which turns a shaft connected to a generator and gearbox (if required). The generator and gearbox are located within a containing structure known as the nacelle, atop the WTG tower. The nacelle is supported by the tower structure which is affixed to the foundation at its base. The nacelle is able to rotate or 'yaw' in order to face the oncoming wind direction.

1.5.10 WTGs operate within a set wind speed range and have a minimum wind speed at which they start generating electricity, and a maximum wind speed at which the WTG becomes unsafe to operate and shuts down. Developments in technology are increasing the range of wind speeds at which WTGs can operate, enabling a gradual ramp up and ramp down of output to support operation of the National Grid.

1.5.11 Each WTG will have a minimum clearance between sea level and the minimum blade tip height at the bottom of the rotor. The rotor diameter will vary depending on the chosen design. An example of a WTG is illustrated in Figure 1.3 and the design envelope for WTGs is described in Table 1.8.

Table 1.8: Design envelope for WTGs

Parameter	Design Envelope	
	Small WTG	Large WTG
Number of WTGs	79	41
Minimum blade tip height above MHWS (m)	28	28
Maximum blade tip height above MHWS (m)	320	420
Maximum blade tip height above LAT (m)	324	424
Rotor diameter (m)	260	360

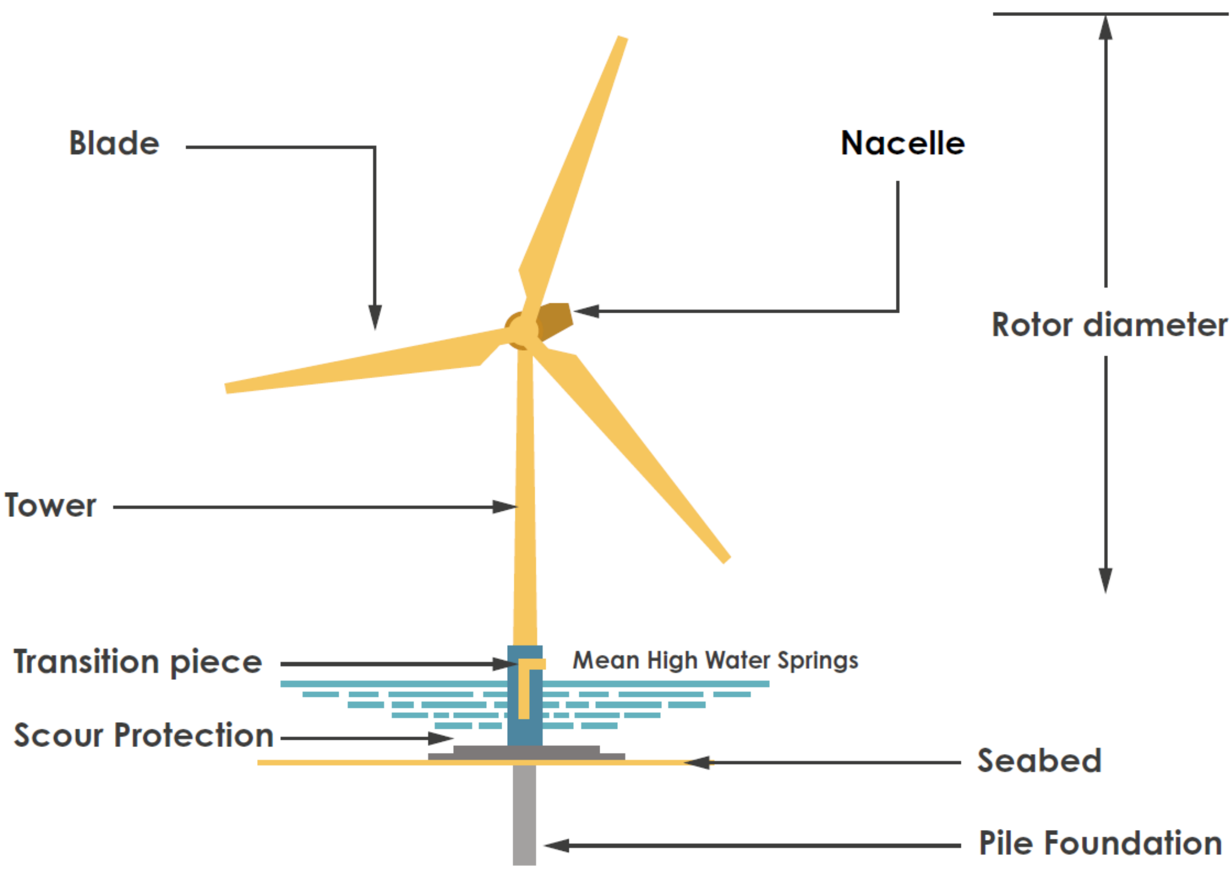


Figure 1.3: Diagram of an offshore WTG

SCENARIOS

1.5.12 As described above, the Applicant requires flexibility in WTG choice to ensure that anticipated changes in available technology and project economics can be accommodated within the project design. The design envelope therefore sets a maximum and, where relevant, a minimum realistic worst-case scenario against which environmental effects can be assessed.

1.5.13 The electrical output (capacity in megawatts (MW)) of the wind farm and that of individual turbines is not considered a material factor in determining the MDS for environmental assessments. Rather, it is the physical dimensions such as tip height, rotor diameter and seabed footprint of WTGs that have meaningful implications for EIA. It is therefore not considered necessary to constrain the design envelope to a particular capacity and as such this is not referred to within the PEIR. In recent years, the capacity of WTGs has become more flexible and may differ depending on the conditions of the site. Improvements in efficiency can also be made without alterations to physical dimensions.

1.5.14 However, for the purposes of defining the MDS, it is necessary to consider likely scenarios that could eventually be built out, based on realistic eventualities, in order that the MDS values can be determined. For VE, two indicative WTG scenarios are considered:

- **Large WTGs –** The largest WTGs within the design envelope. For the purposes of assessment this is assumed to be up to 41 of the largest possible WTGs with a Rotor Diameter (RD) of up to 360 m.; and
- **Small WTGs –** The greatest number of WTGs within the design envelope. For the purposes of this assessment is assumed to be up to 79 smaller WTGs with a RD of up to 260 m.

1.5.15 When WTG parameters are discussed, this chapter presents the MDS for both these scenarios, which have been chosen to represent the realistic worst-case impacts resulting from either the greatest number of smaller WTGs, or the largest WTGs spaced further apart and therefore fewer in number.

1.5.16 In line with the design envelope approach, the eventual built-out scenario may differ from these scenarios but in any event will not be permitted to exceed the MDS assessed. Therefore, confidence can be had that resulting environmental effects will not exceed the worst-case assumptions of the EIA.

INSTALLATION

1.5.17 In general, WTGs are installed via the following process:

- WTG components are picked up from a suitable port facility; most likely in the UK or Europe either by an installation vessel or transport barge. Installation vessels are typically Jack-up vessels (JUVs) or Dynamic Positioning (DP) vessels to ensure a stable platform for installation works when on site. A JUV would also use DP for positioning but would deploy legs during installation. Generally, blades, nacelles and towers for a number of WTGs are loaded separately onto the vessel;
- Typically, as much pre-assembly is completed as can be carried out ahead of transit to site, to ease the installation process. The components will then transit to the wind farm array area and will be lifted onto the pre-installed foundation or transition piece by the crane on the installation vessel. Each WTG will be

assembled at site in this way with technicians fastening components together as they are lifted into place. The exact methodology for the assembly is dependent on WTG type and installation contractor and will be defined in the pre-construction phase post-consent; and

- Alternatively, the WTG components may be loaded onto barges or dedicated transport vessels at port and installed as above by an installation vessel that remains on site throughout the installation campaign.

1.5.18 For the EIA process, assumptions are made on the maximum number of vessels, and the number of return trips to and from site required for the WTG installation campaign (see Section 1.17).

ACCESS

1.5.19 The WTGs can be accessed from a vessel via a boat landing and ladder on the foundation, via a stabilised gangway directly from a vessel, or from a helicopter via a heli-hoist platform on top of the nacelle.

OILS AND FLUIDS

1.5.20 Each WTG will contain components that require lubricating oils, hydraulic fluids and coolants for operation. Indicative maximum requirements for these fluids are described in Table 1.9. All oils and fluids will be contained within the WTG in case of a spill.

Table 1.9: Design envelope for oils and fluids for WTGs

Parameter	Design Envelope	
	Per Small WTG	Per Large WTG
Grease (l)	898	1,736
Hydraulic oil (l)	1,696	3,278
Gear oil (l)	3,330	6,437
Nitrogen (l)	,728	210,207
Transformer silicon/ ester oil (l/ kg)	20,000	20,000
Diesel fuel (l)	1,000	1,000
Sulphur hexafluoride (SF6) kg)	180	180
Glycol/ coolant (l)	23,541	45,513
Batteries (kg)	2,700	4,100

CONTROL SYSTEMS

1.5.21 Each WTG has its own control system to carry out functions like yaw control and ramp down in high wind speeds. All the WTGs are also connected to a central Supervisory Control and Data Acquisition (SCADA) system for the control of the wind farm remotely. This allows functions such as remote shut down. The SCADA system will communicate with the wind farm via fibreoptic cables (embedded within the electrical transmission cabling), radio/microwave or satellite links. Individual WTGs can also be controlled manually from control systems within the nacelle or tower base.

1.5.22 WTGs may have temporary diesel generators for commissioning and O&M activities, as well as back-up power supply for activities such as crane operation, lighting, ventilation etc.

OFFSHORE SUBSTATION PLATFORMS

1.5.23 OSPs are offshore structures housing electrical equipment to provide a range of functions, such as changing the voltage (transformer), current type (converter) or power factor (booster). The OSPs at VE will be the transformer type to step-up the voltage for transmission to shore. The exact locations of OSPs will be determined during the detailed design phase post-consent, taking account of ground conditions and the most efficient cable routeing design. It is assumed that there will be one OSP per array area. The OSP would not be permanently manned but once functional would be subject to periodic O&M visits by staff via boat or helicopter.

1.5.24 The OSP topside unit is prefabricated in the form of a multi-level structure that is lowered and mounted on a foundation. The foundation options for OSPs are described in Section 0. Like WTGs, the OSPs will have diesel generators for commissioning and O&M activities such as crane operation, lighting and ventilation.

1.5.25 An example of an OSP is illustrated in Figure 1.4 and the design envelope for OSPs is described in Table 1.10.

Table 1.10: Design envelope for OSPs

Parameter	Design Envelope
Number of OSPs	2
Topside dimensions (m)	125 x 100
Topside height above LAT (excluding stowed crane, helideck and mast) (m)	105
Topside height above LAT (including stowed crane, helideck and mast)	195
Maximum unstowed crane height above LAT (m)	195
Maximum HVAC system voltage (primary) (kV)	400
Maximum HVAC system voltage (secondary) (kV)	132

Figure 1.4: Example of an OSP

INSTALLATION

1.5.26 OSPs are generally installed in two phases, the first phase will be to install the foundation for the structure using an installation vessel as described in Section 1.17. Secondly, an installation vessel (same or different from the one installing the foundation) will be used to lift the topside from a transport barge/ vessel onto the pre-installed foundation structure. The design envelope for the OSP is described in Table 1.10. The vessel requirements for this process are also described in Section 1.17.

ACCESS

1.5.27 The OSPs may be accessed either from a vessel via a boat landing and ladder on the foundation, via a stabilised gangway directly from a vessel, or from a helicopter via a heli-hoist platform on top of the OSP.

OILS AND FLUIDS

1.5.28 Each OSP will contain components that require lubricating oils, hydraulic fluids and coolants for operation. Indicative maximum requirements for these fluids are described in Table 1.11. All oils and fluids will be contained within the OSPs in case of a spill.

Table 1.11: Design envelope for oils and fluids per OSP

Parameter	Design Envelope
Grease (l)	Minimal
Hydraulic oil (l)	3,000
Gear oil (l)	1,000
Nitrogen (l)	Minimal
Transformer silicon/ ester oil (l/kg)	340,000
Diesel fuel (l)	120,000
Sulphur hexafluoride (SF6) kg)	10,000
Glycol/ coolant (l)	90,000
Batteries (kg)	350,000
Grey water (l)	5,000
Black water (l)	3,000

AIDS TO NAVIGATION, COLOUR, LIGHTING AND MARKING

1.5.29 The wind farm will be designed and constructed to satisfy the requirements of the CAA, Maritime and Coastguard Agency (MCA) and Trinity House Lighthouse Service (THLS) in respect of aids to navigation, lighting and marking. Table 1.12 below describes the aviation and navigation lighting requirements for all VE structures.

1.5.30 All fixed bottom structures will have low level lighting directed onto Identification ID marker boards.

1.5.31 Further information on aids to navigation, marking and lighting can be found in Volume 2: Chapter 9: Shipping and Navigation and Volume 2, Chapter 13: Aviation and Radar. Post-consent, lighting and marking will be specifically developed within a Lighting and Marking Strategy.

1.5.32 The colour scheme for the blades, nacelles and towers is generally light grey, whilst foundation steelwork is generally traffic light yellow from Highest Astronomical Tide (HAT) up to the aids to navigation or a height as directed by THLS.

1.5.33 Where agreed with THLS, buoys may be used to delineate the array areas and remain in place throughout the construction phase.

Table 1.12: Design envelope for lighting requirements

Parameter	Design Envelope WTGs	Design Envelope OSP
Aviation lighting (cd)	Up to 2000	N/A
Navigation lighting (nominal range (nm))	Significant Peripheral Structure (SPS): 5 Intermediate Peripheral Structure (IPS): 2	N/A
Heli-hoist lighting (OSPs only)	Low intensity green light (200 cd) at the heli-hoist platform. Lighting will only be activated when a structure is being prepared for helicopter approach.	
ID marker board lighting	Typically low level baffled (5 – 10 cd/m^2) lighting directed towards the ID marker board. Located on the foundation body or Main Access Platform (MAP).	
Workplace lighting	Illumination levels for external areas will typically be 50 lux located at the foundation level of structures, providing illumination for the access ladder, resting platforms and MAP. Workplace lighting will only be activated during the O&M phase when a structure is infrequently manned for maintenance activities.	

1.6 CONSTRUCTION OF FOUNDATIONS IN THE ARRAY AREAS

OVERVIEW

1.6.1 The WTGs and OSPs are secured to the seabed via foundation structures. There are a number of foundation types that can be used, and the final type will not be confirmed until the detailed design phase post-consent.

1.6.2 The foundations will be fabricated offsite, stored at a suitable port facility and transported to site as needed. The foundations, wind turbines and OSPs, are likely to be installed using specialist installation vessels using either JUVs, anchors or DP technology.

1.6.3 There are a number of foundation types that are being considered for VE, the factors influencing the choice of foundation for a specific project include the type of wind turbine to be used, the nature of the ground conditions on the site, the water depth and sea conditions (i.e. prevailing wave and current climate), as well as supply chain constraints. The foundation type selected in the final design for the WTGs and OSP will be dependent upon the final site investigations (undertaken post consent) and project procurement processes.

1.6.4 Table 1.13 describes which foundation options are considered within the design envelope for VE. A description of each foundation type is provided below. Further detail on the maximum design parameters for the different foundation options is provided in Volume 4, Annex 1-1.

1.6.5 The overall Construction Programme under Section 1.13, presents the expected timings for construction However, as highlighted under Section 1.13, there are several variables that may affect this. Consequently, it is possible the activity may not be carried out in one single campaign.

Table 1.13: Foundation options considered for VE

Foundation type	WTG	OSP
Monopile	✓	✓
Multi-leg pin-piled jacket	✓	✓
Mono suction caisson	✓	✗
Multi-leg suction caisson jacket	✓	✓
Monopile GBS	✓	✓
Multi-leg GBS jacket	✓	✓

PILED FOUNDATIONS

FOUNDATIONS

1.6.6 Monopile foundations typically consist of a single tubular section, consisting of a number of rolled steel plates welded together, which is driven into the seabed, usually via impact or vibro-piling. A Transition Piece (TP) may be fitted over the monopile and secured via bolts or grout. The TP may feature a boat landing, ladders, a small crane and other ancillary components as well as a flange for connection to the WTG tower. The TP is typically painted yellow and marked according to the relevant regulatory guidance and may be installed at a separate time to the monopile itself. An example of a monopile foundation is illustrated in Figure 1.5 and the design envelope for this foundation type is described in Table 1.14.

1.6.7 Monopiles and transition pieces will be transported to site either on the installation vessel itself or on feeder barges as described in Section 0. Once on site, the monopiles will typically be installed using the following process:

- The monopile is lifted into the pile gripper on the side of the installation vessel;
- The hammer (see paragraph 1.6.16 *et seq.*) is lifted onto the monopile;
- The monopile is driven into the seabed until the required embedment depth is achieved;
- In the event of pile refusal, relief drilling may be necessary to embed the pile to the required depth;
- The TP is lifted onto the monopile; and
- The TP is secured using bolts or grout.

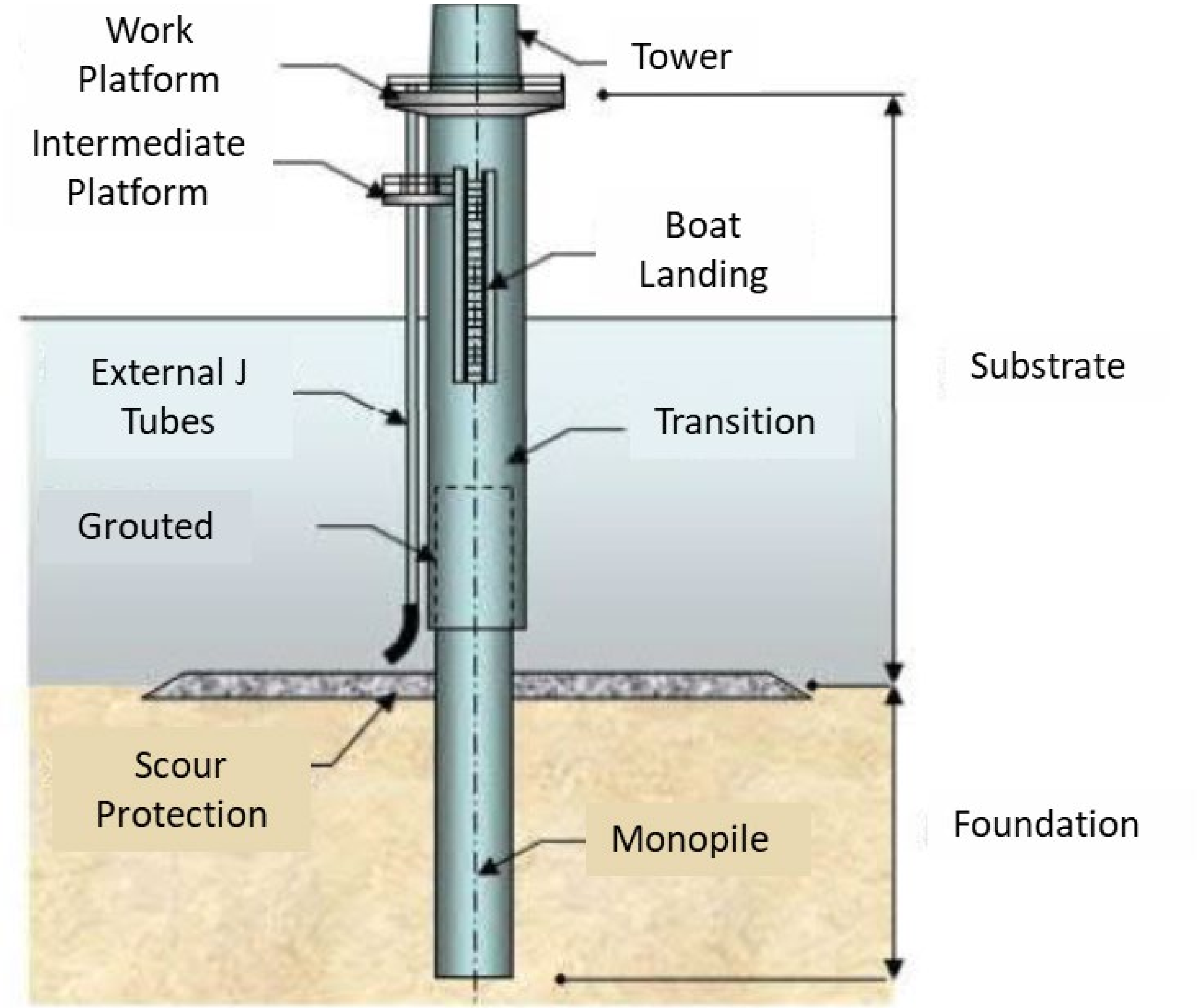


Figure 1.5: Monopile foundation with transitional piece

1.6.8 Seabed preparation for monopiles is usually minimal and may not be required at all. If pre-construction surveys show no presence of boulders or other seabed obstructions at foundation locations. If obstructions are present and the foundation cannot be microsited to avoid the obstruction, these obstructions may be removed (as described in Section 1.4).

1.6.9 As an alternative to a single monopile, the OSP may be installed on a jacket foundation with up to six smaller diameter monopiles up to 8 m in diameter.

1.6.10 As presented in Table 1.14, monopile diameter for small WTG is expected to be 13 m above Mean Sea Level (MSL). It should be noted that monopile diameter is expected to be 15 m below MSL for both large and small WTG.

1.6.11 Further details of the design envelope for monopile foundations is presented in the design envelope for drilling spoil volumes, provided in Volume 4, Annex 1-1.

Table 1.14: Design envelope for monopiles

Parameter	Design Envelope		
	Large WTG	Small WTG	OSP
Number of monopiles	41	79	2
Diameter (m)	15	13	15
Typical embedment depth (m)	68	68	68

MULTI-LEG PIN-PILED JACKET FOUNDATIONS

1.6.12 Multi-leg pin-piled jacket foundations are formed of a steel lattice construction comprising tubular steel supports and welded joints. These are secured to the seabed by steel pin-piles that are similar in construction to monopiles (though typically smaller in diameter) attached to the jacket feet. Unlike monopiles, there is no need for a separate TP, since the TP and ancillary structure is typically fabricated as an integral part of the jacket. An example of a multi-leg pin-piled jacket foundation is illustrated in Figure 1.6 and the design envelope for this foundation type is described in Table 1.15.

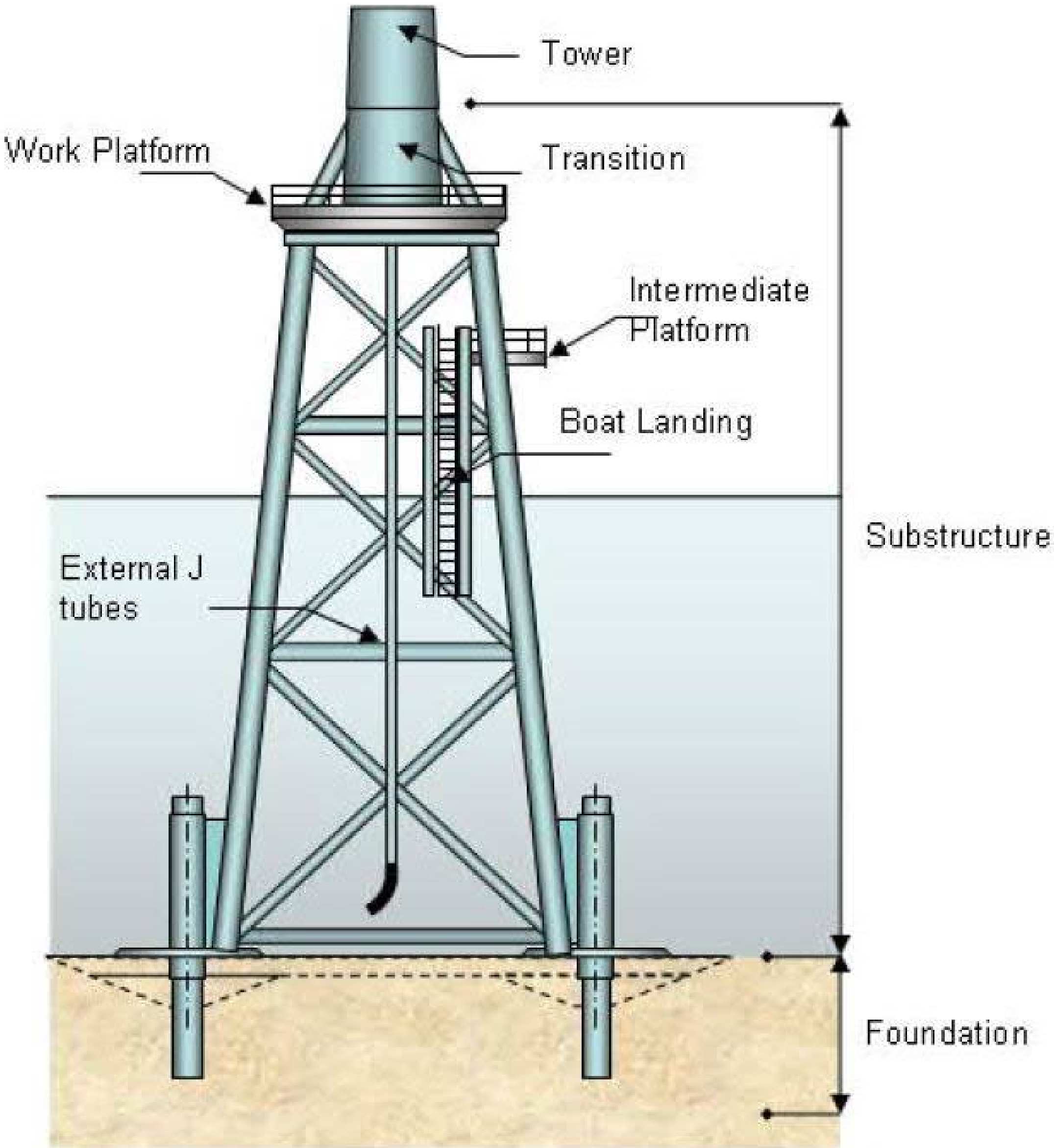


Figure 1.6: Wind turbines on multi-leg jacket foundations

1.6.13 The installation sequence will be similar to that of monopiles (paragraph 1.6.7 *et seq.*), with the structures transported to site by installation vessels or feeder barges, where they will be lowered onto the seabed. The pin-piles can either be installed before or after the jacket is lowered to the seabed. If before, a piling template is typically lowered onto the seabed to guide the pin-piles to the exact required locations. The piles are then installed through the template, which itself is then recovered to the installation vessel, and subsequently the jacket is fixed atop the pin-piles by grout or other means such as welding. Alternatively, the need for a piling template can be negated by installing the pin-piles after the jacket has been placed on the seabed.

1.6.14 As jacket foundations typically have a larger seabed footprint compared to monopiles, some degree of seabed preparation is usually necessary to clear obstacles and provide a level surface for jacket installation (see Section 1.4).

Table 1.15: Design envelope for multi-leg pin-piled jackets

Parameter	Design Envelope		
	Large WTG	Small WTG	OSP
Number of jacket foundations	41	79	2
Number of legs per foundation	4	4	6
Pin-piles per leg	1	1	2
Total pin-piles	164	316	24
Pin-pile diameter (m)	3.5	3.5	3.5
Typical pin-pile embedment depth (m)	60	60	60
Maximum separation of adjacent legs at seabed level (m)	45	45	60 x 100
Maximum separation of adjacent legs at sea level (LAT) (m)	35	35	50 x 90

FOUNDATION IMPACT PILING

1.6.15 Piled foundations are anchored to the seabed via tubular piles driven into the seabed to the required depth, usually by impact piling, but may also be vibro-piled or drilled, or a combination.

1.6.16 The most common method of installing driven piles is to use a percussive hammer. Impact piling is presented as the basis for the design envelope, however alternative piling methods such as vibro-piling, Blue Piling or HiLo Impact may also be considered as technologies that reduce the source level of underwater noise compared to impact piling. The suitability of such technologies would be informed by pre-construction surveys post-consent.

1.6.17 For impact piling, the hammer would use a maximum energy of 7,000 kJ for monopiles and 3,000 kJ for pin-piles. Piling for both scenarios would include the use of a soft start at 15% of the maximum hammer energy, followed by a ‘ramp up’ to the required hammer energy (Volume 7: Report 2: Schedule of Mitigation). The maximum duration for monopiles and pin-piles is 7.5 and 4 hours respectively.

1.6.18 The maximum soft start and ramp up scenarios are described in Table 1.16 below and have been modelled as detailed within Volume 4, Annex 6.1: Subsea Noise Technical Report.

1.6.19 The piling campaign is anticipated to be undertaken within 12 months for both array areas. Both simultaneous (up to two foundations being piled at once) and consecutive piling (being piled one after another) are proposed.

Table 1.16: Piling scenarios

Parameter	Soft Start	Ramp up				Max
Monopile						
Hammer energy (kJ)	1,050	1,400	2,800	4,200	5,600	7,000
Strikes	100	100	100	100	100	14,280
Duration (s)	600	300	300	300	300	25,200
Strike rate (strikes per minute)	10	20	20	20	20	34
Pin-pile						
Hammer energy (kJ)	450	600	1,200	1,800	2,400	3,000
Strikes	100	100	100	100	100	8,100
Duration (s)	600	300	300	300	300	14,580
Strike rate (strikes per minute)	10	20	20	20	20	33

DRILLING

1.6.20 If piling is not possible due to the presence of rock or hard ground conditions, the material inside the pile may be drilled out to facilitate driving the pile to its required embedment depth. This can be done either in advance of piling, or if the embedment rate slows significantly during piling (such as in the event of pile refusal).

1.6.21 Various drilling methodologies are possible, but drills are typically lifted by crane into a part-installed pile, ride inside the pile during drilling, and are removed in the event driving recommences. Drills may only bore out to a diameter equal to the internal diameter of the pile, or they may be capable of expanding their cutting disk below the tip of the pile and boring out to the pile's maximum outer diameter or greater (known as under-reaming).

1.6.22 Drilling systems are available in sizes ranging from those required for small jacket pin piles, to large diameter monopiles. Seawater is continuously pumped into the drill area and any drill arisings generated are flushed out and allowed to disperse at the surface, falling to the seabed in the vicinity of the pile.

1.6.23 It may be necessary to adopt a drive-drill-drive sequence depending on ground conditions. Other similar sequences of drilling and driving are also possible. The design envelope for drilling scenarios is described for the piled solutions above. In the case of piled jacket foundations, drilling may take place at the same time as piling or drilling at an adjacent jacket leg.

1.6.24 The design envelope for drilling spoil volumes is provided in Volume 4, Annex 1-1. The maximum design for drilling spoil is presented in Table 1.17.

Table 1.17: Maximum design parameters for drilling

Parameter	WTG foundations	OSP foundations	Total
Foundation type	79 x monopiles	2 x monopile	N/A
Drilling spoil volume for all foundations (m^3)	540,084	27,346	567,430

CAISSON FOUNDATIONS

MONO SUCTION CAISSON FOUNDATIONS

1.6.25 A mono suction caisson foundation is similar in construction to a monopile but consists of a single suction caisson at its base supporting a single monopile structure. An example of a mono suction caisson foundation is illustrated in Figure 1.7, and the design envelope for this foundation type is described in Table 1.18.

Table 1.18: Design envelope for mono suction caisson foundations

Parameter	Design Envelope	
	Large WTG	Small WTG
Number of foundations	41	79
Suction caisson diameter (m)	40	40
Monopile diameter at sea surface (MSL) (m)	15	13
Typical suction caisson penetration depth (m)	25	25
Height of suction caisson above seabed level (m)	8	8

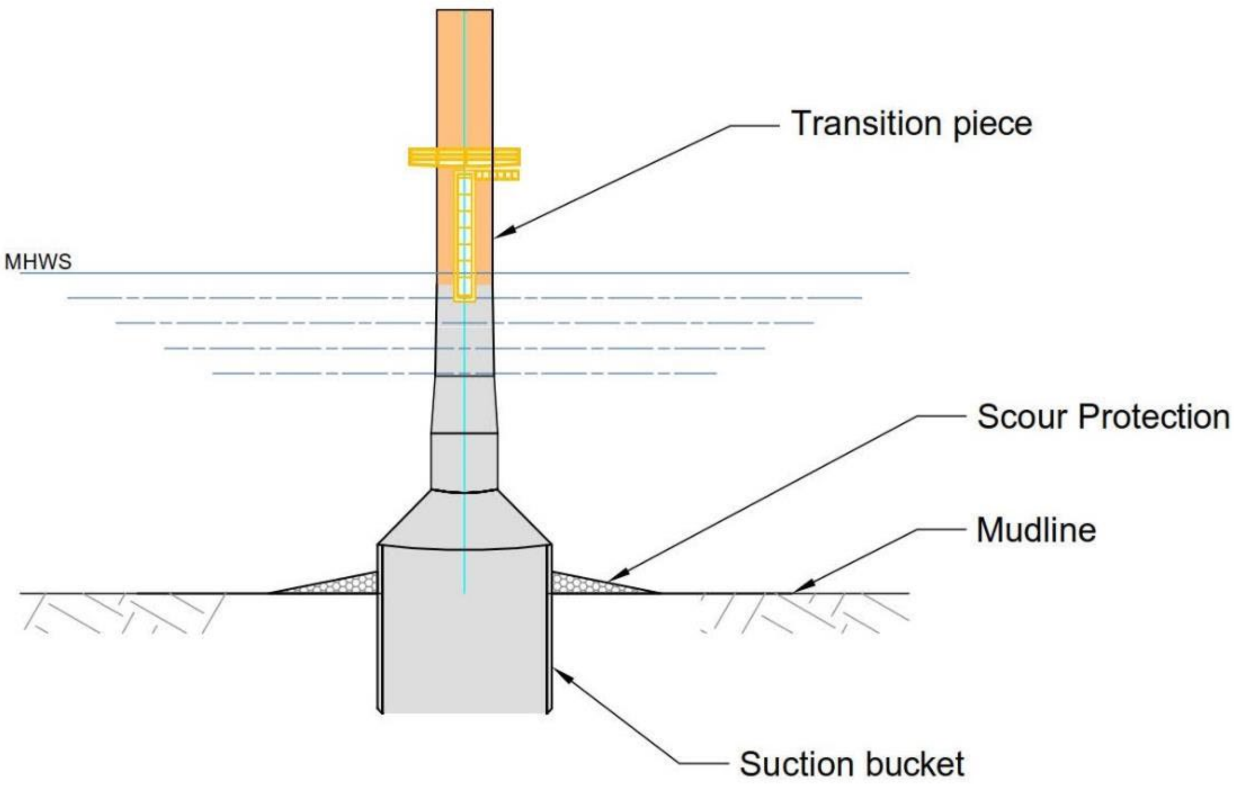


Figure 1.7: Mono-suction caisson foundations

MULTI-LEG SUCTION CAISSON JACKET FOUNDATIONS

1.6.26 Multi-leg suction caisson jacket foundations are similar in construction to a multi-leg pin-piled jacket foundation consisting of a steel lattice structure (paragraph 1.6.12 *et seq.*) but are secured to the seabed via three or more suction caissons, rather than pin-piles. An example of a multi-leg suction caisson foundation is illustrated in Figure 1.8, and the design envelope for this foundation type is described in Table 1.19.

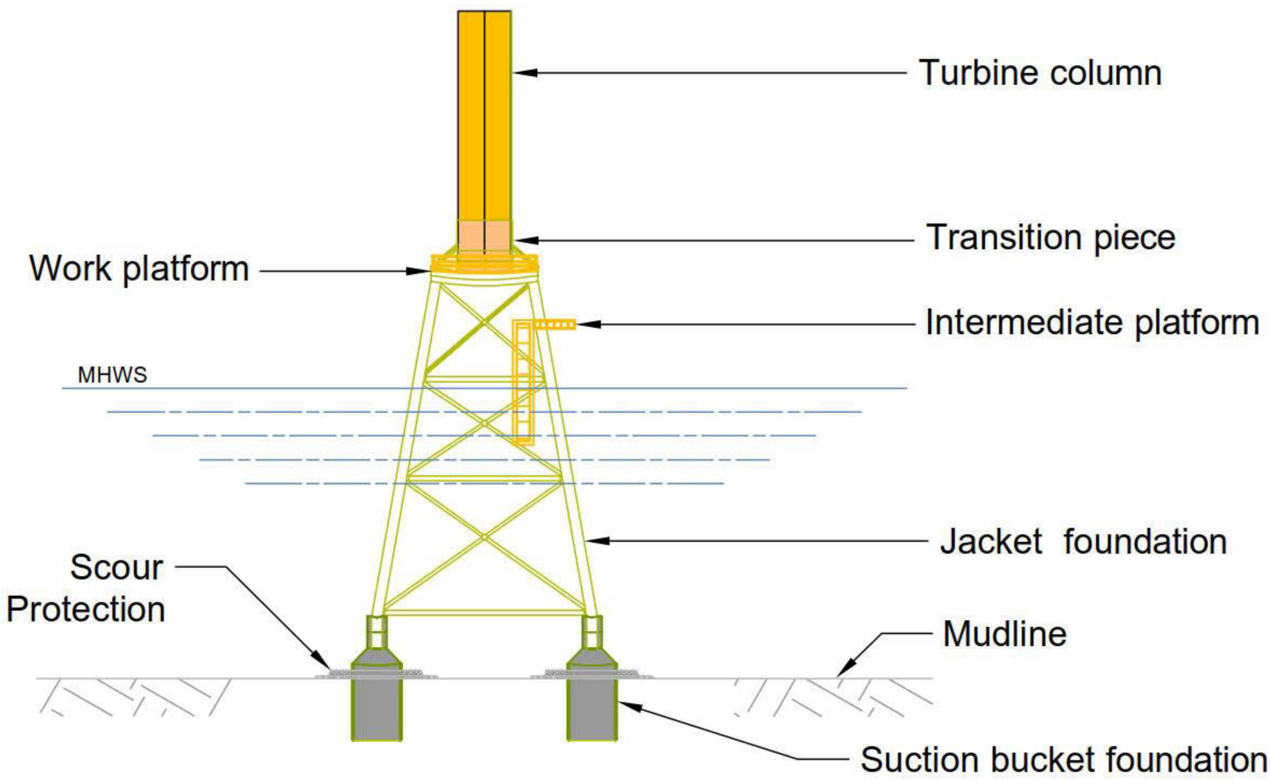


Figure 1.8: A multi-leg suction caisson jacket foundation

Table 1.19: Design envelope for multi-leg suction caisson jacket foundations

Parameter	Design Envelope	
	Large WTG	Small WTG
Number of foundations	41	79
Number of buckets per foundation	4	4
Suction caisson diameter per leg (m)	20	20
Typical suction caisson penetration depth (m)	25	25
Height of suction caisson above seabed level (m)	5	5
Separation of adjacent legs at seabed level (m)	40	40
Separation of adjacent legs at sea level (LAT) (m)	30	30

GRAVITY BASE SYSTEM FOUNDATIONS

1.6.27 GBS foundations are heavy steel and/or concrete structures, sometimes incorporating additional ballast material, that sit on the seabed. GBS foundations vary in shape but are normally significantly wider at the seabed level to provide support and stability to the structure. Generally, these then taper to a smaller width at the sea surface level. GBS foundations also often include skirts that embed into the seabed under the weight of the structure to improve the natural stability and scour resistance of the foundation.

1.6.28 GBS foundations do not require percussive piling and are not attached directly to the seabed. Instead, they rely on their sheer weight to provide stability to the structure above. GBS foundations are typically hollow and can be floated to site before being filled with ballast to sink the foundation to its required position.

1.6.29 GBS foundations in particular can require significant seabed preparation in order to provide a clear and level surface for installation (Section 1.4). In some cases, a layer of gravel may also be laid on the seabed to provide this level surface.

MONO GRAVITY BASE SYSTEM FOUNDATIONS

1.6.30 Mono GBS foundations consist of a single GBS structure supporting a monopile structure, similar in appearance to a mono suction caisson, with a significantly wider base. An example of a mono GBS foundation is illustrated in Figure 1.9, and the design envelope for this foundation type is described in Table 1.20.

Table 1.20: Design envelope for mono GBS foundations

Parameter	Design Envelope		
	Large WTG	Small WTG	OSP
Number of jacket foundations	41	79	2
GBS base diameter (m)	55	55	55
Shaft diameter at sea surface (MSL) (m)	15	15	15
Maximum height of base above the seabed (m) (will taper down above this height)	8	8	8
Gravel bed requirements			
Area of gravel bed (m^2) per foundation	2,827	2,827	7,000
Thickness of gravel bed (m)	1	1	1
Volume of gravel bed per foundation (m^3)	2,827	2,827	7,000
Total area of gravel bed required (m^2)	115,907	223,333	14,000
Total volume of gravel bed required (m^3)	115,907	223,333	14,000

Parameter	Design Envelope		
	Large WTG	Small WTG	OSP
Surface area			
Surface area of water facing structure per foundation (m^2)	5,450	5,450	6,700
Total surface area of water facing structure (m^2)	223,450	430,550	13,400

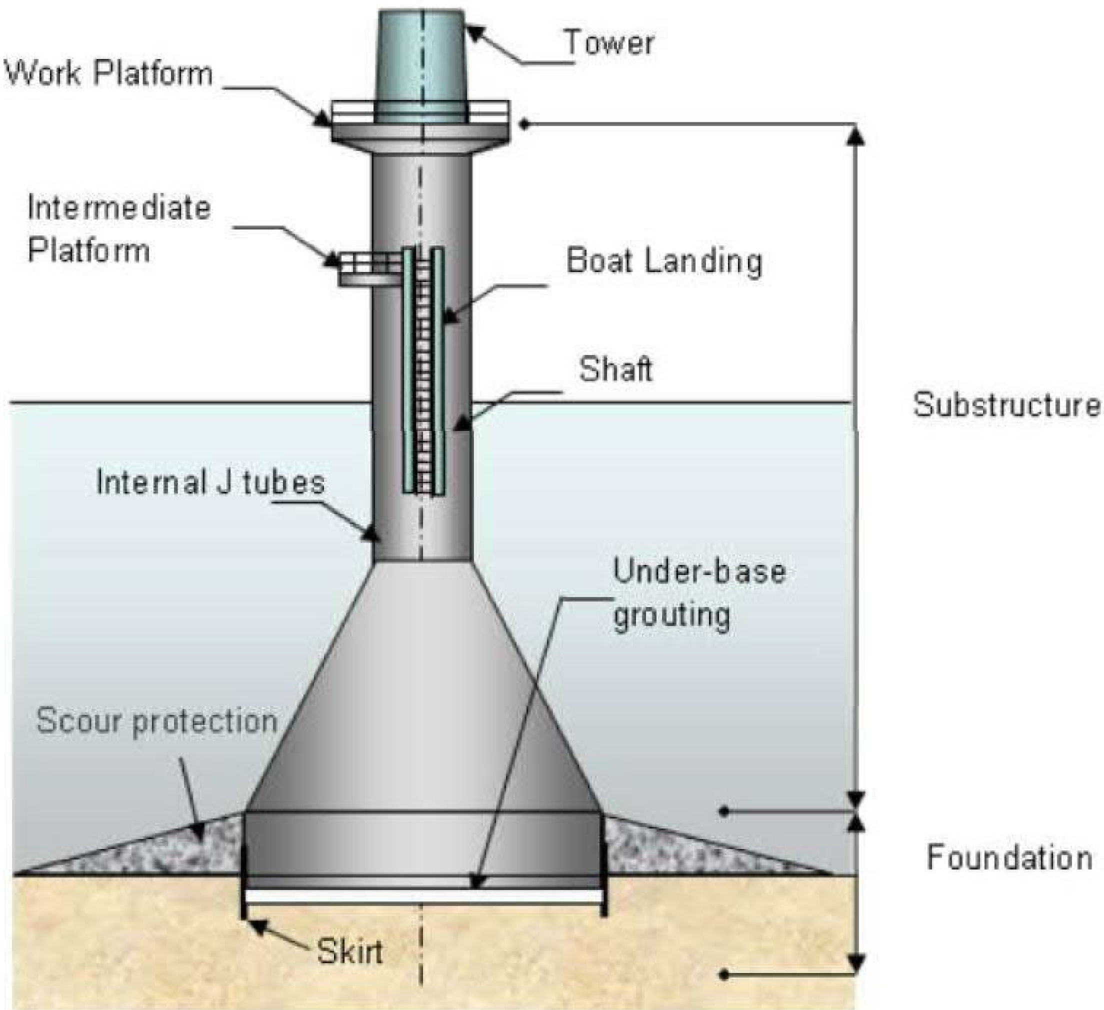


Figure 1.9: A mono GBS foundation

MULTI-LEG GRAVITY BASE SYSTEM JACKET FOUNDATIONS

1.6.31 Multi-leg GBS foundations are similar in appearance to multi-leg suction caisson foundations, but with multiple GBS structures at the base of the legs rather than suction caissons. An example of a multi-leg GBS foundation is illustrated in Figure 1.10, and the design envelope for this foundation type is described in Table 1.21.

Table 1.21: Design envelope for multi-leg GBS foundations

Parameter	Design Envelope	
	Large WTG	**Small WTG**
Number of jacket foundations	41	79
Separation of adjacent legs at seabed level (m)	45	45
Separation of adjacent legs at sea level (LAT) (m)	35	35
Number of bases per foundation	4	4
GBS diameter (m)	20	20
Height of GBS above seabed level (m)	8	8
Gravel bed requirements		
Area of gravel bed (m^2) per foundation (the maximum area assumes a single base rather than up to four separate bases per WTG)	3,600	3,600
Thickness of gravel bed (m)	1	1
Volume of gravel bed per foundation (m^3) (the maximum area assumes a single base rather than up to four separate bases per WTG)	3,600	3,600
Total area of gravel bed required (m^2)	147,600	284,400
Total volume of gravel bed required (m^3)	147,600	284,400

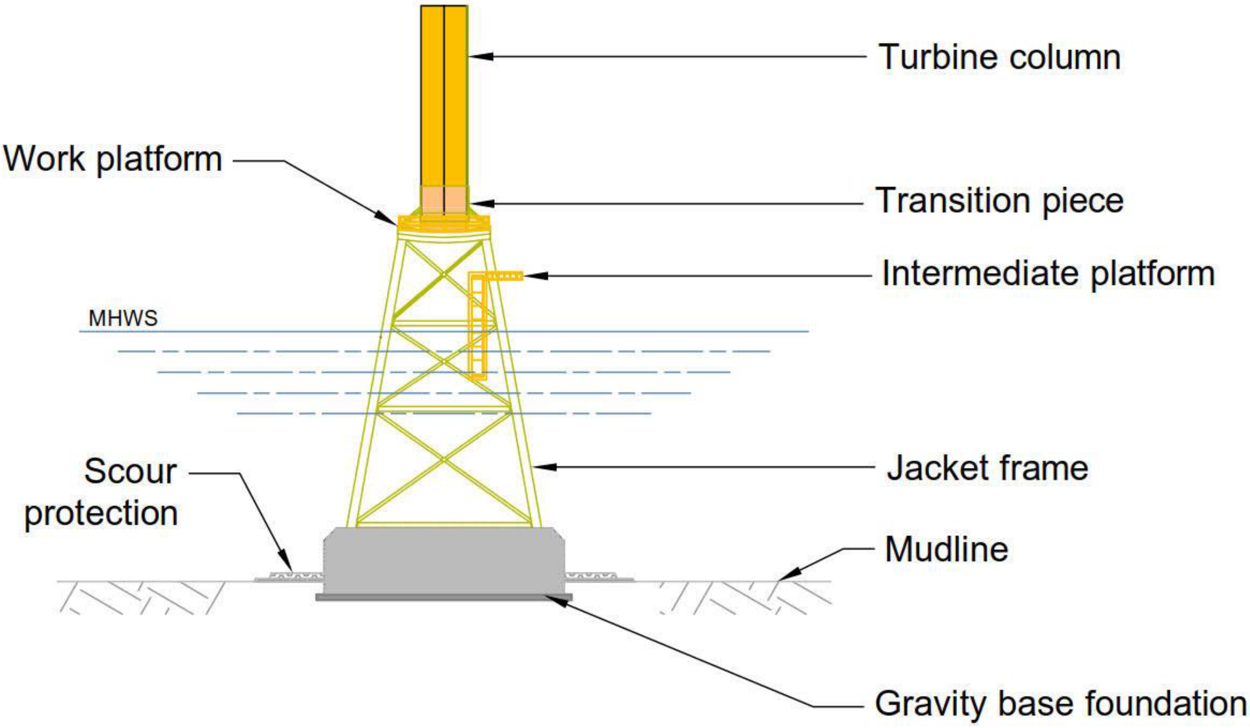


Figure 1.10: Multi-leg GBS jacket foundation with a single base

SCOUR PROTECTION

1.6.32 Scour protection is designed to prevent foundation structures being undermined by hydrodynamic and sedimentary processes, resulting in seabed erosion and subsequent scour pit formation. The shape of a foundation structure is an important parameter in influencing the potential depth of scour pits, as well as the local hydrodynamic regime and seabed sediment conditions. Scour around foundations is usually mitigated by the use of scour protection measures, which include concrete mattresses, rock bags, and flow energy dissipation devices (such as frond mats). The most common type of scour protection, however, is the placement of loose crushed rock around the base of the foundation (rock placement) (see Section 1.9 on cable protection, which describes these methods in more detail).

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

1.6.34 The amount of scour protection required will vary depending on the foundation type selected. Flexibility in scour protection choice is required to ensure that anticipated changes in available technologies and foundation design can be accommodated within the design envelope. The final choice of scour protection solution will be made post-consent in the detailed design phase, taking into account geotechnical data, meteorological and oceanographic conditions, water depth, foundation type and maintenance strategy. Table 1.22 presents the maximum design scenario for scour protections associated with foundations for VE. Volume 4, Annex 2.1: Physical Processes Technical Assessment provides the full design envelope for scour protection.

Table 1.22: MDS for scour protection

Parameter	WTG foundations	OSP foundations	Total
Foundation type	79x GBS monopiles	2 x GBS monopiles	N/A
Foundation and scour area per foundation (m^2)	16,628	40,828	N/A
Foundation and scour area, all foundations (m^2)	1,313,612	81,656	1,395,268
Scour volume per foundation (m^3)	26,700	74,065	N/A
Scour volume for all foundations (m^3)	2,109,300	148,100	2,257,430

1.7 INSTALLATION OF INTER-ARRAY CABLES

1.7.1 Cables carrying the electrical current generated by WTGs will link WTGs together and on to an OSP. A small number of turbines are typically grouped together on a cable ‘string’ that connects those turbines to an OSP and the wind farm array will contain several of these strings.

1.7.2 The array cables will consist of a number of conductor cores, usually made from copper or aluminium. These will be surrounded by layers of insulating material as well as material to armour the cable from external damage and to keep the cable watertight.

1.7.3 Preparatory works will be carried out prior to cable installation (see Section 1.4). The cables will be buried below the seabed wherever possible, with a target burial depth defined post-consent in a Cable Burial Risk Assessment (CBRA) taking account of the ground conditions and other factors.

1.7.4 The design envelope for array cables is described in Table 1.23. Possible installation methods for array cables include:

- Jet trenching;
- Pre-cut and post-lay ploughing;
- Simultaneous lay and plough (such as a burial sledge);
- Mechanical trenching;
- Dredging (Trailer suction hopper dredger or water injection dredger);
- Mass flow excavation; and/ or
- Rock cutting.

1.7.5 The overall Construction Programme under Section 1.13, presents the expected timings for construction. However, as highlighted under Section 1.13, there are several variables that may affect this. Consequently, it is possible the activity may not be carried out in one single campaign.

Table 1.23: MDS for array cables

Parameter	Design Envelope
Cable parameters	
Maximum system voltage (kV)	132
External cable diameter (mm)	250
Total length of array cables (km)	200
Cable installation	
Maximum burial depth (m)	3.5
Minimum burial depth (m)	0 (see cable protection requirements in Section 1.10.)
Maximum installation tool seabed disturbance width (jetting) (m)	18
Total area of seabed disturbed by cable installation (m^2)	3,600,000
Total area of seabed disturbed by cable installation (km^2)	3.6
Total volume of sediment disturbed by cable installation[3] (m^3)	3,150,000
Total volume of sediment disturbed by cable installation[3] (km^3)	0.00315

[3] Assuming a V-shaped trench in which 50% of sediment is fluidised and the remaining 50% re-suspended in the water column

1.8 CONSTRUCTION IN THE EXPORT CABLE CORRIDOR

INSTALLATION

1.8.1 The offshore export cables are typically larger in diameter than the array cables as they contain larger cores to transmit greater power. Like the array cables, the offshore export cables will consist of a number of cores, usually made from copper or aluminium, surrounded by layers of insulation material and armour to protect the cable from external damage.

1.8.2 The maximum cable burial depth will be dependent on numerous factors and will vary along the offshore ECC. The maximum burial depth presented in Table 1.24 is below the level of the non-mobile seabed (i.e. base of sandwaves). The cables will be buried below the seabed wherever possible, with a target burial depth defined post-consent in a Cable Burial Risk Assessment (CBRA) taking account of the ground conditions and other factors.

1.8.3 The design envelope for the export cables is described in Table 1.24. Possible installation methods for array cables include:

- Jet trenching;
- Pre-cut and post-lay ploughing;
- Mechanical trenching;
    - Dredging (Trailer suction hopper dredger, water injection dredger or backhoe dredger);
- Mass flow excavation;
- Vertical injector; and
- Rock cutting.

1.8.4 The transmission technology proposed for VE is High Voltage Alternating Current (HVAC). This is considered the most appropriate technology for VE given its geographical location and promotes the production of affordable energy (relative to alternatives). If required, consideration and assessment for High Voltage Direct Current (HVDC) for the offshore connection option will be included in the Environmental Statement.

1.8.5 The overall Construction Programme under Section 1.13, presents the expected timings for construction.

Table 1.24: MDS for offshore export cables

Parameter	Design Envelope
Cable parameters	
Maximum system voltage (kV)	400
Indicative external cable diameter (mm)	310
Number of export cable circuits	4
Total length of export cables (km)	370
Cable installation	
Indicative maximum burial depth (m) [4]	3.5
Minimum burial depth (m)	0 (see cable protection requirements in Section 1.10.)
Maximum installation tool seabed disturbance width (jetting) (m)	18
Total area of seabed disturbed by cable installation (m^2)	6,660,000
Total area of seabed disturbed by cable installation (km^2)	6.66
Total volume of sediment disturbed by cable installation[3] (m^3)	2,156,175
Total volume of sediment disturbed by cable installation[3] (km^3)	0.00216

CABLE JOINTING

1.8.6 Cable installation vessels are limited in the length of cable they can transport and install in a single loadout. Where lengths of offshore cable must be jointed to one another, it Is not possible to bury the joint using conventional cable burial tools such as ploughs. It is therefore necessary to excavate a pit to accommodate the joint, which is then backfilled to ensure the joint's protection. Each export cable circuit will require up to two joints, giving a maximum requirement of up to eight cable joints for the offshore export cables. It is assumed that the seabed footprint for cable jointing is within the design envelope for seabed preparation and cable installation described in Sections 1.4 and 1.8. Cable O&M requirements are described in Section 1.14.

[4] The maximum cable burial depth will be dependent on numerous factors and will vary along the offshore ECC. The cables will be buried below the seabed wherever possible, with a target burial depth defined post-consent in a Cable Burial Risk Assessment (CBRA) taking account of the ground conditions and other factors.

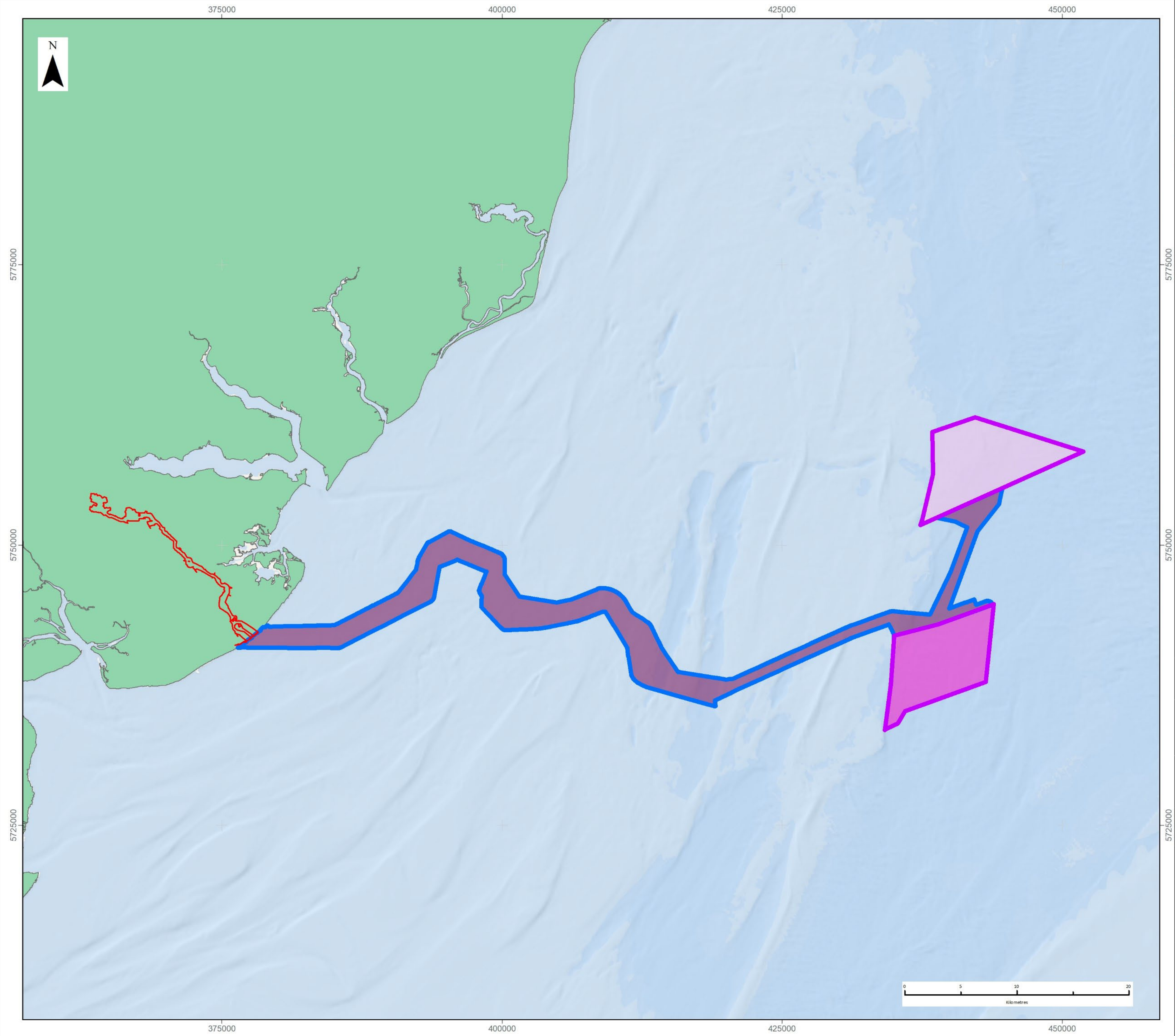
1.9 DISPOSAL OF DREDGED MATERIAL

1.9.1 The proposed disposal sites for VE are presented in Figure 1.11. Table 1.25 details the maximum volume of sediment which may be disposed of as part of the proposed pre-construction works. Material may be collected from seabed preparation for foundations and from sandwave clearance, depending on the selected technique. If material is collected by commercial-scale suction dredger for example, then it will be released at the water surface within the disposal sites.

1.9.2 Depending on site specific ground conditions, drilling may be required to install piles to their target depth (see Section 0). Spoilage created by drilling is disposed of adjacent to the foundation location, and generally comprises inert sub-bottom geological material. Disposal of drill arisings adjacent to installed foundations has been used on existing UK Offshore Wind Farms (OWFs), including London Array and Hornsea Project One, amongst others.

Table 1.25: MDS for dredged material disposal

Parameter	Disposal site 1	Disposal site 2	Disposal site 3	Total
Project location	**Northern array**	**Southern array**	**Offshore ECC**	**N/A**
Drill arisings (m^3)	283,715	283,715	N/A	567,430
Seabed preparation spoil volume for all foundations (m^3)	596,800	596,800	N/A	1,193,600
Maximum volume of material cleared from sandwaves requiring disposal (m^3)	17,500,000	17,500,000	64,750,000	99,750,000
Total (m^3)	18,380,515	18,380,515	64,750,000	101,511,030
Total (km^3)	0.018	0.018	0.065	0.102



LEGEND

- Array Areas
- Offshore Export Cable Corridor
- Onshore Red Line Boundary
- Proposed VE Disposal Sites:
- Disposal Site 1
- Disposal Site 2
- Disposal Site 3

Data Source:
Basemap: Sources: Esri, Garmin, GEBCO, NOAA NGDC, and other contributors

PROJECT TITLE:

FIVE ESTUARIES OFFSHORE WINDFARM

DRAWING TITLE:

Proposed disposal sites for VE

VER	DATE	REMARKS	Drawn	Checked
1	10/02/2023	For Issue	SWM	N/A

DRAWING NUMBER:

1.11

SCALE: 1:350,000	PLOT SIZE: A3	DATUM: WGS84	PROJECTION: UTM31N

FIVE ESTUARIES OFFSHORE WIND FARM

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1.10 CABLE PROTECTION

1.10.1 In some cases, where burial cannot be applied, or where the minimum cable burial depth cannot be achieved, it is necessary to use alternative methods such as rock placement, concrete mattresses or other solutions such as Cable Protection Systems (CPS) or protective aprons to protect the cable from external damage. It should be stressed that cable burial is the preferred method of installation, and additional cable protection will only be used as a contingency where cable burial is not appropriate or achievable. The design envelope for cable protection is described in Table 1.26. The cables will be buried below the seabed wherever possible, with a target burial depth defined post-consent taking account of the ground conditions and other factors.

1.10.2 Cable protection may consist of one or more of the following methods:

- Rock placement;
- Concrete mattresses;
- Flow dissipation devices;
- Protective aprons, coverings, cladding or pipes; and/ or
- Rock bags.

1.10.3 In the nearshore (out to 1,600 m seaward of MHWS), any cable remedial protection will not include loose rock or gravel. Additionally, in the intertidal, any cable remedial protection methods will be buried. Rock bags (or similar) or concrete mattresses may be placed at the ends of the Horizontal Directional Drilling (HDD) ducts (see Section 1.12).

Table 1.26: MDS for cable protection

Parameter	Design envelope for export cables	Design envelope of inter-array cables	Total
Length of cable requiring cable protection (including cable ends protection) (%)	20	20	N/A
Length of cable requiring cable protection (minus cable crossings) (km)	69	54	123
Width of cable protection on seabed (m)	16	6	N/A
Height of cable protection berm (m)	1.4	1	N/A
Total area of seabed covered by cable protection (m^2)	1,104,000	324,000	1,428,000
Total volume of cable protection (m^3)	966,000	189,000	1,155,000

ROCK PLACEMENT

1.10.4 Rocks of different grades or sizes are placed, via a fall pipe vessel, over the cable. typically, smaller rocks are placed over the cable as a covering layer, topped with an armouring layer of larger rocks. The rock grading has a mean (and indicative) rock size of 90-125 mm, up to a maximum of 250 mm. Rock protection generally forms a trapezium shape over the cable, with a slope either side, designed to provide protection from both direct anchor strikes and anchor dragging.

CONCRETE MATTRESSES

1.10.5 Concrete mattresses are formed by interweaving a number of small concrete blocks with rope and wire to provide a flexible protective mattress. They are lowered to the seabed on a frame and, once positioning is confirmed, released over the length of cable requiring protection. Mattresses provide protection from direct anchor strikes but rock protection provides better protection from anchor drag.

FLOW DISSIPATION DEVICES

1.10.6 Flow dissipation devices such as frond mattresses, are suitable for use in soft, mobile sediment environments. They consist of a mattress of buoyant fronds that create a drag barrier that significantly reduces current velocity within the fronds, acting to entrain sediments to build a protective layer out of naturally occurring suspended sediments that pass over the cable. Flow dissipation devices are designed to form protective, localised sand berms and are suited to addressing cable trench stability and scour related issues.

PROTECTIVE APRONS, COVERINGS, CLADDING OR PIPES

1.10.7 Cast iron halfpipe sections or proprietary cable protection products (of which tekduct, uraduct and others are examples) may be used as a remedial measure. Generally, these will be used in combination with rock bags or rock placement, but they may be used as a standalone protection method for short lengths (e.g. on approach to foundations).

ROCK BAGS

1.10.8 Rocks bags consist of various sized rocks constrained within a wire or rope net. They can be placed by a crane to ensure placement in the exact required location. Similar to flow dissipation devices, rock bags are more suited for addressing cable trench stability and scour related issues.

1.11 CABLE CROSSINGS

1.11.1 It is necessary to cross existing cables in the area to achieve connection from the array to the National Grid connection point. Cable crossings are subject to crossing agreements post-consent with the owners of those existing assets, and are necessary to provide protection to both assets, and to ensure a minimum separation so that cables do not overheat.

1.11.2 Cable crossings usually consist of a layer of protection over the existing asset (the separation layer) over which the VE cables would be installed. A secondary layer would then be installed over the VE cable for protection. Cable crossings may utilise rock protection or concrete mattresses or bridging typically of steel or concrete construction.

1.11.3 The maximum design envelope for cable crossings is described in Table 1.27. The total number of cable crossings required is 110. This scenario is not anticipated to occur, but the design envelope includes sufficient contingency should this be necessary.

Table 1.27: Maximum design envelope for cable crossings

Parameter	Design envelope for export cables	Design envelope of inter-array cables	Total
Cables to be crossed	21	N/A	N/A
Total number of crossings required	84	26	110
Length of crossings (m)	300	300	N/A
Total length of cable crossings (m)	25,200	7,800	33,000
Width of crossing (m)	15.22	15.22	N/A
Height of rock berm (m)	1.4	1.4	N/A
Cross sectional area of trapezoid (m^2)	13.7	13.7	N/A
Total area of seabed covered by cable crossings (m^2)	383,544	118,716	502,260
Total volume of cable protection required (m^3)	345,240	106,860	452,100

1.12 CONSTRUCTION AT LANDFALL

OVERVIEW

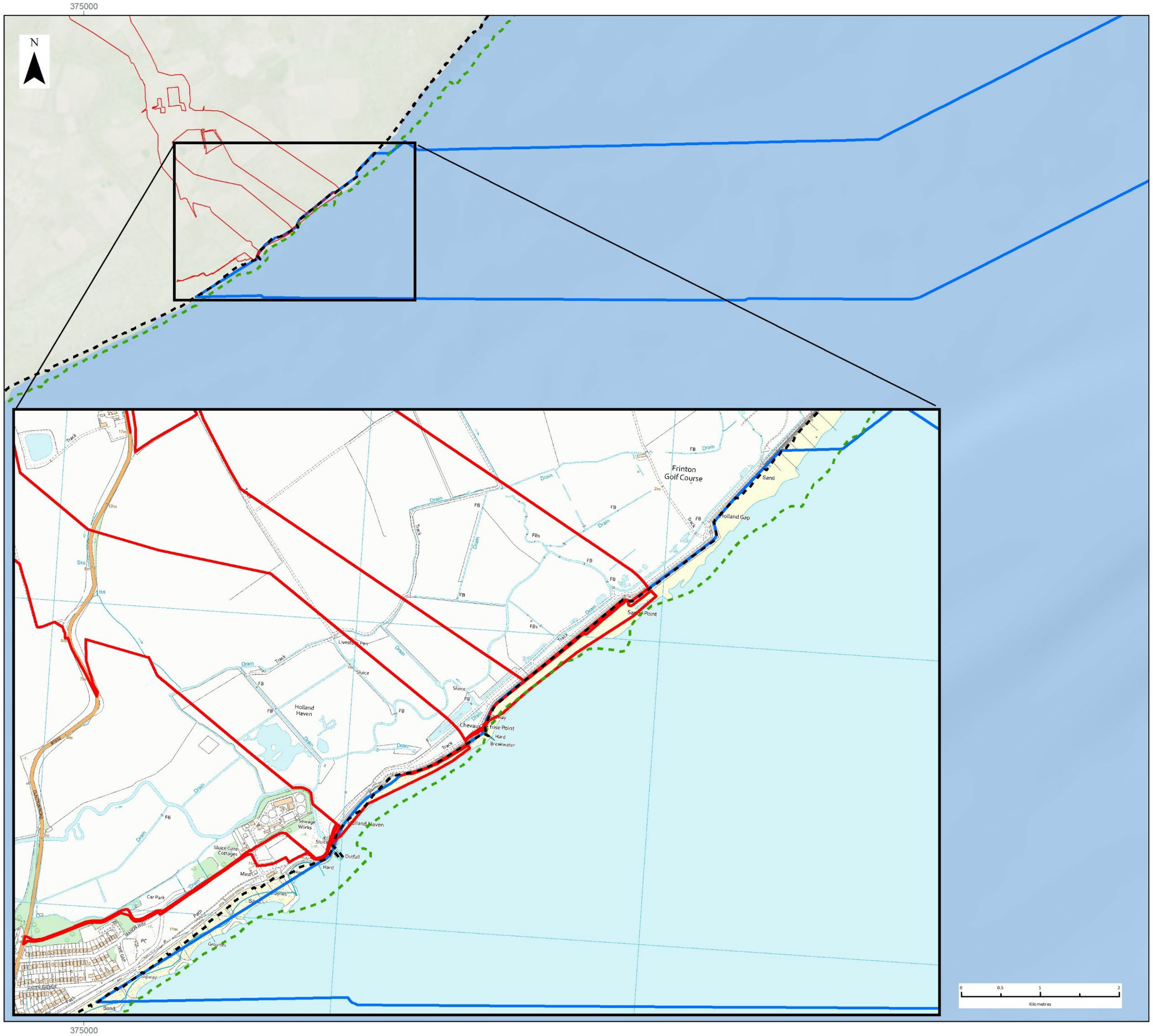
1.12.1 The landfall denotes the location where the offshore export cables are brought ashore and jointed to the onshore export cables in Transition Joint Bays (TJBs) (located onshore). There is a clear overlap in the offshore and onshore study area at the intertidal area of the landfall. However, all works associated with landfall have been presented in this section to aid the reader.

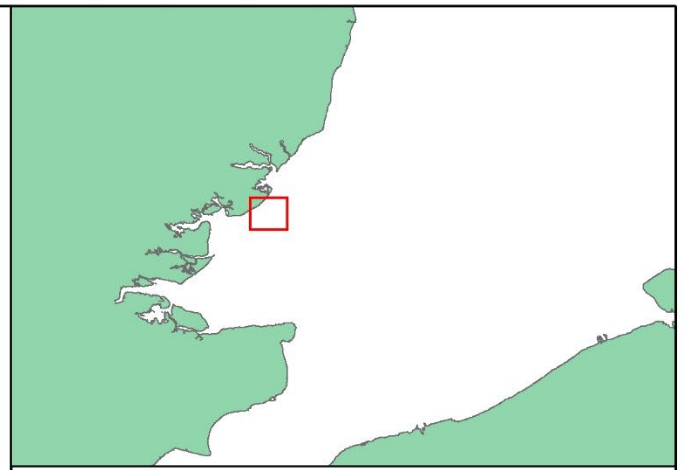
1.12.2 The offshore export cables will make landfall between Holland-on-Sea and Frinton-on-Sea on the Essex coast (Figure 1.2). The works at the landfall include:

- Construction of the landfall compound;
- Horizontal Directional Drilling (HDD) works (or other suitable alternative trenchless techniques such as micro-boring) including temporary construction of HDD exit pits in the intertidal or shallow subtidal;
- Intertidal trenching (this will only be required if the exit pits are located in the intertidal zone);
- Construction of TJBs;
- Installation of offshore export cables (cable pulling);
- Installation of and jointing to onshore export cables;
- Backfilling and re-instatement works.

1.12.3 The techniques used to carry out the landfall works will be trenchless techniques (such as HDD, micro-tunnelling or auger boring. It may be possible to carry out trenchless techniques beyond the intertidal area and install the rest of the cable using an offshore installation spread. Jack-up barges may be required in the shallow subtidal, the footprints of which are within the overall footprint of disturbance within the cable corridor.

1.12.4 Detailed pre-commencement surveys (such as geophysical, geotechnical, ecological or archaeological surveys) will be carried out before works commence in the landfall. An analysis of the results of these surveys will then inform the final locations of TJBs and the cable route. Micro-siting of cable circuits is intended to provide flexibility to make minor adjustments to the project layouts to accommodate unexpected on-site conditions identified in the pre-construction surveys. All infrastructure will be installed within the Order Limits (as defined in the DCO when granted).





LEGEND

- Offshore Export Cable Corridor
- Onshore Red Line Boundary
- Mean Low Water Springs
- Mean High Water Springs

Data Source:
Basemap: Sources: Esri, Garmin, GEBCO, NOAA NGDC, and other contributors

PROJECT TITLE:

FIVE ESTUARIES OFFSHORE WINDFARM

DRAWING TITLE:

Nearshore Project Schematic

VER	DATE	REMARKS	Drawn	Checked
1	10/02/2023	For Issue	SWM	SS

DRAWING NUMBER:

1.12

SCALE:	PLOT SIZE:	DATUM:	PROJECTION:
1:50,000	A3	WGS84	UTM31N

FIVE ESTUARIES OFFSHORE WIND FARM

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TRENCHLESS TECHNIQUES

1.12.5 HDD is the established solution for trenchless installation, however it should be noted that other technologies exist, such as micro-boring. HDD involves drilling a long borehole underground using a drilling rig located within the landfall compound. This technique avoids interaction with surface features and is used to install ducts through which cables can be pulled.

1.12.6 The process uses a drilling head controlled from the rig to drill a pilot hole along a predetermined profile to the exit point. The pilot hole is then widened using larger drilling heads until the hole is wide enough to accommodate the cable ducts. Table 1.28 presents the maximum design scenario for the proposed trenchless techniques.

1.12.7 As the drill is carried out between a start and end point, entry and exit pits must be excavated at either end of the borehole: one in the landfall compound and one on the offshore side. HDDs can vary in length depending on the ground conditions the maximum length proposed for VE is 1,100 m. Two options for the location for the drill exit are being considered either in the intertidal zone or below LAT. It is assumed that the drill start point will be onshore and will ream towards the offshore environment. Note: there will be no direct interaction with the seawall or its toe as the drill will pass below.

1.12.8 Note: Open cut techniques is *not* included as an alternative methodology for connecting the offshore into the TJBs VE.

Table 1.28: MDS for trenchless techniques

Parameter	Design Envelope
Number of cable circuits	4
Number of cable ducts/ HDD bores	5 (one per circuit plus one contingency)
Minimum HDD spacing (offshore) (m)	50 (100-200 m is anticipated)
Maximum HDD depth below the surface (m)	20
Maximum HDD length (m)	1,100

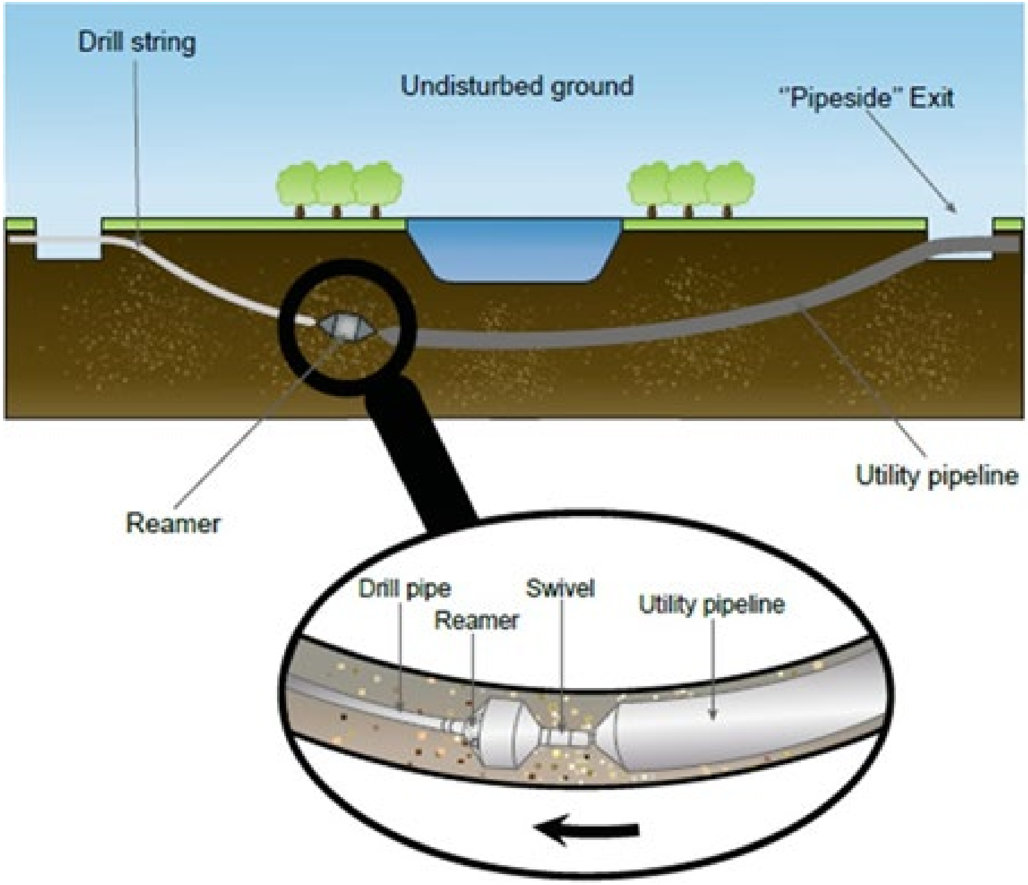


Figure 1.13: Illustrative visualisations of an HDD installation

Figure 1.14: Example of typical HDD equipment

DRILLING MUD

1.12.9 Drilling mud (typically bentonite) is pumped to the drilling head to stabilise the borehole, recover drill cuttings and ensure the borehole does not collapse. The maximum design envelope for drilling mud which could be released to the environment is presented in Table 1.29. The full design envelope for bentonite is presented in Volume 4, Annex 1-1.

Table 1.29: MDS for release of drilling mud

Parameter	Design Envelope
Maximum number of bores	5
Realistic case drilling mud volume based on forward ream (from the beach to offshore) per bore (m^3)	677
Realistic case drill cuttings based on forward ream (from the beach to offshore) per bore (m^3)	50
Worst case drilling mud volume based on back beam (from offshore towards the beach) (m^3)	4,940
Worst case drill cuttings volume based on back beam (from offshore towards the beach) (m^3)	900
Total volume of drilling mud which could be released (m^3)	24,700
Total volume of drill cuttings which could be released (m3)	4,500
Maximum drilling mud volume to be released per tidal cycle (m3)	500

EXIT PITS

1.12.10 The HDD exit pits may be located within the intertidal zone or the shallow subtidal. Exit pits will be excavated or dredged to the required depth, and side-cast material for backfilling may be stored adjacent to the exit pit. Exit pits excavated in the intertidal zone will be excavated using a backhoe dredger (or an equivalent). Whereas exit pits in the shallow subtidal may utilise any of the methods detailed for cable installation in Section 1.8.

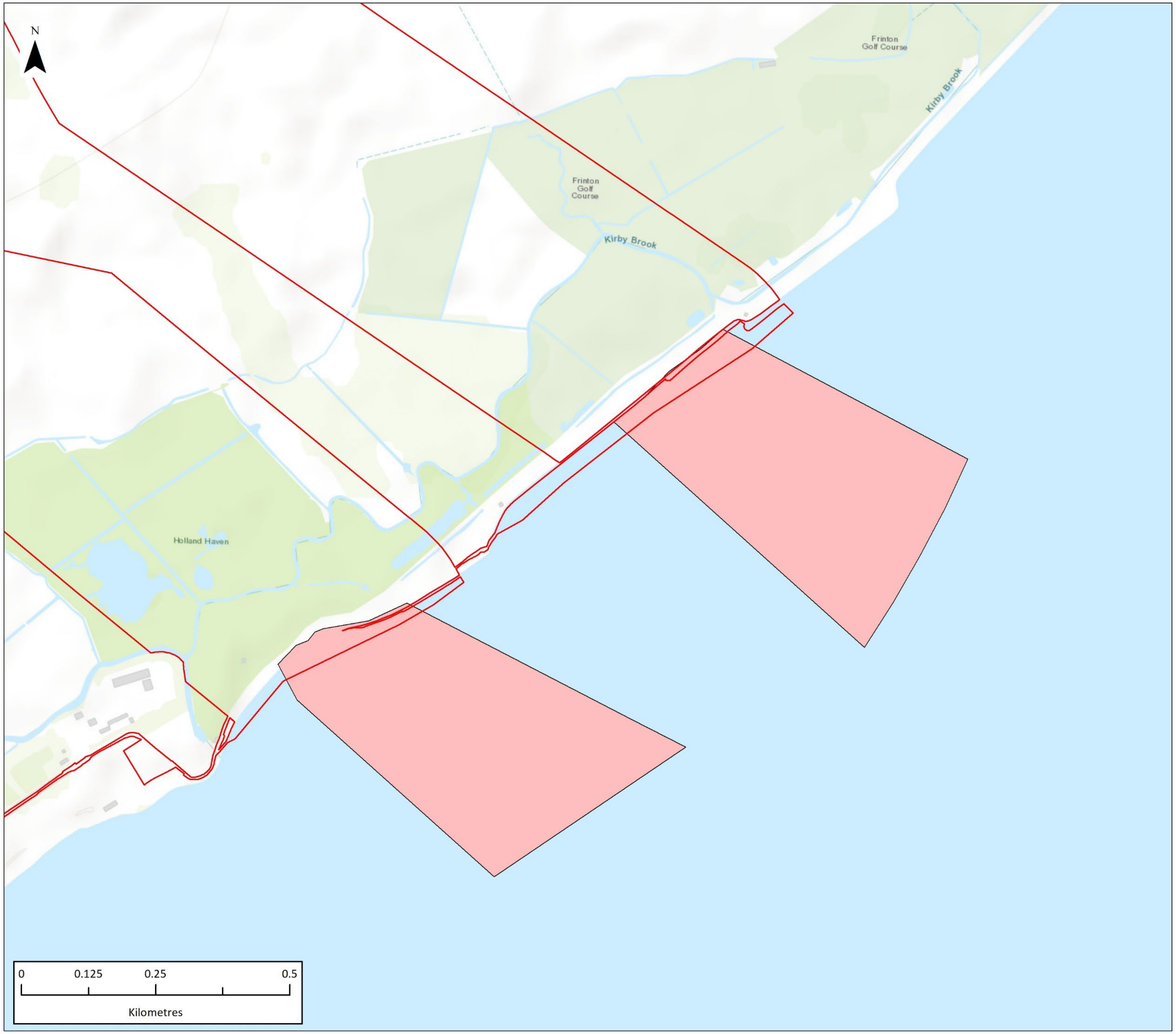
1.12.11 Once the drilling operation has taken place, the ducts will be pulled through the drilled holes. The ducts will either be constructed off-site, then sealed and floated to site by tugs, or will be constructed at the landfall compound and pulled over the beach on rollers. The ducts will then be pulled back through the boreholes either by the HDD rig itself, or by separate winches. There is also the potential to pull the ducts from onshore to offshore through the drilled borehole.

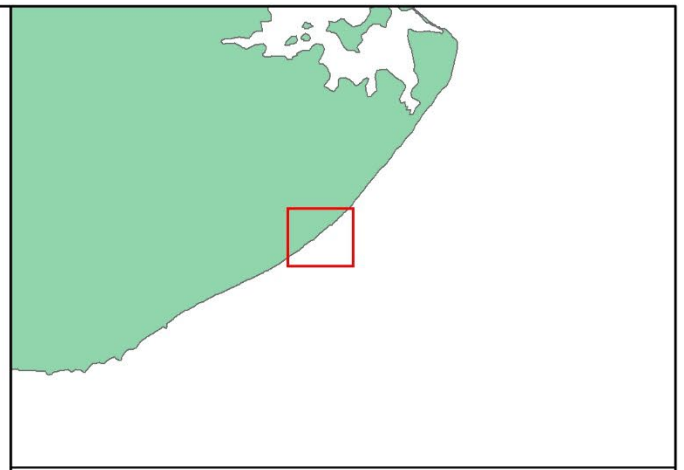
1.12.12 Once the ducts are in place, the exit pits will likely be temporarily backfilled until ready for cable pull-through. Backfilling of the pits is required to prevent collapse and manage natural infill by sediment. Backfill methods may include the use of rock bags or concrete mattresses. Prior to cable installation, the ducts will then need to be re-exposed to pull in the cable using a MFE to remove any accumulated loose sediment and rock bags and/ or mattresses would be retrieved.

1.12.13 Once installation is complete, the subtidal exit pits will be left to naturally backfill. Alternatively, intertidal exit pits will be filled to the natural beach level.

Table 1.30: MDS for exit pits

Parameter	Design Envelope
Number of exit pits	5
Location of exit pits	See Figure 1.15.
Width of each exit pit (m)	10
Length of each exit pit (m)	75
Area of each exit pit (m^2)	750
Total area of all exit pits (m^2)	3,750
Depth of each exit pit (m)	2.5
Volume excavated per exit pit (m^3)	1,875
Total volume excavated from exit pits (m^3)	9,375





LEGEND

Onshore Export Cable Corridor

Indicative Zones of HDD Exit Pits

PROJECT TITLE:

FIVE ESTUARIES OFFSHORE WINDFARM

DRAWING TITLE:

Illustrative zone of the HDD exit pits

VER	DATE	REMARKS	Drawn	Checked
1	10/03/2023	For Issue	SWM	MB

DRAWING NUMBER:

1.15

SCALE:	PLOT SIZE:	DATUM:	PROJECTION:
1:7,500	A3	WGS84	UTM31N

FIVE ESTUARIES OFFSHORE WIND FARM

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SHEET PILED EXIT PITS

1.12.14 Sheet piled exit pits consist of sheets of metal and may be installed temporally by vibropiling or impact piling. The design envelope for the sheet piled exit pits is described in Table 1.31. Depending on the final methodology and location, it may be necessary to install sheet piled exit pits temporarily to reduce water intrusion. If sheet piled exit pits are required, the HDD would exit within them. It is assumed that the sheet piled exit pits would not retain all of the drilling fluid but may reduce the volume released to the marine environment (see above).

1.12.15 It is proposed that the sheet piled exit pits may be installed anywhere seaward of the sea defence structures (including the wall and rock armour). Sheet piled exit pits would be around exit pits, and so the exit pit dimensions dictate the size of the sheet piled exit pits. The volume of sediment removed is included in the exit pit volumes.

Table 1.31: Design envelope for sheet piled exit pits associated with trenchless techniques

Parameter	Design Envelope
Number of sheet piled exit pits required	5

1.12.16 Temporary piling activities may be required to facilitate installation of the sheet piled exit pits (see Table 1.32).

Table 1.32: Design envelope for piling for sheet piled exit pits installation

Parameter	Design Envelope
Indicative hammer energy for sheet piled exit pits installation (kJ)	300 (assumes a 60 kJ soft start for 30 mins and up to full power in 5 minutes)
Sheet pile width (mm)	750
Total number of sheet piles	1,100
Maximum number of piles to be installed per day	8
Maximum installation per sheet pile (hr)	1

OPEN-CUT INSTALLATION OF MARINE CABLES

1.12.17 In the event that the HDD exit pits are located in the intertidal zone, open-cut installation will be required seaward of that location. Open-cut installation in the intertidal zone could be carried out using one or more methods described for the offshore export cables in Section 1.8. (with the exception of jetting and MFE in the intertidal areas). This provision does not provide an alternative for the use of trenchless techniques at the landfall. As with offshore export cable installation, cables may be installed via simultaneous lay and burial, or a trench may be opened and the cable subsequently installed within, after it has been pulled across the beach. Cable installation tools are usually pulled across the beach on skids or tracks.

1.12.18 The design envelope for open-cut installation is included within the design envelope for the offshore export cables described in Section 1.8. Cable protection requirements are included within the envelope for the offshore export cables described within Table 1.26. However, cable protection will be buried in the intertidal section and out to 1,600 m seaward of MHWS will not consist of loose rock or gravel.

TRANSITION JOINT BAYS

1.12.19 The offshore cables will be brought ashore to connect to the onshore export cables within the TJB compound onshore. TJBs are required to join the offshore cables to the onshore cables and provide a stable, clean and safe working environment for cable joining. The design envelope for the TJBs is described in Table 1.33. Since the risk of mechanical damage to onshore cables is lower than that for offshore cables, and as such require less armouring, generally the onshore sections utilise single core, unarmoured cable that is more flexible to install and more easily transportable (see Volume 3, Chapter: Onshore Project Description for details of the installation of onshore cable circuits).

1.12.20 Each TJB will typically be constructed of a reinforced concrete base with concrete walls and may have a removable roof. Once the joint is completed the TJBs are covered and the land above reinstated. The TJBs are typically backfilled with a suitable material such as Cement Bound Sand (CBS) and selected subsoils.

1.12.21 It is not expected that the TJBs will require access for planned maintenance activities during the O&M phase, however, unplanned works such as unforeseen repair may be required. Access to the TJBs for inspection and maintenance of electrical and optical cable joints will be via manholes, located to the side of the TJB.

Table 1.33: Design envelope for the TJB compound

Parameter	Design Envelope
Number of export cable circuits	4
Number of TJBs	4
TJB dimensions (m)	20 x 5
Land take for TJBs compound during construction (m^2)	100 x 200
Permanent land take for all of TJBs during O&M (m^2)[5]	30 x 80

[5] This is the total area. It should be noted that TJBs may be spaced apart i.e. this area may consist of several smaller areas

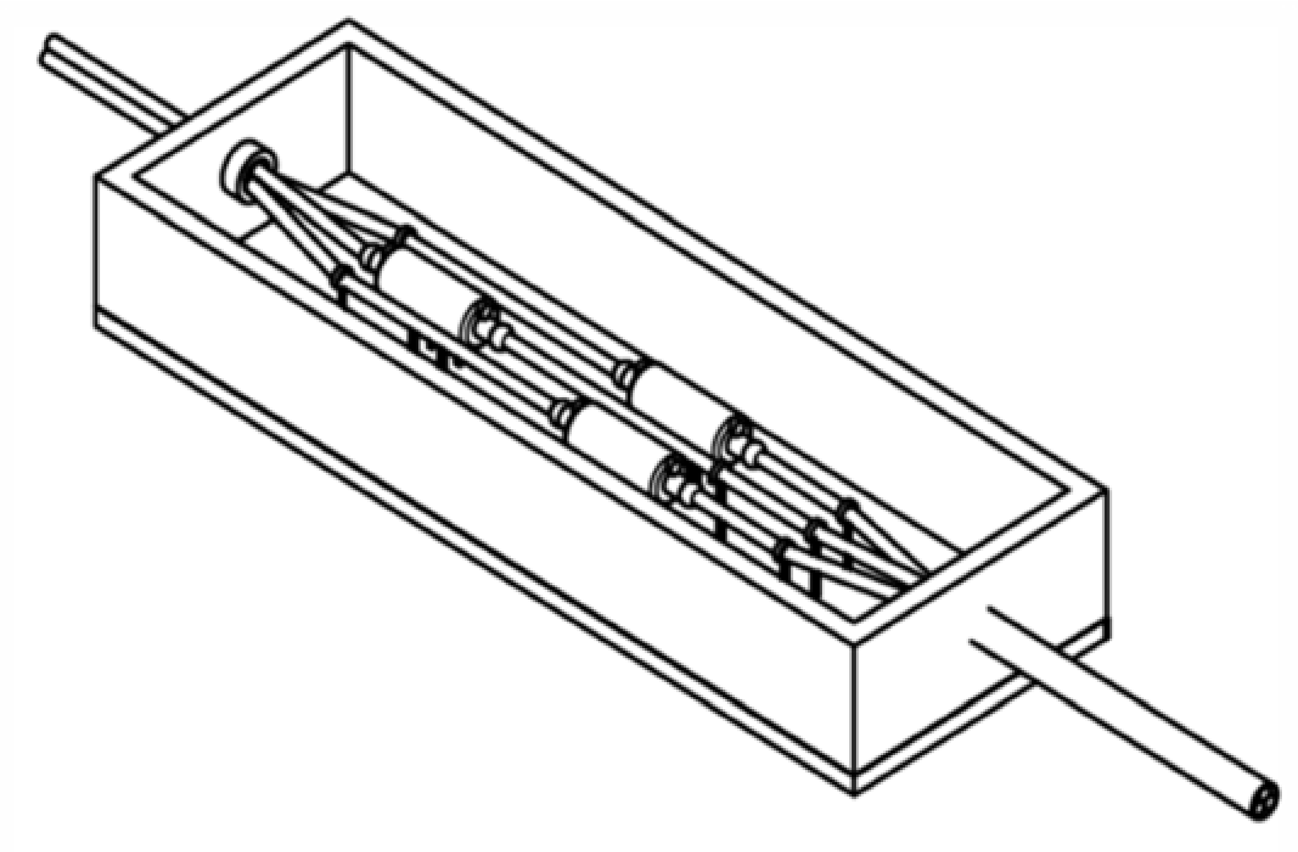

Figure 1.16: Indicative TJB

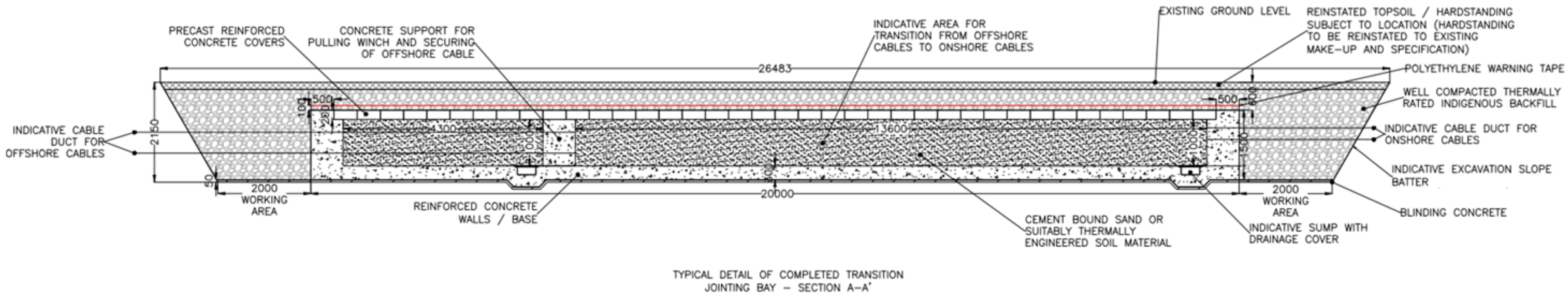

Figure 1.17 Cross section of a TJB

Figure 1.18: Typical TJB during construction (left) and after reinstatement (right)

TEMPORARY CONSTRUCTION COMPOUND

1.12.22 A Temporary Construction Compound (TCC) associated with the landfall works may be required and a location is identified adjacent to the promenade at eastern end of Manor Way to provide further flexibility should it be needed.

BEACH ACCESS

1.12.23 During the landfall HDD works, public access will be maintained on the beach wherever possible (outside the works area and open-cut works). Suitable means will be made available for the public to pass around the HDD works area.

1.12.24 No groynes will be impacted by the work and therefore, no groynes are expected to be removed.

1.12.25 It is proposed that access for equipment and workers will be made via Manor Way. TCC 1 has been included in the RLB adjacent to Manor Way to support any beach operations

PROGRAMME

1.12.26 The overall Construction Programme under Section 1.13, presents the expected timings for construction. However, as highlighted under Section 1.13, there are several variables that may affect this. As explained above, it is likely that the various landfall activities will not be carried out in one single campaign.

1.13 CONSTRUCTION PROGRAMME

1.13.1 The construction programme for VE is dependent on a number of factors which may be subject to change, including:

- The date of a connection to the National Grid;
- The date that the DCO is granted;
- Should it be required, obtaining a Contract for Difference (CfD) from the UK Government within the anticipated programme; and
- The availability and lead-in times associated with procurement and installation of project components.

1.13.2 Main offshore construction works are anticipated to commence in 2029, with some preliminary survey and clearance works potentially taking place in 2026 to 2028. The windfarm is anticipated to be operational in 2030.

1.13.3 Offshore construction works are typically carried out under relatively calm metocean conditions normally experienced during the summer, although some activities may take place throughout the year. Furthermore, 24-hour offshore working will be required, with illumination required on construction vessels during night-time and low light conditions. Figure 1.19 below illustrates the indicative dates and durations for each activity, and the order in which they are expected to occur in the construction campaign.

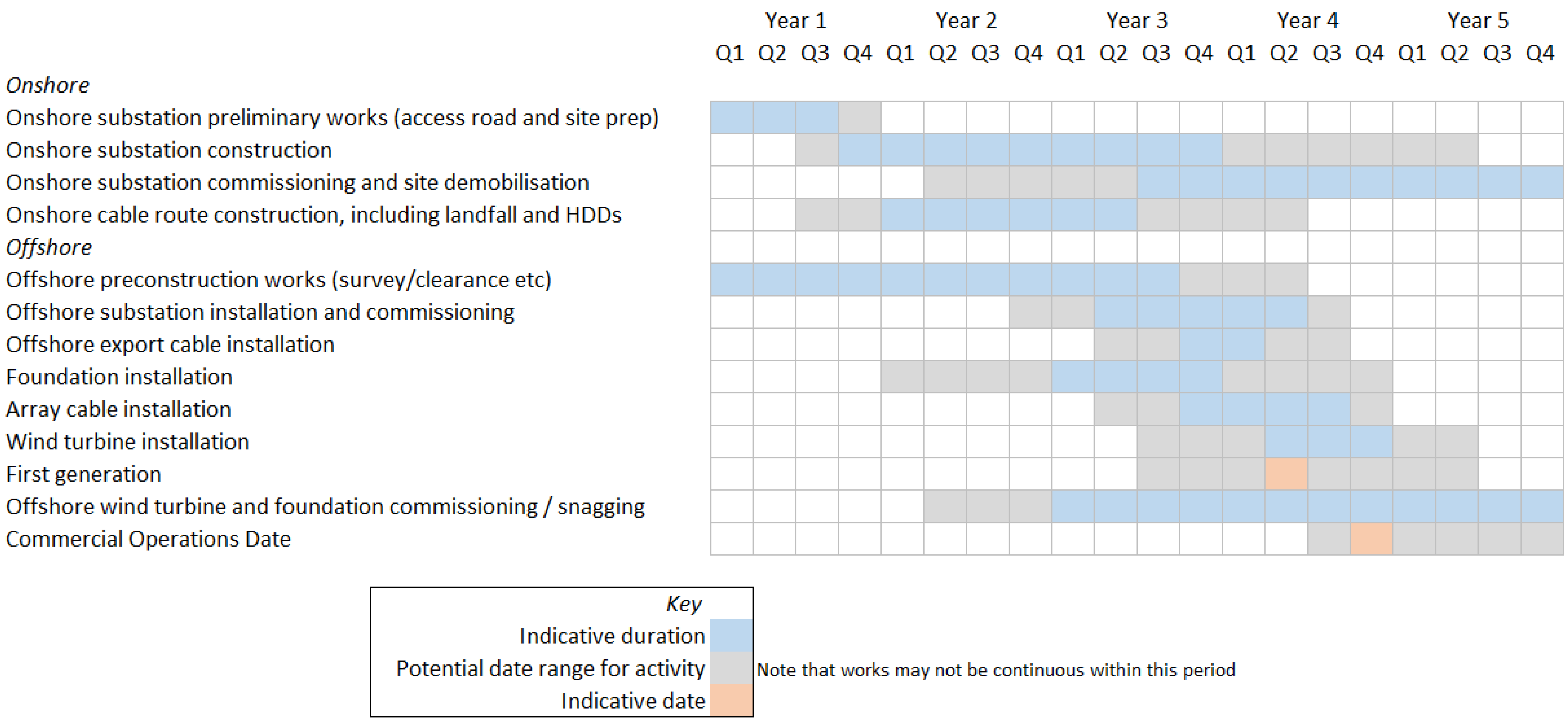

Figure 1.19: Indicative construction programme

1.14 OPERATION AND MAINTENANCE

1.14.1 The indicative project programme states that the project will be fully constructed and operational by 2030, and the operational lifetime of the project is anticipated to be between 24 to 40 years. The overall O&M strategy will be finalised once the technical specification is known, including WTG model and final project layout.

1.14.2 Maintenance activities fall into two categories:

- Preventative; and
- Corrective.

1.14.3 Preventative maintenance is carried out according to regular scheduled services, whereas corrective maintenance covers unexpected repairs, component replacement, retrofit campaigns and breakdowns. Preventative and corrective maintenance considered in this PEIR and so sought to be licenced under the deemed Marine Licence includes, but is not limited to:

- Preventative actions:
  - Guano cleaning; and
  - Painting of turbines.
- Corrective actions:
  - Wind Turbine Anode replacement;
  - Maintenance of Scour protection/cable protection; and
  - Cable repair and/ or replacement.

1.14.4 In recent years, the offshore wind industry has developed understanding and improved monitoring for preventative maintenance of operational wind farms. For cables in particular, VE will be designed to require no cable maintenance or re-burial as these events are disruptive and costly, however, the option is retained for flexibility in the event of unforeseen circumstances. Options for cable maintenance work include cable re-burial via jetting, or placement of cable protection. In the case of a cable repair, required if accidental severing or damage were to take place, a new cable segment may need to be laid and jointed at either end to the existing cable. Alternatively, in the case of array cable failure, complete replacement of an array cable may be carried out. The design envelope for these O&M works is described in Table 1.34.

1.14.5 The scheduled maintenance of the wind turbines and offshore substation assets will be determined when the final equipment design and supplier are chosen. Based on experience this will involve inspections (e.g. drone or ROV) and activities such as painting, cleaning of guano and marine growth. Any non-scheduled repairs or corrective actions may be required to the structures themselves (foundations, transition piece, J-tubes, tower, nacelle, hub, blades, offshore substation) on mechanical, electrical, control & instrumentation, structural components, lifting, access and safety equipment, and repairs to cathodic protection systems.

1.14.6 It is assumed that up to 20% of scour protection may be replaced over the lifetime of VE.

1.14.7 Component and/ or segments of cable replacements may be required over the lifetime of VE. These replacements will require the use of JUVs (see Section Table 1.34).

Table 1.34: MDS for O&M activities

Parameter	Design Envelope
O&M strategy	
Project lifetime (years)	Approximately 40
Surface infrastructure (WTGs and OSPs)	
Number of WTG and OSP major component replacements requiring JUVs over project lifetime	284
Scour replenishment	20%
Array cables	
Number of array cable repairs/ replacements over project lifetime	8
Seabed disturbance per array cable repair/replacement event (including vessel anchors) (m^2)	34,582
Total seabed disturbance for array cables over project lifetime (m^2)	276,656
Total length of array cables requiring remedial burial over project lifetime via jetting or rock placement (m)	5,000
Seabed disturbance volume per array cable repair/replacement event (including vessel anchors) (m^3)	14,072
Total seabed disturbance volume for array cables over project lifetime (m^3)	112,576
Offshore export cables	
Number of offshore export cable repairs over project lifetime	16
Seabed disturbance per array cable repair event (including vessel anchors) (m^2)	16,205

Parameter	Design Envelope
Total seabed disturbance for offshore export cables over project lifetime (m^2)	259,280
Total length of array cables requiring remedial burial over project lifetime via jetting or rock placement (m)	5,000
Seabed disturbance volume per offshore export cable repair event (including vessel anchors) (m3)	9,307
Total seabed disturbance volume for offshore export cables over project lifetime (m3)	148,912

1.15 DECOMMISSIONING

1.15.1 For the purposes of the MDS for EIA, at the end of the operational lifetime of VE, it is assumed that all infrastructure above the seabed will be completely removed. The decommissioning sequence will generally be in the reverse of construction (reverse lay) and is expected to involve similar types and numbers of vessels and equipment and take place over a three-year period.

1.15.2 Closer to the time of decommissioning, it may be decided that removal would lead to a greater environmental impact than leaving some components *in situ*, in which case certain components may be cut off at or below seabed level (e.g. in the case of piled foundations) or left *in situ* (e.g. in the case of subsea cables and rock protection).

1.15.3 As part of the decommissioning works, cables will be removed and HDD ducts will be left in situ and capped appropriately.

1.15.4 An initial Decommissioning Plan, including programme, waste management and proposed end state of the environment is expected to be required to be submitted pre-construction, conditional as part of the suite of post-consent documentation for VE. Under Section 106 of the Energy Act 2004. The initial Decommissioning Plan is required to be signed off by the relevant authority prior to commencement of construction. This plan would be updated during the lifetime of VE to take account of changing best practice and new technologies. A final Decommissioning Plan, prior to the undertaking of decommissioning works, would also require approval from the MMO.

1.16 SAFETY ZONES

1.16.1 During construction and decommissioning, it is assumed for the purposes of assessment that the Applicant will apply for 500 m safety zones around infrastructure that is under construction. Temporary safety zones of 50 m will be sought for incomplete structures such as installed monopiles without transition pieces, or where construction works are completed but commissioning has yet to be completed.

1.16.2 During the O&M phase, the Applicant may apply for temporary 500 m safety zones around infrastructure that is undergoing major maintenance (for example a WTG blade replacement).

1.16.3 Outside of construction, decommissioning and major maintenance works, the applicant does not intend to apply for permanent safety zones around operational infrastructure.

1.17 PROJECT VESSELS

CONSTRUCTION & DECOMMISSIONING

VESSEL NUMBERS

1.17.1 The peak numbers of vessels on-site at any one time during the construction phase and the number of round trips between port and site (defined as a vessel movement from port to site and back to port) are summarised in Table 1.35. It should be noted that many parts of the construction cannot be undertaken concurrently and so the values in Table 1.35 provide the overall MDS that is not representative throughout the majority of the construction period.

1.17.2 The decommissioning sequence will generally be in the reverse of construction (reverse lay) and is expected to involve similar types and numbers of vessels.

Table 1.35: Peak construction vessels and round trips to site

Vessel type	Peak vessels	Round Trips
Foundations		
WTG and OSP foundation installation vessels (includes tugs and feeders)	38	1359
WTGs and OSPs		
WTG installation vessels (includes tugs and feeders)	15	71
OSP topside installation vessels (includes tugs and feeders)	4	8
Other installation vessels		
Commissioning (including accommodation vessels)	5	130
Other vessels	15	2,300

Vessel type	Peak vessels	Round Trips
Cable installation vessels (incl. seabed preparation vessels)		
Array cable installation vessels (includes support, cable protection and anchor handling vessels)	12	166
Export cable installation spreads (includes support, cable protection and anchor handling vessels)	12	1,076
Total construction vessels		
Maximum total construction vessels	101	5,110
Indicative peak vessels on-site simultaneously	35	N/A

JACK-UP VESSEL OPERATIONS

1.17.3 For WTG and OSP, the methodologies available for installation include JUVs operations and anchoring (see below). Therefore, the impacts on the seabed are not additive as the two activities are mutually exclusive. Note: For port calls JUVs may jack down/ up but they would jack in the same footprints and therefore the total area affected would not be increased.

1.17.4 JUVs are installation vessels that are capable of lowering three or more legs onto the seabed and lifting themselves out of the water to provide a stable platform where craning of heavy infrastructure like foundations, WTGs and OSP topsides can take place. The legs of the JUV have direct impacts on the seabed within the footprint of the feet, known as 'spud cans'. Table 1.36 describes the design envelope for JUV operations.

Table 1.36: MDS for JUV operations during the construction phase

Parameter	Design Envelope
Maximum JUV operations during construction	504
Individual spud can footprint (m^2)	275
Maximum seabed area per JUV operation (m^2)	1,100
Maximum seabed area impacted for all JUV operations (m^2)	554,400
Typical seabed penetration (m)	15
Maximum volume of sediment disturbed per JUV operation (m^3)	16,500
Maximum volume of sediment disturbed for all JUV operations (m^3)	8,316,000

ANCHORING

1.17.5 As an alternative to JUVs for the installation of foundations and topsides, multiple anchors may be used to position and secure the vessel, which will also have direct impacts on the seabed and are considered within the overall footprint of the project. Anchoring may also be required for the installation of export cables. The maximum design envelopes for anchors are provided in Table 1.37 and Table 1.39.

1.17.6 In addition, vessels may be required to anchor in and around the RLB for the purposes of maritime navigational safety. Anchoring is not a licensable activity under the Marine and Coastal Access Act (MCAA). Table 1.37 describes the anchor handling footprints in the construction phase.

1.17.7 It should be noted that dynamic position is typically used instead of anchors.

Table 1.37: MDS for anchor footprints for WTG and OSP installation (foundations and topsides) during the construction phase

Parameter	Design Envelope
Number of locations	81 (79 WTGS + 2 OSPs)
Number of anchors per deployment	8
Number of deployments per location	5 (4 per foundation, 1 per topside)
Anchor footprint (deployment and recovery per anchor) (m^2)	117
Total anchor footprint per location (m^2)	936
Total impact area for WTG and OSP installation in the array (m^2)	379,080
Typical anchor penetration depth (m)	4
Total impact volume for WTG and OSP installation in the array (m^2)	1,516,320

Table 1.38: Design envelope for anchor footprints for the inter-array cables during the construction phase

Parameter	Design Envelope
Number of vessel moves	455
Number of anchors per deployment	9
Anchor footprint (deployment and recovery per anchor) (m^2)	61
Total anchor footprint per deployment	549
Total impact area for all anchors for inter-array cables (m^2)	249,795
Typical anchor penetration depth (m)	1.5
Total impact volume for all anchors for inter-array (m^2)	374,693

Table 1.39: Design envelope for anchor footprints in the offshore ECC during the construction phase

Parameter	Design Envelope
Number of vessel moves	841
Number of anchors per deployment	9
Anchor footprint (deployment and recovery per anchor) (m^2)	61
Total anchor footprint per deployment	549
Total impact area for all anchors in the offshore ECC (m^2)	461,709
Typical anchor penetration depth (m)	1.5
Total impact volume for all anchors in the offshore ECC (m^3)	692,564

LAYDOWN AREAS

1.17.8 A laydown area is an area for the temporary storage of materials and infrastructure prior to installation. Vessels will, when necessary, undertake wet storage techniques for anchor blocks and cable sections across the RLB. The maximum area of seabed disturbed by the wet storage area will be 15,000 m^2 (with an indicative shape of 75 m x 200 m).

OPERATION AND MAINTENANCE

VESSEL NUMBERS

1.17.9 The general operation and maintenance strategy may rely on an onshore (harbour based) operation and maintenance base, crew transfer vessels (CTVs), Service Operation Vessels (SOVs), offshore accommodation vessels, supply vessels, cable and remedial protection vessels for the operation and maintenance services that will be performed at VE. The final operational and maintenance strategy chosen may be a combination of the above solutions.

1.17.10 The design envelope for the operation and maintenance vessels are presented in Table 1.40.

Table 1.40: MDS O&M vessel requirements

Vessels	Design Envelope	
	Peak vessels	Annual Round trips
Vessel description		
JUVs	3	9
SOVs	2	52
CTVs	9	1,642
Lift vessels	3	8
Cable maintenance	2	1
Auxiliary vessels	8	64
Total O&M vessels		
Total O&M vessels	27	1,776
Indicative peak vessels on-site simultaneously	27	N/A

JACK-UP VESSEL OPERATIONS

1.17.11 Major component replacements may be required over the lifetime of VE. These replacements will require the use of JUVs (see Table 1.41).

Table 1.41: MDS for JUV requirements during O&M

Parameter	Design Envelope
Number of major component replacements requiring JUVs over project lifetime	284
Number of JUV operations per replacement	1
Individual spud can footprint (m^2)	275
Maximum seabed area per JUV operation (m^2)	1,100
Maximum seabed area impacted for all JUV operations (m^2)	312,400
Typical seabed penetration (m)	15
Maximum volume of sediment disturbed per JUV operation (m^3)	16,500
Maximum volume of sediment disturbed for all JUV operations (m^3)	4,686,000

ANCHORING

1.17.12 Similarly to the construction phase, anchoring may also be required for the remedial burial and replacement export cables. The maximum design envelopes for anchors are provided Table 1.34.

PERMANENT VESSEL MOORINGS

1.17.13 Permanent vessel moorings (PVMs) usually consist of a steel or plastic floating buoy, secured to the seabed via one of several solutions including anchor or gravity-based techniques. Driven or drilled pile solutions are not considered for PVMs. The buoy includes mooring loops, shackles or hooks to provide a suitable and secure mooring point for wind farm vessels throughout the operational lifetime of the wind farm. The PVM buoy may be connected via subsea electrical cables (included in the design envelope for array cables in Section 0) to a WTG or OSP and may be used for electric vessel charging. The maximum design envelope for PVMs is described in Table 1.42.

Table 1.42: MDS for PVMs

Parameter	Design Envelope
Number of PVMs	6
Buoy diameter (m)	6
Maximum number of anchors per mooring	6
Maximum anchor width (m)	7
Anchor installation drag length (m)	80
Anchor penetration depth (m)	6
Total area of seabed disturbed by anchor installation (m^2)	20,160
Total volume of seabed disturbed by anchor installation (m^3)	120,960
Maximum impact footprint of all buoy chains on sea floor during operation (m^2)	283,200

1.18 HELICOPTERS

1.18.1 Any helicopter access would be designed in accordance with the relevant Civil Aviation Authority (CAA) guidance and standards. Helicopters may be used for emergency situations, for training/drills, and if requested by the relevant authorities.

CONSTRUCTION & DECOMMISSIONING

1.18.2 The WTGs and OSPs may be accessed either from a vessel via a boat landing or from a helicopter via a heli-hoist platform on top of the nacelle or OSP respectively. Up to 530 round trips, by up to two helicopters, may be undertaken during the construction and decommissioning phases respectively.

O&M

1.18.3 Helicopters are considered for crew transfer during unplanned maintenance via heli-hoist winching directly onto WTGs and landing on OSP helidecks. Up to 125 helicopter return trips per year may be required.

1.19 REFERENCES

BEIS (2021a) Draft overarching National Policy Statement for energy (EN-1)

BEIS (2021b) Draft National Policy Statement for renewable energy infrastructure (EN-3)

BEIS (2021c) Draft National Policy Statement for electricity networks infrastructure (EN-5)

DECC (2011a) Overarching National Policy Statement for Energy (EN-1)

DECC (2011b) National Policy Statement for Renewable Energy Infrastructure (EN-3)

DECC (2011c) National Policy Statement for Electricity Networks Infrastructure (EN-5)

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