WHITE CROSS

White Cross Offshore Windfarm Environmental Statement

Chapter 5: Project Description

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Glossary of Acronyms

Acronym	Definition
AfL	Agreement for Lease
AOD	Above Ordnance Datum
AoS	Area of Search
BATNEEC	Best available technology not entailing excessive costs
BAS	Burial Assessment Study
BEIS	Department for Business, Energy and Industrial Strategy
CBRA	Cable Burial Risk Assessment
Cefas	Centre for the Environment and Fisheries and Aquaculture Science
CEMP	Construction Environmental Management Plan
CfD	Contracts for Difference
CIRIA	Construction Industry Research and Information Association
CoCP	Code of Construction Practice
DCO	Development Consent Order
DECC	Department for Energy and Climate Change
Defra	Department for Environment, Food and Rural Affairs
EEA	European Economic Area
EEZ	Economic Exclusion Zone
EIA	Environmental Impact Assessment
ERCoP	Emergency Response Co-operation Plan
ES	Environmental Statement
EU	European Union
HDD	Horizontal Directional Drilling
HMSO	Her Majesty's Stationery Office
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
ICP	Independent Connection Provider
IEMA	Institute of Environmental Management and Assessment
IPC	Infrastructure Planning Commission
km	Kilometre
Km^2	Square kilometre
m	Metre
MAIB	Marine Accident Investigation Branch
MCA	Maritime and Coastguard Agency
MCZ	Marine Conservation Zone
MGN	Marine Guidance Note
MMMP	Marine Mammal Mitigation Protocol
MMO	Marine Management Organisation

Acronym	Definition
MoD	Ministry of Defence
MPS	Marine Policy Statement
MSFD	Marine Strategy Framework Directive
MW	Megawatts
NE	Natural England
NGC	National Grid Company
nm	Nautical Mile
NRA	Navigational Risk Assessment
NOAA	National Oceanic and Atmospheric Administration
NPS	National Policy Statement
NPPG	The National Planning Practice Guidance
NRA	Navigational Risk Assessment
OFTO	Offshore Transmission Owner (OFTO)
ONS	Office for National Statistics
OS	Ordnance Survey
OTNR	Offshore Transmission Network Review
OWL	Offshore Wind Ltd
PINS	Planning Inspectorate
PPG	Pollution Prevention Guidelines
PPG	Planning Practice Guidance
TCE	The Crown Estate
TJB	Transition Joint Bay
UK	United Kingdom
UKHO	UK Hydrographic Office
UXO	Unexploded Ordnance
WTG	Wind Turbine Generator

Glossary of Terminology

Defined Term	Description
Agreement for Lease	An Agreement for Lease (AfL) is a non-binding agreement between a landlord and prospective tenant to grant and/or to accept a lease in the future. The AfL only gives the option to investigate a site for potential development. There is no obligation on the developer to execute a lease if they do not wish to.
Applicant	Offshore Wind Limited
Cumulative effects	The effect of the Project taken together with similar effects from a number of different projects, on the same single receptor/resource. Cumulative impacts are those that result from changes caused by other past, present or reasonably foreseeable actions together with the Project.

Defined Term	Description
Department for Business, Energy and Industrial Strategy (BEIS)	Government department that is responsible for business, industrial strategy, science and innovation and energy and climate change policy and consent under Section 36 of the Electricity Act.
Project Design Envelope	A description of the range of possible elements that make up the Project design options under consideration. The Project Design Envelope, or 'Rochdale Envelope' is used to define the Project for Environmental Impact Assessment (EIA) purposes when the exact parameters are not yet known but a bounded range of parameters are known for each key project aspect.
Engineer, Procure, Construct and Install	A common form of contracting for offshore construction. The contractor takes responsibility for a wide scope and delivers via own and subcontract resources.
Environmental Impact Assessment (EIA)	Assessment of the potential impact of the proposed Project on the physical, biological and human environment during construction, operation and decommissioning.
Export Cable Corridor	The area in which the export cables will be laid, either from the OSP or the inter-array cable junction box (if no OSP), to the WPD Onshore Substation comprising both the Offshore Export Cable Corridor and Onshore Export Cable Corridor.
Floating substructure	The floating substructure acts as a stable and buoyant foundation for the WTG. The WTG is connected to the substructure via the transition piece and the substructure is kept in position by the mooring system.
Front end engineering and design	Front-end engineering and design (FEED) studies address areas of windfarm system design and develop the concept of the windfarm in advance of procurement, contracting and construction.
Generation Assets	The infrastructure of the Project related to the generation of electricity within the windfarm site, including wind turbine generators, substructures, mooring lines, seabed anchors and inter-array cables
High Voltage Alternating Current	High voltage alternating current is the bulk transmission of electricity by alternating current (AC), whereby the flow of electric charge periodically reverses direction.
High Voltage Direct Current	High voltage direct current is the bulk transmission of electricity by direct current (DC), whereby the flow of electric charge is in one direction.
In-combination effects	In-combination effects are those effects that may arise from the development proposed in combination with other plans and projects proposed/consented but not yet built and operational.
Inter-array cables	Cables which link the wind turbines to each other and the OSP, or at the inter-array cables junction box (if no OSP). Array cables will connect the wind turbines to one and other and to the OSP (if utilised). The initial section for the inter-array cables will be freely suspended in the water

Defined Term	Description
	column below the substructure (dynamic sections) while the on seabed sections of the cables will be buried where possible.
Jointing bay	Underground structures constructed at regular intervals along the Onshore Export Cable Corridor to join sections of cable and facilitate installation of the cables into the buried ducts
Landfall	Where the Offshore Export Cables come ashore
Link boxes	Underground chambers or above ground cabinets next to the cable trench housing electrical earthing links
Mean high water springs	The average tidal height throughout the year of two successive high waters during those periods of 24 hours when the range of the tide is at its greatest.
Mean low water springs	The average tidal height throughout a year of two successive low waters during those periods of 24 hours when the range of the tide is at its greatest.
Mean sea level	The average tidal height over a long period of time.
Mooring system	The equipment (mooring lines and seabed anchors) that keeps the floating substructure in position during operation through a fixed connection to the seabed.
Mitigation	Mitigation measures have been proposed where the assessment identifies that an aspect of the development is likely to give rise to significant environmental impacts, and discussed with the relevant authorities and stakeholders in order to avoid, prevent or reduce impacts to acceptable levels. For the purposes of the EIA, two types of mitigation are defined: • Embedded mitigation: consisting of mitigation measures that are identified and adopted as part of the evolution of the project design, and form part of the project design that is assessed in the EIA • Additional mitigation: consisting of mitigation measures that are identified during the EIA process specifically to reduce or eliminate any predicted significant impacts. Additional mitigation is therefore subsequently adopted by OWL as the EIA process progresses.
National Grid Onshore Substation	Part of an electrical transmission and distribution system. Substations transform voltage from high to low, or the reverse by means of the electrical transformers.
National Grid Connection Point	The point at which the White Cross Offshore Windfarm connects into the distribution network at East Yelland substation and the distributed electricity network. From East Yelland substation electricity is transmitted to Alverdiscott where it enters the national transmission network.
Offshore Development Area	The Windfarm Site (including wind turbine generators, substructures, mooring lines, seabed anchors, inter-array cables and OSP (as applicable)) and Offshore Export Cable Corridor to MHWS at the Landfall. This

Defined Term	Description
	encompasses the part of the project that is the focus of this application and Environmental Statement and the parts of the project consented under Section 36 of the Electricity Act and the Marine and Coastal Access Act 2009
Offshore Export Cables	The cables which bring electricity from the OSP or the inter-array cables junction box to the Landfall
Offshore Export Cable Corridor	The proposed offshore area in which the export cables will be laid, from OSP or the inter-array cable junction box to the Landfall
Offshore Infrastructure	All of the offshore infrastructure including wind turbine generators, substructures, mooring lines, seabed anchors, OSP and all cable types (export and inter-array). This encompasses the infrastructure that is the focus of this application and Environmental Statement and the parts of the project consented under Section 36 of the Electricity Act and the Marine and Coastal Access Act 2009
the Offshore Project	The Offshore Project for the offshore Section 36 and Marine Licence application includes all elements offshore of MHWS. This includes the infrastructure within the windfarm site (e.g. wind turbine generators, substructures, mooring lines, seabed anchors, inter-array cables and OSP (as applicable)) and all infrastructure associated with the export cable route and landfall (up to MHWS) including the cables and associated cable protection (if required).
OSP	A fixed structure located within the Windfarm Site, containing electrical equipment to aggregate the power from the wind turbines and convert it into a more suitable form for export to shore
Offshore Transmission Assets	The aspects of the project related to the transmission of electricity from the generation assets including the OSP (as applicable)) or offshore junction box, Offshore Cable Corridor to MHWS at the landfall
Offshore Transmission Owner	An OFTO, appointed in UK by Ofgem (Office of Gas and Electricity Markets), has ownership and responsibility for the transmission assets of an offshore windfarm.
Onshore Development Area	The onshore area above MLWS including the underground Onshore Export Cables connecting to the White Cross Onshore Substation and onward to the WPD grid connection at East Yelland. The onshore development area will form part of a separate Planning application to the Local Planning Authority (LPA) under the Town and Country Planning Act 1990
Onshore Export Cables	The cables which bring electricity from MLWS at the Landfall to the White Cross Onshore Substation and onward to the WPD grid connection at East Yelland
Onshore Export Cable Corridor	The proposed onshore area in which the export cables will be laid, from MLWS at the Landfall to the White Cross Onshore Substation and onward to the WPD grid connection at East Yelland
Onshore Infrastructure	The combined name for all infrastructure associated with the Project from MLWS at the Landfall to the WPD grid connection point at East Yelland. The onshore infrastructure will form part of a separate Planning

Defined Term	Description
	application to the Local Planning Authority (LPA) under the Town and Country Planning Act 1990
Onshore Transmission Assets	The aspects of the project related to the transmission of electricity from MLWS at the Landfall to the WPD grid connection at East Yelland including the Onshore Export Cable, the White Cross Onshore Substation and onward connection to the WPD grid connection at East Yelland
the Onshore Project	The Onshore Project for the onshore TCPA application includes all elements onshore of MLWS. This includes the infrastructure associated with the Offshore Export Cable (from MLWS), landfall, Onshore Export Cable and associated infrastructure and new onshore substation (if required).
Offshore Wind Limited	Offshore Wind Ltd (OWL) is a joint venture between Cobra Instalaciones Servicios, S.A., and Flotation Energy Ltd
the Project	the Project is a proposed floating offshore windfarm called White Cross located in the Celtic Sea with a capacity of up to 100MW. It encompasses the project as a whole i.e. all onshore and offshore infrastructure and activities associated with the Project
Safety zones	A marine zone outlined for the purposes of safety around a possibly hazardous installation or works / construction area
Service operation vessel	A vessel that provides accommodation, workshops and equipment for the transfer of personnel to turbine during OMS. Vessels in service today are typically up to 85m long with accommodation for about 60 people.
Scour protection	Protective materials to avoid sediment being eroded away from the base of the foundations as a result of the flow of water
Transition joint bay	Underground structures at the Landfall that house the joints between the Offshore Export Cables and the Onshore Export Cables
Transition piece	The transition piece includes various functionalities such as access for maintenance, cable connection for the energy of the turbine and the corrosion protection of the entire foundation
White Cross Offshore Windfarm	100MW capacity offshore windfarm including associated onshore and offshore infrastructure
White Cross Onshore Substation	A new substation built specifically for the White Cross project. It is required to ensure electrical power produced by the offshore windfarm is compliant with WPD electrical requirements at the grid connection at East Yelland.
Wind Turbine Generators (WTG)	The wind turbine generators convert wind energy into electrical power. Key components include the rotor blades, nacelle (housing for electrical generator and other electrical and control equipment) and tower. The final selection of project wind turbine model will be made post-consent application
Windfarm Site	The area within which the wind turbines, OSP and inter-array cables will be present

Defined Term	Description
Works completion date	Date at which construction works are deemed to be complete and the windfarm is handed to the operations team. In reality, this may take place over a period of time.

5. Project Description

5.1 Introduction

1. This chapter of the Environmental Statement (ES) presents the description of the White Cross Offshore Windfarm Project (seaward of Mean High Water Spring (MHWS)) which is hereafter referred to as 'the Offshore Project'). The Offshore Project is a demonstration scale Floating Offshore Windfarm (FLOW) development. The Offshore Project is being developed by Offshore Wind Ltd (OWL) a joint venture between Cobra Instalaciones Servicios, S.A., and Flotation Energy Ltd.
2. This chapter provides a full description of components and installation required for construction, operation, and decommissioning of the Offshore Project. The details provided inform and underpin the assessments that have been undertaken, although **Chapters 8** to **26** should be referred to for details of the realistic worst-case scenarios that apply to each topic.
3. The set of consents/permission required in order for the Offshore Project to proceed are outlined below:
    - Consent under the Section 36 of the Electricity Act 1989 and a marine licence under the Marine and Coastal Access Act 2009 (MCAA 2009) are required for the following generation assets (within the Windfarm Site):
        - Wind Turbine Generators
        - Semi-submersible floating platforms
        - Subsea mooring lines (catenary, taught or semi-taught)
        - Anchoring solutions (drag embedment anchors, suction anchor, driven or drilled piles)
        - Inter-array cables and associated protection
        - Other associated offshore infrastructure, such as navigational markers.

- A second Marine Licence is required to enable the option for an Offshore Transmission Owner (OFTO) to be appointed under The Electricity (Competitive Tenders for Offshore Transmission Licences) Regulations 2015 for the following transmission assets :
    - OSP (OSP)
    - Offshore Export Cable (to MHWS at Landfall)
    - Other associated offshore infrastructure, such as navigational markers
    - Taw Estuary Crossing (between MHWS on the northern edge to MHWS on the southern edge).

- A separate planning permission under the Town and Country Planning Act 1990 (TCPA 1990) with a separately prepared ES is required for the following Onshore Project (landward of Mean Low Water Springs (MLWS)) transmission assets:

- Onshore Export Cables
- White Cross Onshore Substation
- Onshore Export Cables (66kV from landfall to onshore substation and 132kV from the White Cross Onshore Substation to WPD Grid Connection)
- Temporary main construction compound and temporary construction compounds
- Transition Joint Bay, jointing bays, link boxes, access roads and haul roads
- Grid connection.

4. An overview of the potential impacts associated with the Onshore Project is included within the Section 36 and Marine Licences applications. Further detail on the consenting regime and relevant legislation relevant to the Offshore Project is presented in **Chapter 3: Policy and Legislative Context**.

5.2 Project Design Envelope

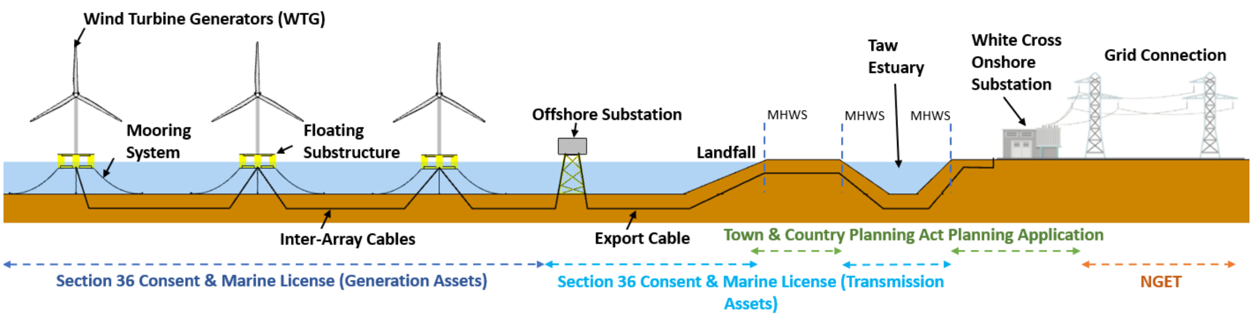
5. At this stage in the development of the Offshore Project, the proposed description is indicative, and a project design envelope (PDE) approach has been utilised in order to undertake the Environmental Impact Assessment (EIA). Further details of the use of a PDE or "Rochdale envelope" are provided in **Chapter 6: EIA Methodology**. This is considered a standard approach and is widely accepted by all stakeholders.
6. The PDE sets out a series of design options for the Offshore Project and has a reasoned best and worst-case extent for several key parameters. The final design would lie between the minimum and the maximum extent of the consent sought, for all aspects of the Offshore Project; this includes spatial and temporal elements, and the proposed methodology to be employed.
7. The PDE is used to establish the extent to which the Offshore Project could impact on the environment. The final detailed design of the Offshore Project will fall within this 'envelope', allowing for detailed design work to be undertaken post-consent without rendering the assessment inadequate.
8. Therefore, the information presented in this chapter outlines the options and flexibility required and the range of potential design and activity parameters upon which the subsequent technical **Chapters 8** to **26** are based.
9. The need for flexibility in the consent is a key aspect of any large development but is particularly significant for offshore wind projects where technology continues to evolve quickly. The PDE must therefore provide sufficient flexibility to enable the Applicant and its contractors to use the most up to date, efficient and cost-effective technology and techniques in the construction, operation, maintenance and decommissioning of the Offshore Project, without compromising the surrounding environment further than the worst-case scenarios assessed in this ES.

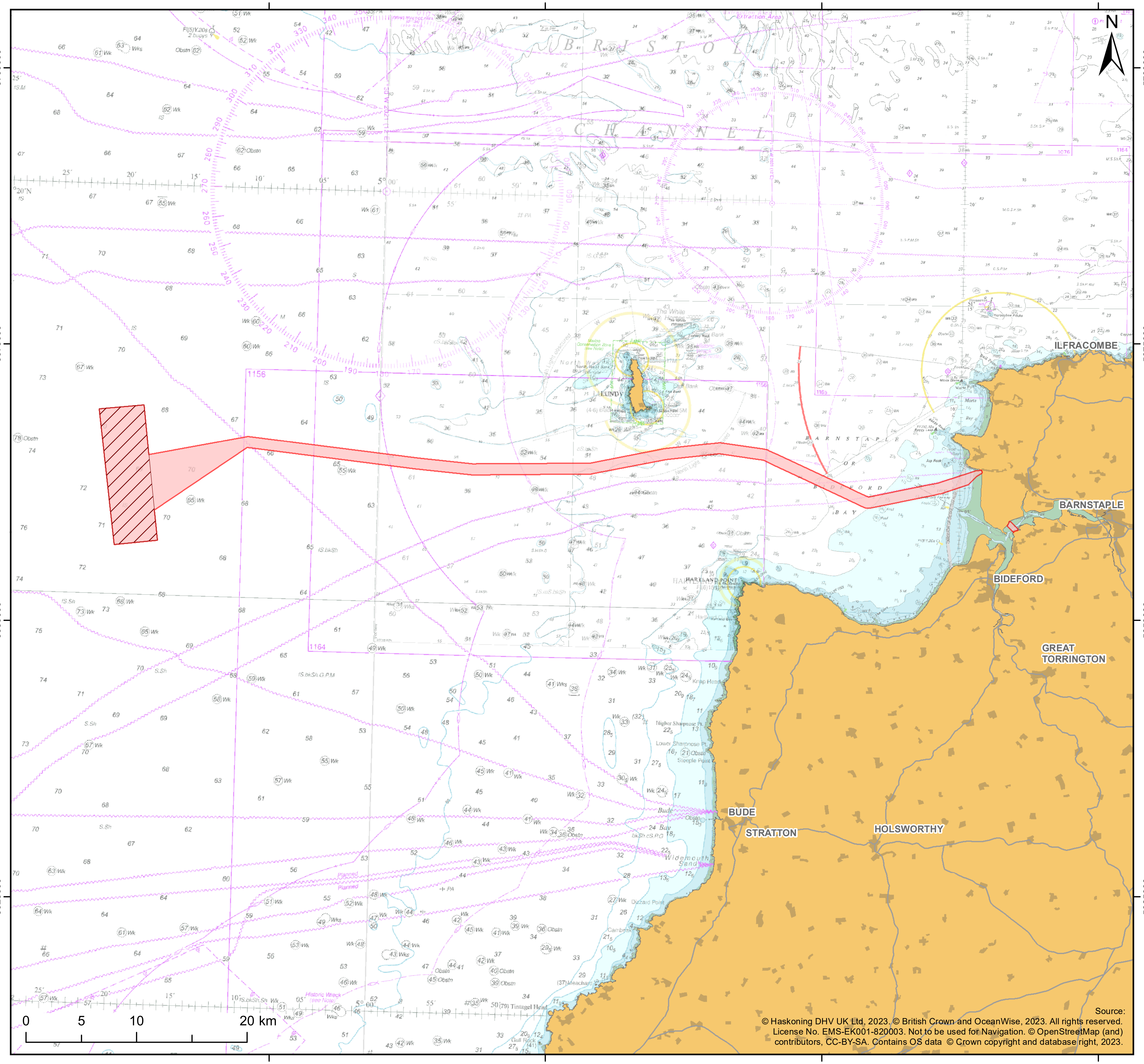
10. Where appropriate, each technical chapter (**Chapters 8** to **26**) contains a section detailing the realistic worst-case scenario for specific receptors and impacts. These realistic worst-case scenario sections are derived from the information provided in this chapter.
11. Design work is ongoing with the intention that the more detailed design work will be completed post-consent. In addition, post-consent/pre-construction site investigation will further inform the detailed design. Key aspects for which flexibility is required include:
    - Wind Turbine Generator (WTG) capacity parameters are required due to the potential evolution of technology prior to offshore construction of the Offshore Project
    - Number and dimensions of the floating substructure proposed due to the direct correlation with size and capacity of WTG selected
    - Numbers and configuration of subsea mooring lines; linked to dimensions of floating substructure and detailed engineering studies
    - Type of mooring line configuration and material i.e. catenary, taught and semi-taught system may be used.
    - Type of mooring seabed anchor i.e. drag embedment anchors, suction anchors or driven or drilled piles may be used depending on the dimensions of floating platforms and site-specific ground conditions
    - WTG and associated inter-array cable layout
    - An Offshore Export Cable Corridor allows for the micro-routing of the cables within the identified corridor taking into account future detailed pre-installation surveys
    - Amount and exact location of cable protection along the Offshore Export Cable is linked to site-specific ground conditions
    - Landfall construction method will be either a trenchless technique or open-cut trenching allowing for unknown ground conditions
    - Construction timing and methodologies are to be fully developed once project design is finalised and installation contractors are appointed
    - Operation and maintenance activities will be adjusted to the final as-built project requirements
    - Decommissioning timing and methodologies to be fully developed once project design is finalised
12. This chapter sets out a series of options and parameters for which the values causing the worst-case impact are shown.

5.3 Overview of the Offshore Project

5.3.1 Overview of the Offshore Project components

13. An illustration of the main components of the Offshore Project is provided in **Plate 5.1** alongside the main components of the Onshore Project. The Offshore Export Cable(s) make landfall at Saunton Sands on the North Devon coast. The Offshore Project location is illustrated in **Plate 5.1**.
14. Above MHWS at Landfall, it will be connected to the Onshore Export Cable via a Transition Joint Bay located in Saunton Sands Car Park. The Onshore Export Cable travels approximately 8km at its maximum inland to a high voltage alternating current (HVAC) onshore substation. This will include a crossing below the Taw Estuary via trenchless technology. A new White Cross Onshore Substation will be constructed to accommodate the connection of the Offshore Project to the existing WPD East Yelland Substation and grid connection Further detail of these onshore components will be described and assessed within the Onshore Project ES.





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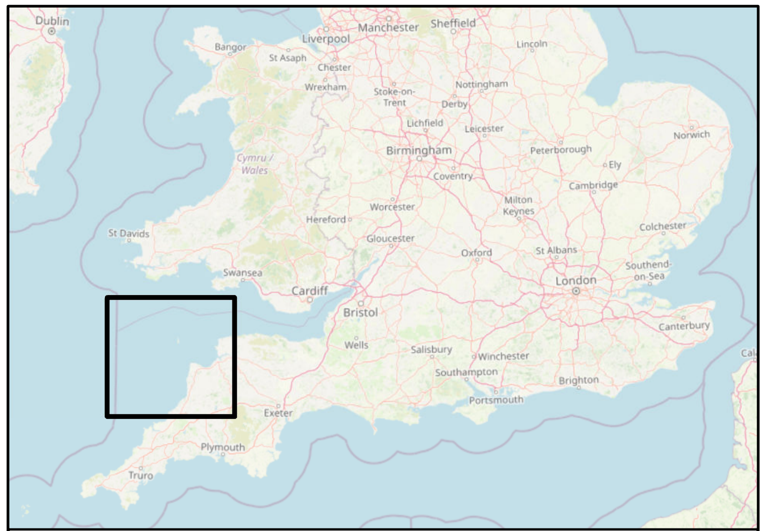

Legend:
- Windfarm Site
- Offshore Development Area

Client:	Project:
Offshore Wind Ltd.	White Cross Offshore Windfarm

Title: Project Location

Figure: 5.1 | Drawing No: PC2978-RHD-ZZ-XX-DR-Z-0466

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
P02	03/03/2023	AB	CB	A3	1:350,000
P01	03/01/2023	AB	CB	A3	1:350,000

Co-ordinate system: WGS 1984 UTM Zone 30N

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Once built, the Offshore Project will have a generating capacity of up to 100MW, with the key offshore components comprising:

- Six to eight semi-submersible floating platforms and Wind Turbine Generators (WTGs)
- One mooring system per substructure comprised of mooring lines (catenary, taught or semi-taught) and seabed anchors (drag embedment anchors or suction, driven pin or drilled piles)
- Up to ten dynamic inter-array cables and associated cable protection
- OSP (if required) with a fixed jacket substructure
- Other associated offshore infrastructure, such as navigational markers.
- Offshore Export Cable connecting the offshore wind farm to the landfall and associated cable protection.

5.3.2 Overview of programme

15. It is anticipated that the realistic worst-case for construction of the Offshore Project will take 28 months (18 months for onshore fabrication and assembly of floating substructures and 16 months offshore construction activities). The operational phase of the Offshore Project will last for a minimum of 25 years, and up to 18 months for decommissioning the Offshore Project.
16. A high-level development and installation programme is provided in **Plate 5.2**.

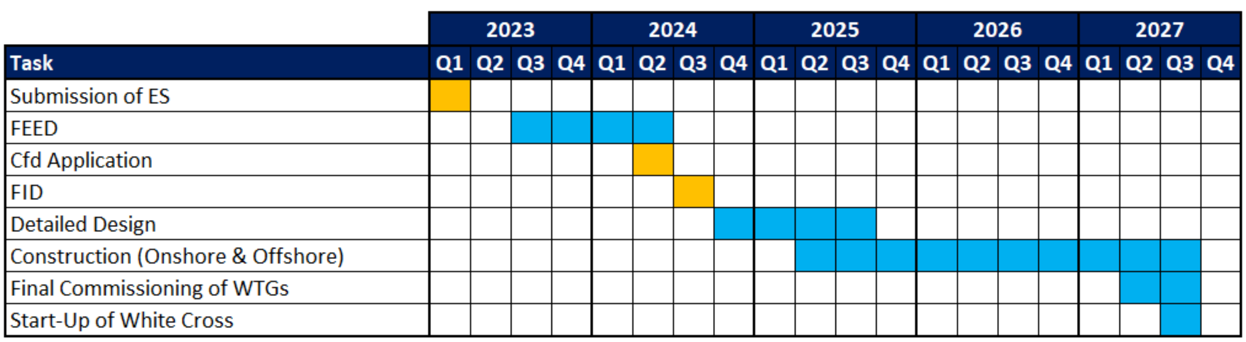


Plate 5.2 Indicative development and installation programme for the Offshore Project

5.4.1 The Windfarm Site

17. The Windfarm Site, is located approximately 52km north-west of the Cornwall and Devon coastline in a water depth of 69m – 78m LAT. The Windfarm Site covers approximately 50km^2. It is proposed an Agreement for Lease will be entered into with The Crown Estate to facilitate its use.

18. The key characteristics of the Windfarm Site are summarised in **Table 5.1**.

Table 5.1 White Cross Offshore Windfarm Site Overview

Area	Parameters	Values
AfL/Windfarm Site	Area	49.35km^2
	Closest distance to shore	52.5km
	Water depth	69m - 78m LAT

5.4.2 Wind Turbine Generators

19. The size and capacity of the WTGs that will be utilised in the Windfarm Site has yet to be selected and as such the Offshore Design Envelope is necessarily broad to accommodate the range of WTGs under consideration and innovations in currently available WTG technologies. Each WTG will follow conventional offshore design architecture with three blades and a horizontal rotor axis. The Offshore Project Design Envelope covers a range of parameters and the worst-case impacts on the relevant receptor(s) have been assessed based upon these. Indicative parameters for the wind turbine generator design envelope for the Offshore Project are illustrated in **Plate 5.3** and **Table 5.2**.

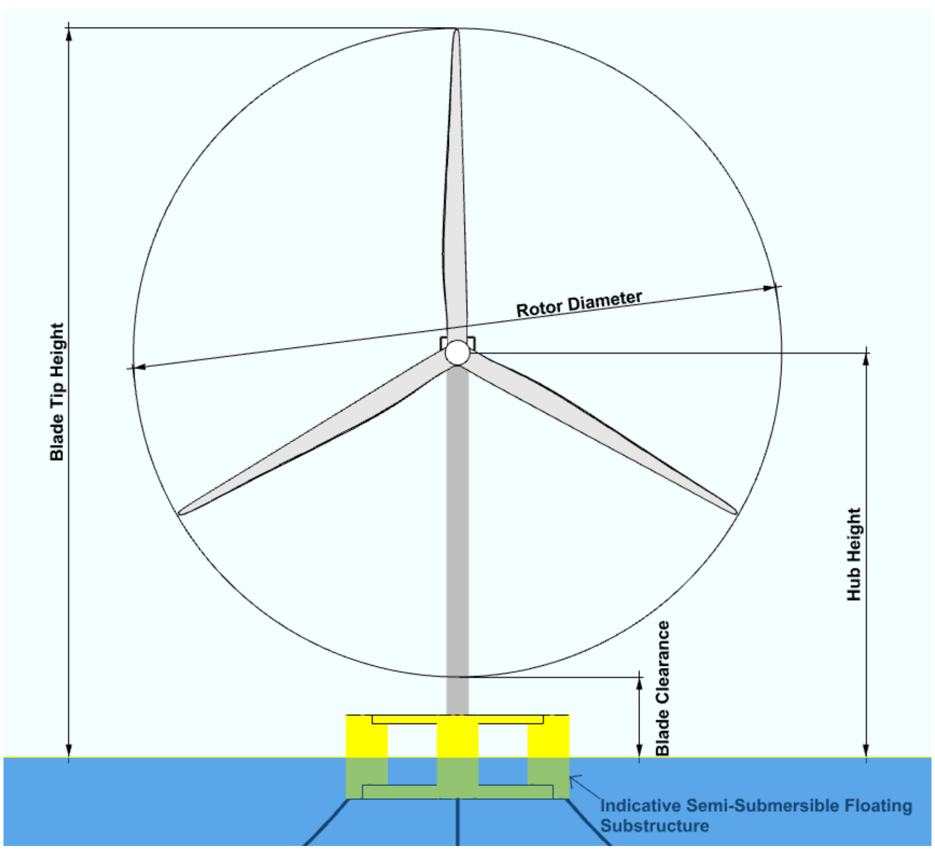


Plate 5.3 Illustration of the design parameter definition for a WTG

Table 5.2 Wind Turbine Generator Worst-case Parameters

WTG Parameter	Minimum	Maximum	Justification
WTG capacity (MW)	12	18	Theoretical maximum of 18MW WTG included to account for anticipated WTG technology development throughout Project design, noting this will be capped to the agreed total export capacity of the Offshore Project of up to 100MW where necessary.
Hub height (from MSL) (m)	n/a	153	Maximum is based on 18MW WTG
Rotor diameter (m)	n/a	262	Maximum is based on 18MW WTG
Rotor speed (rpm)	n/a	9	Based on information received from supplier.
Number of wind turbines	n/a	8	Maximum is based on eight 12MW WTGs
Total rotor swept area (m^2)	n/a	323,477	Maximum is based on six 18MW WTGs with individual rotor swept areas of 53,913m^2 each. This individual rotor swept area value only applies to an 18MW WTG option. Although there could be a higher number of smaller capacity WTG, their corresponding individual total swept area are smaller and therefore the total rotor swept area will not exceed this value.
Tower diameter at top (m)	5	8	Based on information received from supplier.
Tower diameter at bottom (m)	6	10	Based on information received from supplier.
Max tip height (m) above MHWS	n/a	284	Maximum is based on an 18MW WTG height.
Air gap above MHWS (m)	22	n/a	22m is the minimum. 22m is set by the Marine and Coastguard agency for

WTG Parameter	Minimum	Maximum	Justification
			avoidance of collisions with vessels.
Indicative separation distance between turbines (in row) (m)	1,100	n/a	This value is based on 5 x the smallest rotor diameter under consideration.
Indicative separation distance between turbines (inter-row) (m)	2,200	n/a	This value is based on 10 x the smallest rotor diameter under consideration.

5.4.2.1 Lubricating oils, hydraulic oils and coolants

20. Components within each WTG will require lubricating oils, hydraulic oils and coolants for operation. Indicative maximum requirements for these oils and fluids for a single WTG are shown in **Table 5.3**.
21. These values are based on a realistic worst-case using a geared system, rather than a direct drive which would require less. All oils and fluids will be contained within the WTG in case of a spill.

Table 5.3 Indicative maximum requirements of lubricants within each WTG

Parameter	Maximum
Lubrication oil (Grease) per WTG (litres)	1,200
Synthetic oil / Hydraulic oil per WTG (litres)	20,000
Nitrogen (litres)	120,000
Cooling agent per WTG (Water/Glycerol) (litres)	16,000
Silicone Oil (litres)	14,000

22. All WTGs may also have diesel generators for construction, operation and maintenance activities. Generators are typically used for back-up power supply at the platform (crane lifting, etc.). Battery packs may also be used which can provide up to 60 hours of back-up power supply.

5.4.2.2 WTG Control System

23. Each WTG will operate automatically and have the ability to yaw (rotate the nacelle so the rotor blades face into the wind) and pitch its blades (where the blades rotate in to or out of the wind depending on wind speed). Each WTG is self-starting when

the wind speed reaches the WTG cut-in speed (average of 3 metres per second (m/s) to 5 m/s [~10mph]). The power output increases with the wind speed until the wind speed reaches the WTG rated wind speed (typically 10 m/s to 13 m/s [~25 mph]). From this point as wind speed increases the power is regulated at rated (maximum) power. When the maximum operational wind speed (cut-out speed) is reached, typically 25 m/s to 30 m/s (about 60 mph), the WTG will cut-out (stop rotation and pitch blades out of wind). The maximum power and different wind speed regions are dependent on the WTG design.

24. All the WTGs will be connected to a central Supervisory Control and Data Acquisition (SCADA) system for the control of the windfarm remotely (via fibre optic cables, microwave, or satellite links). Fibre optic will be bundled with the electrical cores in a single cable (one cable per circuit). The SCADA monitors and controls the output from each WTG and has an integrated alarm system that will be automatically triggered in the event of a fault. Individual WTGs can also be controlled manually from within the WTG nacelle or tower base to control the WTG for commissioning or maintenance.

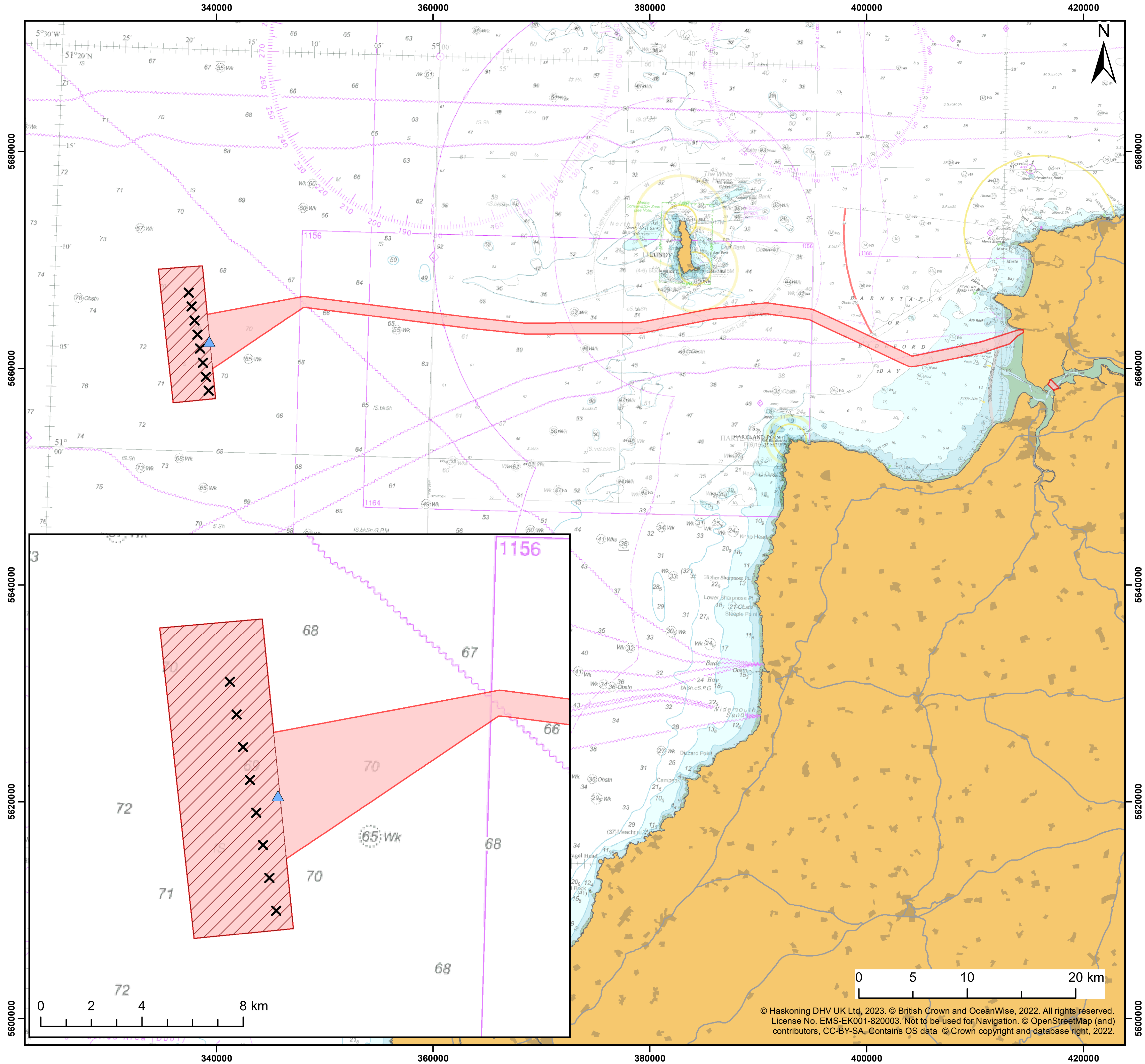
5.4.2.3 Adaption for climate change

25. The WTGs, floating substructures, moorings and inter-array cables will be designed considering environmental loads derived from a hindcast model. Hindcast models provide synthesised long term time series of wind, waves and currents that are correlated to measured conditions near to the project site. The Offshore Project design will be based upon using a time series of data for the period 1979-2022. Therefore, the data captures the effects of climate change over this period. From this data OWL will determine the 10-year, 50-year and 100-year extreme event parameters for wind, wave and current and the offshore infrastructure will be designed to withstand these events. Through this OWL can be confident that the offshore infrastructure can maintain integrity throughout its minimum 25-year design life. There will also be annual inspections of the structures throughout their life cycle. Metocean monitoring systems are being considered which would allow OWL to monitor how conditions change throughout the project's life.

5.4.3 Array Layout Description

26. An indicative WTG array layout is shown in **Figure 5.2**. This layout will be subject to an iterative optimisation process where refinement is made during each project design stage. The final layout selection will balance key project sensitivities such as WTG model choice, predominant wind direction, geophysical characteristics, metocean conditions, benthic habitats, floating substructure and anchor design, and navigational safety considerations. The array layout will consider the requirements of Marine

Guidance Note MGN654 (MCA, 2021; and any subsequent versions) and the final array layout is proposed to be confirmed in consultation with the Regulator post consent and prior to the commencement of construction.



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Legend:

- Windfarm Site
- Offshore Development Area
- Wind Turbine Locations
- Offshore Substation Platform

Client: Offshore Wind Ltd.	Project: White Cross Offshore Windfarm

Title: Indicative Locations of the Infrastructure in the Windfarm Site

Figure: 5.2 Drawing No: PC2978-RHD-ZZ-XX-DR-Z-0562

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
P01	07/03/2023	GC	SF	A3	1:350,000

Co-ordinate system: WGS 1984 UTM Zone 30N

WHITE CROSS

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5.4.3.1 WTG Navigational Lighting Requirements and Colour Scheme

27. With respect to lighting and marking, the wind turbines and OSP topsides will be designed and constructed to satisfy the requirements of the Civil Aviation Authority (CAA), MCA and Trinity House Lighthouse Service (THLS).
28. Further details including reference to the relevant guidance and regulations is presented in **Chapter 15: Shipping and Navigation** and **Chapter 17: Civil and Military Aviation**.
29. The colour scheme for nacelles, blades and towers is expected to be RAL 7035 (light grey).

5.4.3.2 Wind measurements

30. A fixed-bottom offshore metmast will not be installed for wind measurements at site due to the prohibitively deep water depth. Wind measurements are instead being collected by a floating LiDAR deployed within the Windfarm Site. The installation of floating LiDAR has been subject to a separate marine licence (reference: L/2022/00221/1).

5.4.4 Floating Substructures

31. The WTGs will be supported by floating substructures, the specific concept for which has not yet been selected. With many substructure concepts currently available on the market, each at varying stages of development, the project has completed a selection process and feasibility studies to understand which substructure types and concepts will be most suitable for the project. Through this selection process the number of substructure types has been reduced to one, semi-submersibles.
32. Each semi-submersible substructure concept have varying shapes and dimensions as a result of their particular approach to meeting the unique engineering challenges associated with floating WTGs and project-specific requirements. The floating substructure design envelope has been formulated to cover the range of technologies under consideration and largest WTG scenario.
33. Conventional fixed substructures were deemed not suitable for the project due to the prohibilitively deep water depth (>60m). Floating substructure enable WTGs to be installed in deeper waters further from shore where wind resource is larger. Floating substructures offer additional benefits in that their construction is largely onshore yard based, with significantly less offshore construction activity required. This reduces the environmental impacts of the offshore construction campaign and the cost and scheduling uncertainties traditionally associated fixed offshore windfarm construction.

5.4.4.1 Semi-Submersible Floating Substructure

34. A semi-submersible substructure is a buoyancy stabilised platform which floats semi-submerged on the surface of the ocean whilst anchored to the seabed (see illustration in **Plate 5.4**). The substructure gains its stability through the buoyancy force associated with its large footprint and geometry, which ensures the wind loadings on the structure and WTG are countered / dampened by the equivalent buoyancy force on the opposite side of the structure. These can be constructed in various configuration (varying number of columns arranged in varying layouts) but are typically comprised of several buoyancy columns interconnected by either pontoons, beams or braces (see illustration in **Plate 5.4**).

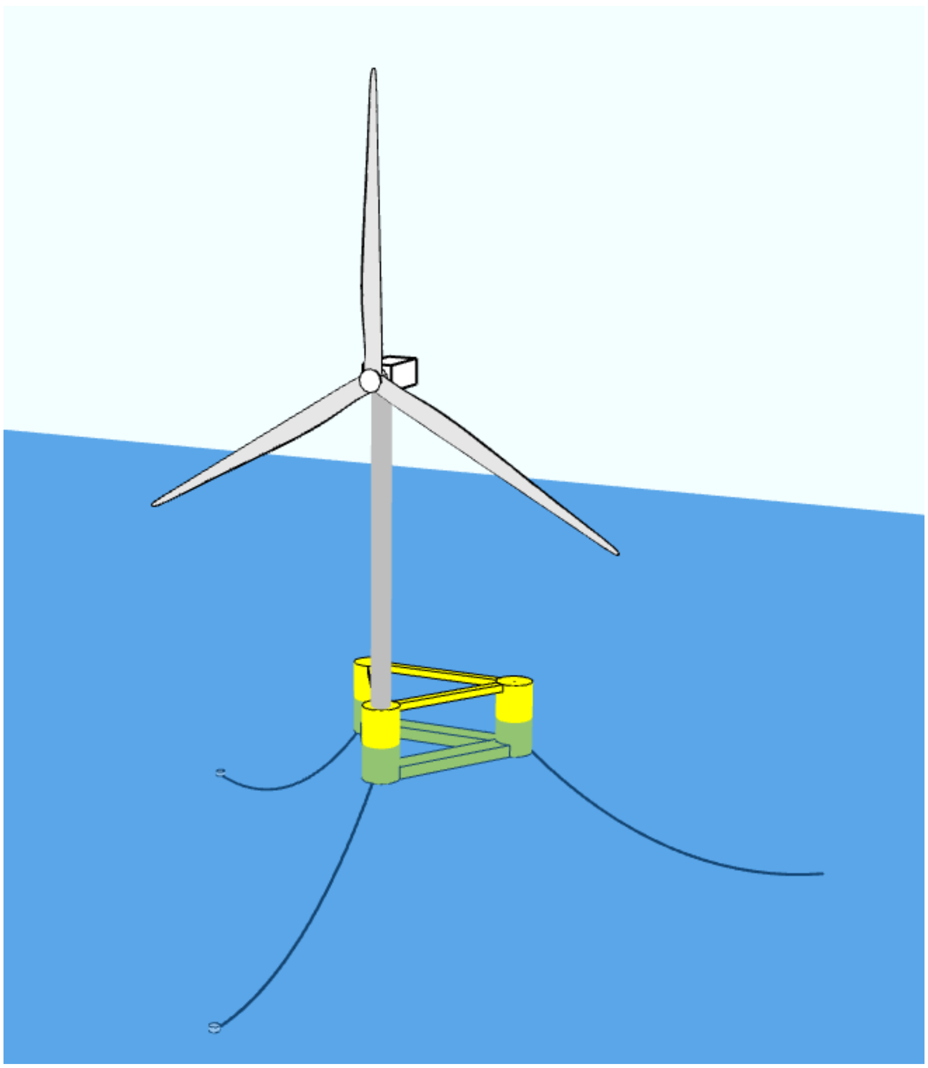


Plate 5.4 Illustration of characteristic semi-submersible floating substructure

35. Semi-submersible substructures will also feature secondary structures such as boat landings, deck space, stairs/ladders and railings (for personnel access) and associated equipment (onboard davit crane, array cable hang-off etc.).

36. A summary of the semi-submersible floating platform dimensions within the PDE are set out in **Table 5.4**.

Table 5.4 Semi-submersible floating platform parameter summary

Parameter	Minimum	Maximum
Number of columns per substructure	3	4
Overall length of each face (m)	n/a	125
Draft in operation (m)	n/a	20
Total substructure unit height (m)	25	35
Freeboard (in operation) (m)	10	20
Maximum footprint per substructure (base of hull assumed) (m^2)	1000	6600
Total maximum volume for floating substructures in operation (m^3)	50,000	110,000
Maximum excursion of hull from slack line position/neutral (m)	n/a	40
Primary material, colour & coating	Steel, RAL 1032 (traffic yellow), low-toxicity anti-fouling marine grade paint	
Lighting	All walkways and boat landing, access platform/davit crane. All sensor activated. An 'Aids to Navigation Management Plan' will be developed with associated navigation markers and lighting (will require approval by the MCA and Trinity House post consent and prior to construction).	

5.4.5 Mooring Systems

37. The mooring system keeps the floating substructure in position during operation and extreme storm events (station-keeping) through a fixed connection to the seabed and is comprised of:

- Anchor
- Mooring line comprising the following single or combined material solutions:
  - Steel Chains
  - Steel Wire Ropes / Cables (multiple configurations)

   - Synthetic Ropes, such as nylon, polyester, polypropylene, kevlar, and high-density polyethylene.

- Various connectors and ancillaries to connect the mooring components and adjust the behaviour of the system:

   - Long-term shackles / links
   - Clump weights
   - Buoys / buoyancy elements
   - Tensioners.

38. There are several options available for each of these components as discussed in the following sections. The type and number of anchors and moorings used for the Offshore Project will depend on the type of floating substructure, loads imposed on the mooring system by the substructure/WTG assembly in the metocean conditions prevailing on site, in addition to geotechnical and environmental considerations. The final design of the mooring system will be determined during the FEED and detailed design phases.
39. There are three types of mooring configuration that are suitable for use with a semi-submersible substructure (illustrated in **Plate 5.5** and **Plate 5.6**):
    - Catenary mooring: Predominantly steel chains but can also include some sections of synthetic elements. The weight of the catenary mooring in the water column provides the restoring force that maintains the position of the floating substructure. A large section of the mooring chain lies on the seabed in order to remove any vertical load acting on the anchors and thus enabling the use of conventional and more cost-effective anchor types (drag embedment anchors). These systems typically have larger footprints, but can be reduced through the attachment of clump weight and/or heavy chain sections near to where the mooring line comes into contact with the seabed.
    - Semi-taut mooring: A combination of synthetic fibres and steel chain, where the chain sections provide the restoring and anchoring benefits of the Catenary system and the synthetic fibres, under some tension, limit the amount of steel chain required, providing benefits in the overall footprint of the mooring system.
    - Taut spread mooring: Synthetic fibres or wires with small link elements of chain arranged in a non-vertical configuration (unlike Tension Leg). The system is placed under significant tension to create a stable mooring system where all of the stability comes from the tension held within the taut mooring line.

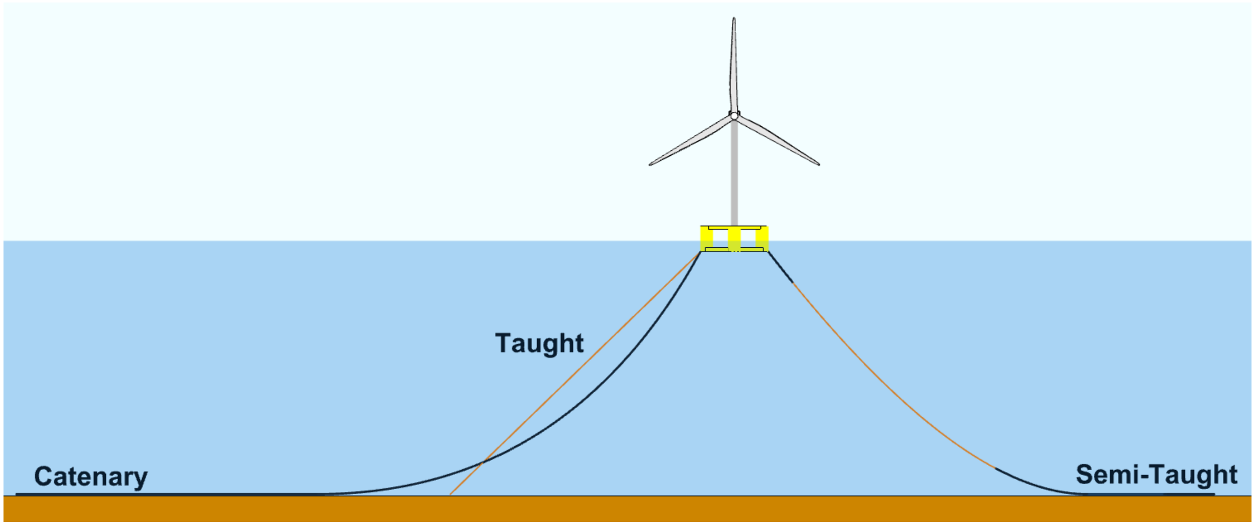


Plate 5.5 Mooring Configurations

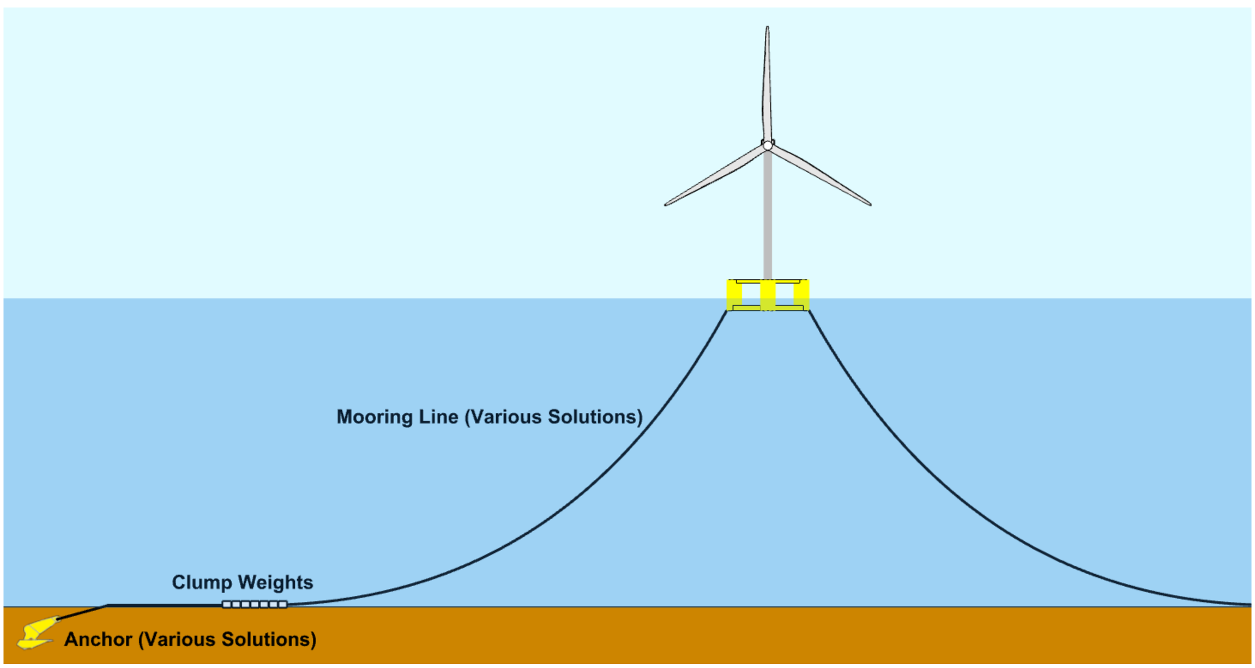


Plate 5.6 Mooring System Components

40. The mooring system configurations under consideration are detailed in **Table 5.5**, with an illustration of the types shown in **Plate 5.5.**

Table 5.5 Indicative Mooring Configuration

Mooring Parameter	Taught	Semi-Taught	Catenary
Maximum number of moorings per WTG	6	6	6
Maximum mooring line length (m/line)	600	680	760
Maximum mooring anchor radius (m)	600	650	750

Mooring Parameter	Taught	Semi-Taught	Catenary
Maximum proportion of mooring line that may come into contact with seabed (%)	15	50	80
Anchor types	Suction anchor, driven piles or drilled piles	Suction anchor, driven piles or drilled piles	Drag embedment anchor, Suction anchor, driven piles or drilled piles
Maximum number of clump weights per mooring line	N/A	30	30
Max individual clump weight	N/A	20Te	20Te
Maximum seabed footprint of each clump weight (m^2)	N/A	2	2
Material of mooring lines	Chains – Steel Cables – Steel Synthetic Rope – Nylon, Polyester or other synthetic equivalent Connectors – Steel	Chains – Steel Cables – Steel Synthetic Rope – Nylon, Polyester or other synthetic equivalent Connectors – Steel	Chains – Steel Cables – Steel Connectors – Steel
Maximum thickness of mooring lines	Chains – 175 mm Synthetic – 350mm	Chains – 175 mm Synthetic – 350mm	Chains – 175 mm

41. **Table 5.6** presents the range of mooring system footprints considered within the design envelope.

Table 5.6 Wind Turbine Anchoring Systems Parameters

Mooring System Parameter	Minimum	Maximum
No. of mooring lines per WTG	3	6
No. of anchors per WTG	3	8
Estimated area of mooring line in contact with seabed per mooring line (m^2)	90	304
Clump footprint per mooring line (m^2)	0	60
Anchor footprint (m^2)	3.14	100

Mooring System Parameter	Minimum	Maximum
Mooring System footprint per WTG (m^2)	144	2984
Footprint for Total WTGs (m^2)	867	23872
Seabed preparation per WTG mooring system (m^2)	N/A	1383

5.4.5.1 Drag Embedment Anchors

42. Drag embedment anchors are similar in concept to the anchors used on vessels (see example shown in **Plate 5.7**). Drag embedment anchors are held in position in the seabed through the resistance between the anchor and seabed substrate which is applied due to the tension of the mooring line. The drag embedment anchor will penetrate the seabed to depths of 8 to 25m, depending on the sediment thickness, with no part of the anchor anticipated to be above the seabed surface once installed.

Plate 5.7 Drag Embedment Anchor Example (Source: Vyrhof, 2021)

43. Each mooring line will be attached to at least one drag embedment anchor, where required for increased load capacity, a piggyback option consisting of two drag embedment anchors, one in front of the other along the mooring line, will be used on the upwind mooring lines only.
44. A summary of the drag embedment anchor parameters is provided in **Table 5.7**

Table 5.7 Drag embedment anchor parameter summary

Parameter	Minimum	Maximum
Number of drag embedment anchors per WTG	3	8
Total Number of drag embedment anchors	18	64
Drag embedment anchor dimensions (LxWxH) (m)	5x5x5	10x10x8
Total drag embedment anchor footprint (m^2)	450	6400
Drag embedment anchors penetration depth (depended on sediment thickness) (m)	8m	25m

5.4.5.2 Suction Anchors

45. Suction anchors (also known as suction buckets or suction caissons) are a capped steel cylinder. The open end of the cylinder is initially penetrated into the seabed using gravity. The seawater trapped inside the cylinder is then pumped out of the capped end causing negative pressure, which sucks the anchor into the seabed causing it to penetrate to its target depth at which point the anchor is sealed off using grout and its valve. An example of a suction anchor is shown in **Plate 5.8**.

Plate 5.8 Suction Anchor Example (Source: Offshore-Engineer, 2020)

46. The technology is only feasible in particular seabed types, including sands and clays and was originally developed for the oil and gas industry. Recently the technology has been used as the anchor solution for the Hywind Floating Offshore Windfarm in Scotland. The main benefit of suction buckets is the avoidance of piling and the associated noise impacts.

Table 5.8 Suction anchors parameter summary

Parameter	Minimum	Maximum
Number of suction anchors per WTG	3	6
Total number of suction anchors	18	48
Suction anchor dimensions (DxL) (m)	6.5 x10	10 x 15
Total suction anchor footprint (m^2)	597	3770

5.4.5.3 Driven Pile Anchor

47. Driven piles are commonly used as foundations in fixed offshore structures and can also be used as an anchor for the mooring lines. A steel cylindrical pile is driven into the seabed using an external force, such as a hammer (impact piling) or vibration depending on the ground conditions. An example of a driven pile anchor is shown in **Plate 5.9**.

Plate 5.9 Driven Pile Example (Pile.com, 2022)

48. The need for driven piles will be confirmed through the results of detailed geotechnical surveys and they will only be utilised where all other options are not viable for the seabed conditions.
49. A precautionary approach will be undertaken and the use of driven piles will only implemented where it can be demonstrated that there is no other best available technology not entailing excessive costs (BATNEEC) solutions. If required, driven piles would be located within discrete locations within the Windfarm Site. However a worst-case of all anchors has been used in the PDE. The worst-case scenario differs by technical topic and as such, different mooring system anchors/piles have been assessed.

Table 5.9 Driven pile parameter summary

Parameter	Minimum	Maximum
Number of driven piles per WTG	3	6
Total number for driven piles	18	42
Driven pile dimensions (DxL) (m)	2 x 20	2.5 x 50
Total driven pile footprint (m^2)	56.55	235.6

5.4.5.4 Drilled Pile Anchor

50. Depending on the soil and the metocean conditions at the project site, drilled pile mooring anchors may be used. Instead of the pile being driven into the seabed, a pile or ground anchor is drilled into the seabed using a subsea drill rig and then sealed with grout. The drill rig required to complete the drilling activity can either be a subsea drill rig or drill rig deployed from the vessel deck. An example of a Drilled Pile Anchor in **Plate 5.10**.

Plate 5.10 Drilled Pile Anchor Example (ABC Moorings, 2022)

51. A precautionary approach will be undertaken and the use of drilled piles will only be implemented where it can be demonstrated that there are no other BATNEEC solutions. Should piling be required, the realistic worst case scenario, depending on the receptor assessment, will use driven pile parameters as these are generally greater than for drilled piles.

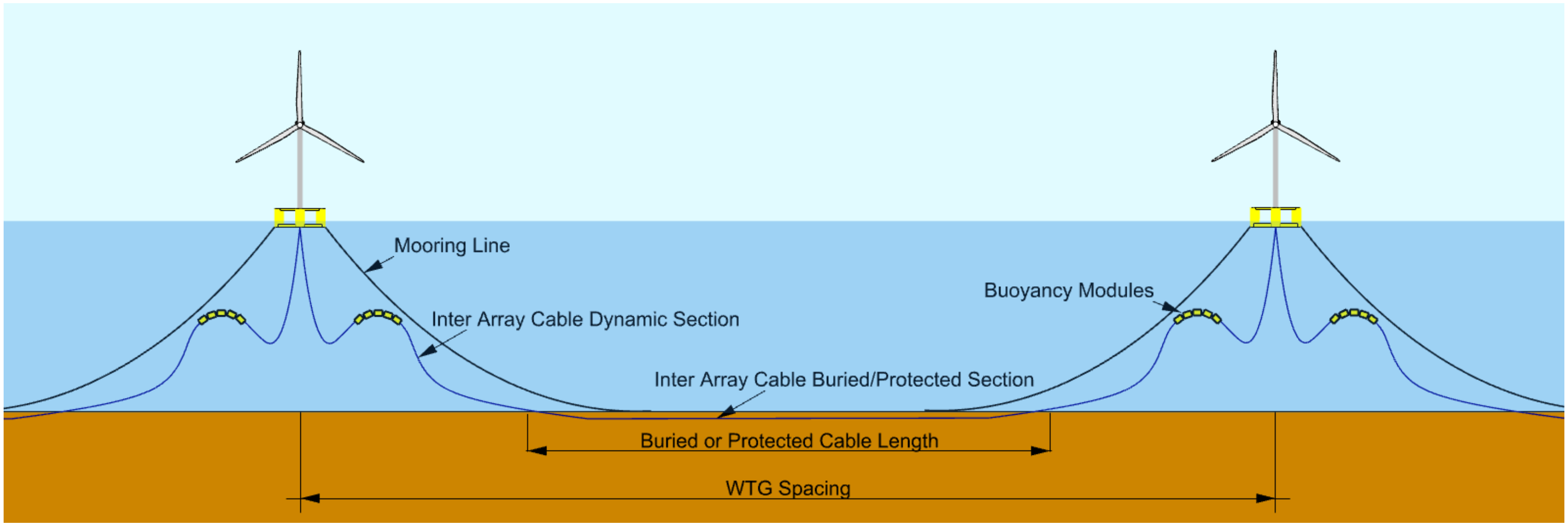
Table 5.10 Drilled pile parameter summary

Parameter	Minimum	Maximum
Number of drilled piles per WTG	3	6
Total number for drilled piles	18	42
Drilled pile dimensions (DxL) (m)	2 x 20	2.5 x 50
Total drilled pile footprint (m^2)	56.55	235.6

5.4.6 Inter-Array Cables

52. The inter-array cables will connect the WTGs to each other and to the OSP or export cable connection point. The WTGs will be laid out in either a two-way split radial array (as is shown in **Plate 5.11**) or in a looped circuit. The inter-array cables will consist of three-core dynamic High Voltage Alternating Current (HVAC) subsea cables rated up to 66kV with a bundled fibre optic system. The cables will be comprised of dynamic sections and sections buried or laying on the seabed.
53. The dynamic section of each inter-array cable will be freely suspended in the water column below each substructure and will adopt a lazy or pliant wave configuration. In this configuration buoyancy modules are attached to the mid portion of the dynamic cable creating a mid-water arc. This de-couples the motion of the cable from the motion of the floating substructure, which reduces the loads on the cables. The cables will also feature bend restrictors at the interface to the floating substructures in order to further reduce cable loads.
54. The on-seabed section of inter-array cables will be buried where possible, typically to a depth of 1m, but may range from 0.5m - 3m, and can be buried via several techniques depending on the seabed conditions along the route. The depth will be determined by a Burial Assessment Study (BAS) and a Cable Burial Risk Assessment (CBRA). These techniques can be ploughing and mechanical cutting, jetting or trenching. Where cable burial is not possible alternative cable protection measures will be used. This includes rock placement or mattresses.
55. An indicative cross-section of the inter-array cable layout is shown in **Plate 5.11**. The length of each inter-array cable will depend on the final layout.

Plate 5.11 Inter-array cable schematic



56. A realistic maximum distance of inter-array cables will be defined for the purposes of the EIA and used as the basis for the assessments. The parameters relating to inter-array cables are outlined in **Table 5.11**.

Table 5.11 Inter-array cable worst-case scenario summary

Parameter	Worst-case
Number of inter-array cables	10
Length of individual inter-array cable (m)	3000
Total length of inter-array cables (km)	29.8
Total length of on seabed protected inter-array cable (km)	24
Total length of suspended inter-array cable (km)	5.8
Burial depth (m)	3
Indicative Installation Corridor width + spoil (m)	20
Area of seabed disturbance (m^2)	480,000
Volume of sediment disturbance during inter-array cable installation (assuming plough trencher) (m^3)	216,000
Seabed preparation for inter-array cables (m^2)	12000

5.5 Offshore Development Area –Transmission Assets

57. The electrical transmission system will collect the power produced at the WTGs and transport it to the UK electricity transmission network. The transmission system will be constructed by OWL.

5.5.1 OSP

5.5.1.1 Overview

58. It is assumed that the inter-array cables from the WTGs will be brought to an OSP. The current assumption for the Offshore Project is that one OSP is required. However, the requirement for an OSP will not be confirmed until after the consent application. The location of the OSP (if required) will be confirmed during the detailed design process and will be determined based upon local water depth and geotechnical conditions, while trying to optimise the inter-array cable and Offshore Export Cable lengths. At the substation, the generated power will be stepped up to a higher AC voltage. This higher voltage will be determined by detailed studies, although it is expected that the OSP will step up the 66kV inter-array cable voltage up to 132kV for the Offshore Export Cable.
59. The OSP will typically comprise components including, but not limited to:
    - High voltage (HV) power transformers
    - Batteries
    - Generators
    - Instrumentation, metering equipment and control systems
    - HV Switchgear and busbars
    - Fire systems
    - Navigation, aviation and safety marking and lighting
    - Systems for vessel access and/or retrieval
    - Communication systems and control hub facilities
    - Modular facilities for operational and maintenance activities

5.5.1.2 Offshore Substation Platform footprint

60. The typical footprint plan of the OSP will be a maximum of 50m by 40m with maximum topside height of 80m above Lowest Astronomical Tide (LAT). The OSP will comprise a topside platform installed on a fixed foundation. The OSP foundation type will likely be a fixed jacket substructure. The jacket foundation will have up to 4 legs and will be secured to the seabed through suction anchors, drilled or driven piles. Leg spacing at the seabed will be up to 40m. **Table 5.12** describes the OSP foundation parameters for jacket foundation option.

Table 5.12 OSP foundation options parameters

OSP Foundation Options Parameters	Maximum (unless specified)
Footprint (inc. foundation structure & scour protection) (m^2)	1,257
Volume of OSP in water column (m^3)	15,000
Volume of scour protection (m^3)	2,513
Jack up vessel footprint – OSP installation (m^2)	314
Prepared seabed area (m^2)	1,257
Prepared area % total seabed taken	0.00%
Depth of seabed preparation (m)	1.00
Seabed volume removed (m^3)	1,257

5.5.1.3 Fluids used on OSP

61. Some of the equipment at the OSP would contain fluids that are used for a variety of purposes. The key types of fluids that may be used include:
    - Diesel fuel for the emergency generators (in diesel storage tanks)
    - Oil for the transformers (oil will be monitored and filtered, top-up may be required)
    - Engine oil
    - Glycol
    - Lead acid contained within batteries
    - Sulphur Hexafluoride (SF6).

62. It is highly unlikely a spill will occur, however a number of measures will be in place to deal with potential spills. The OSP design will include self-contained bunds to collect any possible oil spill. Transfer of oil/fuel between the OSP and service vessels will follow best practice procedures, with additional procedures in place should there be a spill to the marine environment.
63. Any oil spillage would be collected in a separate oil waste tank. Both oil waste and other wastes (wastewater, etc.) would be brought to shore in a secure container and disposed of according to industry best practice procedures.
64. All other waste streams would be processed on the OSP or transferred to shore as required.

5.5.1.4 Scour protection for OSP

65. Scour protection may be required around the base of the foundations to protect against localised erosion of the seabed. The types of scour protection are:
    - Rock or gravel placement
    - Concrete mattresses

- Flow energy dissipation devices (used to describe various solutions that dissipate flow energy and entrap sediment, and including options such as frond mats, mats of large, linked hoops, and structures covered with long spikes). It is noted that these technologies are often only appropriate for use in areas with significant mobile seabed sediments, and examples such as the spiked designs are only appropriate for use in areas which are not trawled
- Protective aprons or coverings (solid structures of varying shapes, typically prefabricated in concrete or high-density plastics)
- Bagged solutions, (including geotextile sand containers, rock-filled gabion bags or nets, and grout bags, filled with material sourced from the site or elsewhere).

66. The installation method will depend on the scour protection system selected. Rock would be placed by dynamically positioned fall pipe vessel, whilst the other options would be more suited to the use of a smaller crane vessel or similar. The diameter, area and volume requirements for scour protection will be discussed once it is confirmed whether an OSP will be required and that this OSP is not floating.

5.5.2 Offshore Export Cable

67. Electricity from the Windfarm Site will be transmitted via one or two subsea export cable(s) to shore depending on whether an OSP is required. Each offshore export circuit would have three conductors (one for each phase) and a fibre-optic bundled/ wrapped into one cable.
68. For a two-circuit design there would be two cables. In this scenario the configuration could change when transitioned to the Onshore Export Cables, at which point the cables may split into individual phases and become arranged in a trefoil formation. The circuits may then be bundled, but this will be determined based on thermal properties and cable derating. The final arrangement will be subject to outputs of detailed design post-consent.
69. If an OSP is required, the Offshore Export Cable (up to 132kV AC) is likely to run from the OSP to a transition joint bay (TJB) at the Landfall above MHWS. However, if an OSP is not required, the Offshore Export Cable will run from the Windfarm Site to the TJB. The TJB connects the Offshore Export Cable and Onshore Export Cable. Each Offshore Export Cable will be installed in an individual trench and protected in line with good industry practice. **Table 5.13** describes the main cable parameters, details of how the export cable has been developed are provided in **Chapter 4: Site Selection and Alternatives**.
70. The cable will be buried where possible to ensure that the cable is protected from damage by external factors. Typical burial depth is 1m but may range from 0.5m -

3m. The depth will be determined by a BAS and CBRA. The cable will be delivered in sections and jointed in-situ due to the distance from the Windfarm Site to the Transition Joint Bay. If seabed conditions make burial unfeasible, as well as in the immediate proximity of turbine foundations, cable may be protected by a hard-protective layer such as rock or concrete mattresses. The appropriate level of protection will be determined based on an assessment of the risks posed to the Offshore Project in specific areas.

71. It is likely that the Offshore Export Cable will have to cross other subsea cables. Formal agreements with regards to existing cable crossings will be entered into by OWL and the existing owners / operators. Installation techniques will be discussed and agreed to ensure integrity of the existing infrastructure and any new cables associated with the Offshore Project. Several techniques can be utilised, including concrete mattresses and rock placement.

Table 5.13 Offshore Export Cable parameters (based on an HVAC export cable system)

Parameter	Minimum	Maximum
Export cable/trench	1*	2
Export cable burial depth (m)	0.5	3
Fibre optic cables	Bundled in export cable	
Export cable route standard working width (m)	25	50 (25m width per export cable)
Export cable length (km)	70	93.6
Total Offshore Export Cable Corridor Area (m^2)	1,750,000	4,680,000
Number of Cable & pipeline crossings	3	8
Total area of Offshore Export Cable protection due to cable crossings (m^2)	5,250	14,000
Total volume of Offshore Export Cable protection due to cable crossings (m^3)	3,000	14,400

* The baseline assumption is that the project will feature **one OSP** and therefore only one Offshore Export Cable will be required. However, if an OSP is not included in project design, this may result in the need for two separate Offshore Export Cables.

5.5.2.1 Seabed preparation

72. Pre-lay intervention activities may be required prior to the installation of cables including grapnel run, boulder removal, sand wave clearance, installation of equipment at crossings and the cutting and removal of any out-of-service cables.

73. There will be no separate cables for fibre optics. Fibre optics will be integrated with the Offshore Export Cable. **Table 5.14** outlines the maximum area required for seabed preparation for Offshore Export Cable installation.

Table 5.14 Seabed preparation for Offshore Export Cable installation

Infrastructure	Maximum footprint (m^2)
Estimated Seabed preparation for Offshore Export Cable Corridor (sand wave levelling & boulder clearance)	842,400

5.5.2.2 Offshore Export Cable Corridor lifetime footprint

74. **Table 5.15** describes the maximum footprints for the protection of the Offshore Export Cable. The Offshore Export Cable will be buried for the majority of its length. However, there will be some areas where this is not possible due to seabed characteristics or where it is crossing existing subsea cables. In these locations external cable protection may be used. The cable will be buried at the trenchless technique exit.

Table 5.15 Maximum lifetime footprints for Offshore Export Cables protection

Infrastructure	Maximum footprint
External cable protection for unburied cables (m^2)	99,400
External cable protection at cable crossings (m^2)	14,000
Total external cable protection (m^2)	114,800

5.5.2.3 Cable crossings

75. The Celtic Sea has a significant number of cables, primarily telecommunication connections between the UK and north America and Europe. No cables are present within the Windfarm Site (see **Chapter 18: Infrastructure and Other Users**). Four telecommunications cables traverse the Offshore Export Cable Corridor, these include:
    - Ormonde UK-Ireland 2 Crossing (Active)
    - TAT 11 (Decommissioned)
    - TATA Atlantic South (Active)
    - TATA W.Europe UK-Spain (Active).

76. Within the Offshore Export Cable Corridor, up to eight (**Table 5.13**) cable crossings have been identified. Crossings are designed to protect the obstacle being crossed, as well as the Offshore Project's cables once they have been installed. Detailed methodologies for the crossing of cables and pipelines will be determined in consultation with the owners of the infrastructure to be crossed. However, a number of techniques may be utilised, including:
    - Pre-lay and post lay concrete mattresses
    - Pre-lay and post lay rock placement.

5.6 Landfall (up to MHWS)

77. **Table 5.16** shows the main construction parameters for the Landfall up to MHWS. The Landfall above MHWS will be considered within the Onshore Project ES. **Figure 5.3** shows the location of the Landfall.

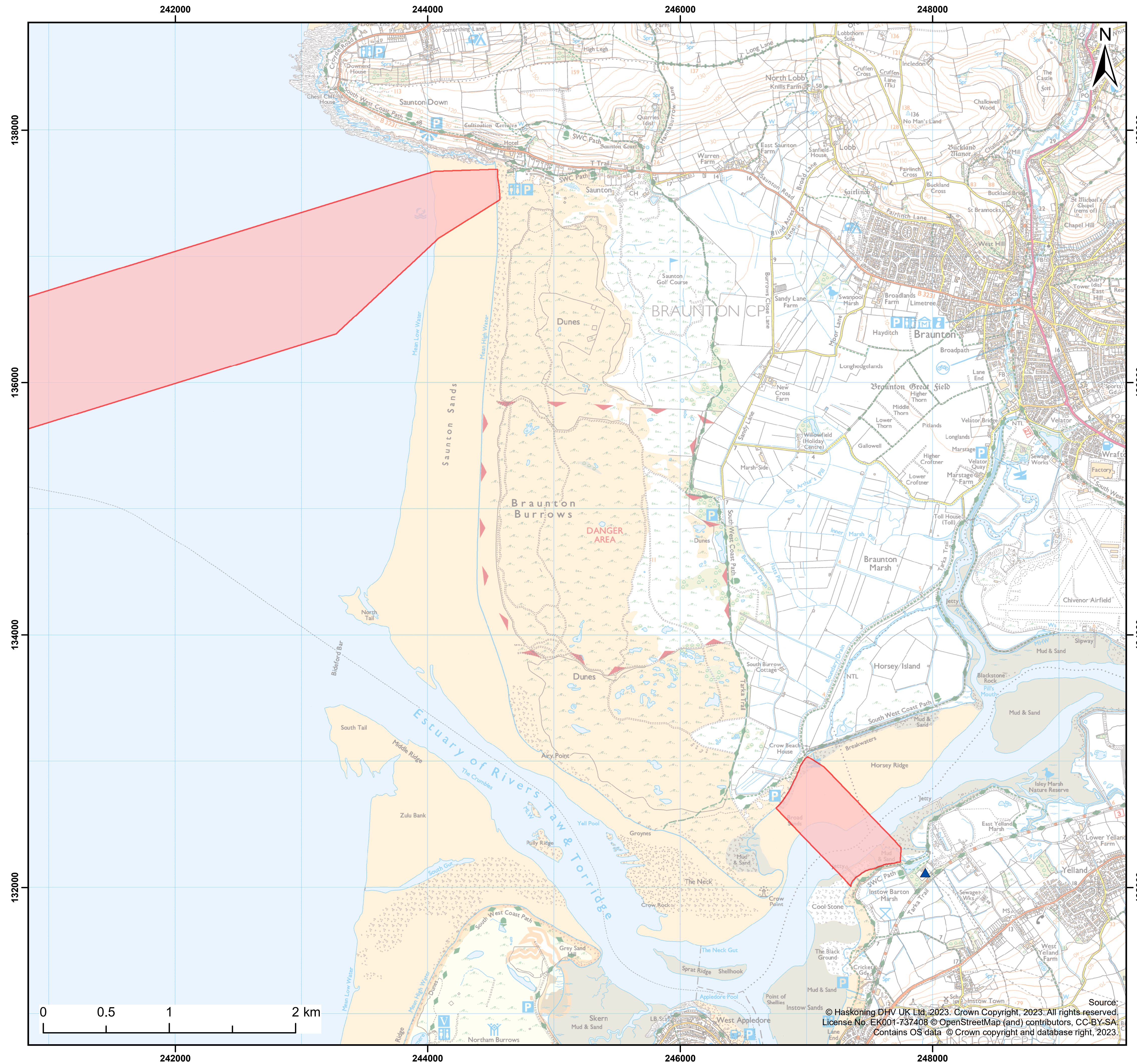
Table 5.16 Landfall construction parameters

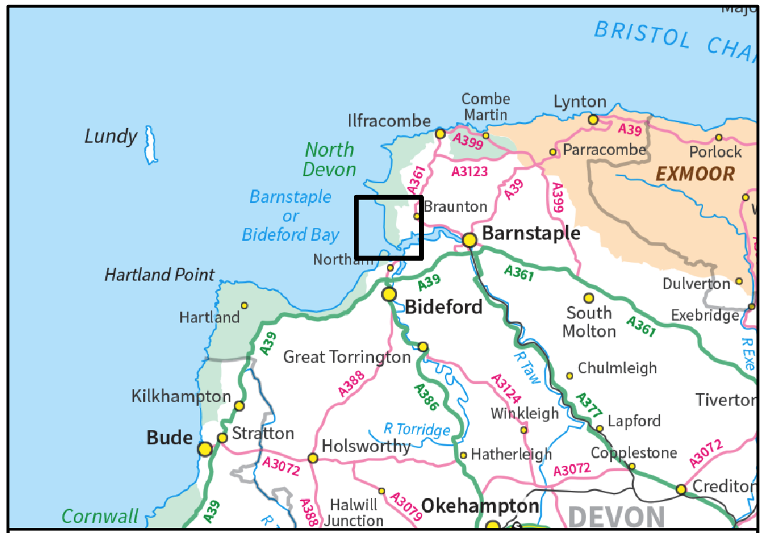
Landfall	Minimum	Maximum
Landfall installation method	trenchless technique and/or open trench where no obstruction	
Number of drills	n/a	2
Trenchless technique compound area (above MHWS at Landfall) (length x width) (m)	75 x 50	200 x 200
Trenchless technique horizontal length (m)	n/a	1,500
Trench dimensions for open trench at Landfall (MLWS to MHWS) for two cables (m)	n/a	270 (L) x 0.5 (W) x 1.2 (D)
Total open trench volume at Landfall (MLWS to MHWS) for two cables ((m^3)	n/a	162m^3

78. Cable installation methodology at the landfall will be selected based on a comparative assessment of environmental, commercial and technical factors. It is assumed that suitable technologies will include a mix of open cut trenching and trenchless technique.

79. Open cut is a well-known installation methodology for underground cabling in relatively unconstrained areas. It can also be used to install a cable in a landfall and would require an open trench to be dug out before a cable is installed and the trench refilled.

80. If trenchless technique is chosen as the appropriate installation methodology at Landfall, the trenchless technique is drilled from above MHWS at an onshore construction compound and will exit the seabed in an exit pit at a suitable water depth. The length of the trenchless technique will depend upon factors such as water depth, seabed topography, shallow geology/soil conditions and environmental constraints. Infrastructure above MHWS is considered as part of the separate Onshore Project.





Legend:

- Offshore Development Area
- National Grid Onshore Substation

Client: Offshore Wind Ltd.	Project: White Cross Offshore Windfarm

Title: Landfall (up to MHWS) and the Taw Estuary Crossing (from MHWS to MHWS)

Figure: 5.3 | Drawing No: PC2978-RHD-ZZ-XX-DR-Z-0467

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
P02	03/03/2023	AB	CB	A3	1:30,000
P01	03/01/2023	AB	CB	A3	1:30,000

Co-ordinate system: British National Grid

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5.7 Taw Estuary Crossing (MHWS to MHWS)

81.5. A section of the Onshore Export Cable Corridor re-enters the marine environment where the Export Cable crosses underneath the Taw Estuary (MHWS north of the estuary to MHWS south of the estuary) (hereafter referred to as 'the Taw Estuary Crossing').

82. Trenchless crossing techniques have been proposed for the Taw Estuary Crossing, with two options being considered, namely Horizontal Directional Drilling (HDD) and Direct Pipe. Both options will utilise the same location for the entry and exit points and involve a drill length of approximately 1.3km below the River Taw. Cable installation works will be undertaken from south to north, with temporary compound area and access requirements for the entry and exit points.

83. The crossing site is located at a natural narrowing of the River Taw. This site was determined based on an appraisal of constraints and engineering feasibility from both offshore and onshore perspectives. The location of the Taw Estuary Crossing is shown in **Figure 5.3**. Further information of the design, drilling methodology and approach to geotechnical investigation is presented in **Appendix 5.B: Taw Estuary Crossing Method Statement**.

84. OWL's commitment to the use of trenchless crossing techniques at the Taw Estuary Crossing ensures that potential impacts on designated sites and the wider estuarine and riverine environment are avoided as part of the Offshore Project's embedded mitigation. This commitment is anticipated to:

- Avoid direct physical disturbance to the natural environment and non-statutory and statutory designated sites of ecological importance, including the Taw-Torridge Estuary SSSI and Braunton Burrows SSSI and SAC (which will be considered further in the ES for the Onshore Project).
- Mitigate disturbance or harm to species such as waterfowl and migratory salmon and potential destruction, damage or disturbance to priority habitats such as coastal grazing marsh and mudflats
- Avoid direct disturbance to the River Taw's sediment transport pathways
- Avoid direct disturbance of the Taw/Torridge surface water catchment and the potential to alter the geomorphology and hydrology of the watercourse
- Mitigate increased sediment supply to the Taw/Torridge surface water catchment
- Mitigate the risk of contaminants supply to the Taw/Torridge surface water catchment and the River Taw and North Devon Streams groundwater catchment
- Avoid direct disturbance to surface drainage patterns and surface flows of the Taw/Torridge surface water catchment and therefore its associated flood risk
- Avoid the need for cable protection measures across the river bed.

85. OWL will consult stakeholders and seek agreement on the design and methodology set out in **Appendix 5.B: Taw Estuary Crossing Method Statement** prior to the commencement of construction works at the Taw Estuary Crossing. Where conflict arises between environmental constraints or obligations, OWL will liaise with the relevant stakeholders to determine the optimal, acceptable solution for the crossing and would not proceed where reasonable concern from stakeholders was not being addressed.

5.8 Offshore Construction Activities

5.8.1 Overall Construction Programme

86. Initial onshore fabrication and offshore construction is planned to start in Q2 of 2025 following the Final Investment Decision (FID) process. Offshore construction is scheduled to take approximately 16 months, with the aim of connecting the Offshore Project to the UK grid by Q3 2027 and thus beginning the Offshore Project's operational phase.
87. There are uncertainties remaining in the current construction methodology for the Offshore Project. However, an overview of the anticipated construction methodology has been summarised below.
88. Project construction will be completed in a number of stages which are as follows:
    - Pre-construction surveys
    - Assembly of substructures and WTG integration - see **Section 5.8.2**
    - Offshore installation of WTGs and floating substructures - see **Section 5.8.3**
    - Installation of inter-array cables - see **Section 5.8.4**
    - Installation of OSP - see **Section 5.8.5**
    - Offshore Export Cable connection – see **Section 5.8.6**
    - Final WTG commissioning – see **Section 5.10**.

89. The indicative high-level construction programme for the Offshore project shown in **Plate 5.12.**

	2025				2026				2027			
Task	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Intertidal/HDD Operations						■	■					
Export Cable Installation							■					
Anchor & Mooring Pre-Lay									■	■		
WTG Integration on Substructure									■	■	■	
WTG Installation at Windfarm										■	■	
Inter-Array Cable Installation											■	
Offshore Commissioning											■	
Operation of White Cross											■	

Plate 5.12 Indicative Offshore Project Construction Programme

90. All elements of the Offshore Project including WTGs, mooring systems, potential OSP and electrical infrastructure will be fabricated offsite, stored at a suitable port or fabrication facility and transported to site as required. Fabrication contracts have not been awarded and OWL will run competitive tendering processes to identify the best suited contractors to deliver the different elements of the Offshore Project. Fabrication can take place in the UK, in Europe or elsewhere dependent upon the location of the chosen contractor and available facilities in the UK.

5.8.2 Substructure Assembly & WTG Integration

91. It is proposed that the WTGs will be assembled and commissioned on the semi-submersible floating substructure in the sheltered waters of a port/harbour. It is also anticipated that the final stages assembly of the semi-submersible floating substructure, prior to WTG integration, are also undertaken at the same port, if facilities are determined sufficient to support this work. However, this will be confirmed following submission of the consent application.

92. Pre-fabricated primary sub-components of the substructure will be received by barge from the fabrication facilities and stored on quayside until required for assembly. The assembly of the substructure may take place at the same or different location to the integration activities. When required the substructure sub-components will be moved into position using self-propelled modular transporters or crawler cranes to be fully assembled through welded, bolted or grouted connections. Fabrication aids such as grillages or bespoke cradles may be utilised to optimise crane operations and access towers or working platforms will be used to ensure safe access.

93. To optimise assembly time, the majority of secondary structures will have been pre-installed prior to final assembly. Depending on the yard facilities, a dry dock, semi-submersible barge or ring crane could be employed to launch the assembled substructure from the quayside into quay. (**Plate 5.13**).

94. Depending on the location of the substructure assembly the substructure will then be launched to begin WTG Integration or prepared for transport to the WTG integration site by barge or tow.
95. To minimise WTG assembly time, the tower may be pre-assembled and pre-commissioned prior to installation. A land-based ring crane or offshore jack-up crane vessel (located at quayside or in sheltered water) will be required to lift the WTG component parts onto the floating substructure. Lifting aids may be used to reduce risks associated with working under suspended loads. Once assembled, the WTG commissioning team will perform all necessary bolting activities. The substructure will then be towed to a holding location away from the assembly line for all remaining commissioning and testing activities.
96. The following activities are anticipated to be undertaken when integrating the WTG to the semi-submersible floating platform and transfer to the array area:
    - Mobilisation and erection of high-capacity land-based crane or jack-up crane vessel
    - Unloading in-bound WTG components from supply vessel
    - Laying down of WTG components
    - Wet store/moor semi-submersible floating platform at quayside
    - A spacer barge or fenders may be used to separate the semi-submersible floating substructure from the side of the quay. Mooring and spring lines would keep the unit in a stable position at quayside
    - Preparation of WTG components for assembly (tower sections, nacelles, hubs, rotor blades)
    - Sequentially, the WTG components will be lifted and secured to the unit. The semi-submersible floating platform unit should remain even keel during the whole operation by adding or removing ballast water to / from the different compartments, or grounding at the quayside as the weight of each WTG component is being transferred from the crane onto the unit
    - Pre-commissioning of fully assembled semi-submersible floating platform and WTG unit at quayside.

Plate 5.13 Example of WTG assembly onto a semi-submersible platform at quay side (Source: Photo courtesy of Principle Power)

5.8.3 Offshore Installation of WTGs and floating substructures

5.8.3.1 Seabed preparation

97. Some form of seabed preparation may be required prior to the installation of the WTGs and floating substructures. Seabed preparation includes seabed levelling, ground reinforcement, cutting and removal of any out of service cables, surface and subsurface debris such as boulders, fishing nets, lost anchors etc. If debris are present below the seabed then excavation may be required for access and removal. Any unexploded ordnances found with live ammunition will be detonated and any remaining debris removed, where practicable.
98. Consent for Unexploded Ordnance (UXO) removal will be sought in a future Marine Licence application when geophysical survey data of suitable spatial resolution is available to identify and quantify UXO risk.

5.8.3.2 Mooring System Pre-Lay

99. Using Anchor Handling and Tug Supply vessels and specialist Remote Operated Vehicles (ROVs), the anchors and mooring lines will be laid one after another for each unit. Due to water depths on site, all vessels will be Dynamically Positioned (DP Class) with no vessel anchor deployment required. Final anchor/foundation types will be confirmed during the Front-End Engineering Design (FEED) stage following inputs from site surveys and design refinement. After their deployment, the anchors will be

proof load tested to the required tension levels determined during the engineering phase. The mooring line connected to the anchors will be wet-stored on the seabed prior to hook-up to the substructures. In order to verify the correct positioning of the anchors after the test, the mooring lines may be equipped with transponders, or similar systems.

5.8.3.2.1 Drag Embedment Anchors

100. The Installation method for a drag embedment anchors is as follows:

- A pre-lay survey will be performed to identify and remove any debris along the route of the mooring lines.
- The anchors will be deployed off the back of an anchor handling tug and lowered to the seabed on the mooring line. The anchor will be lowered to the seabed into a pre-determined target box and orientated to face the WTG location. The location of the anchor on the seabed will be recorded for comparison with the post embedment location. The chain will then be deployed and laid along the survey corridor. Upon completion of the laying operation, the chain end will be transferred onto the main winch wire for the load test procedure.
- The embedment of the anchor involves the anchor handling tug applying a large tension force to the mooring line to pull the anchor down into the seabed. Whilst the load is gradually applied, the tension is monitored using a load cell on the main winch. Once the target tension is reached, the load will be maintained for a period of time to ensure the anchor has reached its final location. The anchor will usually embed to a depth well below the seabed level. The final position of the anchor will be determined accurately by measuring the movement of a pre-defined point on the mooring line. The length of the chain can then be adjusted to compensate for the drag distance of the anchor.

5.8.3.2.2 Suction Anchors

101. The installation method for suction anchors is as follows:

- A pre-lay survey will be performed to identify and remove any debris at the target anchor locations.
- The suction anchors may be deployed by crane or winch from back deck of tailored offshore construction vessel or anchor handling tug.
- The open end of the cylinder is initially penetrated into the seabed using gravity. The seawater trapped inside the cylinder is then pumped out of the capped end causing negative pressure, which sucks the anchor into the seabed causing it to penetrate to its target depth at which point the anchor is sealed off using grout and its valve.

- Connection of the mooring lines or tendons will be performed using remotely operated vehicle (ROV) anchor chain connectors.

5.8.3.2.3 Driven Pile Anchors

102. The installation method for driven pile anchors is as follows:
    - A pre-lay survey will be performed to identify and remove any debris at the target pile locations.
    - The pile may be deployed by crane or winch from back deck of tailored offshore construction vessel or anchor handling tug.
    - Once in position a hydraulic hammer would be used to drive the pile to its target depth. Operations will include a soft-start where by the hammer impact energy is initially limited to 10% of maximum energy before ramping up to maximum energy. Depending on the soil conditions encountered, maximum hammer energy may only be required at the later stages of the piling operation.
    - Connection of the mooring lines or tendons will be performed using remotely operated vehicle (ROV) anchor chain connectors.

103. **Table 5.17** outlines the parameters that have been applied to the driven pile installation for mooring of the floating substructure. This represents the realistic worst-case scenario in terms of underwater noise generation. They are assessed within **Chapter 11: Fish and Shellfish Ecology** and **Chapter 12: Marine Mammals and Marine Turtle Ecology**.

Table 5.17 Driven pile installation regime for mooring

Parameter	Parameter
Total number of driven piles	42
Soft-Start	
Soft-start assumed hammer energy (kJ)	128 - 640
Soft-start assumed duration (minutes)	29
Soft-start assumed strikes per minute	15
Max Energy	
Maximum Hammer energy (kJ)	800
Maximum energy duration (minutes)	103
Strikes per minute at max energy	35
Total Durations	
Maximum number of strikes per pile	3607
Maximum duration per pile (minutes)	132
No. of piles installed in 24 hours	8
No of strikes within 24 hours	32,000
Duration of strikes within 24 Hours	17.67
No of days of piling	5.25

5.8.3.2.4 Drilled Pile Anchors

104. The installation method for drilled pile anchors is as follows:

- A pre-lay survey will be performed to identify and remove any debris at the target pile locations.
- A drill bit will be used to drill into the seabed to the required depth, with a casing installed as the borehole is created.
- Compressed air or water is used to flush cuttings from the borehole; these will be discharged at the seabed around the borehole. The sediments drilled from each pile will be up to a maximum of 350 cubic metres (m^3); these will be either in the form of large clasts deposited on the seabed in the immediate vicinity of the drilled hole or disaggregated and dispersed within a sediment plume near the seabed. It is expected that the drilled cuttings will be a combination of these two forms.
- Once the drilling is complete and the casing installed, the pile will be installed in the borehole. The pile may be deployed by crane or winch from back deck of tailored offshore construction vessel or anchor handling tug and lowered into its casing.
- The borehole will finally be sealed with grout to provide additional stability and strength. The grout (an inert cement mix) will be pumped either from the installation vessel or a support vessel.
- Connection of the mooring lines or tendons will be performed using remotely operated vehicle (ROV) anchor chain connectors.

5.8.3.3 Mooring Hook-Up

105. Following deployment of the anchors and mooring lines the cable ends will have been buoyed off temporarily for recovery and attachment to the WTG/substructure assembly following their arrival to site.

106. Following seabed preparation if required, substructures will be towed to site using anchor handling tugs (**Plate 5.14**). The towing operation will be planned to coincide with appropriate weather windows through analysis of the towing route and weather forecast. Once the substructures have arrived at their designated location it will be held in position by the anchor handling tugs while the mooring hook-up operation takes place. The pre-laid mooring lines will be lifted from the seabed and attached to the substructure using pull-in cables and winches onboard the anchor handling tugs. Automatic connection systems such as ball grab connectors may be installed to reduce weather downtime, potentially shorten deployment of installation vessels, and decrease exposure of personnel on deck.

107. All regulatory and required marine navigation notifications, such as Notice to Mariners, will be issued in advance of the works or installation.

Plate 5.14 Tug vessel towing the Kincardine's integrated WTG and semi-submersible substructure unit out to Windfarm Site.

5.8.4 Installation of Inter-Array Cables

5.8.4.1 Pre-Installation

108. The routing of the inter-array cables will be determined through a combination of desktop studies using existing survey data and offshore surveys. Prior to inter-array cable installation, surveys will be performed to confirm there are no obstacles such as rocks, wrecks, metal objects, debris, or unexploded ordinance (UXO). If an obstruction is identified an appropriate strategy will be developed to remove or route around the obstruction.

109. Immediately prior to cable installation a survey will be performed to confirm mooring line and anchor locations. Should any hazards be identified, minor modifications to the location or protection of inter-array cables may be required. However, it would be ensured that these modifications would have no worse of an impact than what is assessed within this ES.

5.8.4.2 Installation

110. Each WTG will be connected via a 66kV dynamic inter-array cable. The cable installed between each WTG will include buoyancy modules, dynamic bend stiffeners and touchdown protection.

111. Installation of the inter-array cables will most likely take place once the floating substructures and WTGs have been installed. Installation of the inter-array cables may occur before the floating substructures. In this scenario, the cables would be wet stored on the seabed and marked appropriately following consultation with the MCA. A typical sequence for the installation of the inter-array cabling (also relevant for export cabling) is as follows.

112. Pre-lay surveys (using ROV and potentially MBES) of proposed cable corridors will be undertaken to identify any requirement for obstacle removal; due to the site conditions, these are likely to be just prior to installation. If required, identified obstacles and/or boulders will be removed along the proposed cable route (for the section of dynamic cabling laid on the seabed). This would be achieved by a pre-lay grapnel run (2-m wide along the length of the cable route) to hook any linear debris; if any debris is hooked, it will be recovered to the vessel for onwards disposal / recycling ashore. Areas of boulders and confirmed UXO may also require clearance if not avoidable by a minor cable route deviation.

113. Boulders would be removed by either a boulder clearance plough or a grab unit lowered from a construction vessel, with the boulders being moved onto the seabed adjacent to the cable route. It is assumed that it will be possible to avoid any UXO encountered. Should any further mitigation be required, such as clearance or detonation, this would be subject to separate assessment and licence applications.

114. Seabed preparation may be required to level a proportion of the seabed for the burial techniques to be employed effectively. The cable installation vessel moves to the site of the pre-installed floating structure where the cable is pulled into the floating structure and secured. The cable (with buoyancy modules) is then deployed into the water column. The second end of the cable is then deployed and pulled and secured into another floating structure.

115. Different approaches and techniques are available for installation of the inter-array cables laid on the seabed and these are:

- Pre-lay trenching using a displacement plough to create a pre-lay trench which the cable is then installed into. A separate backfill plough may then be used to push the spoil heaps created by trenching over the cable, thus creating the required cable cover;
- Post-lay trenching using a variety of tools including:

- Jet trenchers (either self-propelled or mounted as skids onto ROVs) which inject water at high pressure into the sediment surrounding the cable. The seabed is temporarily fluidised and the cable is lowered to the required depth. Displaced material is suspended in the water and then resettles over the cable. This process is controlled, to ensure that sediment is not displaced too far from the cable;
- Mechanical trenchers which bury the cable by lifting the laid cable whilst excavating a trench below, and then replacing the cable at the base of the trench and allowing the soil to naturally backfill behind the trencher;
- Non-displacement ploughs which simultaneously lift a share of seabed whilst depressing the cable into the bottom of the trench. As the plough progresses, the share of the seabed is replaced on top of the cable; and

- Simultaneous cable lay and burial, using a jet trencher or non-displacement plough.

116. A combination of the above methods may be used for inter-array cable installation, depending on the ground conditions. **Plate 5.15** provides an illustration of the inter-array cable installation.

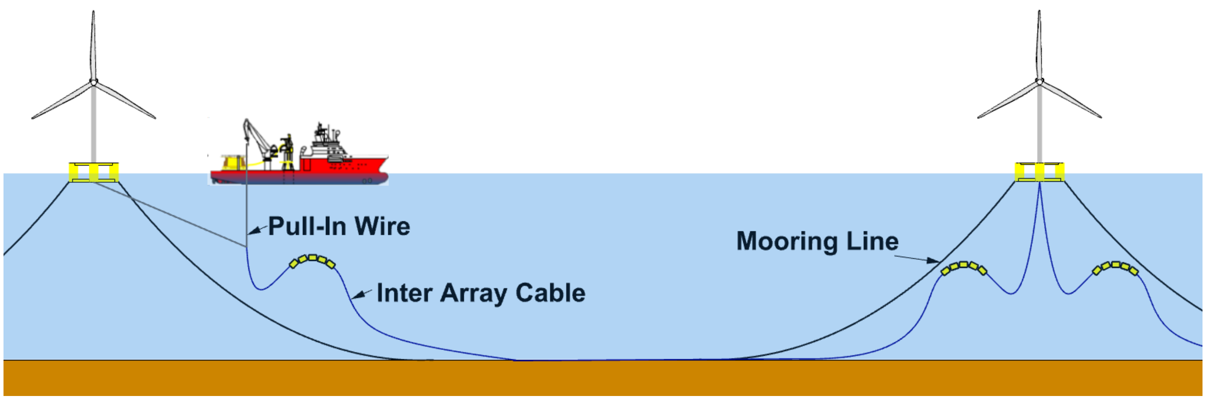

Plate 5.15 Inter-array cable installation

117. Where required, the inter-array cable will be trenched to a minimum depth of burial (DOB) of 0.5m using either simultaneous lay and burial, or post-lay burial via jetting or trenching.

118. If the minimum depth of burial of the cable is not achieved consideration will be given to protection in the form of rock dumping or concrete mattresses in the localised areas. A CBRA will be carried out prior to the remedial work.

119. Inter-array cable installation will be undertaken by a Cable Lay Vessel (CLV) such as that pictured in **Plate 5.16**.

120. The final decision on the method of inter-array cable installation will be made at the detailed design phase which will occur after the consent application submission.

Plate 5.16 A Normand Clipper Cable Lay vessel involved in inter-array cable installation at the Kincardine windfarm

5.8.5 Installation of OSP

121. As described in **Section 5.5.1**, the requirement for an OSP as part of the Offshore Project will be established during detailed design. If an OSP is required, the jacket foundation legs may be fixed to the seabed either with pin piles or suction anchors.

122. The indicative construction programme for the OSP is:

- Fabrication lasting one year from Q2 2026 to Q2 2027
- Installation campaign from Q2 2027 to Q3 2027.

5.8.5.1 Driven Pile Jacket Option

123. The piles, the OSP and jacket will be collected and transported to site by a combination of heavy lift installation vessel (HLV), transportation vessels, or barges.

124. Following pre-installation surveys and seabed preparation to remove any obstacles such as boulders, the HLV lift will place the jacket into position on the seabed.

125. The piles will be upended into vertical orientation and lowered to the seabed for installation. Using pile sleeves at the base of the jacket legs as a template, the piles will be installed using a hydraulic hammer.

126. Soft start procedures will be employed using energy as low as reasonably practicable to check hammer operation, initially embed the pile and to allow marine mammals to leave the area.

127. The HLV will be used to lift and install the OSP onto the jacket. Pile grippers may be employed to level the jacket into the correct position and create a secure connection whilst the pile grout is curing. A pile gripper secures the jacket structure to the pile below.

128. **Table 5.18** outlines the parameters that have been applied to the driven pile installation for the OSP installation. These represent the realistic worst-case scenario in terms of underwater noise generation. This process is illustrated in **Plate 5.17**. They are assessed within **Chapter 11: Fish and Shellfish Ecology** and **Chapter 12: Marine Mammals and Marine Turtle Ecology**.

Table 5.18 Driven pile installation regime for the OSP jacket substructure

Parameter	Parameter
Total number of driven piles	4
Soft-Start	
Soft-start assumed hammer energy (kJ)	400-2000
Soft-start assumed duration (minutes)	60
Soft-start assumed strikes per minute	15
Max Energy	
Maximum Hammer energy (kJ)	2500
Maximum energy duration (minutes)	210
Strikes per minute at max energy	35
Total Durations	
Maximum number of strikes per pile	8150
Maximum duration per pile (minutes)	270
No. of piles installed in 24 hours	4
No of strikes within 24 hours	32,600
Duration of strikes within 24 Hours	18
No of days of piling	1

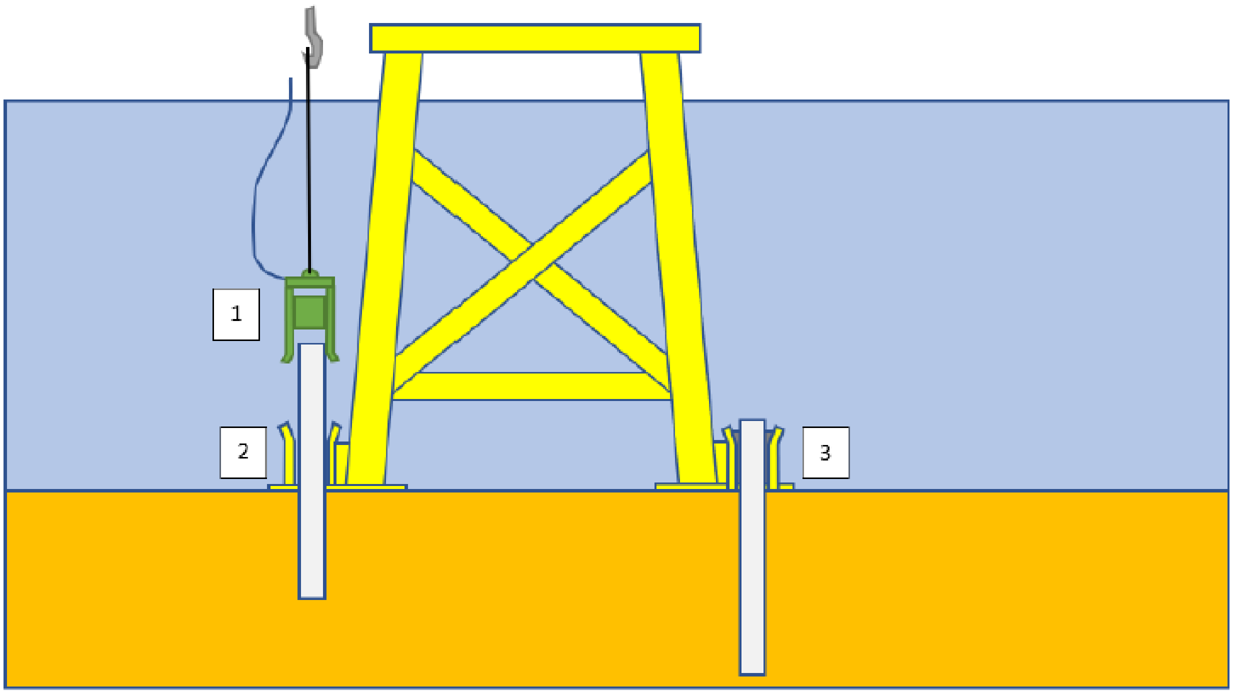

Plate 5.17 An overview of pin pile jacket installation method. 1 = Pile installation tool uses a controlled hammer device supported on a crane to drive the pile into the seabed. 2 =The pin pile passed through a guide that is a structural part of the jacket base. 3 = The pin pile is grouted within the guide that bonds the jacket to the pins, forming a connected foundation.

5.8.5.2 Suction anchor Jacket Option

129. In areas where the seabed is level, the suction anchor foundation may not require significant seabed preparation. However, measures may be required in areas where sand waves are present to provide a level formation for the installation and to allow scour protection to be later placed around the foundation.

130. The jacket and OSP will be collected and transported to site by a combination of the HLV, transportation vessels, or barges. At the base of the jacket, suction anchors will have been pre-installed into the legs during fabrication.

131. Following pre-installation surveys and seabed preparation to remove any obstacles such as boulders, the HLV lift will place the jacket into position on the seabed. Once placed on the seabed and settled under its own weight, water will be pumped out of the suction anchors (**Plate 5.18**). The open end of the cylinder is initially penetrated into the seabed using gravity. The seawater trapped inside the cylinder is then pumped out of the capped end causing negative pressure, which sucks the anchor

into the seabed causing it to penetrate to its target depth at which point the anchor is sealed off using grout and its valve.

132. Penetration is expected to take up to 8 hours but the whole operation may take approximately 1 day.

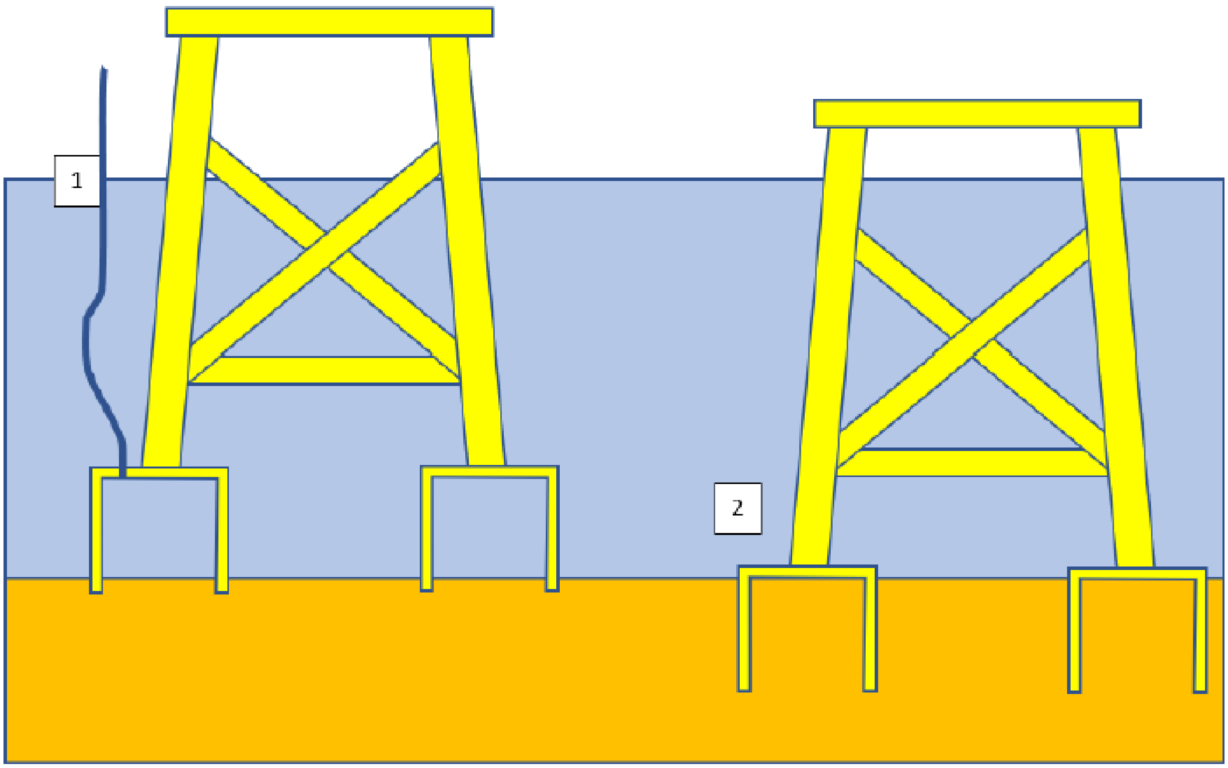

Plate 5.18 An overview of suction anchor jacket installation method. 1 = As the jacket is lifted on the seabed, water is pumped out of all suction cans at the same time, effectively drawing the cans into the seabed. 2 = Once the jacket is in final position, the hoses are removed and the suction cans are sealed to maintain the foundation.

5.8.6 Installation of Offshore Export Cable Corridor

5.8.6.1 Seabed preparation

133. Pre-installation surveys and activities for the installation of Offshore Export Cable Corridor (e.g. UXO, Boulder Clearance, works which will be undertaken under separate marine licences) will be performed in the same manner as described for inter-array cables. In addition, cable installation activities will be preceded with a pre-lay grapnel run to clear debris from the cable route or an alternative method to check for debris. A Hazard Assessment, which will utilise the findings of the pre-installation survey, will identify whether there is a requirement for a pre-sweep of the seabed ahead of cable installation.

5.8.6.2 Offshore Export Cable Installation

134. A typical export cable installation approach is as follows – the onshore end of the cable is connected to the onshore winch wire through the pre-installed trenchless technique borehole and pulled to the transition joint bay. Once secured, the installation vessel will move along the cable route paying out the Offshore Export Cable to the seabed or trench, ensuring cable integrity is maintained. The in-field end of the cable is installed onto the floating structure in line with the steps outlined for inter-array cables in 5.8.4. The exact installation sequence and lay direction can differ depending on in-field conditions and the final Offshore Export Cable design adopted.

135. If a second Offshore Export Cable is required as part of the Offshore Development, the cable will be laid in a separate trench with a minimum separation distance of 50 m between the two cable trenches. Commissioning will then take place, and lastly installation of cable protection systems (as detailed below) where necessary.

136. Following the shore pull the cable will be laid along the predetermined route. Pipeline and cable crossings will require rock placement or mattressing. Cable burial may be achieved by simultaneous lay and burial or post-lay burial to a target Depth of Burial of 1.5 m. The preferred method of cable installation would involve the simultaneous lay and burial of the cable from a dedicated cable installation vessel; this will be reviewed following the completion of the engineering work and export cable survey.

137. Where possible, to minimise the extent of any unnecessary habitat disturbance, the Offshore Project will aim to actively backfill material displaced as a result of cable burial activities, in order to promote recovery. Cable burial depth will be monitored in the midzone, where the seabed is active with mega-ripples.

5.8.6.3 Installation of Offshore Export Cable Corridor via trenchless technique at Landfall (to MHWS)

138. Landfall will be located at Saunton Sands. Although the majority of the activities associated with Landfall and the Onshore Export Cable works will the subject of the separate Onshore Project EIA, there are some activities which take place below MHWS mark and therefore need to be considered in the Offshore Project ES.

139. HDD may be selected as the Landfall method. HDD involves drilling of small pilot hole(s) from the landward side to an exit point below MLWS. Up to two ducts will be required to accommodate up to two Offshore Export Cables and this may require up to five bore attempts. In the event that a bore fails, it would be abandoned and backfilled. During HDD, the hole(s) is widened to accommodate a conduit pipe through which the cable is pulled. For the base case cable, the outer diameter (OD) will be approximately 165mm and the duct size will be 255mm OD or larger to provide at

least 1.5 times the cable diameter. The size of the final HDD bore diameter would be approximately 312mm with a maximum HDD bore diameter of 500mm per drilled hole. Once installed, the cable is fed into a cable joint transmission bay. HDD requires a temporary landward working area (typically called an HDD compound) during construction to accommodate the drilling equipment and ancillary plant. The HDD compound, which contains the cable joint transmission bay, will be above MHWS and is therefore included within the Onshore EIA. **Plate 5.19** provides an illustration of the installation of Offshore Export Cable via HDD at Landfall (to MHWS).

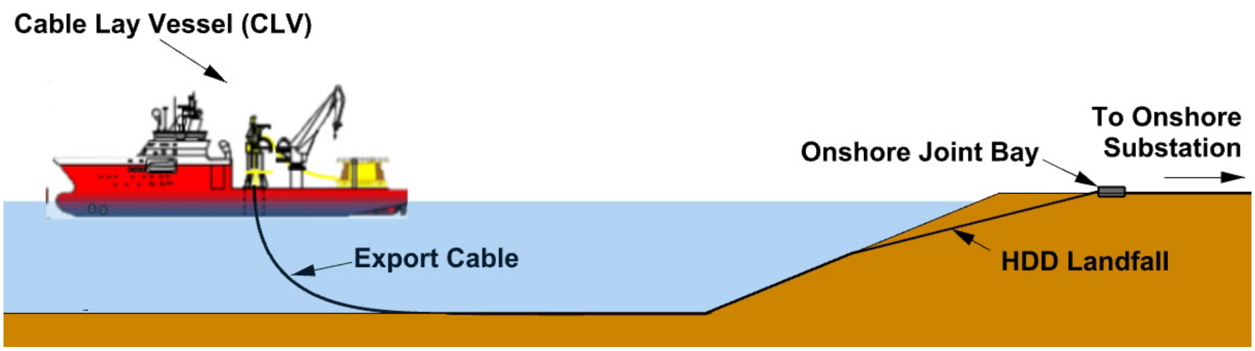

Plate 5.19 Installation of Offshore Export Cable via trenchless technique at Landfall (to MHWS)

5.9 Offshore Operation and Maintenance Activities

140. Across the operational life of the Offshore Project, Operation and Maintenance activities can be split into four main categories as follows:

- Scheduled maintenance
- Unscheduled maintenance
- Emergency / special maintenance (in the event of major equipment breakdown and repairs)
- Refurbishment and replacement.

141. The Offshore Project lifespan is 25 years and the operation and maintenance will cover this lifespan. Offshore operation and maintenance are considered within this section.

5.9.1.1 Offshore Operations

142. A summary of the typical Offshore Project operational time, availability and downtime is provided in **Table 5.19**.

Table 5.19 Summary of typical project operational time, wind availability and downtime

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wind availability	97.27%	96.72%	96.07%	93.74%	93.56%	91.55%	92.18%	91.56%	93.65%	96.15%	96.50%	97.36%
Mean downtime	3.00%	3.00%	3.00%	3.00%	3.00%	3.00%	3.00%	3.00%	3.00%	3.00%	3.00%	3.00%
Proportion of time operational	94.35%	93.82%	93.19%	90.93%	90.75%	88.80%	89.41%	88.81%	90.84%	93.27%	93.61%	94.44%

5.9.1.2 Offshore maintenance

5.9.1.2.1 Overview

143. At this stage, based on current understanding the operation and maintenance activities will include but not be limited to the following:

- Wide ranging inspections of mooring system, transition pieces, blades, safety equipment, OSP equipment, etc.
- System performance assessments and fault-finding
- Replacement of lubricants, oils, filters, etc.
- Painting and coating application of turbines, etc.
- Replacement of wind turbine parts including bearings, gearboxes, generators, nacelles, transformers and blades
- Minor repair and replacements including access ladders, corrosion protection system including anodes and protective coatings, secondary steel, boat landings, cable penetrations and ducting, aids to navigation
- Removal of marine growth and guano
- Structural surveys
- Periodic cable burial surveys, including any crossings and at interfaces at subsurface structures
- Reburial or other remedial actions of inter-array cables, export cable and crossings array cables
- Repair or replacement of offshore export and inter-array cables
- Replenishment of rock protection as additional cable and scour protection.

144. The strategy for operation and maintenance will be finalised based on the location of a suitable port / harbour which is yet to be defined. The onshore operation and maintenance base and port for return-to-shore maintenance of the WTG/floating

substructure will be selected during FEED based upon technical and economic constraints. In choosing a suitable port / harbour there will be requirements to ensure sufficient access to a fleet of vessels with the capabilities to complete any required operation and maintenance activities. The overall operation and maintenance strategy will also reflect the technical specification once known, including wind turbine type, electrical transmission design and final project layout.

145. Maintenance and inspection activities will be performed after the WTG in question has been shut down. Boarding of the units will most likely be undertaken by Crew Transfer Vessel (CTV) but airlifting via a helicopter could potentially be an option. Access to the substructure will occur from the CTV by docking and using ladders, while the use of airlifting will hoist personnel directly onto the nacelle.

5.9.1.2.2 Frequency of maintenance activities

146. **Table 5.21** details the expected operation and maintenance frequencies for the WTGs and substructures. It is assumed that the duration of servicing activities will be up to 4 days per visit. These frequencies cover statutory inspections, maintenance recommended by suppliers and a probabilistic estimate of unplanned maintenance.

147. Offshore Export Cables, moorings, substructures and the OSP will normally be inspected on an annual basis using vessels with ROVs. This is to allow for adequate inspection and biofouling may also have to be removed from substructures, cables and mooring lines.

148. The frequency of the inspections and maintenance will vary but in total it's expected this could be up to 2,400 visits over the lifespan of the Offshore Project.

Table 5.20 WTG & Substructure Operation and Maintenance Frequencies

Parameter	Minimum	Maximum
Vessel visits per turbine per year	3	15
Minor maintenance per turbine per year (in line with WTG manufacturer maintenance recommendations)	1	4
Major maintenance per turbine per year (asset return to port)	0	0.2
Mooring line replacement per turbine per year	0	0.1

149. It is possible that major WTG components (rotor blades, generators, gearbox etc.) may need to be replaced during the life of the project. In these extreme events the WTG would need to be disconnected from their mooring system and array cables and towed to shore where major maintenance would be carried out using an onshore crane or jack-up vessel. The tow to shore would be carried out by tug boat(s) and

anchor handling vessel(s). The remaining WTGs will continue to operate when one WTG unit has been removed.

5.9.1.3 Cable repairs / remediation

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

151. To conduct a cable repair, a section of cable will be recovered either side of the fault of sufficient length to enable a repair. The repair comprises two new joints connecting a new section of cable with the ends of the original cables.

152. The recovery of the cable will be performed by a suitable Dynamic Positioning vessel or anchor barge if in the nearshore region. A suitable dive spread/platform may also be needed, depending on the operation. The length of cable exposed and recovered to a cable handling vessel will be proportional to 1.5 times the deepest tidal water depth at the location of the fault to ensure sufficient slack in the cable system and prevent unnecessary strain on the component parts during repair and reburial.

153. The total length of cable exposed and replaced in any one repair event is unlikely to exceed 200m. All recovered and redundant cable will be disposed of and recycled as appropriate onshore. Cut and exposed cable ends will be sheathed and buoyed to the surface for the repair operation. The buoyed end will then be recovered onto the cable handling vessel and cable jointing will commence.

154. Once jointed, the cable handling vessel will re-lay the cable to the seabed via lowering from the repair vessel deck. Upon completion and re-laying, the cable will be assessed to ensure it is in the correct position and sufficient slack is available.

155. If mechanical re-burial is required, jetting with a Mass Flow Excavator suspended approximately 1 to 2m above the seabed will be conducted. The target burial depth of 0.5 to 3m (**Table 5.13**) will be sought via these operations. These techniques do not permanently add or remove any material from the seabed and take place along the existing Offshore Export Cable route. The operation is not expected to disturb more than 2m width of seabed sediment (maximum 7m if the cable cannot be reburied to the original trench from where it was initially recovered).

156. Where jetting is not feasible, trenching could be undertaken with the use of a backhoe dredger as a last resort. Both methods will occupy a similar seabed footprint, however trenching represents the realistic worst-case scenario due to the potential for more seabed sediment to be suspended into the water column. Re-burial via ploughing is not technically feasible in this instance, due to the export cables already being in-situ.

157. Rates of re-burial will vary depending on ground conditions and final tools used. Estimated figures for re-burial range from 100 to 250m/hr. An average length of re-burial from cable repair in this application is expected to take approximately five days. Upon completion of re-burial, a post survey will be conducted to assess whether the cable is at the correct position and depth.

158. For cable remediation, previous as-laid cable data and/or data from recent geophysical surveys will be reviewed to finalise the area requiring remediation. A cable pre-burial survey will follow this using a Multibeam Sonar (pipe/cable tracker) or similar device to confirm the exact location and current cable burial depth/areas of exposure.

159. Key parameters related to these activities are detailed in **Table 5.21**. As with the initial cable installation works, further details are included in the Cable Burial Management Plan (**Appendix 8.C**).

Table 5.21 Maximum temporary maintenance activity footprints in the Windfarm Site and Export Cable Corridor

Parameter	Minimum	Maximum
Offshore Export Cable(s)		
No. of cable repairs over lifetime	0	5
Length of individual cable repair (length of seabed affected)	50m	1km
Width of individual cable repair (width of seabed affected)	30m	50m
Area of seabed affected by individual cable repair	150m^2	50,000m^2
Area of seabed affected by all Offshore Export Cable repairs	0m^2	250,000m^2
Number of remediation events (re-burial)	6	20
Area of seabed affected by remediation events	30m x 1km x 6 Area = 180,000m^2	50m x 1km x 20 Area = 1,000,000m^2
Inter-array cables		
No. of inter-array cable repairs over lifetime	0	5
Length of individual inter-array cable repair (length of seabed affected)	500m	3km
Width of individual inter-array cable repair (width of seabed affected)	30m	50m
Area of seabed affected by individual inter-array cable repairs	15,000m^2	150,000m^2
Area of seabed affected by all inter-array cable repairs	0m^2	750,000m^2
Number of remediation events (re-burial)	6	20
Area of seabed affected by remediation events	30m x 500m x 6 = 90,000m^2	50m x 500m x 20 = 500,000m^2

Parameter	Minimum	Maximum
Total area of seabed affected by cable remediation		
Total number of cable repairs of lifetime	0	10
Total number of remediation events (re-burial)	12	40
Total area of seabed affected by remediation events	270,000m^2	1,500,000m^2

5.10 Offshore Decommissioning Activities

160. Decommissioning will occur at the end of the operational lifetime of the Offshore Project which is provisionally anticipated to be a minimum 25 years.

161. The decommissioning process will largely be the reverse of that undertaken during the construction phase. It is expected that the WTG, semi-submersible floating platforms and moorings will be completely removed and returned to port for disassembly, re-use or disposal. All electrical cables will be left in-situ to minimise environmental impacts associated with their removal. Any mooring anchors driven or drilled into the seabed will be cut at or below surface level. Embedded material will be left in situ and emergent structures will be removed from site.

162. At this stage, the full detail of the required decommissioning activities is not currently known. A decommissioning plan will be prepared during detailed design and developed and refined during the Offshore Project's lifetime and as decommissioning approaches. To reflect future best practice and new technologies, the approach and methodologies of the decommissioning activities will be compliant with the relevant legislation, guidance and policy requirements at the time of decommissioning.

5.11 References

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White Cross Offshore Windfarm Environmental Statement

Appendix 5.: Outline Construction Environmental Management Plan

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Table of Contents

Glossary of Acronyms

Acronym	Definition
EIA	Environmental Impact Assessment
EMS	Environmental Management System
ES	Environmental Statement
EU	European Union
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
IMCA	International Marine Contractors Association
IMO	International Maritime Organization
IOPP	International Oil Pollution Prevention Certificate
MCA	Maritime and Coastguard Agency
MMMP	Marine Mammal Mitigation Protocol
MMO	Marine Management Organisation
MPCP	Marine Pollution Contingency Plan
PPG	Pollution Prevention Guidelines
SOPEP	Shipboard Oil Pollution Emergency Response Plan
TBT	Toolbox Talk
UXO	Unexploded Ordnance
WSI	Written Scheme of Investigation

Glossary of Terminology

Defined Term	Description
Applicant	Offshore Wind Limited
Department for Business, Energy and Industrial Strategy (BEIS)	Government department that is responsible for business, industrial strategy, science and innovation and energy and climate change policy and consent under Section 36 of the Electricity Act.
Environmental Impact Assessment (EIA)	Assessment of the potential impact of the proposed Project on the physical, biological and human environment during construction, operation, maintenance, and decommissioning.
Floating substructure	The floating substructure acts as a stable and buoyant foundation for the WTG. The WTG is connected to the substructure via the transition piece and the substructure is kept in position by the mooring system.
Generation Assets	The infrastructure of the Project related to the generation of electricity within the windfarm site, including wind turbine generators, substructures, mooring lines, seabed anchors and inter-array cables
Mooring system	The equipment (mooring lines and seabed anchors) that keeps the floating substructure in position during operation through a fixed connection to the seabed.
Mitigation	Mitigation measures have been proposed where the assessment identifies that an aspect of the development is likely to give rise to significant environmental impacts, and discussed with the relevant authorities and stakeholders in order to avoid, prevent or reduce impacts to acceptable levels. For the purposes of the EIA, two types of mitigation are defined: • Embedded mitigation: consisting of mitigation measures that are identified and adopted as part of the evolution of the project design, and form part of the project design that is assessed in the EIA • Additional mitigation: consisting of mitigation measures that are identified during the EIA process specifically to reduce or eliminate any predicted significant impacts. Additional mitigation is therefore subsequently adopted by OWL as the EIA process progresses.
Offshore Development Area	The Windfarm Site (including wind turbine generators, substructures, mooring lines, seabed anchors, inter-array cables and Offshore Substation Platform (as applicable)) and Offshore Export Cable Corridor to MHWS at the Landfall (up to MHWS). This encompasses the part of the project that is the focus of this application and Environmental Statement and the parts of the project consented under Section 36 of the Electricity Act and the Marine and Coastal Access Act 2009

Defined Term	Description
Offshore Export Cables	The cables which bring electricity from the Offshore Substation Platform or the inter-array cables junction box to the Landfall (up to MHWS)
Offshore Infrastructure	All offshore infrastructure including wind turbine generators, substructures, mooring lines, seabed anchors, Offshore Substation Platform and all cable types (export and inter-array). This encompasses the infrastructure that is the focus of this application and Environmental Statement and the parts of the project consented under Section 36 of the Electricity Act and the Marine and Coastal Access Act 2009
the Offshore Project	The Offshore Project for the offshore Section 36 and Marine Licence application includes all components offshore of MHWS. This includes the infrastructure within the windfarm site (e.g. wind turbine generators, substructures, mooring lines, seabed anchors, inter-array cables and Offshore Substation Platform (as applicable)) and all infrastructure associated with the export cable route and landfall (up to MHWS) including the cables and associated cable protection (if required).
Offshore Substation Platform	A fixed structure located within the Windfarm Site, containing electrical equipment to aggregate the power from the wind turbines and convert it into a more suitable form for export to shore
Offshore Wind Limited	Offshore Wind Ltd (OWL) is a joint venture between Cobra Instalaciones Servicios, S.A., and Flotation Energy Ltd
the Project	the Project is a proposed floating offshore windfarm called White Cross located in the Celtic Sea with a capacity of up to 100MW. It encompasses the project as a whole i.e. all onshore and offshore infrastructure and activities associated with the Project
White Cross Offshore Windfarm	100MW capacity offshore windfarm including associated onshore and offshore infrastructure
Wind Turbine Generators (WTG)	The wind turbine generators convert wind energy into electrical power. Key components include the rotor blades, nacelle (housing for electrical generator and other electrical and control equipment) and tower. The final selection of project wind turbine model will be made post-consent application
Windfarm Site	The area within which the wind turbines, Offshore Substation Platform and inter-array cables will be present

Appendix 5.A: Outline Construction Environmental Management Plan

1. Introduction

1. There are potential environmental sensitivities associated with an offshore windfarm development, which need to be identified and considered before construction of the Project and its associated infrastructure takes place.

2. These potential effects are outlined in the Project's Environmental Statement (ES), including embedded mitigation in the form of good practice that will require an adherence to during the construction phase as a minimum standard. A description of the proposed development is presented in **Chapter 5: Project Description**.

3. Offshore Wind Limited (henceforth the 'Applicant') recognises from feedback during the Environmental Impact Assessment (EIA) consultation and stakeholder engagement process, that the provision of an Outline Construction Environmental Management Plan (CEMP) for the Offshore Project adds value by demonstrating the linkages between the ES, site activities, and likely conditions associated with the Section 36 and Marine Licences consents.

4. The main purpose of this document is therefore to set out the typical framework of an offshore CEMP, including the controls that are proposed to be adopted to manage the environmental risks associated with the construction of the Offshore Project. The document is based on the Applicant's minimum requirements, industry good practice and relevant legislation (at the time of preparation).

5. This document is for both internal and public use (the latter via inclusion in Environmental Statements and Planning Submissions).

2. Scope

6. A CEMP sets out the controls and processes that are to be adopted to mitigate environmental impacts throughout the construction phase of a project and measures set out to comply with consent conditions. The CEMP is considered to be an iterative document that develops throughout the pre-construction and construction phases of a project.

7. Principal Contractors will be responsible for the construction of the main infrastructure associated with the Offshore Project including Wind Turbine Generators (WTGs), semi-submersible floating platforms, mooring system, inter-

array cables, Offshore Substation Platform (OSP) and Offshore Export Cable. These may be managed as individual projects or as a framework.

8. Preparation of a project CEMP will be the responsibility of the appointed Principal Contractor for the Offshore Project that they have been awarded. The Principal Contractor is likely to have internal management system requirements and CEMP templates, so the actual project CEMP may vary from what is set out within this document.

9. Additional information with regard to the Applicant's environmental management requirements and project specific requirements are set out in the Applicant's infrastructure contract documents (including the Environmental Statement (and therefore this Document)), development planning conditions and the Company's Environmental Policy.

10. Compliance with the Applicant's environmental management requirements will be audited as part of the Applicant's annual environmental audit programme.

11. Typical contents for an offshore project CEMP are set out below. Outline content for each section is described in **Sections 3** to **13**:

- Project Description and Environmental Sensitivities
- Environmental Management Structure and Responsibilities
- Associated Documentation
- Management of Key Environmental Issues
- Environmental Incident Response and Contingency
- Monitoring and Site Inspections
- Legislative and Regulatory Compliance
- Training and Awareness
- Communication and Reporting
- Sub-contractor Management
- Sustainable Construction.

3. Project Description and Environmental Sensitivities

12. This section of the CEMP for the Offshore Project should set out information or links to information with regards to the Offshore Project and environmental sensitivities. In particular, sensitive ecological, archaeological or human receptors, such as protected habitats, protected wrecks, constraints, site layout plans, and the scope of works to be undertaken, including identification of environmental aspects and impacts, should be considered.

13. The Principal Contractor for the construction of the Offshore Project will be expected to have their own Aspect and Impacts Register as part of their Environmental Management System (EMS).

4. Environmental Management Structure and Responsibilities

14. Environmental Management roles and responsibilities for the Offshore Project are required to be documented. This section should set out the environmental responsibilities for the Offshore Project, including identification of key site staff, their environmental management responsibilities and how these link with other members of the project team, such as the Project Manager, the project Health and Safety / Environmental Manager(s) and / or Advisors and environmental specialists such as Environmental Liaison Officer, Fisheries Liaison Officer, Ornithologists, Marine Mammal Observers or Archaeologists.

15. Interactions with stakeholders such as the Marine Management Organisation (MMO), Natural England, Environment Agency (EA), Local Planning Authority, etc. should also be covered in this section.

16. An organisational chart depicting the environmental management arrangements is often a useful mechanism to illustrate the Offshore Project's environmental management structure. The contact details for the individuals listed should also be included in this section or attached as an appendix to the CEMP.

17. On most construction projects, the Applicant will employ a Principal Contractor who will be responsible for environmental management on site, including the preparation of onsite environmental documentation.

5. Associated Documentation

18. This section should refer to relevant associated EMS and project / site specific documentation that is required to be taken into consideration in developing the CEMP. Examples include, but are not limited to:

- Contract requirements (such as environmental standards)
- Principal Contractor's EMS requirements
- Project Environmental Management Plan (PEMP)
- Project Emergency Response Plan
- Project Health and Safety Plan
- Project Environmental Statement
- Marine Licence conditions
- Risk registers

- Legal registers.

6. Management of Key Environmental Issues

19. This section should set out details of the controls and procedures to be adopted to mitigate the environmental impacts associated with the development.

20. Typically, this would cover the following issues:

- Noise and vibration
- Marine ecology
- Offshore ornithology
- Marine archaeology and cultural heritage
- Dropped object(s) in the marine environment
- Wastewater discharges
- Oils, fuel and chemicals
- Waste management and circular economy
- Vessel management
- Emissions to air
- Method Statements and Risk Assessments.

21. It is recognised that some of the issues identified above relate only to the marine environment, whilst others will apply to both onshore and offshore construction activities. An onshore Outline CEMP will be produced and included in the separate Town and Country Planning Act planning application for the Onshore Project.

22. **Chapters 8: Marine Geology, Oceanography, and Physical Processes to 26: Major Accidents and Disasters** in the ES for the Offshore Project outline the conclusions of the EIA process for the issues presented in this section. A brief overview of some of the key issues for each item is provided below. However, it must be noted that the list of issues identified above is not exhaustive and will be specific to the final design of the Offshore Project. Furthermore, the key issues will be re-examined following the Section 36 and Marine Licences determination period.

6.1 Noise and vibration

23. There is the potential for noise and vibration to be generated during the construction process, especially from piling and Unexploded Ordnance (UXO) removal. Measures will be required to be implemented on site to minimise any effects and a programme of monitoring may be required.

24. The Offshore Project's ES will identify receptors that are potentially sensitive to noise and vibration impacts together with mitigation measures, which must be implemented.

25. For offshore construction, it is likely that a risk assessment for European Protected Species (cetaceans and marine turtles) will require to be incorporated into the CEMP.

26. For offshore construction projects involving piling and foundation works in the marine environment, a specific noise and vibration mitigation and monitoring plan to mitigate potential impacts on marine mammals/fish will be required. In addition, a specific Marine Mammal Mitigation Protocol (MMMP) will be prepared and agreed with the regulator.

27. In addition, an Environmental / Ecological Monitoring Plan will be prepared, as required, setting out requirements and responsibilities; this may include noise and vibration monitoring.

6.2 Marine ecology

28. The Offshore Project's ES will identify areas of conservation / protection and set out mitigation as appropriate. The CEMP should include the measures to be adopted. This will enable communication of awareness of any sensitive areas (such as Bideford to Foreland Point Marine Conservation Zone) and potential protected features (e.g., reefs) to the project team. The procedures to be adopted in the event of an incident in proximity to these features should also be set out in the CEMP.

29. The Principal Contractor's CEMP will align with the PEMP. It will be required to consider, and make mitigation provisions for, potential seabed and sediment movement impacts. The CEMP will also set out requirements for monitoring benthic habitats as appropriate.

6.3 Offshore ornithology

30. The CEMP will include the final procedures to be adopted within vessels transit corridors to minimise disturbance to bird species during construction activities. The PEMP will include procedures for the operation and maintenance phase. Potential impacts on bird species during construction will be mitigated through:

- Restricting vessel movements where possible to existing navigation routes
- As far as possible maintaining direct transit routes
- Where it is necessary to go outside of established navigational routes, avoid rafting birds either en-route to the Offshore Development Area from port and/or

and where possible avoid disturbance to areas with consistently high bird densities

- Avoidance of over-revving of engines (to minimise noise disturbance)
- Briefing of vessel crew on the purpose and implications of these vessel management practices.

31. The Project Team would make maintenance vessel operators aware of the importance of the species and the associated mitigation measures through tool box talks.

6.4 Marine archaeology

32. The Offshore Project's ES identifies sites, wrecks, etc. of potential archaeological importance and these are also presented in the Outline Written Scheme of Investigation (WSI) (see **Appendix 16.B: Offshore Archaeological WSI**) with appropriate mitigation, such as establishment of exclusion and buffer zones clearly marked out. The CEMP should include the measures to be adopted to communicate awareness of sensitive archaeological sites to the project team and the procedures to be adopted in the event of an unanticipated find.

33. The Offshore Project's Archaeological WSI, once developed, will require referencing in the CEMP.

6.5 Dropped Objects in the marine environment

34. A Dropped Objects into the Marine Environment Plan or similar should feature as a component of the Principal Contractor's CEMP. This may be a specific condition of consent.

35. This procedure should detail the proposed recovery for both floating and non-floating objects and the reporting and documenting of the incident to the project Team and the regulator. The procedure will be required to be reviewed by the Project team prior to the Principal Contractor commencing work.

6.6 Wastewater discharges

36. For offshore construction, any wastewater discharges to sea must comply with current legislation, regulatory limits and good practice such as effluent discharges, ballast waters, bilge waters and deck runoff. Controls for discharges should be included in the CEMP. All vessels involved with construction and operation of the

Offshore Project will be required to comply with the International Convention for the Prevention of pollution from Ships (MARPOL)73/78.

37. Monitoring records in relation to the disposal of grey water, foul water, bilge water or ballast water during the construction phase must be retained.

6.7 Oils, fuels, and chemicals

38. It is the responsibility of each Principal Contractor to have in place adequate controls for the delivery, storage and use of fuels, oils and chemicals on site and on vessels and other materials as required. This includes checks that chemicals to be used offshore comply with relevant regulations.

39. Within their environmental management plan, each Principal Contractor must consider the delivery, storage and handling of hazardous materials, in particular oils and fuels, taking into account the legal requirements and good practice guidelines.

40. Oils and chemicals must be clearly labelled and each Principal Contractor should retain an up-to-date hazardous substance register. Activities involving the handling of large quantities of hazardous materials, such as deliveries and refuelling, should have detailed method statements in place and be undertaken by designated and trained personnel.

41. Oil and fuel storage tanks must be robust and provide adequate secondary containment and be located in designated areas taking into account security, the location of sensitive receptors and pathways such as drains and watercourses, and safe access and egress for plant and manual handling.

42. Spill response materials should be provided nearby and be readily accessible, with project personnel trained in spill response.

43. Vessels of more than 400 gross tonnes should maintain an oil record book and the sulphur content of fuels must comply with MARPOL Annex VI requirements in relation to Sulphur Emission Control Areas (SECAs) and hold a valid International Oil Pollution Prevention Certificate (IOPP). A Marine Pollution Contingency Plan (MPCP) will be developed post consent.

44. Within the port, fuel and chemical management will be developed following discussions with the port authority. It will be required to be documented in the CEMP and in alignment with the port authority's Oil Spill Contingency Plan.

6.7.1 Control of Substances Hazardous to Health (COSHH)

45. The Principal Contractor is responsible for ensuring that all materials ordered or brought to site listed as hazardous under the Control of Substances Hazardous to Health (COSHH) Regulations are accompanied with a hazardous information sheet. The Principal Contractor will comply with the COSHH Regulations.

6.8 Waste management and circular economy

46. Where waste is produced, reuse, recycle or recovery should be considered where practical and economically feasible prior to considering disposal.

47. Each Principal Contractor is responsible for the collection, storage and disposal of any waste produced as part of the Offshore Project and will be required to prepare a Waste Management Plan in line with legislation, good practice and the PEMP. The Plan should record the following information, as a minimum:

- The types and quantities of waste generated
- The management approach for each waste type (Reuse, Recycle, Recover, Dispose) including any treatment
- The storage arrangements for each waste type
- The site waste monitoring and reporting arrangements.

48. Duty of care requirements in relation to the storage, transfer and disposal of waste must be complied with.

49. The waste management principles outlined above, also apply to vessels, in particular the requirement to have a compliant Garbage Management Plan and Garbage Record Book; vessel operators are required to liaise with port operators to facilitate appropriate segregation/disposal of waste.

50. Circular economy principles should be considered, where practical and economically feasible, specifically the priority area of circular construction and adopting circular economy interventions such as:

- adopting circular design principles and construction processes, particularly the opportunity to create a physical and virtual resource recovery and material exchange hub to make better use of material wasted in construction; and
- supporting the growth of regional specialist circular products and services in the construction industry.

6.9 Vessel management

51. For offshore construction, it is likely that a specific Project Vessel Coordination Plan will be developed. Vessels will be subject to inspections and audits as described in

Section 8 below. Vessel movements within the site will be monitored and directed as required by the Principal Contractor.

6.9.1 Vessel welfare facilities

52. Vessel welfare facilities will be provided for site operatives under the Construction (Design and Management) Regulations 2015 including sanitary conveniences, washing facilities, drinking water, changing rooms and accommodation for clothing not worn during working hours and rest facilities.

6.10 Emissions to air

53. For offshore construction and operations, vessel emissions must comply with MARPOL Annex VI requirements in relation to ozone depleting substances regulations, nitrogen oxide, sulphur oxide and particulate and volatile organic compounds. Where relevant, vessels shall have a valid International Air Pollution Prevention (IAPP) certificate.

6.11 Method Statements and Risk Assessments

54. It is the responsibility of the Principal Contractor to have in place approved method statements and risk assessments for works being carried out on-site. Where relevant, the method statement should cross reference applicable environmental risk assessments. The risk assessments should identify environmental hazards and outline subsequent control measures. Control measures should be developed, implemented and monitored to ensure that any impact on the environment is avoided or minimised. Approval for these method statements with the relevant authorities may be required.

55. Key personnel involved in the work activities should be given a method statement briefing by the Principal Contractor or Contractor, in the form of a toolbox talk (TBT). The TBT should outline the risks involved and the control measures that personnel are expected to comply with. It is expected that individuals sign a method statement attendance briefing record sheet, acknowledging receipt of the information; these records should be maintained by the Principal Contractor. TBT's should also be used to inform sub-Contractors of other environmental sensitivities as appropriate.

7. Environmental Incident Response and Contingency

56. It is essential that any environmental incidents (including dropped objects into the marine environment) are reported and managed correctly to allow their impact to be reduced to a minimum and to decrease the risk of the incident re-occurring. All

reporting will be undertaken as stated in Health, Safety, Environmental and Quality minimum requirements document.

7.1 Emergency response plan

57. Principal Contractors will be required to have an environmental emergency response plan. This will be in additional to individual management plans already in place for day to day operations. The plan should include a response flow chart and detail how to report and respond to an environmental incident, including the measures available to contain / clean up an incident (e.g. local spill kits, waste reception facilities), manage dropped objects in the marine environment and offsite emergency response resources.

58. For offshore activities, a MPCP, which should form an integral component of the CEMP, will also be required to be developed for the Offshore Project.

59. Vessels working on behalf of the Offshore Project will be required to have a Shipboard Oil Pollution Emergency Response Plan (SOPEP) in accordance with International Maritime Organization (IMO) and Maritime and Coastguard Agency (MCA) guidelines or an Oil Pollution Plan if under 400GT.

7.2 Reporting

60. All environmental incidents (including dropped objects into the marine environment) and near misses must be reported, investigated and recorded to the project Team and the Health and Safety Executive.

61. Principal Contractors are required to produce monthly reports for the project Team to record health, safety and environment performance.

7.3 Lessons learned / incident follow-up

62. If an environmental incident should occur, it shall be thoroughly investigated by the relevant Principal Contractor to establish the root cause and prevent any recurrence. Dependent on the severity of the incident, the Project team may wish to manage or assist with the investigation process.

8. Monitoring and Site Inspections

63. The establishment of a programme of performance and compliance monitoring will be established for the Offshore Project. This should be documented in the CEMP and include, but not necessarily be restricted to, the following items listed in **Section 8.1** to **8.4**, where relevant.

8.1 Site inspections

64. The Principal Contractor, or appointed delegate, will undertake site inspections on at least a weekly basis. These site inspections will include an environmental component which should, as a minimum, and where relevant, cover the key issues outlined within this document. Weekly inspections should be complimented by a combination of daily/monthly inspections, dependant on site-specific requirements.

65. The Principal Contractor is responsible for ensuring the close out of any actions identified during the inspections. Records of the inspections carried out should be retained onsite by the Principal Contractor and a copy provided to the Applicant; any remedial actions required must also be recorded.

8.2 Environmental audits

66. Environmental audits should comprise both internal and external audits.

67. The Applicant's audit programme includes a requirement to audit construction sites on a periodic basis. An audit checklist will be used by the Applicant to ensure that a standard approach is applied consistently. The Applicant's environmental audits are carried out by experienced auditors, either from within the Applicant's environmental team, or via delegated specialists.

68. All actions raised from the Applicant's audits are logged within a central system. Progress of audit actions is tracked, and a closing date assigned when the action is complete.

8.3 Vessel inspections and audits

69. Vessel inspections will be based on the International Marine Contractors Association (IMCA) standards, IMCA M 189/S 004 (Marine Inspection Check List for Small Boats) or IMCA M 149 (Common Marine Inspection Document). A log of all vessel audits and associated close out actions should be maintained.

8.4 Environmental monitoring

70. A programme of environmental monitoring such as for water quality, noise, vibration, archaeology, vessels, scour, and ecological surveys may be required as part of consent conditions. This will be incorporated into specific project plans, such as the CEMP, for offshore construction.

71. Where appropriate, the scope of monitoring shall be agreed prior to construction with the appropriate authority.

9. Legislative and Regulatory Compliance

9.1 Section 36 application conditions

72. UK Offshore sites are granted permission to be constructed under specific consents and licenses issued by Government bodies such as the Planning Inspectorate, Local Authority, MMO and the EA.

73. Specific limits for emissions to air, discharges to the marine environment and working practices (such as seasonal exclusions) are contained within these consents / licenses and may not be breached at any time. The Section 36 Application and DML will be the key permissions to be adhered to for offshore projects.

74. The Principal Contractor must ensure that all relevant planning conditions for the Offshore Project are complied with.

75. Planning conditions will be reviewed by the Project team on a periodic basis, to ensure that the conditions are being complied with.

9.2 Legal register

76. It is the Applicant's policy to minimise the impact of its construction activities on the environment by complying with all relevant environmental legislation and good practice. To ensure that the Applicant is aware of the requirements of current environmental legislation and good practice, an Environmental and Planning Legal Register will be maintained by the Applicant's Environmental Team.

77. The Legal Register details relevant environmental legislation requirements for the business and includes details of associated control measures.

78. The Principal Contractor will be required to ensure that all relevant environmental legislation and good practice are complied with on site. Adequate records of environmental information and audits to demonstrate compliance with both legal and Project environmental requirements, will be required to be maintained by the Principal Contractor.

79. The Principal Contractor will be responsible for applying for and obtaining any permits / licenses related to their activities.

80. The Applicant will assess compliance with relevant environmental legislation as part of the Applicant's environmental audit programme.

9.3 Regulatory reference material

81. Key reference material in this section of the CEMP should include the following:

- Register of relevant Planning Consent / Marine License / Permit Conditions
- Project Legal Register
- Good Practice Guidance / Industry Standards such as Pollution Prevention Guidance Notes (. PPG Notes and other guidance documents are available from the EA and MMO websites. As requested within the MMO's Scoping Opinion (Case reference: EIA/2022/00002), PPG5 – *Works and maintenance in or near water* and PPG6 – *Working at construction and demolition sites* will be adhered to.

10. Training and Awareness

82. A range of mechanisms is used for training and raising awareness of project environmental issues; these include environmental inductions, TBTs, environmental notice boards, and environmental bulletins and alerts.

10.1 Project / vessel / site inductions

83. All site personnel will be required to have a site / vessel induction that includes an environmental component. Designated on-site/vessel personnel from the Principal Contractor's Project team should be responsible for preparing and delivering the site / vessel induction and maintaining documented attendee records.

84. It is expected that the environmental management contents of site/vessel inductions will include reference to compliance with:

- relevant planning / license conditions
- environmental management contacts
- site specific environmental sensitivities
- waste management arrangements
- water and wastewater management
- hazardous material management
- fuel, oil and chemical management
- environmental emergency response
- reporting of incidents and complaints.

10.2 Toolbox Talks (TBTs)

85. TBTs are considered to be an effective method for the dissemination of information relating to work activities. Environmental TBTs will be required to be delivered by

the Principal Contractor to on-site/vessel personnel as required. Tool box talks are an opportunity for the Principal Contractor to disclose any other environmental sensitivities that the sub-Contractors must be aware of.

86. It is the responsibility of the Principal Contractor to ensure that all personnel attending the TBT have signed a TBT attendance sheet; TBT attendance sheets are likely to be inspected as part of environmental audits.

10.3 Environmental notice board

87. It is a requirement of the Applicant that all construction sites/vessels have an environmental notice board. The notice board must be displayed in an appropriate and prominent location and must be used to display copies of relevant environmental management information, including but not limited to the following:

- Environmental Policies
- Key Contacts Details, including Principal Contractor's Environmental Management Representative
- Environmental Bulletins
- Offshore Project Location Plan showing ecologically / archaeologically sensitive areas, key management areas and location of contingency materials / features
- Emergency Response Contact Details
- Emergency Response Flowchart.

10.4 Emergency response

88. The Principal Contractor must ensure that all staff including any sub-Contractors are trained in the Offshore Project's environmental emergency response procedures, so that they are able and prepared to respond to an incident promptly and effectively on-site. Where appropriate, the Applicant may request environmental emergency response plans to be tested on-site by the Principal Contractor. All vessels should carry relevant plans (e.g. MPCP) on board in hard copy.

11. Communication and Reporting

11.1 Meetings

89. Periodic health, safety and environment (HSE) meetings are required to be held on all construction sites, including vessels, and are likely to comprise representatives from the Applicant's project team, the Principal Contractor, and key sub-contractors. Minutes of meetings will be recorded, and standard agenda items will include status of outstanding items, reports of environmental incidents or complaints, stakeholder

engagement, TBTs issued / delivered, and key findings of environmental inspections and audits. All reporting will be undertaken as stated in Health, Safety, Environmental and Quality minimum requirements document.

90. The Principal Contractor is expected to convene regular project team meetings to convey environmental information to the project team, including sub-Contractors and to raise awareness of environmental issues.

11.2 Community complaints

91. The Applicant values its relationship with the communities that surround the Offshore Project. All work shall be carefully planned to minimise disturbance to the local communities.

92. The Principal Contractor must ensure that any complaints are reported to the Project team and investigated promptly.

93. Within their environmental management plan, the Principal Contractor must have a procedure in place to report public complaints.

11.3 Community liaison and land use

94. Depending on the site location, a public / community relations plan may be developed for the site by the Principal Contractor. The purpose of the plan, which must be developed in liaison with the Project team, should set out the approach to community liaison for the duration of the Offshore Project. For the Offshore Project, Fishery Liaison and Environment Liaison Officers will be appointed for the duration of the works, as required.

95. The CEMP will be developed measures that limit and manage the timing of construction activities at Landfall up to MHWS with the potential to affect public use of Saunton Sands Beach. These measures will include:

- Communication and engagement activities to ensure that visitors to Saunton Sands are aware of the timing and extent of construction activities in the nearshore/intertidal zone
- Maintaining access to Saunton Sands during construction – no closure of the beach
- Providing safety marshals for the protection of the public
- Apply health and safety requirements proportionately: for example, balance the need for fencing/hoarding/barriers in nearshore/intertidal zone to protect swimmers and surfers from accessing construction and/or maintenance works with the need to maintain access to Saunton Sands.

11.4 Stakeholders

96. Reference should also be made to any reporting requirements in relation to stakeholders set out under the Section 36 Consent and / or Marine Licences.

12. Sub-Contractor Management

97. The PEMP and CEMP will set out how the Principal Contractor manages their sub-Contractors onsite. This may range from the selection and assessment processes through to the assessment of performance on site.

98. For example, expectations of Principal Contractors working on behalf of the Applicant are primarily detailed in this and the following documents:

- Contract Schedules including specific environmental requirements
- Environmental Policy
- Project Environmental Statement.

13. Sustainable Construction

99. During the design phase, sustainable construction should be considered when planning out the construction phase of the Offshore Project.

100. For guidance, "Sustainable Construction", is described by the Institute of Environmental Management and Assessment as:

"*Application of sustainable development to the construction industry, whereby the construction and management of a development is based on principles of resource efficiency and the protection/enhancement of natural and built heritage. Sustainable construction comprises such matters as site planning and design, material selection, resource and energy use, recycling, and waste minimisation*". (Institute of Environmental Management and Assessment, 2008).

14. References

Environment Agency (2014) Pollution Prevention Guidance. Available at: https://www.gov.uk/government/collections/planning-practice-guidance. [Accessed February 2023].

Institute of Environmental Management and Assessment (2008) Environmental Management Plans Practitioner, Volume 12. Available at: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwic37H1xqf9AhVRsKQKHQSWB7sQFnoECBgQAQ&url=https%3A%2F%2Fwww.iema.net%2Fdownload-document%2F7014&usg=AOvVaw37vBz691GKel7dL9wojy1G. [Accessed February 2023]

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White Cross Offshore Windfarm Environmental Statement

Appendix 5.B: Taw Estuary and Braunton Burrows Crossing Method Statement

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Approved by Client :	OG	*Electronic Signature*

Version Number	Reason for Issue / Major Changes	Date of Change
00	For issue	15/08/2023

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Glossary of Acronyms

Acronym	Definition
AOD	Above Ordnance Datum
BGL	Below Ground Level
BGS	British Geological Survey
CEFAS	Centre for Environment, Fisheries and Aquaculture Science
CEMP	Construction Environmental Management Plans
COSHH	Control of Substances Hazardous to Health
CTMP	Construction Traffic Management Plan
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
ES	Environmental Statement
FEED	Front-End Engineering Design
HDD	Horizontal Directional Drilling
HDPE	High Density Polyethylene
IAQM	Institute of Air Quality Management
IDB	Internal Drainage Board
kV	Kilovolt
km	Kilometre
MCAA	Maritime and Coastguard Agency Act
MHWS	Mean High Water Springs
MLWS	Mean Low Water Springs
mm	Millimetre
MW	Megawatt
NE	Natural England
NGC	National Grid
OFTO	Offshore Transmission Owner
OSP	Offshore Substation Platform
OWL	Offshore Wind Ltd
PLONAR	Pose Little or No Risk to the Environment
SAC	Special Area of Conservation
SHW	Specification For Highway Works
SSSI	Site of Special Scientific Interest
SUDS	Sustainable Urban Drainage Schemes
TBM	Tunnel Boring Machine
TCPA	Town and Country Planning Act
TJB	Transition Joint Bay
TMCo	Traffic Management Coordinator
UXO	Unexploded Ordnance

Acronym	Definition
WSI	Written Scheme of Investigation
WTG	Wind Turbine Generators

Glossary of Terminology

Defined Term	Description
Applicant	Offshore Wind Limited
Environmental Impact Assessment (EIA)	Assessment of the potential impact of the proposed Project on the physical, biological and human environment during construction, operation and decommissioning.
Generation Assets	The infrastructure of the Project related to the generation of electricity within the windfarm site, including wind turbine generators, substructures, mooring lines, seabed anchors and inter-array cables
Mitigation	Mitigation measures have been proposed where the assessment identifies that an aspect of the development is likely to give rise to significant environmental effects, and discussed with the relevant authorities and stakeholders in order to avoid, prevent or reduce impacts to acceptable levels. For the purposes of the EIA, two types of mitigation are defined: • Embedded mitigation: consisting of mitigation measures that are identified and adopted as part of the evolution of the project design, and form part of the project design that is assessed in the EIA • Additional mitigation: consisting of mitigation measures that are identified during the EIA process specifically to reduce or eliminate any predicted significant effects. Additional mitigation is therefore subsequently adopted by OWL as the EIA process progresses.
Offshore Wind Limited	Offshore Wind Ltd (OWL) is a joint venture between Cobra Instalaciones Servicios, S.A., and Flotation Energy Ltd
the Project	the Project is a proposed floating offshore windfarm called White Cross located in the Celtic Sea with a capacity of up to 100MW. It encompasses the project as a whole i.e. all onshore and offshore infrastructure and activities associated with the Project
White Cross Offshore Windfarm	Up to 100MW capacity offshore windfarm including associated onshore and offshore infrastructure
Wind Turbine Generators (WTG)	The wind turbine generators convert wind energy into electrical power. Key components include the rotor blades, nacelle (housing for electrical generator and other electrical and control equipment) and tower. The final selection of project wind turbine model will be made post-consent application
Windfarm Site	The area within which the wind turbines, Offshore Substation Platform and inter-array cables will be present

Appendix 5.B: Taw Estuary and Braunton Burrows Crossing Method Statement

1. Introduction

1.1 Overview

1. White Cross Offshore Windfarm is a proposed floating offshore windfarm located in the Celtic Sea with a capacity of up to 100MW (hereafter referred to as 'the Project'. The Project is split into 'the Offshore Project' and 'the Onshore Project'.

2. The Offshore Project requires Section 36 consent and Marine Licences for all components seaward of Mean High Water Springs (MHWS). This includes the infrastructure within the Windfarm Site (e.g., wind turbine generators, substructures, mooring lines, seabed anchors, inter-array cables and Offshore Substation Platform (as applicable)) and all infrastructure associated with the offshore export cable, Landfall (up to MHWS) and the crossing underneath the Taw Estuary (between MHWS on the northern edge to MHWS on the southern edge).

3. The Onshore Project is a separate Town and Country Planning Act 1990 (TCPA) application to the Offshore Project components. The Onshore Project includes the infrastructure associated with the Landfall at Saunton Sands (to MLWS) where the onshore components connect to the Offshore Project infrastructure, Onshore Export Cable (including joint bays and link boxes), Taw Estuary Crossing, a new White Cross Onshore Substation, and an Interconnecting Cable to the Grid Connection Point at the existing East Yelland Substation.

4. An overview of the Project infrastructure is illustrated in **Plate 1.1**. A full project description of the Offshore Project can be found in **Chapter 5: Project Description** of the Offshore Environmental Statement (ES), and a full project description of the Onshore Project can be found in **Chapter 5: Project Description** of the Onshore ES.

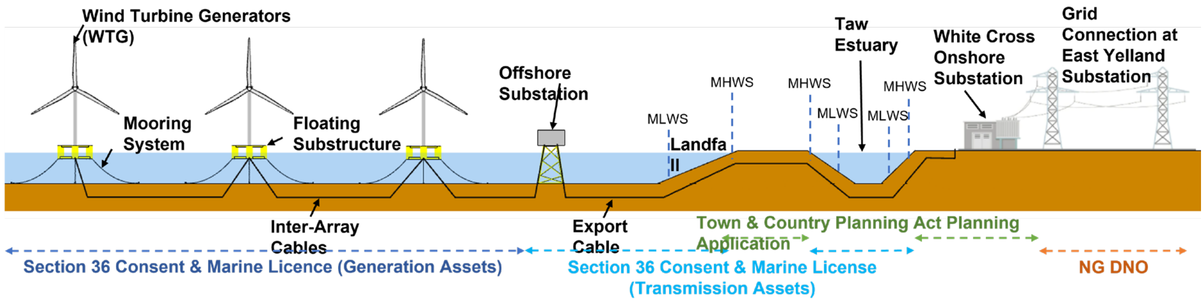


Plate 1.1 The Project Infrastructure

5. The set of consents/permission required in order for the Project as a whole to proceed are outlined below:

- Consent under the Section 36 of the Electricity Act 1989 and a Marine Licence under the Marine and Coastal Access Act 2009 (MCAA 2009) are required for the following generation assets (within the Windfarm Site):
    - Wind Turbine Generators
    - Semi-submersible floating platforms
    - Subsea catenary mooring lines
    - Anchoring solutions (drag embedment anchors, suction anchor or pin piles)
    - Inter-array cables and associated protection
    - Other associated offshore infrastructure, such as navigational markers.

- A second Marine Licence is required to enable the option for an Offshore Transmission Owner (OFTO) to be appointed under The Electricity (Competitive Tenders for Offshore Transmission Licences) Regulations 2015 for the following transmission assets:
    - OSP Platform (OSP)
    - Offshore export cable (to Mean High Water Springs (MHWS) at Landfall)
    - Other associated offshore infrastructure, such as navigational markers
    - Taw Estuary Crossing (between MHWS on the northern edge to MHWS on the southern edge).

- A separate planning permission under the Town and Country Planning Act 1990 (TCPA 1990) is required for the Onshore (landward of Mean Low Water Springs (MLWS)) transmission assets:
    - Onshore export cables
    - White Cross Onshore Substation
    - Onshore export cables (66kV from Landfall to onshore substation and 132kV from the White Cross Onshore Substation to NGC Grid Connection Point)
    - Temporary main construction compound and temporary construction compounds

- Transition Joint Bay (TJB), jointing bays, link boxes, access roads and haul roads.

6. Further detail on the consenting regime and relevant legislation is presented in **Chapter 3: Policy and Legislative Context** of the Offshore ES for the Offshore Project and in **Chapter 3: Policy and Legislative Context** of the Onshore ES for the Onshore Project.

7. This Braunton Burrow and Taw Estuary Crossing Method Statement (hereafter referred to as 'the Method Statement') presents information related to the two crossings (Landfall and Saunton Golf Course) crossings at Braunton Burrows (hereafter referred to as 'the Braunton Burrows Crossings') and Taw Estuary (MHWS north of the estuary to MHWS south of the estuary) (hereafter referred to as 'the Taw Estuary Crossing') by the onshore export cables and its associated construction activities and requirements.

1.2 Site Description

1.2.1 Braunton Burrows Crossing

8. The Braunton Burrows Crossing is proposed within two different sections, one is intertidal at landfall (to MLWS) and the other crossing the Saunton Golf Club. The Braunton Burrows Crossing at landfall (to MLWS), is from the Transition Joint Bay (TJB) at Saunton Sands car park out to offshore. The Braunton Burrows Crossing at Saunton Golf Club is from Saunton Sands car park to the east side of Saunton Golf Club. The location of the Braunton Burrow Crossings is shown in **Figure 1.1**.

9. This site was determined based on an appraisal of constraints and engineering feasibility from both offshore and onshore perspectives. A full discussion of the process undertaken to identify the Offshore and Onshore Export Cable Corridors for the Offshore Project is laid out in **Chapter 4: Site Selection and Assessment of Alternatives** of the ES.

10. The techniques that have been proposed for the Braunton Burrows Crossing at landfall (to MLWS) are either open-trenching or a trenchless technique. Or a combination of the two. Following consultation, Natural England (NE) recognise that trenchless techniques are generally a 'preferred method' as it is considered the impact to the intertidal is significantly reduced if trenching is not required (i.e. trenchless technique is used). The potential options include:

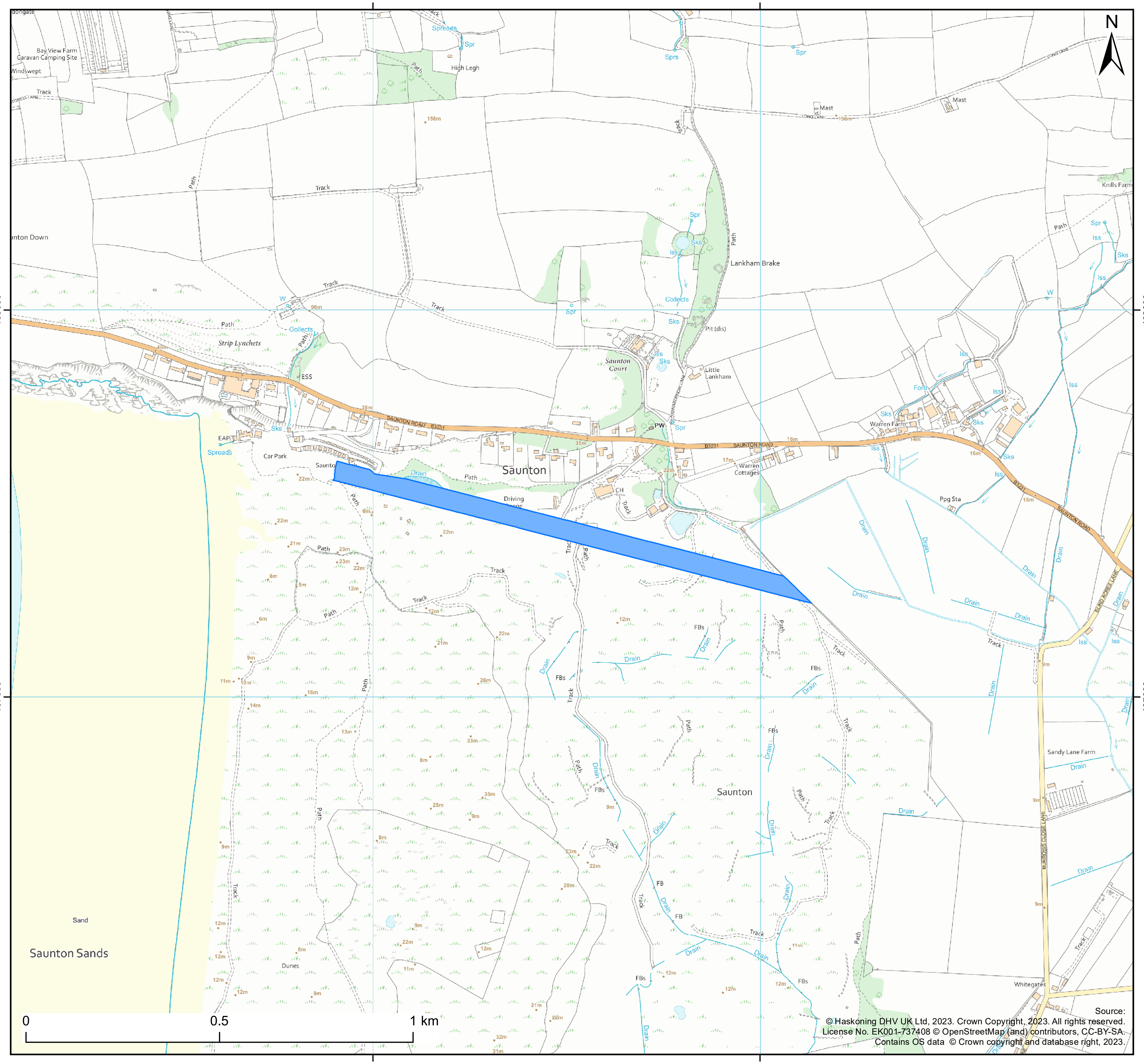
- Option 1 – Piperam duct (trenchless) and open cut in intertidal zone. This option consists of a combination of a trenchless technique to cross the dunes at the edge of the Saunton Sands carpark, with open cut used across the beach and into the intertidal zone

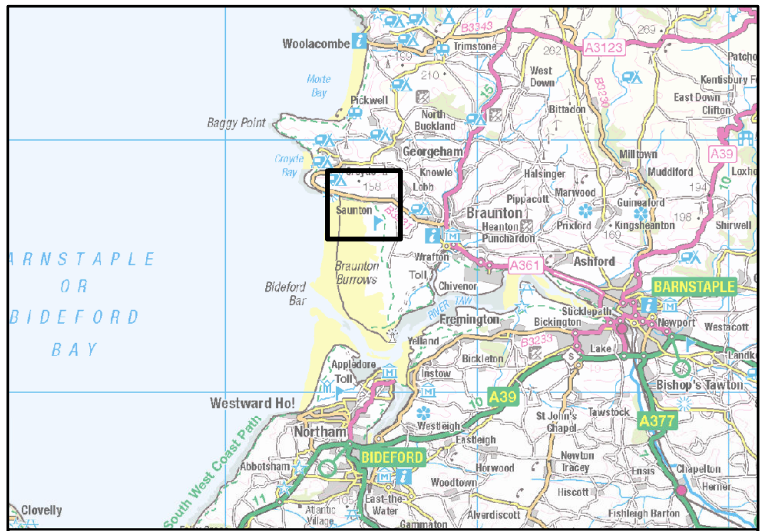
- Option 2 – HDD duct with intertidal exit. This option will utilise Horizontal Directional Drilling (HDD) to install a maximum of two ducts from the carpark to the intertidal zone at a depth of 0m Above Ordnance Datum (A.O.D)
- Option 3 – HDD duct with offshore exit. This option will utilise Horizontal Directional Drilling (HDD) to install a maximum of two ducts from the carpark to exit offshore at a depth of -5m A.O.D.

11. Whichever option is selected for the landfall (to MLWS) a section of open cut trench will be required to connect the TJB to the exit point for the trenchless crossing of the Saunton Golf Club. This will be located entirely within the carpark and will have a maximum length of 200m.

12. The technique proposed for the cable installation for the Braunton Burrows Crossing at Saunton Golf Club is a trenchless technique, either Horizontal Directional Drilling (HDD) or Direct Pipe. Both options will utilise the same location for the entry and exit points and involve a drill length of approximately 1.3km.

13. The crossing site runs through the Braunton Burrows SSSI and Special Area of Conservation (SAC), however both launch pits and the reception pit for the golf course crossing are located outside of the SSSI and SAC boundary. Braunton Burrows is characterised by an extensive system of coastal sand dunes and variably flooded slacks, grassland and scrub. The estuary is also designated as a shellfish water protected area under the Water Environment (Water Framework Directive) (England and Wales) Regulations 2017 (as amended) and a coastal sensitive area (eutrophic).





Legend:

Braunton Burrows Crossing

Client: Offshore Wind Ltd.

Project: White Cross Offshore Windfarm

Title: Braunton Burrows Crossing Location

Figure: 1.1

Drawing No: PC2978-RHD-ZZ-XX-DR-Z-0724

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
P01	11/08/2023	AB	TM	A3	1:10,000

Co-ordinate system: British National Grid

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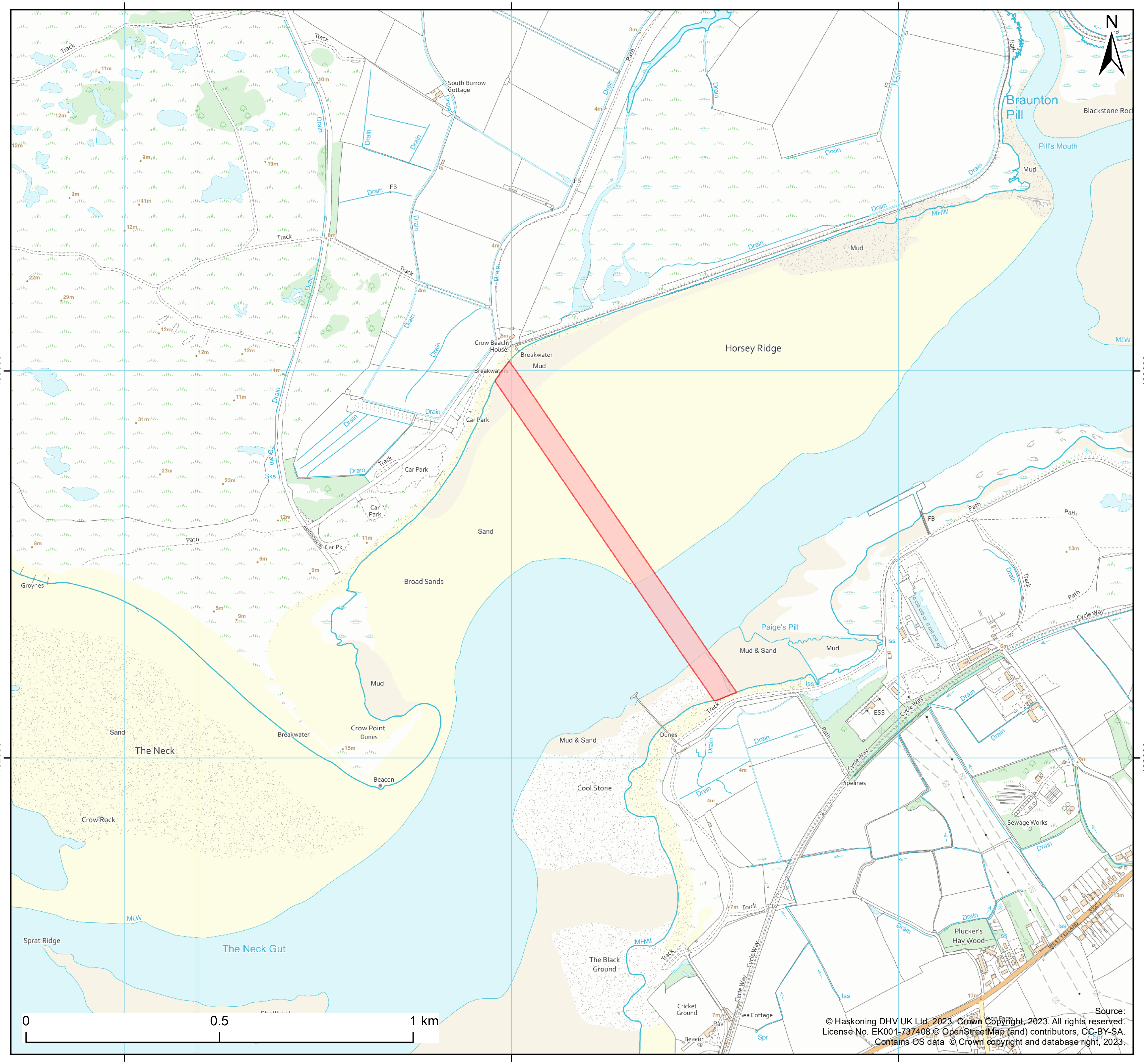
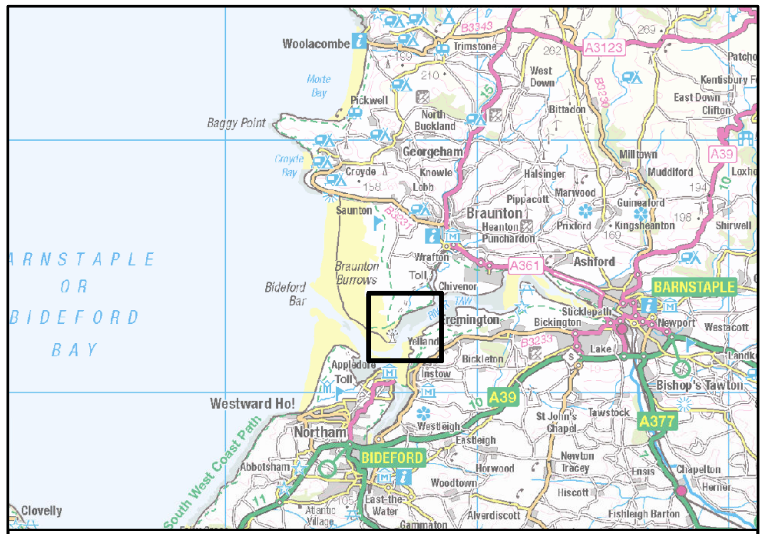
1.2.2 Taw Estuary Crossing

14. The Taw Estuary Crossing is proposed between an entry point on the south bank and an exit point on the north bank of the River Taw. The entry and exit compounds and pit locations will be set a minimum of 16m from the River Taw. The crossing site is located at a natural narrowing of the River Taw.

15. This site was determined based on an appraisal of constraints and engineering feasibility from both offshore and onshore perspectives. The location of the Taw Estuary Crossing is shown in **Figure 1.2**. A full discussion of the process undertaken to identify the Offshore Export Cable Corridor for the Offshore Project is laid out in **Chapter 4: Site Selection and Assessment of Alternatives** of the Offshore ES. A full discussion of the process undertaken to identify the Onshore Export Cable Corridor for the Onshore Project is laid out in **Chapter 4: Site Selection and Assessment of Alternatives** of the Onshore ES.





Legend:

Taw Estuary Crossing

Client: Offshore Wind Ltd.	Project: White Cross Offshore Windfarm

Title: Taw Estuary Crossing Location

Figure: 1.2	Drawing No: PC2978-RHD-ZZ-XX-DR-Z-0624

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
P01	23/06/2023	AB	TM	A3	1:10,000

Co-ordinate system: British National Grid

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16. Trenchless crossing techniques have been proposed for the Taw Estuary Crossing, with two options being considered, namely Horizontal Directional Drilling (HDD) and Direct Pipe. Both options will utilise the same location for the entry and exit points and involve a drill length of approximately 1.3km below the River Taw. Cable installation works will be undertaken from south to north, with temporary compound area and access requirements for the entry and exit points.

17. The area surrounding the crossing site and the River Taw form part of the Taw-Torridge Estuary Site of Special Scientific Interest (SSSI), which is of major importance for its overwintering and migratory populations of wading birds and rare plants that grow along the shores of the river.

18. In addition, the crossing site is also located in the vicinity of Braunton Burrows SSSI and Special Area of Conservation (SAC). Braunton Burrows is characterised by an extensive system of coastal sand dunes and variably flooded slacks, grassland and scrub. The estuary is also designated as a shellfish water protected area under the Water Environment (Water Framework Directive) (England and Wales) Regulations 2017 (as amended) and a coastal sensitive area (eutrophic).

19. The Taw Estuary Crossing lies within the Taw/Torridge operational catchment. At this location, the estuary channel has an asymmetrical cross-section at low tide. A geomorphology baseline survey (**Appendix 14.A: Geomorphology Baseline Survey)** was undertaken on 29th April 2022 and 17th August 2022 for the Onshore Project. The recorded channel width was around 1,000m, a wetted channel width at low water at around 250m and tidal range between 4m immediately downstream of Barnstaple and 8m at the estuary mouth. The channel bed substrates were characterised as sandy in the main channel and as finer silts in lower energy areas. The entry and exit points will be located on the adjacent floodplains of the Taw Estuary (Sir Arthur's Pill catchment) and coastal catchment (Braunton Burrows).

1.3 Rationale

1.3.1 Rationale for the Use of Trenchless Crossing underneath the Taw Estuary

20. OWL's commitment to the use of trenchless crossing techniques at the Taw Estuary Crossing ensures that potential impacts on designated sites and the wider estuarine and riverine environment are avoided as part of the Offshore and Onshore Project's embedded mitigation. All commitments laid out within the Onshore and Offshore ESs are set out in **Appendix 6.B: Mitigation Register** of the Onshore ES. This commitment is anticipated to:

- Avoid direct physical disturbance to the natural environment and non-statutory and statutory designated sites of ecological importance, including the Taw-Torridge Estuary SSSI and Braunton Burrows SSSI and SAC (which are considered further in **Chapter 16: Onshore Ecology and Ornithology** of the ES for the Onshore Project)
- Mitigate disturbance or harm to species such as waterfowl and migratory salmon and potential destruction, damage or disturbance to priority habitats such as coastal grazing marsh and mudflats
- Avoid direct disturbance to the River Taw's sediment transport pathways
- Avoid direct disturbance of the Taw/Torridge surface water catchment and the potential to alter the geomorphology and hydrology of the watercourse
- Mitigate increased sediment supply to the Taw/Torridge surface water catchment
- Mitigate the risk of contaminants supply to the Taw/Torridge surface water catchment and the River Taw and North Devon Streams groundwater catchment
- Avoid direct disturbance to surface drainage patterns and surface flows of the Taw/Torridge surface water catchment and therefore its associated flood risk
- Avoid the need for cable protection measures across the river bed.

1.3.2 Rationale for the Use of Trenchless Crossing underneath the Braunton Burrows

21. OWL's commitment to the use of trenchless crossing techniques at the Braunton Burrows Crossing ensures that potential impacts on designated sites and the wider environment are avoided as part of the Onshore and Offshore Project's embedded mitigation. All commitments laid out within the Onshore and Offshore ESs are set out in **Appendix 6.B: Mitigation Register** of the Onshore ES. This commitment is anticipated to:

- Avoid direct physical disturbance to the natural environment and non-statutory and statutory designated sites of ecological importance, including the Braunton Burrows SSSI and SAC (which are considered further in **Chapter 16: Onshore Ecology and Ornithology** of the ES for the Onshore Project)
- Mitigate disturbance or harm to species such as whitethroat and skylark and potential destruction, damage or disturbance to priority habitats such as shifting and fixed coastal dunes
- Avoid direct physical disturbance of Saunton Golf Club
- Avoid direct disturbance to surface drainage patterns and surface flows of the surface water catchment and therefore its associated flood risk
- Avoid the need for cable protection measures across the Braunton Burrows.

1.4 Consultation

22. OWL notes the interests of Natural England (NE) and other stakeholders regarding the Taw Estuary Crossing and Braunton Burrows Crossing and its associated construction activities. This Method Statement has been prepared to demonstrate how the Offshore and aspects of the Onshore Project will avoid, minimise or mitigate environmental effects associated with the export cables crossing the Braunton Burrows and between the north and south bank of the River Taw.

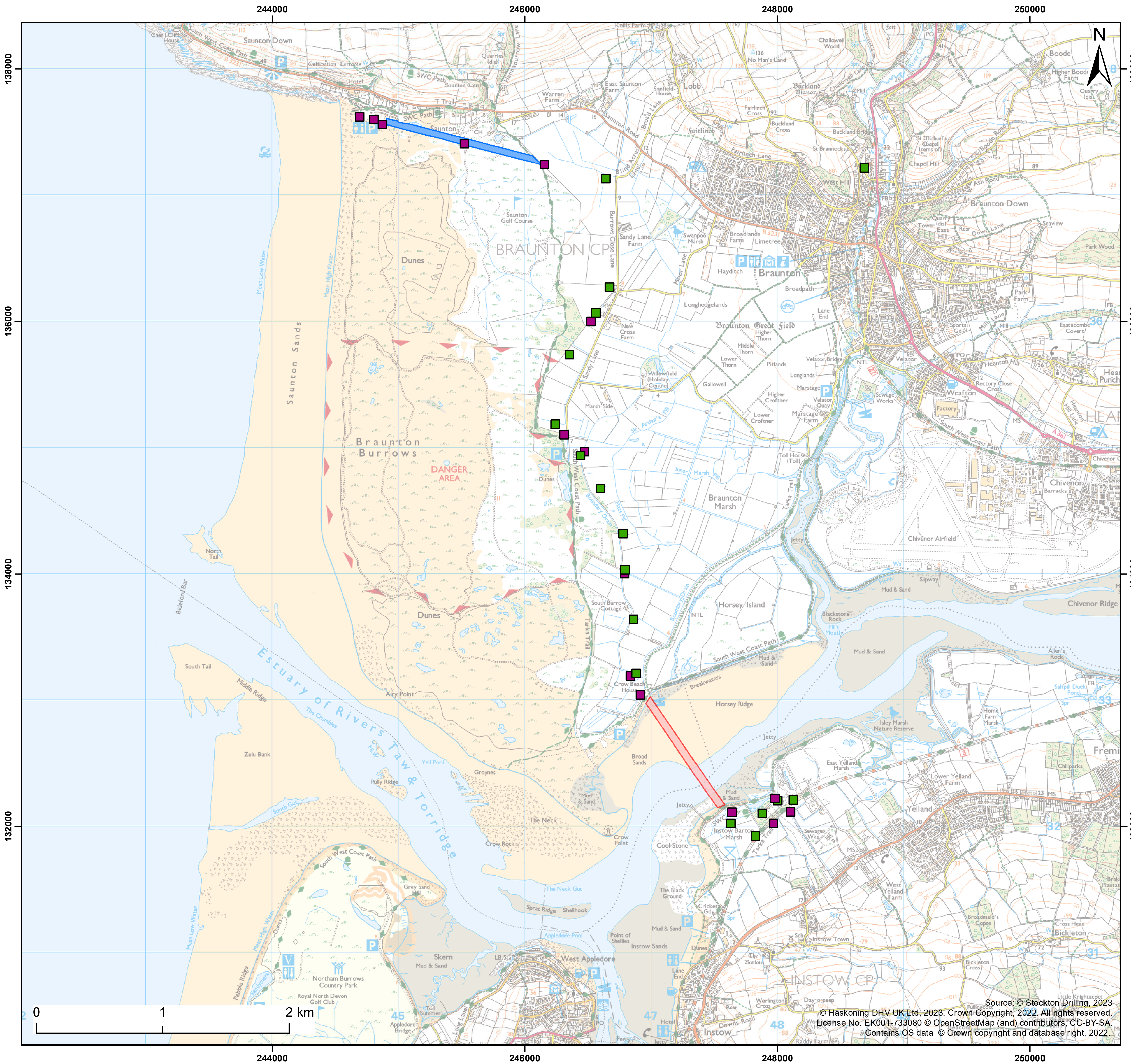
23. OWL will consult these stakeholders and seek agreement on the design and methodology set out in this document prior to the commencement of construction works at the Taw Estuary and Braunton Burrows Crossing. Where conflict arises between environmental constraints or obligations, OWL will liaise with the relevant stakeholders to determine the optimal, acceptable solution for the crossing and would not proceed where reasonable concern from stakeholders was not being addressed.

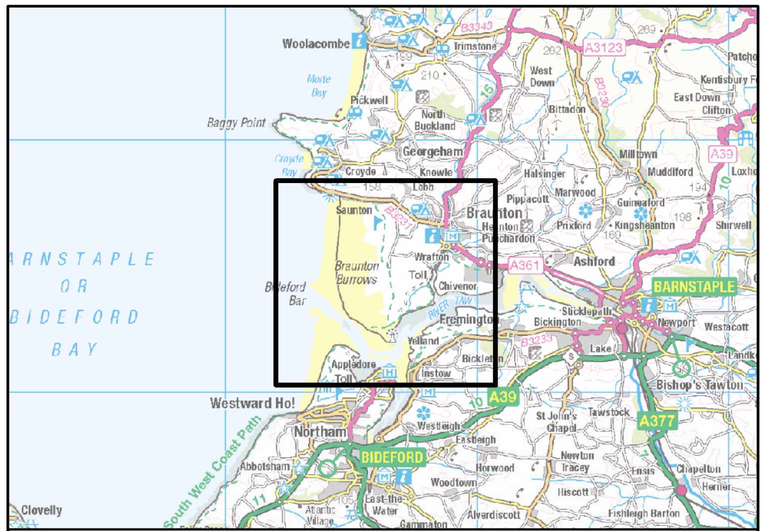
2. Geotechnical Investigation

24. Key to ensuring that the design is appropriate for the location and that it can be constructed safely is understanding the ground and river conditions on-site. Detailed geotechnical investigations will be conducted to characterise ground conditions, establish the chemical and mechanical properties of the ground, map water depths and topography of the river bed and identify the hydrology and hydrogeology of the Taw Estuary Crossing and Braunton Burrows Crossing site. It is proposed that full geotechnical investigations and production of a subsequent report should be a post-consent planning condition that must be adhered to prior to any trenchless crossing works commencing.

25. Geotechnical investigations will be undertaken for the Taw Estuary and Braunton Burrows Crossing, this will include boreholes as a minimum and other surveys where deemed necessary.

26. Geological desk-based studies have been undertaken as part of an Onshore Export Cable Corridor feasibility assessment. Analysis of a total of 11 historic boreholes identified within the vicinity of Onshore Export Cable Corridor were identified and are shown in **Figure 2.1**.





Legend:

- Taw Estuary Crossing
- Braunton Burrows Crossing
- Boreholes
- Trial holes

Client:	Project:
Offshore Wind Ltd.	White Cross Offshore Windfarm

Title:

BGS Historic Ground Investigation Locations

Figure:	2.1	Drawing No:	PC2978-RHD-ZZ-XX-DR-Z-0542

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
P02	23/06/2023	AB	TM	A3	1:30,000
P01	22/02/2023	AB	CB	A3	1:30,000

Co-ordinate system: British National Grid

WHITE CROSS

Royal HaskoningDHV
Enhancing Society Together

2.1 Hydrofracture Assessment

27. The preliminary hydrofracture assessment has been undertaken to determine the risk of drill fluid breakout to the surface at the Taw Estuary and Braunton Burrows trenchless crossings (Waterman Infrastructure & Environment Ltd, 2023). Hydrofracture occurs if during the drilling process the drilling fluid pressure in the borehole exceeds the resistance of the overburden soils resulting in a breakout at the surface.

28. Hydrofracture was one of Natural England's (NE) specific concerns raised about the project having dealt with similar projects where HDD in fluvial systems where silty sediments and air pockets exist has failed, including hydrofracture.

29. NE highlighted that the Taw Estuary trenchless crossing goes beneath the Taw-Torridge Estuary SSSI which is designated due to its overwintering and migratory populations of wading bords and in addition rare plants grow along the shores within wide areas of saltmarsh, mudflats and sandbanks. The Estuary also supports typical estuarine species such as mullet, flat fish, bass, pollack, migratory salmon, sea trout and eels along with many invertebrates.

30. Therefore, a hydrofracture assessment has been undertaken to determine the risk of drill fluid breakout to the surface at the Taw Estuary and Braunton Burrows Crossings.

2.1.1 Analysis Methodology

31. The preliminary hydrofracture assessment has been undertaken prior to the Geotechnical Investigation. Therefore, the assessment relies on a conservative assumption that the ground conditions are made up of granular materials (rather than firm to stiff clays or competent rock). The geotechnical analysis parameters are shown in **Annex 1: Hydrofracture Assessment**.

32. The groundwater level has been conservatively assumed as commensurate with the ground surface throughout the analysis. The groundwater level assumption is likely to be relaxed following the completion of ground investigation with associated groundwater monitoring.

33. The bore diameters are yet to be confirmed. It is anticipated that there will be a TJB between the onshore and offshore cables within Saunton Sands Car Park. The landfall calculations therefore assume an offshore cable specification within the golf course crossing and the Taw Estuary Crossing assumes an onshore cable specification (with a consequent reduction in likely cable and duct diameter).

2.1.2 Assessment Results

34. At each of the assessed trenchless crossings (Taw Estuary, Golf Course and Landfall), the assessment demonstrates that there is no significant risk of hydrofracture along the bore profiles with the exception of the final stages of the bore where the profiles begin to rise resulting in loss of cover. This is unavoidable but can easily be controlled by site measures such as sandbagging and casing in line with general working methodologies. Hydrofracture calculations and further information is set out within **Annex 1: Hydrofracture Assessment**.

35. The design will incorporate measures to address hydrofracture, ensuring sufficient depth of cover for the bore path. This approach minimises the hydrofracture risk through increased overburden pressure.

36. The risk of drilling fluid breakout is considered to be very low based on analysis of historical borehole and desk-based assessment of the geology present in the area. However, this cannot be fully assessed beforehand. Substantial decreases in the volume of returning drilling fluid to the entry pit will trigger the need for site personnel to assess the situation and respond accordingly. Therefore, a close watching brief during drilling activities and a detailed contingency plan are essential to ensure that any drilling fluid breakout is contained, bunded and pumped back to the entry pit with minimum disturbance to the surrounding environment.

2.2 Braunton Burrows Historical Borehole Analysis

37. A programme of geotechnical works are being undertaken for the offshore components of the Project, and this includes a Phase 2: Reconnaissance Geotechnical Investigation. The desk-based analysis undertaken as part of these works were reviewed to inform the preliminary design for the Landfall Crossing.

38. This indicated that within the nearshore area of the offshore export cable route (i.e. at landfall), the top of the Pilton Shales Formation, consists of Devonian and Carboniferous rocks of mudstone, sandstone, and limestone nature. The only layer observed below this unit was bedrock. Overlying this horizon, a continuous layer of sediments (Unit E) mainly composed of fine sand, is prominent.

39. Unit E has a thickness of around 7m at the landfall approach. Then, approximately 1 km away from the shoreline, the Unit thickness decreases rapidly to 2-3 m. From there, an unconformity within the seabed and underlying R1 is recognizable. During the following four kilometres, the thickness ranges from 2 to 5 m on the average.

40. It is recommended that further site investigation is undertaken to determine the Marine sediments present at the HDD Exit points, and that a Seismic/Mag survey

should be undertaken to provide sediment depth/depth to rockhead data across the intertidal area. But from this analysis **Table 2.1** suggests that a trenchless crossing is not precluded by the geology present, the cables can be installed, and the chosen methodology is relatively low risk.

Table 2.1 Braunton Burrows Landfall Crossing Conceptual Ground Model Stratum Depths

Location	Stratum	Depth (m bgl)	Thickness (m)
Entry Point	Blown Sand	0.00	0.00 to 10
	Marine Beach Deposits (Unit E)	10.00	7.00
	Rock (Pilton Shales Formation)	17	-
Exit Point (Option 2 1850m)	Blown Sand	-	-
	Marine Beach Deposits (Unit E)	0.00	2.00
	Rock (Pilton Shales Formation)	2.00	-

41. The analysis of historical borehole located onshore indicates within Braunton Burrows Blown Sands are likely to be present, overlying Holocene Estuarine Alluvium and Marine Beach Deposits and or Pleistocene/Fluvial Sands and Gravels. Superficial deposits and bedrock beneath the Saunton Golf Club Crossing are expected to be encountered up to 15m bgl at the eastern side of the golf course and 5m bgl at Saunton Sands carpark.

42. A conceptual ground model was developed as part of the feasibility assessment to provide information on the composition and depths likely to be encountered at the crossings of the Braunton Burrow. It is assumed that the entry point is underlain by a layer of Blown Sand and Marine Beach Deposits, overlaying rock. This strata composition continues to the exit point. It is noted that at this location, the Blown Sands are vegetated suggesting a more mature state and likely of increased density/cohesion, however, this would require confirmation via ground investigation. **Table 2.2** suggests that a trenchless crossing is not precluded by the geology present, the cables can be installed, and the chosen methodology is relatively low risk. Similarly, to in **Section 2.3,** this will be confirmed prior to commencement of drilling activity via appropriate and agreed geotechnical investigations.

Table 2.2 Braunton Burrows Golf Course Crossing Conceptual Ground Model Stratum Depths

Location	Stratum	Depth (m bgl)	Thickness (m)
Entry Point	Blown Sand	0.00	0.00 to 10
	Marine Beach Deposits	10.00	5.00
	Rock	15	-
Exit Point	Blown Sand	-	-

Location	Stratum	Depth (m bgl)	Thickness (m)
	Marine Beach Deposits	0.00	5.00
	Rock	5.00	-

2.3 Taw Estuary Crossing Historical Borehole Analysis

43. The historical borehole analysis indicates that the drift geology of the site is predominantly underlain by Marine or Estuarine Alluvium, Blown Sand and Tidal Flat Deposits, while its solid geology is predominantly underlain by Ashton Mudstone Member and Crackington Formation (Undifferentiated) and is typically presented as Mudstone and Siltstone.

44. It was noted that bedrock may be visible at the surface on the south bank of the River Taw but is expected to deepen substantially within the area to the north. However, ground investigation is required to confirm this observation. A borehole (SS43SE/25) drilled in 1963 was also noted east of the proposed entry point, where groundwater was encountered at a depth of 8.53m below ground level (bgl).

45. In addition, a conceptual ground model was developed as part of the feasibility assessment to provide information on the composition and depths likely to be encountered at the crossing site. This was informed by the geological desk-based studies and aerial images and topographic/bathymetric data (**Appendix 8.B: Geophysical Survey Results** of the Offshore ES) collected for the Offshore Project. The model shown in **Table 2.3** suggests that a trenchless crossing is not precluded by the geology present, the cables can be installed, and the chosen methodology is relatively low risk. This will be confirmed prior to commencement of drilling activity via appropriate and agreed geotechnical investigations.

Table 2.3 Taw Estuary Crossing Conceptual Ground Model

Location	Stratum	Depth (m bgl)	Thickness (m)
Entry Point	Drift (Tidal Flats Deposit)	0.00	0.00 to 6.40
	Rock	6.40	-
River Crossing	Drift (Tidal Flats Deposit)	0.00	3.50
	Marine or Estuarine Alluvial Deposits	3.50	-
Exit Point	Drift (Tidal Flats Deposit)	0.00	3.30
	Marine or Estuarine Alluvial Deposits	3.30	13.00
	Rock	16.30	-

3. Design

46. The crossing design will be refined and finalised post-consent and will rely on inputs from onshore and offshore pre-construction site investigations, as well as

information from the detailed cable system design. Awaiting these pre-construction site investigations will ensure that the most appropriate design is selected in order to minimise impact to the surrounding environment. Site characterisation data of the entry and exit points and potential drill paths will inform the detailed design of the selected crossing technique.

47. Sufficient flexibility exists in the capabilities of modern trenchless technologies such as the capacity of drill rigs and range of drill heads available, to ensure a suitable solution can be delivered at the site within the parameters assessed within the ES.

48. The two trenchless crossing techniques being investigated for the Braunton Burrows: Saunton Golf Course Crossing (if a trenchless technique is applicable) and Taw Estuary Crossing to minimise disturbances to the physical and natural environment are:

- Option 1 - HDD: a construction technique whereby a tunnel is drilled below ground to avoid obstacles such as waterways and designated sites, and a pipeline, cable or other conduit is pulled through the drilled tunnel
- Option 2 - Direct Pipe: a construction technique that combines HDD and micro-tunnelling whereby the drilling of the underground tunnel and the installation of the pipeline, cable or other conduit occurs simultaneously in a one-pass operation.

49. Indicative drawings of the two options are shown in **Figure 3.1** and **Figure 3.2**. respectively. Key advantages and disadvantages associated with HDD and Direct Pipe are compared in **Table 3.1**.

Table 3.1 Trenchless Crossing Technique Comparisons

Trenchless Crossing Technique Option	Advantages	Disadvantages
HDD	• Relatively economical trenchless option • Fast mobilisation and site setup • No requirement for large entry or exit pits.	• Borehole only supported by bentonite, potential for collapse • Not suitable for non-supporting ground due to a high risk of tool snapping or loss of control during push reaming • Potential to lose tools downhole.

Trenchless Crossing Technique Option	Advantages	Disadvantages
Direct Pipe	• Able to retract the assembly to the entry pit and change cutting tools if required • Relatively low pressure used at the cutting face, enabling shallower drill depths • Suitable for superficial geology such as fluvial and alluvial • Borehole permanently supported, very low risk of collapse.	• Longer mobilisation and site setup time than HDD • More expensive than HDD.

50. Three techniques being investigated for the Braunton Burrows: Landfall Crossing:

- Option 1 – Piperam duct (trenchless) and open cut in intertidal zone: combination of a trenchless technique to cross the dunes at the edge of the Saunton Sands carpark (approx. 60m), with open cut used across the beach and into the intertidal zone using a cable plough (approx. 700m)
- Option 2 – HDD duct with intertidal exit: HDD will be used to install ducts from the carpark to the intertidal zone at a depth of 0m A.O.D., with a length for the drill of approximately 650m to MLWS
- Option 3 – HDD duct with offshore exit: HDD will be used to install ducts from the carpark to exit offshore at a depth of -5m A.O.D., with a length for the drill of approximately 1850m.

51. Only Options 2 and 3 for Landfall Crossing are discussed further in this document as they are the major trenchless techniques similar in design and methodology to the HDD option being considered for the crossings of the Golf Course and Taw Estuary.

52. A full description of Option 1 is provided in **Chapter 5: Project Description**.

This drawing should not be scaled. Dimensions to be verified on site.
Any discrepancies should be referred to the Engineer prior to work being put in hand.

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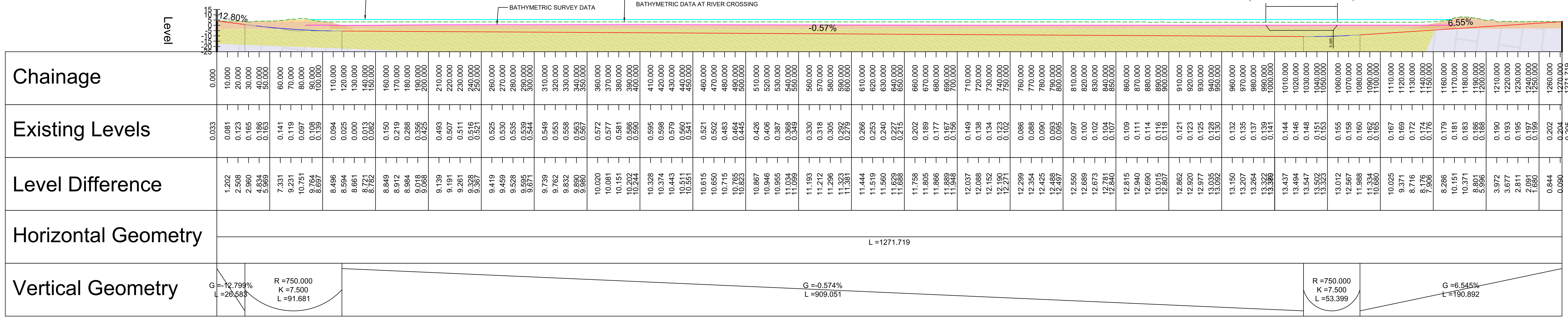
GENERAL NOTES

1. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ALL ENGINEER'S, ARCHITECT'S OR OTHER RELEVANT DRAWINGS AND SPECIFICATIONS.
2. ALL DIMENSIONS AND LEVELS ARE TO BE CHECKED ON SITE BY THE CONTRACTOR PRIOR TO PREPARING ANY WORKING DRAWINGS OR COMMENCING ON SITE.
3. THE CONTRACTOR MUST ENSURE AND WILL BE HELD RESPONSIBLE FOR THE OVERALL STABILITY OF THE BUILDING/STRUCTURE/EXCAVATION AT ALL STAGES OF THE WORK.
4. ALL WORK BY THE CONTRACTOR MUST BE CARRIED OUT IN SUCH A WAY THAT ALL REQUIREMENTS UNDER THE HEALTH AND SAFETY AT WORK ACT ARE SATISFIED.
5. ALL WORK IS TO BE CARRIED OUT IN COMPLIANCE WITH THE REQUIREMENTS OF THE RELEVANT STATUTORY AUTHORITIES AND REGULATIONS.

SITE COMPOUND LAYOUT KEY:
1. 50 KVA GENERATOR 2M X 2M
2. TOILET BLOCK 6M X 2M
3. DRY/CHANGE ROOM 6M X 2M
4. CANTEEN 6M X 2M
5. OFFICE 6M X 2M
6. OFFICE 6M X 2M
7. 21 TON TRACKED 360 EXCAVATOR
8. DRILL PIPE STORAGE 10M X 2M
9. HDD DRILL RIG 16M X 2M
10. POWER PACK 6M X 2M
11. CONTROL CABIN 6M X 2M
12. MUD LAB 3M X 2M
13. MUD ENTRY PIT 3M X 4M
14. HIGH PRESSURE MUD PUMP 6M X 2M
15. MUD MIXING TANK 7M X 2M
16. 350 KVA GENERATOR 5M X 2M
17. RECYCLING UNIT 6M X 2M
18. WATER STORAGE TANK 6M X 2M
19. DRY DRILLING FLUID STORAGE 4M X 10M
20. WORKSHOP 6M X 2M
21. STORES 6M X 2M

ILFRACOMBE TIDE GAUGE SITE	
TIDE LEVELS	ORDNANCE DATUM NEWLYN (mAOD)
HIGHEST ASTRONOMICAL TIDE	5.46
MEAN HIGH WATER SPRINGS	4.47
MEAN HIGH WATER NEAPS	2.19
MEAN LOW WATER NEAPS	-1.69
MEAN LOW WATER SPRINGS	-3.94
LOWEST ASTRONOMICAL TIDE	-4.89

RIVER CROSSING - LONGSECTION
SCALE: H 1:2000,V 1:2000. DATUM: -25.000



GEOLOGY KEY
- BLOWN SANDS (SAND DUNES)
- DRIFT DEPOSITS
- ESTUARINE DEPOSITS
- ROCK

Rev	Date	Description	By	Chk
P03	11.08.23	SITE COMPOUND LAYOUTS REMOVED. RE-ISSUED FOR INFORMATION AS PART OF PLANNING SUBMISSION	LP	CG
P02	10.03.23	TITLE UPDATED & DRAFT BANNER REMOVED	LP	CG
P01	23.05.22	DRAFT ISSUE FOR INFORMATION ONLY	LP	CG

Amendments

Project
WHITE CROSS FLOATING WINDFARM

Title
RIVER TAW OUTLINE HDD PLAN AND PROFILE

Client
FLOTATION ENERGY LTD

Broxden House Broxden Business Park Lamberkine Drive Perth PH1 1RA
t: 01738 449 801
mail@watermangroup.com www.watermangroup.com

Suitability
FOR PLANNING SUBMISSION

Designed By LP	Director CG	Waterman Ref WIE12731-135
Drawn By LP	Date 20.05.22	Scales @ A0 AS NOTED
Stockton Checker	Stockton Approver	Date

Project - Originator - Volume - Level - Type - Role - Number	Revision
12731-135-WIE-ZZ-XX-M3-C-91003	P03
110-099-DRG-022	A01
FLO-WHI-LAY-0019	A1

1:2000 0 20m 40m 60m 80m 100m 120m 140m 160m 180m 200m
1:1 0 10 20 30 40 50 60 70 80 90 100

File Path N:\Projects\WIE12731_Stockton_HDD\135 - White Cross Floating Windfarm\100\6_Design\C3D\ALIGNMENTS & PROFILE\

ONSHORE

OFFSHORE

CHAINAGE (m)	ONSHORE EXISTING LEVELS (m AOD)	OFFSHORE EXISTING LEVELS (m AOD)	BORE PROFILE LEVEL (m AOD) (TOP OF PIPE)
0+000	12.966		12.966
0+010	13.080		11.208
0+020	13.181		9.450
0+030	13.580		7.692
0+040	14.118		5.935
0+050	14.147		4.177
0+060	13.984		2.419
0+070	13.739		0.661
0+080	13.452		-1.061
0+090	13.362		-2.717
0+100	13.277		-4.306
0+110	13.223		-5.829
0+120	13.372		-7.284
0+130	16.245		-8.674
0+140	15.014		-9.996
0+150	12.462		-11.252
0+160	8.021		-12.441
0+170	7.558		-13.563
0+180	5.960		-14.619
0+190	5.286		-15.608
0+200	4.717		-16.531
0+210	4.298		-17.387
0+220	3.972		-18.176
0+230	3.662		-18.898
0+240	3.393		-19.554
0+250	3.174		-20.143
0+260			-20.666
0+270			-21.122
0+280			-21.511
0+290			-21.833
0+300			-22.089
0+310			-22.278
0+320			-22.401
0+330			-22.456
0+340			-22.468
0+350			-22.480
0+360			-22.491
0+370			-22.502
0+380			-22.513
0+390			-22.524
0+400			-22.535
0+410			-22.546
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0+440			-22.579
0+450			-22.590
0+460		-4.792	-22.601
0+470		-4.746	-22.612
0+480		-4.718	-22.624
0+490		-4.739	-22.635
0+500		-4.760	-22.646
0+510		-4.780	-22.657
0+520		-4.800	-22.668
0+530		-4.800	-22.679
0+540		-4.800	-22.690
0+550		-4.800	-22.701
0+560		-4.800	-22.712
0+570		-4.800	-22.723
0+580		-4.800	-22.734
0+590		-4.800	-22.745
0+600		-4.749	-22.756
0+610		-4.681	-22.768
0+620		-4.612	-22.779
0+630		-4.544	-22.790
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0+690		-4.134	-22.856
0+700		-4.065	-22.867
0+710		-4.003	-22.878
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0+730		-3.981	-22.900
0+740		-3.970	-22.912
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0+800		-3.989	-22.978
0+810		-4.011	-22.989
0+820		-4.041	-23.000
0+830		-4.070	-23.011
0+840		-4.100	-23.022
0+850		-4.124	-23.033
0+860		-4.146	-23.044
0+870		-4.167	-23.056
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0+920		-4.503	-23.111
0+930		-4.575	-23.122
0+940		-4.627	-23.133
0+950		-4.707	-23.144
0+960		-4.790	-23.155
0+970		-4.888	-23.166
0+980		-4.989	-23.177
0+990		-5.089	-23.188
1+000		-5.189	-23.200
1+010		-5.290	-23.211
1+020		-5.390	-23.222
1+030		-5.490	-23.233
1+040		-5.591	-23.244
1+050		-5.691	-23.255
1+060		-5.778	-23.266
1+070		-5.851	-23.277
1+080		-5.927	-23.288
1+090		-6.003	-23.299
1+100		-6.079	-23.310
1+110		-6.155	-23.321
1+120		-6.231	-23.332
1+130		-6.303	-23.344
1+140		-6.367	-23.355
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1+160		-6.501	-23.377
1+170		-6.549	-23.388
1+180		-6.598	-23.399
1+190		-6.646	-23.410
1+200		-6.695	-23.421
1+210		-6.743	-23.432
1+220		-6.748	-23.443
1+230		-6.751	-23.454
1+240		-6.770	-23.465
1+250		-6.794	-23.476
1+260		-6.851	-23.488
1+270		-6.922	-23.499
1+280		-6.992	-23.510
1+290		-7.062	-23.521
1+300		-7.132	-23.532
1+310		-7.203	-23.543
1+320		-7.273	-23.554
1+330		-7.340	-23.565
1+340		-7.407	-23.576
1+350		-7.474	-23.587
1+360		-7.539	-23.598
1+370		-7.605	-23.609
1+380		-7.670	-23.620
1+390		-7.736	-23.632
1+400		-7.801	-23.643
1+410		-7.852	-23.654
1+420		-7.903	-23.665
1+430		-7.953	-23.676
1+440		-8.004	-23.687
1+450		-8.055	-23.698
1+460		-8.106	-23.709
1+470		-8.157	-23.720
1+480		-8.208	-23.731
1+490		-8.259	-23.732
1+500		-8.309	-23.712
1+510		-8.360	-23.673
1+520		-8.411	-23.614
1+530		-8.462	-23.534
1+540		-8.513	-23.435
1+550		-8.564	-23.316
1+560		-8.614	-23.176
1+570		-8.665	-23.017
1+580		-8.714	-22.838
1+590		-8.761	-22.638
1+600		-8.802	-22.419
1+610		-8.840	-22.180
1+620		-8.882	-21.920
1+630		-8.923	-21.641
1+640		-8.960	-21.341
1+650		-8.997	-21.022
1+660		-9.034	-20.683
1+670		-9.072	-20.323
1+680		-9.116	-19.944
1+690		-9.160	-19.545
1+700		-9.204	-19.125
1+710		-9.248	-18.686
1+720		-9.292	-18.227
1+730		-9.336	-17.747
1+740		-9.380	-17.248
1+750		-9.424	-16.728
1+760		-9.468	-16.189
1+770		-9.512	-15.630
1+780		-9.556	-15.050
1+790		-9.600	-14.451
1+800		-9.643	-13.832
1+810		-9.687	-13.192
1+820		-9.731	-12.533
1+830		-9.774	-11.854
1+840		-9.816	-11.155
1+850		-9.855	-10.450
1+860		-9.893	
1+870		-9.932	
1+880		-9.971	
1+890		-10.009	
1+900		-10.048	

BORE VERTICAL GEOMETRY

G =-17.577% L =69.709m	R =1500.000m K =15.000 L =262.001m	G =-0.111% L =1148.071m	R =5000.000m K =50.000 L =357.991m	G =7.049% L =20.231m

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Rev	Date	Description	By	Chk
P02	11.08.23	UPDATED WITH CLIENT COMMENTS. RE-ISSUED FOR INFORMATION	LP	CG
P01	28.07.23	ISSUED AS DRAFT FOR INFORMATION	LP	CG

Amendments

Project

WHITE CROSS FLOATING WINDFARM

Title

CABLE LANDFALL OUTLINE HDD PLAN AND PROFILE

Client

FLOTATION ENERGY LTD

waterman STOCKTON

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Suitability: FOR PLANNING SUBMISSION

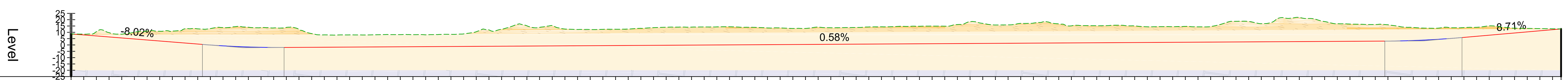
Designed By: LP	Director: CG	Waterman Ref: WIE12731-153
Drawn By: LP	Date: JULY 23	Scales @ A0: 1:1250
Stockton Checker	Stockton Approver	Date

Project - Originator - Volume - Level - Type - Role - Number	Revision
12731-153-WIE-LF-XX-M3-C-91001	P02
110-099-DRG-020	A01
FLO-WHI-LAY-0017	A1

A0-Wat-SDL-S

File Path N:\Projects\WIE12731_Stockton_HDD\153 - White Cross Phase 2\7_CAD\91\

GOLF COURSE CROSSING - LONGSECTION
SCALE: H 1:2000,V 1:2000. DATUM: -25.000

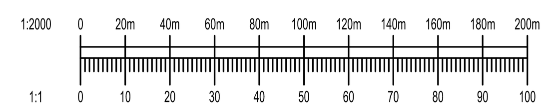


Chainage	Existing Levels	Level Difference
0.000	8.743	-0.014
10.000	8.569	0.614
20.000	10.513	3.360
30.000	9.745	3.394
40.000	8.543	2.994
50.000	10.018	5.271
60.000	11.081	7.136
70.000	10.848	7.706
80.000	10.998	8.657
90.000	12.770	11.233
100.000	12.756	12.020
110.000	12.944	12.984
120.000	13.763	14.455
130.000	14.512	15.723
140.000	14.023	15.619
150.000	13.739	15.587
160.000	13.453	15.421
170.000	13.887	15.842
180.000	12.436	14.333
190.000	8.995	10.835
200.000	7.997	9.779
210.000	7.882	9.606
220.000	7.975	9.641
230.000	7.907	9.516
240.000	8.065	9.616
250.000	8.261	9.755
260.000	8.198	9.633
270.000	8.138	9.516
280.000	8.022	9.343
290.000	8.258	9.520
300.000	8.405	9.610
310.000	8.761	9.909
320.000	10.486	11.576
330.000	11.898	12.931
340.000	12.385	13.359
350.000	15.458	16.375
360.000	15.163	16.022
370.000	13.924	14.725
380.000	15.365	16.108
390.000	12.590	13.276
400.000	12.258	12.886
410.000	12.220	12.790
420.000	12.362	12.875
430.000	12.430	12.886
440.000	12.577	12.975
450.000	13.165	13.505
460.000	13.695	13.977
470.000	14.033	14.258
480.000	14.138	14.305
490.000	14.137	14.246
500.000	14.269	14.320
510.000	14.310	14.304
520.000	14.392	14.329
530.000	13.997	13.876
540.000	13.935	13.756
550.000	13.460	13.223
560.000	13.519	13.225
570.000	13.047	12.695
580.000	13.073	12.663
590.000	14.098	13.631
600.000	13.629	13.104
610.000	13.735	13.152
620.000	13.853	13.212
630.000	14.248	13.550
640.000	14.366	13.610
650.000	14.493	13.680
660.000	14.647	13.776
670.000	14.796	13.867
680.000	14.929	13.943
690.000	14.877	13.833
700.000	16.152	15.050
710.000	18.458	17.299
720.000	17.079	15.862
730.000	15.813	14.538
740.000	15.873	14.540
750.000	17.068	15.678
760.000	17.302	15.854
770.000	18.433	16.928
780.000	16.645	15.082
790.000	15.133	13.512
800.000	15.299	13.621
810.000	15.206	13.469
820.000	15.406	13.612
830.000	15.583	13.731
840.000	15.103	13.194
850.000	14.361	12.394
860.000	14.491	12.467
870.000	14.441	12.359
880.000	14.672	12.532
890.000	14.318	12.121
900.000	14.550	12.295
910.000	16.951	14.638
920.000	18.731	16.361
930.000	18.609	16.181
940.000	16.851	14.365
950.000	18.812	16.269
960.000	21.090	18.489
970.000	21.760	19.101
980.000	20.882	18.166
990.000	18.539	15.765
1000.000	16.761	13.930
1010.000	16.551	13.662
1020.000	16.336	13.389
1030.000	16.163	13.158
1040.000	15.989	12.923
1050.000	14.429	11.205
1060.000	13.817	10.303
1070.000	13.331	9.393
1080.000	13.353	8.857
1090.000	13.624	8.437
1100.000	13.759	7.750
1110.000	13.961	7.081
1120.000	15.095	7.344
1130.000	14.112	5.491
1140.000	13.297	3.805
1150.000	13.097	2.735
1160.000	12.951	1.718
1170.000	12.796	0.692
1176.745	12.740	0.049

Horizontal Geometry: L =1176.745

Vertical Geometry				
G =-8.022% L =103.742	R =750.000 K =7.500 L =64.488	G =0.577% L =869.295	R =750.000 K =7.500 L =60.976	G =8.707% L =78.827

GEOLOGY KEY
- BLOWN SANDS (SAND DUNES)
- DRIFT DEPOSITS
- ROCK



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SITE COMPOUND LAYOUT KEY:
1. 50 KVA GENERATOR 2M X 2M
2. TOILET BLOCK 6M X 2M
3. DRY/CHANGE ROOM 6M X 2M
4. CANTEEN 6M X 2M
5. OFFICE 6M X 2M
6. OFFICE 6M X 2M
7. 21 TON TRACKED 360 EXCAVATOR
8. DRILL PIPE STORAGE 10M X 2M
9. HDD DRILL RIG 16M X 2M
10. POWER PACK 6M X 2M
11. CONTROL CABIN 6M X 2M
12. MUD LAB 3M X 2M
13. MUD ENTRY PIT 3M X 4M
14. HIGH PRESSURE MUD PUMP 6M X 2M
15. MUD MIXING TANK 7M X 2M
16. 350 KVA GENERATOR 5M X 2M
17. RECYCLING UNIT 6M X 2M
18. WATER STORAGE TANK 6M X 2M
19. DRY DRILLING FLUID STORAGE 4M X 10M
20. WORKSHOP 6M X 2M
21. STORES 6M X 2M

Rev	Date	Description	By	Chk
P03	11.08.23	SITE COMPOUND LAYOUTS REMOVED, RE-ISSUED FOR INFORMATION AS PART OF PLANNING SUBMISSION	LP	CG
P02	10.03.23	TITLE UPDATED AND DRAFT BANNER REMOVED	LP	CG
P01	20.05.22	DRAFT ISSUE FOR INFORMATION ONLY	LP	CG

Amendments

Project
WHITE CROSS FLOATING WINDFARM

Title
SAUNTON GOLF CLUB OUTLINE HDD PLAN AND PROFILE

Client
FLOTATION ENERGY LTD

waterman
STOCKTON

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Suitability
FOR PLANNING SUBMISSION

Designed By: LP	Director: CG	Waterman Ref: WIE12731-135	
Drawn By: LP	Date: 20.05.22	Scales @ A1: AS NOTED	
Stockton Checker	Stockton Approver	Date	

Project - Originator - Volume - Level - Type - Role - Number | Revision

12731-135-WIE-ZZ-XX-M3-C-91006	P03
110-099-DRG-021	A01
FLO-WHI-LAY-0018	A1

3.1 Braunton Burrows Crossing design parameters

3.1.1 Landfall Crossing

53. Preliminary engineering appraisal was undertaken regarding the Landfall constructability. The following parameters are indicated for HDD components of Options 2 and 3, it should be noted these parameters will be refined, as a preferred trenchless crossing technique is determined for the final design:

54. The proposed cable landing is located in Saunton Sands car park, which is approximately 1km to the west of Saunton village.

55. It is assumed that offshore cable with a maximum outside diameter of 294mm will be required for the landfall crossing, this will typically require a duct with a minimum diameter of 458mm, or 1.56 times the cable diameter.

56. Due to available duct sections it is assumed a 560mm HDPE SDR 11 pipe diameter duct will be required. This size ducting requires a minimum diameter 914mm reamed borehole to install it. The initial trenchless pilot hole would therefore be reamed out to circa 312mm diameter prior to the 250mm duct being pulled through the bore.

57. Where two ducts are to be installed a minimum 10m separation will be required between the ducts.

58. As the HDD approaches the exit point, a reception pit will be excavated to clear the exit zone of beach/marine sediments, in order to prevent debris ingress into the bore.

59. It is proposed to install the ducts from offshore to onshore. This will require remote fabrication of the HDD ducts, either offsite at a local port or at the onshore compound. Marine support to install the ducts, such as floating on barges to the exit point, will also be required.

60. The proposed entry compound will be located within the Saunton Sands car park, and it is anticipated that this should be sufficient for the compound setup without any earthworks required.

61. Construction works at this location are to be completed during the off season between September and April. Movements to site for plant and materials should be optimised in order to minimise project traffic movements wherever possible. Due to the proximity of dwellings to the proposed construction compound, due consideration should be given to minimising noise, emissions, and light pollution wherever possible.

62. Access the HDD compound will be via the B3231 (Saunton road) and via the Car park access road. Due to the seasonal constraints and proximity to a public car park, and dwellings, it is proposed to install the landfall HDD from the west side of the HDD compound, and when complete, reposition the HDD rig to the east side of the HDD compound, in readiness for the HDD installation of the Golf course crossing to the east.

63. A Transition Joint Bay (TJB) will be required where the offshore cable is connected to the onshore cable. Typically a TJB will consist of precast reinforced concrete units to create an approximate 20m x 8m x 2m concrete box, infilled with a sand / gravel surround. These can be installed at depth such that they are trafficable with incorporation of vehicle rated covers.

3.1.2 Saunton Golf Course Crossing

64. Preliminary engineering appraisal undertaken as part of the Onshore Export Cable Corridor feasibility assessment indicates the following parameters. However, it should be noted these parameters will be refined, as a preferred trenchless crossing technique is determined for the final design:

65. The crossing is located from Saunton Sands car park to the east of Saunton Golf Club, with an approximate crossing length of 1.2 km.

66. At the Saunton Golf Course Crossing, it has been assumed that an onshore cable with a maximum outside diameter of 165mm will be required, which will typically require a duct with a minimum diameter of 225mm, or 1.5 times the cable diameter.

67. Due to available duct sections, and assuming HDPE SDR 21, a nominal 250mm diameter duct will be required. The initial trenchless pilot hole would therefore be reamed out to circa 312mm diameter prior to the 250mm duct being pulled through the bore.

68. The proposed entry compound will be located within the Saunton Sands car park, and it is anticipated that this should be sufficient for the compound setup without any earthworks required.

69. For a typical trenchless application, an ideal compound size of 50m x 50m will typically be required with level and stable terrain. The compound is required to site a variety of containers which contain welfare, offices, storage, mud labs, mud mixing, mud recycling units and workshops.

70. An entry pit should be formed for the containment of drill fluids and may require temporary support. Given that the overburden at site consists of Blown Sand

deposits and groundwater is considered likely to be shallow, there may be issues with leakage of the drill fluid which should be overcome through lining the pit with an impermeable barrier such as visqueen sheeting, so as to form a sump.

71. The exit compound is located within an area of arable farmland to the east of Saunton Golf Club. In typical HDD applications a minimum area of 100m length by 20m width behind the exit pit is used to facilitate stringing out the product pipe with the support of stilts and rollers. In this instance if HDD is the selected method of installation, it is anticipated that the product pipe will be pulled from the exit compound to the entry compound.

72. The Exit Compound will typically be required with level and stable terrain which will require minor earthworks on site. It is not anticipated that earthworks will require substantial excavation of solid deposits, the drilling contractor should be consulted during this aspect of the design.

73. A 3.5m to 4.0m wide temporary access track suitable for the equipment to be employed will need to be formed through the fields from the access off the Burrows Lane to the exit compound. This will require the placing of a suitable depth of imported clean angular stone, such as SHW Type A to Clause 801, placed on top of a geotextile separation membrane. Alternatively, temporary metal roadway could be used.

74. Depending on the location of the TJB a short section of onshore cable, installed in an open cut trench, may be required to connect the cable for the Golf Course Crossing to the TJB and the Landfall Crossing.

75. Joint bays will be required at either end of the trenchless crossing. Joint bays typically consist of precast reinforced concrete units, which create a box of approximately 12m by 4m by 1.5m infilled with a sand/gravel surround. The joint bays within the Saunton Sands car park will also incorporate vehicle rated covers.

76. The final design will be included within the final Method Statement to be produced pre-construction and will identify the following:

- Entry pit and exit pit locations and their surrounding compounds. When crossing Internal Drainage Board (IDB) maintained watercourses, the entry and exit pits will be located at least 16m from the banks of the watercourse
- Drill paths between the entry and exit pit locations, with the separation between drill lines being dictated by parameters from the cable design
- Drill profiles based on an analysis of the site conditions and cable installation requirements.

77. Output from the design phase will provide recommendations on the drilling methodology to be adopted to best suit the selected crossing technique and the site conditions.

78. No ongoing requirement for regular maintenance of the onshore export cables following installation is anticipated. However, access would be required to conduct emergency repairs, if necessary.

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

3.2 Taw Estuary Crossing design parameters

80. Preliminary engineering appraisal undertaken as part of the Onshore Export Cable Corridor feasibility assessment indicates the following parameters. However, it should be noted these parameters will be refined, as a preferred trenchless crossing technique is determined for the final design.

81. At the Taw Estuary Crossing, it has been assumed that an onshore cable with a maximum outside diameter of 165mm will be required, which will typically require a duct with a minimum diameter of 255mm, or 1.5 times the cable diameter.

82. Due to the available duct sections and assuming HDPE SDR 21, a nominal 250mm diameter duct is assumed. This will require an initial pilot hole to be reamed out to 312mm diameter prior to the pull back operation for the HDD option. For the Direct Pipe option, the duct would be installed within the Direct Pipe Casing prior to the annulus being grouted up, which will likely require a Direct Pipe diameter of 1,422mm, subject to ground investigation.

83. Both options will likely require a drill length of 1.3km and will use the same entry and exit point locations.

84. Joint bays will be required at either end of the trenchless crossing. Joint bays typically consist of precast reinforced concrete units, which create a box of approximately 12m by 4m by 1.5m infilled with a sand/gravel surround.

85. The final design will be included within the final Taw Estuary Crossing Method Statement to be produced pre-construction and will identify the following:

- Entry pit and exit pit locations and their surrounding compounds. When crossing main rivers or IDB maintained watercourses, the entry and exit pits will be located at least 16m from the banks of the watercourse

- Drill paths between the entry and exit pit locations, with the separation between drill lines being dictated by parameters from the cable design. The depth of the drill path below the channel bed at the Taw Estuary Crossing will be confirmed following completion of hydrofracture (the inadvertent loss of drilling fluid from the borehole annulus to the surrounding soil due to excess fluid pressure) calculations and geotechnical investigations
- Drill profiles based on an analysis of the site conditions and cable installation requirements.

86. Output from the design phase will provide recommendations on the drilling methodology to be adopted to best suit the selected trenchless crossing technique and the site conditions.

87. No ongoing requirement for regular maintenance of the onshore export cables following installation is anticipated. However, access would be required to conduct emergency repairs, if necessary.

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

4. Drilling Methodology

4.1 Site Set Up

4.1.1 General Set Up

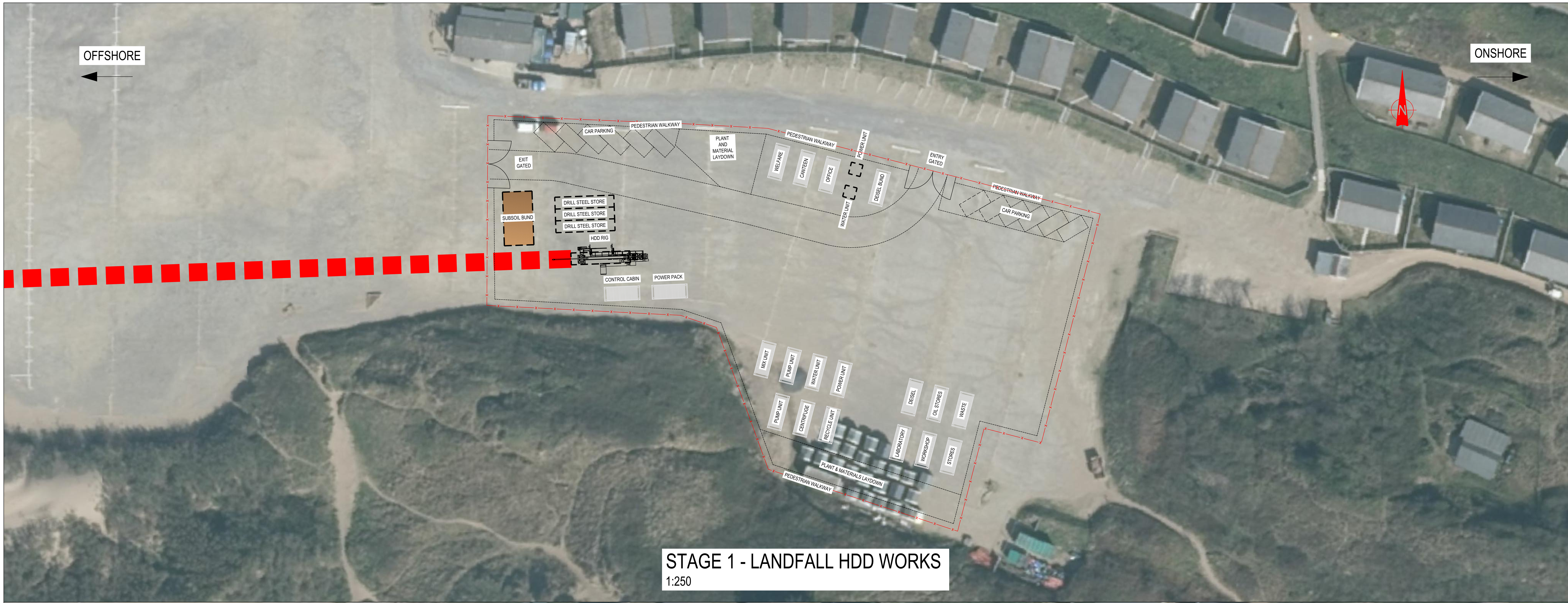
89. Prior to commencement of construction works at the Crossings, the general site area will be prepared to a suitable level to ensure construction safety and good operating conditions for drilling works.

90. Access will be required to allow the establishment of temporary compounds around the entry and exit points. The entry point compounds will also include a control cabin and welfare facilities for site personnel, including connection of utilities such as water, power, lighting and telecommunications services. Other plant and equipment anticipated within the compound include storage containers, power packs, mud labs, recycling units, mud mixing units, mud pumps, hydraulic excavators, power generators and other construction vehicles and machinery.

91. Temporary site lighting will also be installed and assessed for effectiveness ahead of starting construction activities. The compounds will be enclosed in temporary Heras fencing, and 24-hour security will be present until site reinstatement and demobilisation is complete. Information on existing underground utilities will also be obtained, and their location will be located and marked to ensure adequate separation distances. Any utilities that conflict with the proposed drill paths or site operations will be exposed to confirm their exact location, and appropriate measures will be taken to protect them from damage and ensure construction safety.

4.1.1.1 Braunton Burrows Crossing (Landfall and Saunton Golf Course Crossings)

92. A single temporary onshore compound will be required for the entry point for both the landfall and Saunton golf course crossings, which will be set within the car park at Saunton Sands. This would be up to 100m long by 50m wide for the landfall (Stage 1 **Figure 4.1**), reduced to 50m long by 50m wide (Stage 2 **Figure 4.1**) for the crossing of the golf course. This location is outside of the Braunton Burrows SAC.



STAGE 1 - LANDFALL HDD WORKS

1:250

STAGE 2 - GOLF COURSE HDD WORKS

1:250

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Rev	Date	Description	By	Chk
P02	11.08.23	UPDATED WITH CLIENT COMMENTS. RE-ISSUED FOR INFORMATION	LP	CG
P01	21.07.23	ISSUED FOR INFORMATION	LP	CG

Amendments

Project
WHITE CROSS FLOATING WINDFARM

Title
HDD SITE COMPOUND LAYOUT (LANDFALL / GOLF COURSE CROSSINGS)

Client
FLOTATION ENERGY LTD

waterman
STOCKTON

Broxden House Broxden Business Park Lamberkine Drive Perth PH1 1RA
t 01738 449 801
mail@watermangroup.com www.watermangroup.com

Suitability
INFORMATION S2

Designed By LP	Director CG	Waterman Ref WIE12731-153
Drawn By LP	Date JULY 23	Scales @ A0 1:250
Stockton Checker	Stockton Approver	Date

Project - Originator - Volume - Level - Type - Role - Number	Revision
12731-153-WIE-GC-XX-DR-C-90001	P01
110-099-DRG-013	A01
FLO-WHI-LAY-0013	A1

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93. Access to the entry point compound will be from Saunton Road (B3231) using the existing car park access road. It is not anticipated that any major works will be needed to improve this access for the Onshore Project.

94. The initial site setup and establishment will be undertaken outside of the peak summer holiday season, defined as July – August in order to mitigate any impacts on either the local highways or the users of the car park. Movement to site for plant and materials will be optimised in order to minimise traffic movements from the Onshore Project wherever possible.

95. When the works associated with the crossings are completed the area will be reinstated and the areas with the carpark returned to the operator.

96. The temporary exit compound for the Saunton golf course crossing will be located within the fields to east, outside of the Braunton Burrows SAC. There will be no exit compound for the landfall crossing as the exit location will be below MLWS.

97. Access to the exit point compound for the Saunton golf course crossing will be through the Onshore Export Cable Corridor using the temporary main access from Saunton Road (B3231) and the Onshore Project haul road.

98. For the landfall crossing the ducts would be fabricated onshore, either at a local port or at the onshore compound, and then floated out to the exit point on barges to be installed from offshore to onshore. The stringing and welding of the ducts for the Saunton golf course crossing will be undertaken in the fields to the east of the golf course within the Onshore Export Cable Corridor, therefore the ducts would be pulled from the exit to the entry compound.

4.1.1.2 Taw Estuary Crossing

99. The entry compound will be located within an area of farmland adjacent to the East Yelland substation on the south bank of the River Taw. Minor earthworks will be required to level the working area, which typically involve stripping and storing the topsoil, installing geotextile membranes to the sub-surface and laying and compacting suitable hard material to form a firm working platform, although substantial excavation of solid deposits is not anticipated.

100. Preliminary engineering appraisal indicates that a compound area of 50x50m is considered ideal for a typical trenchless application. In addition, for the HDD option, a cast in-situ reinforced concrete anchor block would be installed adjacent to the entry point as an anchor for the HDD rig. For the Direct Pipe option, a sheet pile launch pit would be required.

101. Access to the entry compound on the south bank will be from the new haul road connecting to the existing private road and then to the highway at the West Yelland Road (B3233).

102. The entry compound would be located outside of the Taw-Torridge Estuary SSSI.

This drawing should not be scaled. Dimensions to be verified on site.
Any discrepancies should be referred to the Engineer prior to work being put in hand.

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2. ALL DIMENSIONS AND LEVELS ARE TO BE CHECKED ON SITE BY THE CONTRACTOR PRIOR TO PREPARING ANY WORKING DRAWINGS OR COMMENCING ON SITE.
3. THE CONTRACTOR MUST ENSURE AND WILL BE HELD RESPONSIBLE FOR THE OVERALL STABILITY OF THE BUILDING/STRUCTURE/EXCAVATION AT ALL STAGES OF THE WORK.
4. ALL WORK BY THE CONTRACTOR MUST BE CARRIED OUT IN SUCH A WAY THAT ALL REQUIREMENTS UNDER THE HEALTH AND SAFETY AT WORK ACT ARE SATISFIED.
5. ALL WORK IS TO BE CARRIED OUT IN COMPLIANCE WITH THE REQUIREMENTS OF THE RELEVANT STATUTORY AUTHORITIES AND REGULATIONS.

Rev	Date	Description	By	Chk
P02	11.08.23	UPDATED WITH CLIENT COMMENTS. RE-ISSUED FOR INFORMATION	LP	CG
P01	24.07.23	ISSUED FOR INFORMATION	LP	CG

Amendments

Project

WHITE CROSS FLOATING WINDFARM

Title

HDD SITE COMPOUND LAYOUT (RIVER TAW CROSSING)

Client

FLOTATION ENERGY LTD

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Suitability: INFORMATION		S2
Designed By: LP	Director: CG	Waterman Ref: WIE12731-153
Drawn By: LP	Date: JULY 23	Scales @ A0: 1:200
Stockton Checker	Stockton Approver	Date

Project - Originator - Volume - Level - Type - Role - Number	Revision
12731-153-WIE-RT-XX-DR-C-90001	P02
110-099-DRG-014	A01
FLO-WHI-LAY-0014	A1

A0-Wat-SDL-S

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103. The exit compound will be located within an area of farmland adjacent to the Crow Point Carpark. The stringing-out and welding of the HDPE ducts (for the HDD option) would be undertaken on the north side of the Taw Estuary within the Onshore Export Cable Corridor, therefore the ducts would be pulled from the exit to the entry compound. Similar minor earthworks are anticipated for the exit compound.

104. Access to the exit point compound for the Taw Estuary crossing will be through the Onshore Export Cable Corridor using the temporary main access from Saunton Road (B3231) and the Onshore Project haul road.

105. The exit compound would be located outside of the Braunton Burrows SAC, Braunton Burrows SSSI, and the Taw-Torridge Estuary SSSI.

4.1.2 Construction Environmental Controls

106. All construction activities at the Taw Estuary and Braunton Burrows Crossing will observe the best practice measures and conditions documented in **Appendix 5.C: Outline Construction Environmental Management Plan** and other relevant management plans submitted in support of the Offshore and Onshore Project's consenting and planning permission applications. Works will also be carried out in accordance with the contractor's own site management plan, risk assessments and method statements.

107. Prior to the commencement of construction works at the Taw Estuary and Brunton Burrows Crossings, OWL will consult NE and other stakeholders and seek agreement on the design and methodology set out in this document.

108. Within **Sections 4.1.2.1** to **4.1.2.12,** relevant construction environmental controls are laid out.

4.1.2.1 Noise and Vibration

109. Construction environmental controls relevant to noise and vibration anticipated for the site include but are not limited to:

- Adequate control measures to minimise noise and vibration impacts will include temporary screening and traffic management measures specified the Construction Traffic Management Plan (CTMP).

4.1.2.2 Terrestrial Ecology

110. Construction environmental controls relevant to terrestrial ecology anticipated for the site include but are not limited to:

- Adequate control measures to avoid and minimise impacts on flora and fauna and any protected species
- Consents/licences may also be required in relation to protected species and habitats
- Specific measures to mitigate impacts on wintering birds (including high tide roosts), such as screening, minimising the movement of personnel and timing of the works.

4.1.2.3 Terrestrial Archaeology and Cultural Heritage

111. Construction environmental controls relevant to terrestrial archaeology and cultural heritage anticipated for the site include but are not limited to:

- Sites of archaeological importance will be identified in the Written Scheme of Investigation (WSI) and appropriate environmental control measures such as the establishment of exclusion and buffer zones will be implemented where required.

4.1.2.4 Wastewater Discharges

112. Construction environmental controls relevant to wastewater discharges anticipated for the site include but are not limited to:

- Relevant permits will be obtained by the principal contractor from the regulator associated with the use of septic tanks for other effluent/washout water treatment facilities
- Wastewater management through the use of septic tanks or other effluent/washout water treatment facilities. In addition, monitoring and recording specified volumetric, quality or reference conditions to demonstrate compliance will be undertaken
- Waste sludge from septic tanks and effluents from cesspits and sewage holding tanks must be removed by a suitably licenced and registered waste carrier in accordance with Duty of Care requirements
- Monitoring records in relation to the disposal of grey water, foul water, bilge water or ballast water during the construction phase must be retained.

4.1.2.5 Oils, Fuels and Chemicals

113. Construction environmental controls relevant to oils, fuels and chemicals anticipated for the site include but are not limited to:

- Ensure adequate controls for the delivery, storage and use of fuels, oils and chemicals on site

- Oils and chemicals must be clearly labelled and a up-to-date hazardous substance register must be retained
- The principal contractor will wherever possible use drilling fluids that are on the PLONAR (Poses Little Or No Risk), the list is controlled and maintained by The Centre for Environment, Fisheries and Aquaculture Science (CEFAS)
- Activities involving the handling of large quantities of hazardous materials, such as deliveries and refuelling, should have detailed method statements and be undertaken by designated and trained personnel
- Oil and fuel storage must be robust and provide adequate secondary containment and be located in designated areas taking into account security, the location of sensitive receptors and pathways such as drains and watercourses, and safe access for plant and manual handling
- Spill response materials should be provided nearby an be readily accessible, with project personnel trained in spill response
- All materials ordered or brought to site listed as hazardous under the Control of Substances Hazardous to Health (COSHH) Regulations are accompanied with hazardous information sheet.

4.1.2.6 Waste Management and Circular Economy

114. Construction environmental controls relevant to waste management and circular economy anticipated for the site include but are not limited to:

- The waste reduction hierarchy (Avoid, Reuse, Recycle or Recover) should be considered where practical and economically feasible prior to considering disposal
- The principal contractor is required to prepare a Waste Management Plan to record the following information, as a minimum:
    - The types and quantities of waste generated
    - The management approach for each waste type (Reuse, Recycle, Recover, Dispose) including any treatment
    - The storage arrangements for each waste type
    - The site waste monitoring and reporting arrangements.
    - Waste carrier details and waste management/disposal facilities.
- Duty of care requirements in relation to the storage, transfer and disposal of waste must be complied with
- Circular economy principles should be considered, where practical and economically feasible, specifically the priority area of circular construction and adopting circular economy interventions such as:

- adopting circular design principles and construction processes, particularly the opportunity to create a physical and virtual resource recovery and material exchange hub to make better use of material wasted in construction
- supporting the growth of regional specialist circular products and services in the construction industry.

4.1.2.7 Traffic Management

115. Construction environmental controls relevant to traffic management anticipated for the site include but are not limited to:

- Appointment of a Traffic Management Coordinator (TMCo)
- Obtain technical approval for construction of accesses and crossings
- Implement direction signing
- Establish monitoring systems
- Agree scope of and undertake pre-commencement highway condition surveys
- Agree and implement measures for each access to control the deposition of detritus on the public highway
- Inspect the highway for detritus and request regular cleansing as required
- Monitoring of CTMP measures
- Produce monthly monitoring reports
- Update condition surveys and agree any remedial works.

4.1.2.8 Surface Water Management

116. Construction environmental controls relevant to surface water management anticipated for the site include but are not limited to:

- A detailed surface water management design/drainage plan for the site included in the CEMP. The plan should detail the surface water management measures to be implemented during the works. The detailed design should be supported by the rationale for selecting the chosen mitigation measures, together with associated calculations and methodologies for sizing. Where appropriate, the principles of Sustainable Urban Drainage Schemes (SUDS) should be applied
- Mitigation measures must be maintained and monitored on a regular basis. A record of inspections of mitigation measures and any required maintenance carried out must be maintained.

4.1.2.9 Water Abstraction

117. Construction environmental controls relevant to water abstraction anticipated for the site include but are not limited to:

- Abstraction of water may be required for potable supply or for use during site activities, such as concrete batching or washing. Where this is required, any permits for the use of abstracted water during the construction related activities must be obtained
- Monitoring and recording associated abstraction rates or other licence requirements to demonstrate compliance.

4.1.2.10 Emissions to the Air

118. Construction environmental controls relevant to emissions to the air anticipated for the site include but are not limited to:

- Measures recommended by the Institute of Air Quality Management (IAQM)
- Appropriate mitigation measures to suppress dust and minimise emissions to the air during the construction works.

4.1.2.11 UXO Risk

119. Construction environmental controls relevant to UXO risk anticipated for the site include but are not limited to:

- Surveys and assessments of the construction site, identifying potential UXO presence or historical activities should be undertaken by the Principal Contractor. In the event of any suspected or confirmed UXO findings, Principal Contractor will be required to implement appropriate measures, such as notifying relevant authorities, establishing exclusion zones, and engaging specialised personnel for safe removal and disposal.

4.1.2.12 Project Programme and Working Hours

120. Construction environmental controls relevant to project programme and working hours anticipated for the site include but are not limited to:

- Working times will be restricted to 12-hour shifts, except for circumstances in which longer periods are required due to the nature of works, to avoid night time working. However, in exceptional circumstances longer periods may be required due to the nature of works. These will be agreed in advance with the relevant authorities.

4.2 HDD

121. The description provided within this appendix is an indicative description applicable to all of the crossings.

4.2.1 Drill Rig Set Up

122. For the HDD options, a 1.5m deep entry pit would be excavated adjacent to the entry point, measuring approximately 4m by 4m. This pit would be surrounded by the excavated subsoil and enclosed using barrier fencing to prevent access by unauthorised personnel and provide a safe working environment. Given that the overburden around the entry point location consists of Tidal Flat deposits and groundwater is considered likely to be shallow, the entry pit may require temporary support and would be lined with an impermeable membrane such as plastic sheeting to form a sump and containment of drilling fluids. Excavated topsoil will be stored in a designated area and kept separate from the subsoil to prevent contamination.

123. The HDD rig, control cabin, power packs, mud labs, recycling units, mud mixing units, mud pumps, hydraulic excavators and other equipment will be delivered to the site via heavy goods vehicles, offloaded and assembled on the working platform. A slurry pump will be installed adjacent to the excavated entry pit to pump the drilling fluid-laden cuttings to the recycling units.

124. A steel casing pipe will be installed by an excavator as a guide pipe at the entry point. The HDD rig and ancillary equipment will be positioned at their working positions, and all necessary connections and checks will be made. The rig will be anchored to the concrete anchor block and adjusted vertically to the correct ground entry angle in accordance with the HDD design.

125. An indicative layout for the HDD rig set up will be presented at a later stage to reflect the final design and the nature of equipment and machinery to be used on-site.

4.2.2 Pilot Hole

126. Following all site preparation works, the pilot hole will be drilled through the ground following the predetermined profile trajectory to the exit point on the other side of the river bank. The HDD rig uses a drill string, which comprises of a drill bit connected to a gyroscope and magnetic steering system and a series of drill pipes. Drilling fluid is jetted through the centre of the drill string and out through nozzles within the drill bit to provide hydraulic power to a steerable mud motor. The drilling fluid-laden cuttings are transported back through the drilled hole to the surface and into the entry pit where the mixture is constantly pumped through the mud separation and recycling system and reused as drilling fluid, with the addition of new water and bentonite clay as needed.

127. Directional guidance is achieved via a signal transmitted from the gyroscope and magnetic steering system in the first drill pipe to the drilling control unit in the control room. The guidance engineer uses the directional data and records of the length of the drill pipe to calculate the progress and position of the drill bit. Such calculations will be performed at regular intervals, typically at every point the drill advances one drill pipe length, and steering corrections will be made when necessary.

128. The pilot hole will stop a short distance from exiting the bedrock at the exit point location, also known as the stop short point, to contain the drilling fluid within the bore during the reaming phase. The drill string will then be retracted back through the hole to the entry point by the HDD rig.

4.2.3 Reaming

129. After the pilot drill string has been withdrawn from the bore, an opener reamer will be assembled onto the drill string at the entry point in order to increase the pilot hole diameter. A bull nose and stabilisers attached to the front and back of the reamer respectively will help centralise the reamer within the pilot hole. The reamer is rotated and advanced along the pilot hole whilst pumping drilling fluid through the reamer nozzles. As with the pilot hole drilling, drilling fluid-laden cuttings are transported to the entry point to be recycled.

130. Upon reaching the stop short point, the drill string will be retracted, and the next-sized reamer will be assembled onto the string and re-deployed to continue widening the hole. This process will continue until the hole is large enough to accommodate the size of the cable duct assembly.

131. A final jetting and steering assembly are then installed to the drill string at the entry point and advanced through the reamed bore to punch out at pre-determined exit point. The final assembly will be removed from the drill string and replaced with a pull back assembly to facilitate the cable duct installation.

4.2.4 Pull Back

132. The cable duct to be installed will be positioned at the exit compound. The drill string with the pull back assembly will be attached to the cable duct at the swivel, and the HDD rig will then pull the drill string along with the cable duct through the reamed bore through to the entry point, at which point the installation process is complete.

4.2.5 Demobilisation

133. Once quality and safety checks have been performed and the HDD operations have fully concluded, the contents of the entry pit along with all drilled cuttings, drilling fluid, buffer tank mixture and other construction waste will be disposed of via a registered waste carrier to a licenced facility. All geotextile membranes will be removed, and the entry pit will be backfilled with its original soil. The HDD rig will be de-rigged, and all ancillary equipment and structures will be disassembled on the working platform and transported back, allowing the site to be cleared.

4.3 Direct Pipe

134. The description provided within this appendix is an indicative description applicable to all of the crossings.

4.3.1 Pipe Thruster and Tunnel Boring Machine Set Up

135. For the Direct Pipe option, an entry pit would be excavated adjacent to the entry point in line with the approved temporary compound design. Calculations will be undertaken as part of the design to ensure that the entry pit and the required anchoring system are capable of withstanding the horizontal and vertical thrust forces generated by the Pipe Thruster within acceptable safety margins.

136. The Pipe Thruster, control cabin, and ancillary equipment and structures will be delivered to the site via heavy goods vehicles, offloaded and assembled on the working platform. After securing the launch cradle to the underlying geology where the entry pit is excavated, the base frame of the Pipe Thruster, which comprise two separate parts, will be lifted into place at the base of the pit and securely fixed to the launch cradle. Hydraulic thrust cylinders will then be positioned in the pit and securely fixed to the thruster base at the correct ground entry angle.

137. Securing ports on each side of the base frame parts will be used to secure the thruster base to the launch cradle, providing both horizontal and vertical mechanical anchoring. Once the anchoring system is installed, the Pipe Thruster can then be lowered into position and secured. A launch seal will also be mechanically secured to the entry pit headwall to prevent the ingress of groundwater, cuttings and drilling fluid returns into the pit.

138. In general, the minimum width of the entry pit is determined by the width of the base frame, the maximum width of the opened clamping unit and a minimum of 1 m clearance on each side for safety purposes. The minimum length of the entry pit is determined by the maximum length of the Pipe Thruster unit and the minimum distance of the unit from the front face of the entry pit, which is dependent upon

the ground entry angle and the size of the Pipe Thruster. The typical entry pit size is 6.3m width by 20m length. The depth of the entry pit is determined by the minimum required cover over the launch seal. A minimum of 1.5 times the outer diameter of the tunnel boring machine (TBM) is recommended for cover above the launch seal.

139. The TBM and its associated components will be lifted into position centred on the launch seal, at the correct ground entry angle and parallel to the thrust cylinders of the Pipe Thruster. An antiroll unit will be secured to the launch cradle and Pipe Thruster to prevent the potential rotating of the clamping unit and subsequently the TBM assembly and the attached pipeline. The TBM assembly contains the cutting head at the front, power packs, feed and slurry lines for drilling fluid transport and a conical interface ring at the rear.

4.3.2 Pipe String Preparation

140. The pipeline may be strung out and welded onto the TBM assembly as a single continuous pipe string, sufficient to complete the installation from the entry to the exit pit in a single operation. Alternatively, should the site have working space limitations, it is possible to weld the pipeline and perform the installation in sections. Typically, the pipe string will be welded with a set back from the rear of the entry pit and subsequently placed on rollers to allow the pipe string to travel linearly into the borehole. Roller cradles and a ramp may also be needed at the rear of the entry pit to align with the ground entry angle of the TBM assembly and account for the difference in elevation.

141. In addition, supply lines will also be installed externally and/or internally to the pipe string, connecting into the control cabin and the mud separation and recycling system. These supply lines include electric and data cables, slurry and discharge hoses and drilling fluid hoses. Slurry pumps and feed line coolers will also be inserted into pipe string. In order to reduce the required length of the feed and slurry lines, it is recommended that the mud separation and recycling plant and drilling fluid injection pump are located close to the midpoint of the pipe string.

142. Once the welding, testing and coating operations are completed on the pipe string and all ancillary equipment has been installed, the front of the pipe string will be secured to a weld-on adaptor, which is then connected to the rear of the TBM assembly at the conical interface ring. All supply lines inside the pipe string will also be connected to the corresponding inlets inside the TBM assembly.

143. The clamping unit of the Pipe Thruster will then be opened to a sufficient width and positioned above the pipe string using a mobile lifting appliance. Once the clamping

unit is lowered into the entry pit and seated over the pipe string, the clamp will be closed, and the clamping plates will be hydraulically extended until the clamp is securely holding the pipe string. Hydraulic thrust cylinders on the Pipe Thruster will then be extended to the clamping unit and connected mechanically to finalise the site setup.

4.3.3 Pipe Thrust and Insertion

144. Prior to tunnelling works, the hydraulic, electric and pneumatic systems of the entire assembly will be activated and tested to confirm correct functionality. Once a functional test is complete, the TBM assembly is then inserted through the launch seal at the front of the entry pit. The cutting head on the TBM will then continue to drill forward along the predetermined profile trajectory to the exit point on the other side of the river bank. The pipe string, which is connected to the TBM assembly, will also be thrusted into the borehole and transported along the drill path, allowing the pipeline to be installed simultaneously with the drilling operations.

145. If required, the pipe string may also be installed in multiple sections. After the TBM assembly and initial pipe string is inserted into the borehole, a new pipe string can be lowered into the entry pit and welded to the rear end of the already inserted pipe string. The process is then repeated until the full length of the pipeline is achieved.

4.3.4 Demobilisation

146. Once the TBM assembly reaches the exit point on the other side of the river bank, the components of the assembly will be disconnected either individually or together in one piece. The dimensions of the exit pit would need to provide sufficient length for the disassembly. The supply lines, slurry pumps and feed line coolers within the installed pipe string will also be disassembled by retracting the wheeled carrier racks. Supply lines are then disconnected, cleaned and inspected for damage prior to storage.

147. Once quality and safety checks have been performed and all Direct Pipe operations have fully concluded, the contents of the entry pit along with all drilled cuttings, drilling fluid, buffer tank mixture and other construction waste will be disposed of via a registered waste carrier to a licenced facility. All geotextile membranes will be removed, and the entry pit will be backfilled with its original soil. The Pipe Thruster and anchoring system will be de-rigged, and all ancillary equipment and structures will be disassembled on the working platform and transported back, allowing the site to be cleared.

4.4 Working Hours

148. The typical working hours expected at the Braunton Burrows and Taw Estuary Crossing are 07:00 to 19:00 Monday to Friday, Saturday 07:00 – 13:00; however some 24 hour working we be required for the drilling associated with the trenchless cable installation methods. A maximum of 14 days of 24 hour working for each drill has been assessed. Continuous periods of construction may be required depending on the nature of works and where these are required they will be agreed in advance with the relevant authorities. Supervision will not be reduced when night shifts are undertaken. All site housekeeping checks and refuelling will be scheduled during daylight hours.

5. Drilling Fluid Management

5.1 Purpose of Drilling Fluid

149. Trenchless crossing techniques are undertaken with the aid of a viscous drilling fluid, typically a mixture of water, polymers and ground and refined bentonite clay (a non-toxic clay commonly used in agricultural practices). Bentonite clay is typically delivered to site as a dried and finely ground powder, which is then rehydrated in a mix tank with water. Bentonite clay is included on the OSPAR Commission's List of Substances Used and Discharged Offshore which are Considered to Pose Little or No Risk to the Environment (PLONOR) (OSPAR Commission, 2021).

150. Drilling fluid serves many purposes such as providing hydraulic cutting action to any alluvial geology, providing hydraulic power to the downhole mud motor, transporting cuttings out of the bore, keeping cuttings in suspension when drilling operations are halted and cooling and lubricating the drill string and product pipe. It also gives support to the borehole and equalises pressure differences between the borehole and the geological formation by building a filter cake (a thin layer of drilling fluid that lines and seals the borehole to prevent fluids from permeating to the surrounding soil).

151. The general approach to drilling fluid management and preventive and corrective measures to drilling fluid breakout, as outlined below, are applicable to both the HDD and Direct Pipe option.

5.2 General Management Approach

152. Drilling fluid will be recycled as far as practicable by separating out the solid drill cuttings, which the fluid recovers from the cutting head or drill bit and transports to the surface via the borehole. The recycling system conveys the dirty drilling fluid upon return through a loop, which is capable of removing large solid particles such as gravel and finer particles such as sand through a variety of mechanical techniques. The cleaned drilling fluid is then pumped to the drill rig for reuse after adding new water and bentonite clay to maintain the right consistency and volume. This reduces raw material consumption, in particular water and bentonite clay, the time taken for the drilling process to be completed and the amount of waste produced.

153. The spoil from the drilling and recycling process will be collected, stored and disposed of in line with the approved Site Waste Management Plan (as part of a CEMP) at the end of operations. Likewise, excess drilling fluid will be stored in tanks to manage the expected volumes and removed from site when necessary.

5.3 Measures to Prevent Drilling Fluid Breakout

154. Trenchless crossing techniques carry a potential risk of drilling fluid breakout. This may occur when the fluid is forced through highly fissured ground at pressure or where there are large, interconnected fissures in the ground or other man-made features such as old boreholes. However, drilling fluid breakouts are rare, given that bentonite clay is a thixotropic fluid of high viscosity, which enters and seals fissures within the borehole. Under these circumstances, it is only likely that the drilling fluid would reach ground level where there is a continuous path available to the surface. **Section 2.1** details the hydrofracture assessment and identifies the level of risk of drilling fluid breakout for the Project.

155. The geotechnical investigations undertaken on-site prior to drilling operations will help establish site conditions along the drill profile, allowing a suitable trenchless crossing design to be developed. Findings from these investigations will provide critical information such as the equipment to be used, the entry and exit points, drill profile, drill depth below ground, drilling fluid viscosity and borehole diameter, all of which will minimise the risk of drilling fluid breakout during drilling operations. The review of historical borehole data suggests that the overall risk of drilling activity is low and that the probability of drilling fluid breakout during drilling operations is unlikely. This will be confirmed prior to commencing activity through targeted geotechnical investigations and through agreement with the relevant authorities.

156. During drilling, site monitoring will be carried out by dedicated personnel, which will include monitoring of the annular pressure and the drilling fluid levels. The site to be monitored will include an area of 100m in front or behind the drill head and 25m on either side of the centre line of the drill path. The site will be divided into separate areas which will be monitored regularly, and inspection records shall be maintained. In addition, a down hole annular pressure sensor will be installed to the drill string. The maximum allowable annular pressure according to the design calculations will be plotted on screen for the guidance engineer in the control cabin, with an alarm sounding when 90% of the allowable limit is reached. In this event, drilling operations will be immediately halted, and the drill string will be retracted until an all clear has been given to resume drilling.

157. A key component of preventing drilling fluid breakout is the effective removal of drill cuttings from the borehole (see **Section 5.2** for details of the drill cuttings removal process). If cuttings are not removed, they may form cutting beds at the base of the borehole, which decreases the hole’s cross-sectional area and increases the annular pressure. Cutting beds may also lead to increased drilling forces, which can eventually cause equipment to be lost or stuck downhole.

158. It is anticipated that the following equipment (or equivalent alternatives) will be available on-site at all times to respond to drilling fluid breakout:

- Silt fencing
- Mobile suction pumps
- Seal pups (large cylinder-shaped containment and absorption pads)
- Straw bales
- Timber stakes
- Sand bags
- Tools for erecting temporary bunds.

159. The risk of drilling fluid breakout is considered to be very low based on analysis of historical borehole and desk-based assessment of the geology present in the area. Refer to **Section 2.1** for further information.

5.4 Drilling Fluid Breakout Response Planning

160. Contingency measures to be adopted at the Braunton Burrows and Taw Estuary Crossing will be agreed before drilling operations commence. Possible containment and clean-up steps are provided below. These measures will form part of the CEMP and/or a specific EMP for the crossings.

161. This is additional mitigation included in the unlikely event that a breakout occurs.

5.4.1 Breakout on Land

- Report immediately to the control cabin using the site two-way radio
- Stop drilling immediately
- Contain the drilling fluid by constructing a bund with sandbags
- Recover the drilling fluid from the bund by using 4in pump sets and 4in hoses
- Discharge the drilling fluid into the recycling pit for recycling
- Watch the area closely to check if breakout channel has sealed when pumping
- Pump lost circulation material or cement grout into the borehole and allow to swell in the fracture
- Continue pumping drilling fluid after waiting for lost circulation material to set according to the manufacturer's recommendations. If the fracture cannot be sealed, continue to recover drilling fluid from the bunded area using 4in pumps
- For containment of breakouts on land, sandbags will be stored where they can be easily and quickly brought to the breakout point. Personnel monitoring the site will be equipped with radios for instant communication with the driller.

5.4.2 Breakout under Water

- Any loss of drilling fluid in the entry pit is reported immediately to the driller
- Stop drilling immediately
- Pump lost circulation material to seal the fissure
- Wait for the lost circulation material to swell in the fracture
- Pump a mixture of 'Pure Bore' to see if circulation can be maintained
- If not, repeat the process with lost circulation material
- If the fracture cannot be sealed, either a cement grout will be pumped to the end of the bore, or the drill string will be withdrawn by an appropriate distance and a new profile drilled to avoid the problem area. This is dependent upon the rate of fluid loss and the geology encountered.

162. Fast and essential reporting is an essential component of the contingency plan. Emergency telephone numbers will be available to all the appropriate parties. Contact details of the relevant authority and Statutory Nature Conservation Body will also be provided for ease of reference.

163. In the unlikely event of drilling fluid breakout, an investigation will be conducted by the designated personnel, and the trenchless crossing design parameters will be reviewed to determine whether any modifications to the design or Method Statement are needed to reduce the risk of further breakouts.

6. References

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Waterman Infrastructure & Environment Ltd (2023). White Cross Wind Farm: Export Cable Landfall and Onshore Crossings HDD Hydrofracture Assessment – Feasibility Stage.

Annex 1 HDD Hydrofracture Assessment

Export Cable Landfall and Onshore Crossings (Feasibility Stage)

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Prepared by:	Waterman Infrastructure & Environment Ltd	
Checked by:	Mark Gardner	M.B.G[illegible]
Approved by Client:	Oliver Gardner	

Version Number	Reason for Issue / Major Changes	Date of Change
A1	Issued for Client Review	28-07-2023
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CLIENT	**Flotation Energy**
PROJECT TITLE	**White Cross Offshore Windfarm**
CONTRACT NO.	**110-099**

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DOCUMENT NUMBER

110-099-TIN-004

DOCUMENT TITLE

HDD Hydrofracture Assessment – Export Cable Landfall and Onshore Crossings (Feasibility Stage)

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White Cross Wind Farm: Export Cable Landfall and Onshore Crossings

HDD Hydrofracture Assessment – Feasibility Stage

Date: 11th August 2023

Client Name: Stockton Drilling Ltd (on behalf of Flotation Energy Ltd)

Document Reference: WIE12731-153-TN-2-2-3

This document has been prepared and checked in accordance with
Waterman Group's IMS (BS EN ISO 9001: 2015, BS EN ISO 14001: 2015 and BS EN ISO 45001:2018)

Issue	Prepared by	Checked & Approved by
2-1-3	Lewis Phin Engineer	Chris Gell Technical Director
2-2-3	Lewis Phin Engineer	Chris Gell Technical Director

1. Background

Waterman Infrastructure & Environment Ltd ('WIE') have been appointed by Stockton Drilling Limited ('SDL') to provide support of the onshore cable route Front-End Engineering Design (FEED) for the proposed White Cross Offshore Wind Farm, located approximately 50km off the Devon Coast. The 8 No. Wind Turbine Generators will comprise innovative floating substructure technology that is anchored to the seabed. The maximum capacity of the completed windfarm will be 100MW. Power will be exported by means of a subsea cable(s) that will make landfall on the Devon coast at Saunton Sands before running generally south to either a new or the existing sub-station at East Yelland.

As part of the cable route, 3 No. trenchless drills, by Horizontal Directional Drilling (HDD) methodology, are required for passing constraints. These drills are denoted as the 'Landfall', 'Golf Course Crossing' and 'River Taw Crossing'.

Within the HDD process, there can be a risk of drill fluid breakout to the surface, which is a phenomenon known as Hydrofracture, commonly termed 'frac-out'. In support of the FEED design, WIE have completed a preliminary assessment of the likelihood of hydrofracture based on the feasibility stage crossing profiles developed. The assessment should be revised on completion of ground investigation and finalisation of design profiles.

This Technical Note presents the results of the hydrofracture assessment. The crossing profile drawings and hydrofracture calculations are appended.

1.1 Limitations

A number of assumptions have been made to undertake these calculations including but not limited to, ground conditions, bore dimensions and bore profiles. Whilst WIE have endeavoured to make assumptions conservatively and realistically, we can accept no liability for any inaccuracies. The calculations should be treated as preliminary until such time the variables become more defined whereby the calculations should be revised accordingly.

2. Analysis Methodology

2.1 General

Hydrofracture occurs if during the drilling process the drilling fluid pressure in the borehole exceeds the resistance of the overburden soils resulting in a breakout at the surface. In this instance, there is a potential risk that this could occur within the intertidal zone, on the golf course, or within the River Taw leading to a potential pollution incident.

The HDD designer typically accounts for hydrofracture by ensuring that there is adequate cover depth of the bore path, which in turn provides a larger overburden pressure, and best mitigates hydrofracture. In granular soils, casing is typically used over the initial length of the bore to assist with mitigating the risk.

There are several possible methodologies for assessing the likelihood of hydrofracture, but this analysis has been based upon the widely used 'Dutch' method which was developed by Luger & Hergarden (1988) assuming a cavity expansion.

2.2 Geotechnical Parameters

The geology beneath the site is to be confirmed following a campaign of ground investigation, but expected to consist of superficial deposits, in the form of blown sand or marine beach deposits, overlying Mudstone, Slate or Shale bedrock.

It is anticipated that the bores would be cased through loose superficial deposits into more competent clays / weathered rock.

Due to the lack of Ground Investigation data, this preliminary hydrofracture assessment conservatively assumes granular materials (i.e. rather than firm to stiff clays or competent rock). The geotechnical parameters considered in all analysis are presented in Table 1.

Table 1: Analysis Parameters

Parameter	Assumed Value
Gravity (m/s/s)	9.81
Density of Water (kg/m^3)	1000
Density of Drilling Mud (kg/m^3)	1300
Soil Density (kg/m^3)	1950
Cohesion (kN/m^2)	2
Friction Angle (°)	25
Poission's Ratio	0.3
Elasticity Modulus (kPa)	40000
Allowable Plastic Radius Factor	0.50

2.3 Groundwater

The groundwater level has been conservatively assumed as commensurate with the ground surface throughout the analysis. It is likely that this assumption could be relaxed after completion of ground investigation with associated groundwater monitoring.

2.4 Bore Diameters

The bore diameters for the HDD crossings are to be confirmed as part of detailed design once all cable specifications are confirmed and ground conditions proven. It is anticipated that there will be a transition joint bay between the offshore and onshore cable(s) within the vicinity of the Staunton Sands beach car park. The landfall calculations therefore assume an offshore cable specification, with the Golf Course and River Taw calculations assuming an onshore cable specification (with a consequent reduction in likely cable and duct diameter).

The diameters assumed within the preliminary calculations, based on the feasibility stage designs, are summarised in Table 2.

Table 2: Bore Diameters

Cable Specification	Pilot Hole Diameter (m)	Reamed Hole Diameter (m)
Onshore (River Taw / Golf Course)	0.305 (12”)	0.610 (24”)
Offshore (Landfall)	0.305 (12”)	1.118 (44”)

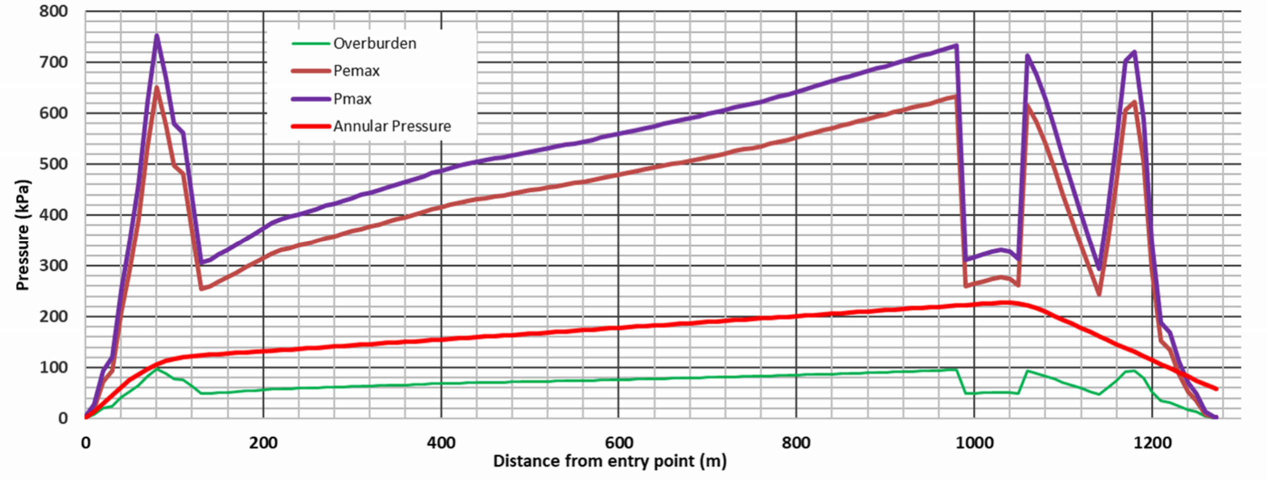
3. Assessment Results

3.1 River Taw Crossing

Under WIE’s original appointment for the Pre-FEED Study of the onshore cable route a bore profile for crossing the River Taw was developed. This profile is presented on drawing 12731-135-WIE-ZZ-XX-M3-C-91003 included in Appendix A and is discussed within the Onshore Cable Route Feasibility Assessment (WIE12731-135-R-1-2-4, June 2022). Considering the profile developed in terms of hydrofracture, results in estimates as presented in Figure 1.

Calculations are presented in Appendix B.

Figure 1: River Taw Crossing - Hydrofracture and Annular Pressure Estimates



The variation in pressures along the borehole are shown in Figure 1, where it can be seen the permissible boreholes pressures P_{emax} and P_{max} graphs initially vary due to cover depth changes where the topography rises before trending downwards into the river channel. The deepened channel that is indicatively drawn on the profile drawing (not picked up by bathymetric survey) results in a loss of cover depth and thus a drop in permissible pressure and then the point where the profile passes back of the river channel creates some varation in the cover and hence an erratic permissible pressure.

Another feature to note on this graph is that the permissible pressures are significantly larger than the overburden pressure and this is due to the nature of the assumptions in the 'Dutch' model. The difference between P_{emax} and P_{max} arises from consideration of the water table level and the added confinement pressure due to its hydrostatic effect.

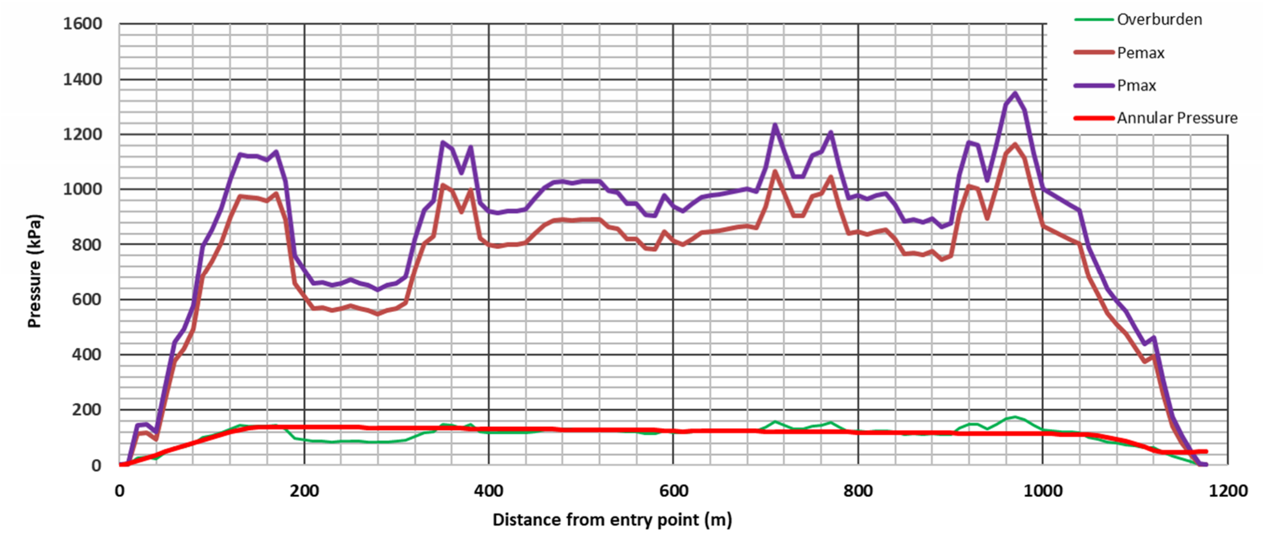
The most significant line on Figure 1 is the Annular Pressure which is the pressure in the borehole due to the drill fluid return flow. This pressure varies as the borehole progresses and is the sum of the static head and friction (flow) head. For most of the distance the annular pressure is well below P_{emax} and thus hydrofracture is not considered a concern. In the final stages of the bore profile the calculations show hydrofracture is likely as the profile begins to lose cover depth shortly before punch-out at CH1250. This is unavoidable but the effects can be easily controlled / mitigated onshore by putting appropriate site measures in place such as sandbagging and/or casing, to reduce and contain any hydrofracture. All drill fluids used should also be self-flocculating, environmentally inert and CEFAS approved.

3.2 Golf Course Crossing

Under WIE's original appointment for the Pre-FEED Study of the onshore cable route a bore profile for crossing the Golf Course was developed. This profile is presented on drawing 12731-135-WIE-ZZ-XX-M3-C-91006 included in Appendix A and is discussed within the Onshore Cable Route Feasibility Assessment (WIE12731-135-R-1-2-4, June 2022). Considering the profile developed in terms of hydrofracture, results in estimates as presented in Figure 2.

Calculations are presented in Appendix B.

Figure 2: Golf Course Crossing - Hydrofracture and Annular Pressure Estimates



The variation in pressures along the borehole are shown in Figure 2, where it can be seen the permissible boreholes pressures P_{emax} and P_{max} graphs vary due to topography changes across the golf course causing cover depth alterations.

Another feature to note on this graph is that the permissible pressures are significantly larger than the overburden pressure and this is due to the nature of the assumptions in the ‘Dutch’ model. The difference between P_{emax} and P_{max} arises from consideration of the water table level and the added confinement pressure due to its hydrostatic effect.

The most significant line on Figure 2 is the Annular Pressure which is the pressure in the borehole due to the drill fluid return flow. This pressure varies as the borehole progresses and is the sum of the static head and friction (flow) head. For most of the distance the annular pressure is well below P_{emax} and thus hydrofracture is not considered a concern. In the final stages of the bore profile the calculations show hydrofracture is likely as the profile begins to lose cover depth shortly before punch-out at CH1130. As with the River Taw crossing, this is unavoidable but the effects can be easily controlled / mitigated onshore by putting appropriate site measures in place such as sandbagging and/or casing, to reduce and contain any hydrofracture. All drill fluids used should also be self-flocculating, environmentally inert and CEFAS approved.

3.3 Landfall

In support of the cable route FEED study, WIE have developed an indicative profile for the cable landfall in order to demonstrate that an HDD methodology is feasible and to form the basis of preliminary hydrofracture calculations.

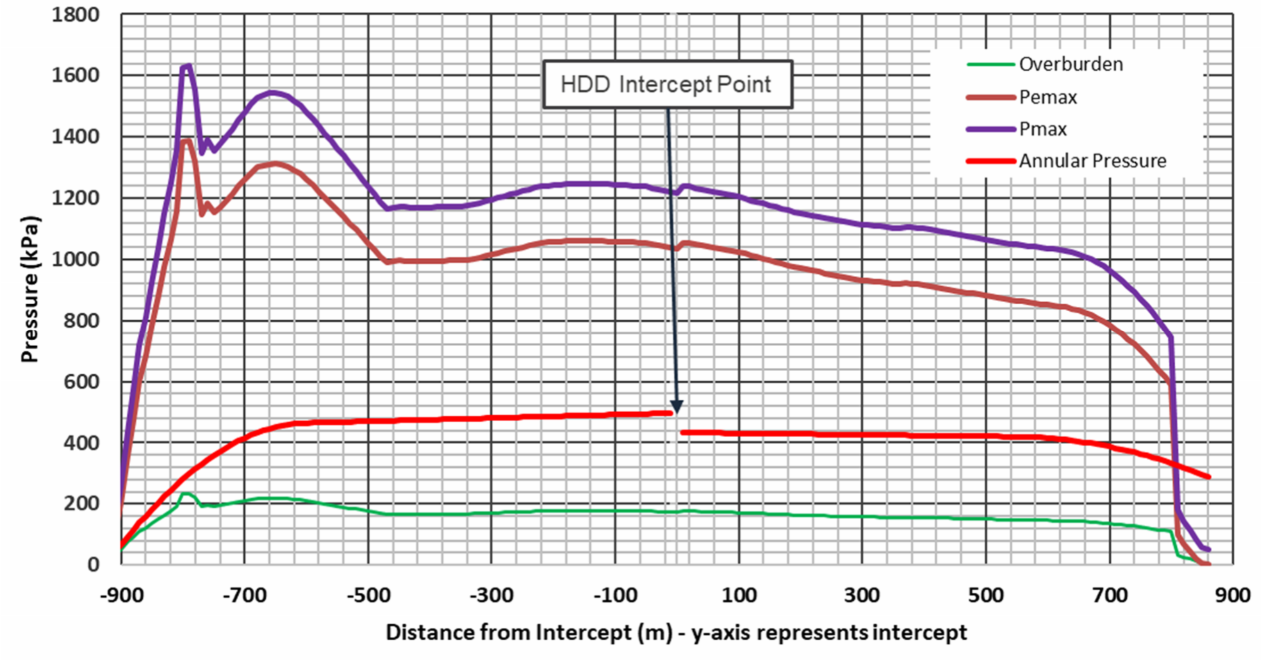
The preliminary profile design is presented on Drawing 12731-153-WIE-LF-XX-M3-C-91001 included in Appendix A. This indicative concept design has considered an entry point within the Saunton Sands beach car park extending out to a minimum water depth of -5m LAT, which is considered a likely minimum water depth for the follow-on cable installation works. This results in a bore length of circa 1860m.

Owing to the length of bore, and required ream size, at this stage it is considered likely that an intercept HDD methodology would be required with an onshore and offshore spread drilling pilot holes to 'intercept' at a point approximately mid-way along the bore. The bore would then be reamed by push-pull reaming from the onshore and offshore spreads. The offshore spread would require a Jack-Up Barge (JUB).

On this basis, considering a hydrofracture calculation requires consideration of the pressure head at both the onshore end, denoted by the entry hole level, and also the level of the jack-up barge sitting offshore. This would be determined by the HDD contractor at detailed design stage, thus, for the purpose of these calculations an arbitrary level of 8m AOD has been assumed based on a typical JUB deck height and allowing for wave clearance.

Calculations are presented in Appendix B.

Figure 3: Landfall - Hydrofracture and Annular Pressure Estimates



The variation in pressures along the borehole are shown in Figure 3, where it can be seen the permissible boreholes pressures P_{emax} and P_{max} initially vary due to cover depth changes within the sand dunes before trending gently downwards as per the seabed profile and subsequent cover depth.

Another feature to note on this graph is that the permissible pressures are significantly larger than the overburden pressure and this is due to the nature of the assumptions in the 'Dutch' model. The difference between P_{emax} and P_{max} arises from consideration of the water table level and the added confinement pressure due to its hydrostatic effect.

The most significant line on Figure 3 is the Annular Pressure which is the pressure in the borehole due to the drill fluid return flow. This pressure varies as the borehole progresses and is the sum of the static head and friction (flow) head. For most of the distance the annular pressure is well below P_{emax} and thus hydrofracture is not considered a concern. In the final stages of the bore profile the calculations show hydrofracture is likely as the profile begins to lose cover depth shortly before punch-out at CH1860. This is unavoidable, but would be mitigated through use of casing which will be required in any case to support the bore between the JUB deck and the seabed. All drill fluids used should also be self-flocculating, environmentally inert and CEFAS approved.

4. Conclusions & Recommendations

This preliminary hydrofracture assessment demonstrates that there is no significant risk of frac-out along the bore profiles with the exception of the final stages of the bore where the profile begins to rise resulting in loss of cover. This is unavoidable, but can be easily controlled onshore by site measures such as sandbagging and casing, in line with general HDD working methodologies. For the landfall, and assuming an intercept methodology, the risk will be controlled by the use of casing extending from the JUB deck down to the seabed (which is required regardless, to support the bore over this length).

These preliminary calculations should be updated as the design process develops and the variables become more known, such as bore diameters, ground conditions and groundwater levels. This will increase the accuracy of the assessment and inform any required design amendments, such as deepening of bore profiles, to mitigate risk should such be identified.

A. Design Drawings

This drawing should not be scaled. Dimensions to be verified on site.
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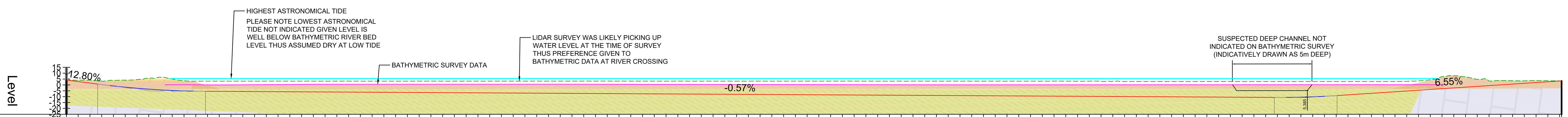
SITE COMPOUND LAYOUT KEY:

1. 50 KVA GENERATOR 2M X 2M
2. TOILET BLOCK 6M X 2M
3. DRY/CHANGE ROOM 6M X 2M
4. CANTEEN 6M X 2M
5. OFFICE 6M X 2M
6. OFFICE 6M X 2M
7. 21 TON TRACKED 360 EXCAVATOR
8. DRILL PIPE STORAGE 10M X 2M
9. HDD DRILL RIG 16M X 2M
10. POWER PACK 6M X 2M
11. CONTROL CABIN 6M X 2M
12. MUD LAB 3M X 2M
13. MUD ENTRY PIT 3M X 4M
14. HIGH PRESSURE MUD PUMP 6M X 2M
15. MUD MIXING TANK 7M X 2M
16. 350 KVA GENERATOR 5M X 2M
17. RECYCLING UNIT 6M X 2M
18. WATER STORAGE TANK 6M X 2M
19. DRY DRILLING FLUID STORAGE 4M X 10M
20. WORKSHOP 6M X 2M
21. STORES 6M X 2M

ILFRACOMBE TIDE GAUGE SITE	
TIDE LEVELS	ORDNANCE DATUM NEWLYN (mAOD)
HIGHEST ASTRONOMICAL TIDE	5.46
MEAN HIGH WATER SPRINGS	4.47
MEAN HIGH WATER NEAPS	2.19
MEAN LOW WATER NEAPS	-1.69
MEAN LOW WATER SPRINGS	-3.94
LOWEST ASTRONOMICAL TIDE	-4.89

RIVER CROSSING - LONGSECTION
SCALE: H 1:2000,V 1:2000. DATUM: -25.000



Chainage	Existing Levels	Level Difference
0.000	0.033	
10.000	0.081	1.202
20.000	0.123	2.508
30.000	0.165	2.960
40.000	0.186	4.834
50.000	0.163	5.969
60.000	0.141	7.331
70.000	0.119	9.231
80.000	0.097	10.751
90.000	0.108	9.764
100.000	0.139	8.697
110.000	0.094	8.496
120.000	0.025	8.594
130.000	0.000	8.661
140.000	0.013	8.721
150.000	0.082	8.782
160.000	0.150	8.849
170.000	0.219	8.912
180.000	0.288	8.984
190.000	0.356	9.018
200.000	0.425	9.068
210.000	0.493	9.139
220.000	0.507	9.191
230.000	0.511	9.261
240.000	0.516	9.328
250.000	0.521	9.367
260.000	0.525	9.419
270.000	0.530	9.459
280.000	0.535	9.528
290.000	0.539	9.595
300.000	0.544	9.671
310.000	0.549	9.739
320.000	0.553	9.762
330.000	0.558	9.832
340.000	0.563	9.890
350.000	0.567	9.980
360.000	0.572	10.020
370.000	0.577	10.081
380.000	0.581	10.151
390.000	0.586	10.202
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410.000	0.595	10.328
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450.000	0.541	10.551
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470.000	0.502	10.650
480.000	0.483	10.715
490.000	0.464	10.765
500.000	0.445	10.823
510.000	0.426	10.867
520.000	0.406	10.946
530.000	0.387	10.955
540.000	0.368	11.034
550.000	0.349	11.099
560.000	0.330	11.193
570.000	0.318	11.212
580.000	0.305	11.296
590.000	0.292	11.323
600.000	0.279	11.381
610.000	0.266	11.444
620.000	0.253	11.519
630.000	0.240	11.560
640.000	0.227	11.629
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680.000	0.177	11.866
690.000	0.167	11.889
700.000	0.156	11.948
710.000	0.149	12.037
720.000	0.138	12.088
730.000	0.134	12.152
740.000	0.123	12.190
750.000	0.102	12.271
760.000	0.086	12.299
770.000	0.088	12.354
780.000	0.090	12.425
790.000	0.093	12.488
800.000	0.095	12.497
810.000	0.097	12.550
820.000	0.100	12.689
830.000	0.102	12.673
840.000	0.104	12.781
850.000	0.107	12.840
860.000	0.109	12.815
870.000	0.111	12.940
880.000	0.114	12.690
890.000	0.116	13.015
900.000	0.118	12.807
910.000	0.121	12.862
920.000	0.123	12.920
930.000	0.125	12.977
940.000	0.128	13.035
950.000	0.130	13.092
960.000	0.132	13.150
970.000	0.135	13.207
980.000	0.137	13.264
990.000	0.139	13.322
1000.000	0.141	13.380
1010.000	0.144	13.437
1020.000	0.146	13.494
1030.000	0.148	13.547
1040.000	0.151	13.502
1050.000	0.153	13.323
1060.000	0.155	13.012
1070.000	0.158	12.567
1080.000	0.160	11.988
1090.000	0.162	11.334
1100.000	0.165	10.680
1110.000	0.167	10.025
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1170.000	0.181	10.151
1180.000	0.183	10.371
1190.000	0.186	8.801
1200.000	0.188	5.996
1210.000	0.190	3.972
1220.000	0.193	3.677
1230.000	0.195	2.811
1240.000	0.197	2.091
1250.000	0.199	1.680
1260.000	0.202	0.844
1270.000	0.204	0.090
1271.719	0.205	

Horizontal Geometry: L =1271.719

Vertical Geometry: G =-12.799% L =26.583 | R =750.000 K =7.500 L =91.681 | G =-0.574% L =909.051 | R =750.000 K =7.500 L =53.399 | G =6.545% L =190.892

GEOLOGY KEY

- BLOWN SANDS (SAND DUNES)
- DRIFT DEPOSITS
- ESTUARINE DEPOSITS
- ROCK

1:2000 0 20m 40m 60m 80m 100m 120m 140m 160m 180m 200m
1:1 0 10 20 30 40 50 60 70 80 90 100

Rev	Date	Description	By	Chk
P03	11.08.23	SITE COMPOUND LAYOUTS REMOVED. RE-ISSUED FOR INFORMATION AS PART OF PLANNING SUBMISSION	LP	CG
P02	10.03.23	TITLE UPDATED & DRAFT BANNER REMOVED	LP	CG
P01	23.05.22	DRAFT ISSUE FOR INFORMATION ONLY	LP	CG

Amendments

Project
WHITE CROSS FLOATING WINDFARM

Title
RIVER TAW OUTLINE HDD PLAN AND PROFILE

Client
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STOCKTON

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Suitability
FOR PLANNING SUBMISSION

Designed By	Director	Waterman Ref
LP	CG	WIE12731-135
Drawn By	Date	Scales @ A0
LP	20.05.22	AS NOTED
Stockton Checker	Stockton Approver	Date

Project - Originator - Volume - Level - Type - Role - Number	Revision
12731-135-WIE-ZZ-XX-M3-C-91003	P03
110-099-DRG-022	A01
FLO-WHI-LAY-0019	A1

File Path
N:\Projects\WIE12731_Stockton_HDD\135 - White Cross Floating Windfarm\100\6_Design\C3D\ALIGNMENTS & PROFILE\

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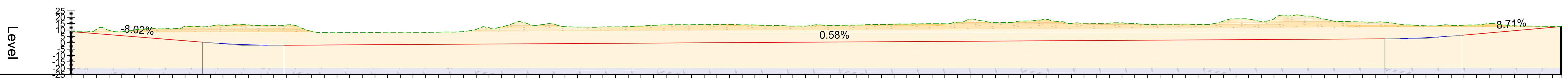
8. DRILL PIPE STORAGE 10M X 2M
9. HDD DRILL RIG 16M X 2M
10. POWER PACK 6M X 2M
11. CONTROL CABIN 6M X 2M
12. MUD LAB 3M X 2M
13. MUD ENTRY PIT 3M X 4M
14. HIGH PRESSURE MUD PUMP 6M X 2M
15. MUD MIXING TANK 7M X 2M
16. 350 KVA GENERATOR 5M X 2M
17. RECYCLING UNIT 6M X 2M
18. WATER STORAGE TANK 6M X 2M
19. DRY DRILLING FLUID STORAGE 4M X 10M
20. WORKSHOP 6M X 2M
21. STORES 6M X 2M

GOLF COURSE CROSSING - LONGSECTION
SCALE: H 1:2000,V 1:2000. DATUM: -25.000



Chainage	Existing Levels	Level Difference
0.000	8.743	-0.014
10.000	8.569	0.614
20.000	10.513	3.360
30.000	9.745	3.394
40.000	8.543	2.994
50.000	10.018	5.271
60.000	11.081	7.136
70.000	10.848	7.706
80.000	10.998	8.657
90.000	12.770	11.233
100.000	12.756	12.020
110.000	12.944	12.984
120.000	13.763	14.455
130.000	14.512	15.723
140.000	14.023	15.619
150.000	13.739	15.587
160.000	13.453	15.421
170.000	13.887	15.842
180.000	12.436	14.333
190.000	8.995	10.835
200.000	7.997	9.779
210.000	7.882	9.606
220.000	7.975	9.641
230.000	7.907	9.516
240.000	8.065	9.616
250.000	8.261	9.755
260.000	8.198	9.633
270.000	8.138	9.516
280.000	8.022	9.343
290.000	8.258	9.520
300.000	8.405	9.610
310.000	8.761	9.909
320.000	10.486	11.576
330.000	11.898	12.931
340.000	12.385	13.359
350.000	15.458	16.375
360.000	15.163	16.022
370.000	13.924	14.725
380.000	15.365	16.108
390.000	12.590	13.276
400.000	12.258	12.886
410.000	12.220	12.790
420.000	12.362	12.875
430.000	12.430	12.886
440.000	12.577	12.975
450.000	13.165	13.505
460.000	13.695	13.977
470.000	14.033	14.258
480.000	14.138	14.305
490.000	14.137	14.246
500.000	14.269	14.320
510.000	14.310	14.304
520.000	14.392	14.329
530.000	13.997	13.876
540.000	13.935	13.756
550.000	13.460	13.223
560.000	13.519	13.225
570.000	13.047	12.695
580.000	13.073	12.663
590.000	14.098	13.631
600.000	13.629	13.104
610.000	13.735	13.152
620.000	13.853	13.212
630.000	14.248	13.550
640.000	14.366	13.610
650.000	14.493	13.680
660.000	14.647	13.776
670.000	14.796	13.867
680.000	14.929	13.943
690.000	14.877	13.833
700.000	16.152	15.050
710.000	18.458	17.299
720.000	17.079	15.862
730.000	15.813	14.538
740.000	15.873	14.540
750.000	17.068	15.678
760.000	17.302	15.854
770.000	18.433	16.928
780.000	16.645	15.082
790.000	15.133	13.512
800.000	15.299	13.621
810.000	15.206	13.469
820.000	15.406	13.612
830.000	15.583	13.731
840.000	15.103	13.194
850.000	14.361	12.394
860.000	14.491	12.467
870.000	14.441	12.359
880.000	14.672	12.532
890.000	14.318	12.121
900.000	14.550	12.295
910.000	16.951	14.638
920.000	18.731	16.361
930.000	18.609	16.181
940.000	16.851	14.365
950.000	18.812	16.269
960.000	21.090	18.489
970.000	21.760	19.101
980.000	20.882	18.166
990.000	18.539	15.765
1000.000	16.761	13.930
1010.000	16.551	13.662
1020.000	16.336	13.389
1030.000	16.163	13.158
1040.000	15.989	12.923
1050.000	14.429	11.205
1060.000	13.817	10.303
1070.000	13.331	9.393
1080.000	13.353	8.857
1090.000	13.624	8.437
1100.000	13.759	7.750
1110.000	13.961	7.081
1120.000	15.095	7.344
1130.000	14.112	5.491
1140.000	13.297	3.805
1150.000	13.097	2.735
1160.000	12.951	1.718
1170.000	12.796	0.692
1176.745	12.740	0.049

Horizontal Geometry: L =1176.745

Vertical Geometry				
G =-8.022% L =103.742	R =750.000 K =7.500 L =64.488	G =0.577% L =869.295	R =750.000 K =7.500 L =60.976	G =8.707% L =78.827

GEOLOGY KEY
- BLOWN SANDS (SAND DUNES)
- DRIFT DEPOSITS
- ROCK

1:2000 0 20m 40m 60m 80m 100m 120m 140m 160m 180m 200m
1:1 0 10 20 30 40 50 60 70 80 90 100

Rev	Date	Description	By	Chk
P03	11.08.23	SITE COMPOUND LAYOUTS REMOVED. RE-ISSUED FOR INFORMATION AS PART OF PLANNING SUBMISSION	LP	CG
P02	10.03.23	TITLE UPDATED AND DRAFT BANNER REMOVED	LP	CG
P01	20.05.22	DRAFT ISSUE FOR INFORMATION ONLY	LP	CG

Amendments

Project
WHITE CROSS FLOATING WINDFARM

Title
SAUNTON GOLF CLUB OUTLINE HDD PLAN AND PROFILE

Client
FLOTATION ENERGY LTD

waterman
STOCKTON

Broxden House Broxden Business Park Lamberkine Drive Perth PH1 1RA
t: 01738 449 801
mail@watermangroup.com www.watermangroup.com

Suitability
FOR PLANNING SUBMISSION

Designed By	LP	Director	CG	Waterman Ref	WIE12731-135
Drawn By	LP	Date	20.05.22	Scales @ A0	AS NOTED
Stockton Checker		Stockton Approver		Date	

Project - Originator - Volume - Level - Type - Role - Number	Revision
12731-135-WIE-ZZ-XX-M3-C-91006	P03
110-099-DRG-021	A01
FLO-WHI-LAY-0018	A1

File Path
N:\Projects\WIE12731_Stockton_HDD\135 - White Cross Floating Windfarm\1006_Design\C3D\ALIGNMENTS & PROFILE\

ONSHORE

OFFSHORE

This drawing should not be scaled. Dimensions to be verified on site.
Any discrepancies should be referred to the Engineer prior to work being put in hand.

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2. ALL DIMENSIONS AND LEVELS ARE TO BE CHECKED ON SITE BY THE CONTRACTOR PRIOR TO PREPARING ANY WORKING DRAWINGS OR COMMENCING ON SITE.
3. THE CONTRACTOR MUST ENSURE AND WILL BE HELD RESPONSIBLE FOR THE OVERALL STABILITY OF THE BUILDING/STRUCTURE/EXCAVATION AT ALL STAGES OF THE WORK.
4. ALL WORK BY THE CONTRACTOR MUST BE CARRIED OUT IN SUCH A WAY THAT ALL REQUIREMENTS UNDER THE HEALTH AND SAFETY AT WORK ACT ARE SATISFIED.
5. ALL WORK IS TO BE CARRIED OUT IN COMPLIANCE WITH THE REQUIREMENTS OF THE RELEVANT STATUTORY AUTHORITIES AND REGULATIONS.

Rev	Date	Description	By	Chk
P02	11.08.23	UPDATED WITH CLIENT COMMENTS. RE-ISSUED FOR INFORMATION	LP	CG
P01	28.07.23	ISSUED AS DRAFT FOR INFORMATION	LP	CG

Amendments

Project
WHITE CROSS FLOATING WINDFARM

Title
CABLE LANDFALL OUTLINE HDD PLAN AND PROFILE

Client
FLOTATION ENERGY LTD

waterman STOCKTON

Broxden House Broxden Business Park Lamberkine Drive Perth PH1 1RA
t 01738 449 801
mail@watermangroup.com www.watermangroup.com

Suitability
FOR PLANNING SUBMISSION

Designed By LP	Director CG	Waterman Ref WIE12731-153
Drawn By LP	Date JULY 23	Scales @ A0 1:1250
Stockton Checker	Stockton Approver	Date

Project - Originator - Volume - Level - Type - Role - Number	Revision
12731-153-WIE-LF-XX-M3-C-91001	P02
110-099-DRG-020	A01
FLO-WHI-LAY-0017	A1

A0-Wat-SDL-S

File Path N:\Projects\WIE12731_Stockton_HDD\153 - White Cross Phase 2\7_CAD\91\

B. Hydrofracture Calculations

Hydrofracture - Longitudinal Profile Check

[redacted]

$$Pmax = Pemax + U \quad \text{Eqn(1)}$$

$$Pemax = (Pf + c.cot\emptyset).\left\{\left(\frac{Ro}{Rpmax}\right)^2 + Q\right\}^{\frac{-sin\emptyset}{1+sin\emptyset}} - c.cot\emptyset \quad \text{Eqn(2)}$$

$$Q = \frac{(\sigma o.sin\emptyset + c.cos\emptyset)}{G} \quad \text{Eqn(3)}$$

$$Pf = \sigma o\,(1 + sin\emptyset) + c.cos\emptyset \quad \text{Eqn(4)}$$

$$G = \frac{E}{2}\,(1 + \vartheta) \quad \text{Eqn(5)}$$

Where:

Pmax	maximum allowable mud pressure
U	initial in-situ pore pressure
Pemax	maximum allowable effective mud pressure
σ_o	initial effective stress
ϕ	internal angle of friction
c	cohesion
Ro	internal radius of borehole
Rpmax	maximum allowable radius of plastic zone
G	shear modulus
E	elasticity modulus
N	Poisson's ratio

[redacted]

General variables

Gravity (m/s/s):	**g**	9.81		
Density of water (kg/m3):	**ɣw**	1000		
Density of drilling mud (kg/m3):	**ɣm**	1300		
Soil density (kg/m^3):	**ɣs**	1950		
Cohesion (kN/m^2):	**Coh**	2		
Friction angle (deg):	**Φ**	25	Radians Φr =	0.4363
Poission's ratio :	**v**	0.3		
Elasticity modulus (kPa):	**Emod**	40000		
Shear modulus (kPa):	Gmod =	15385		

Soil characteristic values are all assumed and should be confirmed by Intrusive Ground Investigation.

Product pipe OD (m):				
Drill bit diameter (inch):	24.00 inch	**Do**	0.610 m	
Drill pipe OD (inch):	12.00 inch	**Di**	0.305 m	

Diameters assumed at feasibility stage.

Initial radius of borehole (m):	**Ro**	0.305	*Equal half drill bit diameter*
Allowable plastic radius factor	**Rpmax**	0.50	

Rpmax usually assumed between 1/2 and 2/3 depth, assumed 1/2 as worst case scenario

Consider lateral soil pressure: **No** ***Use drop-down to select Y/N***

Passive coefficient **ko** = IF(Y_N = "Yes", 1 - SIN(Φr), 0)
= IF(= "Yes", 1 - SIN(0.43633), 0)
= **0**

Conservative to not consider lateral soil pressures

Annular pressure calculations

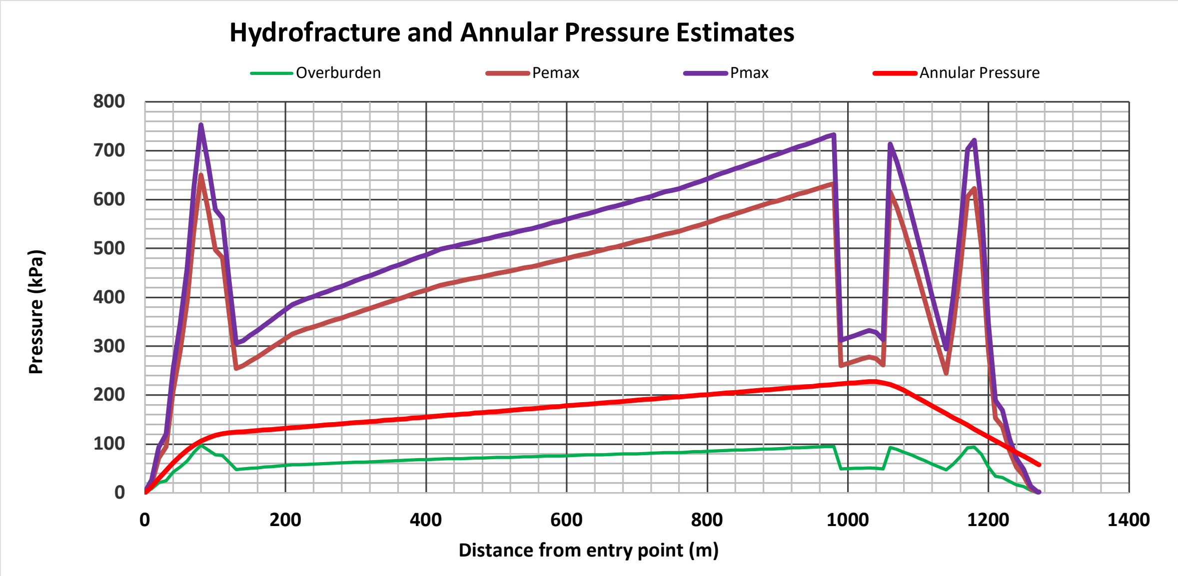
Darcy Weisbach equation for flow in an annulus is: H = f(L/Dh)(V^2/2g), where Dh is the hydraulic diameter, V the flow velocity, L flow pipe length and f is a friction factor. In the case of co-centered circular pipes Dh = Do - Di. The exact drilling operational parameters, such as flow rate are unknown, but some estimated values have been applied - but require verification. The total head is the flow head plus the static head.

Assumed flow velocity (m/s):	V	0.50
Assumed friction coefficient:	f	1.00

The calculations at each chainage location are performed in the frac-out table

Summary Figures

Elevation of entrance hole mOD =	**4.11**	**mOD**			
Elevation of exit hole mOD =	**3.44**	**mOD**	***Diff =***	***0.67***	m
Maximum cover to HDD borehole =	**10.4**	**m**			
Maximum overburden pressure =	**97.3**	**kN/m²**		***1.0***	***Bar***
Maximum safe effective stress **Pemax** =	**650**	**kN/m²**		***6.5***	***Bar***
Maximum safe stress **Pmax** =	**753**	**kN/m³**		***7.5***	***Bar***



Expressions used in hydrofracture calculations

In the tabulation below the following functions are applied

Saturated Layer **Sat'd**: IF (WTL<=HDD, Elevn-HDD, Max(Elevn-WTL, 0))

Bouyant Layer **Bou't**: IF (WTL<=HDD, 0, Min(WTL-HDD, Elevn-HDD))

σv = (ɣs*Satd+(ɣs-ɣw)*Bout)*g/1000

σo = SQRT((ɣs*Satd+(ɣs-ɣw)*Bout)^2 + (ko * (ɣs*Satd + (ɣs-ɣw)*Bout))^2))

Q = (σo*SIN(Φr) + Coh*COS(Φr)) / Gmod

Pf = (σo * (1+SIN(Φr))) + (Coh * COS(Φr))

Pemax = (Pf + Coh*COT(Φr)) * (((Ro/Rpmax)^2 + Q)^(-SIN(Φr)/(1+SIN(Φr)))) - Coh*COT(Φr)

Pelim = (Pf + Coh*COT(Φr)) * (Q^(-SIN(Φr)/(1+SIN(Φr)))) - Coh*COT(Φr)

LAT

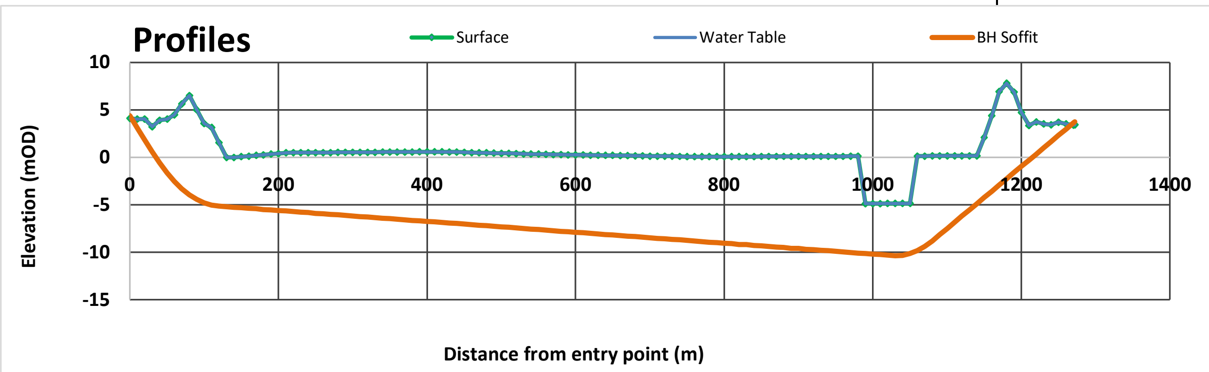
WT controls: 0 -4.89

Dist (m)	Elev'n (mOD)	Loc'n	WTL (mOD)	C-Line (mOD)	Soffit (mOD)	Cover (m)	Sat'd (m)	Bou't (m)	U kN/m2	Hs kN/m3
0.00	4.11		4.11	4.11	4.41	0.00	0.00	0.00	0	0
10.00	4.03		4.03	2.83	3.13	0.90	0.00	0.90	9	12
20.00	4.06		4.06	1.55	1.85	2.21	0.00	2.21	22	29
30.00	3.24		3.24	0.28	0.58	2.66	0.00	2.66	26	45
40.00	3.94		3.94	-0.89	-0.59	4.53	0.00	4.53	44	60
50.00	4.04		4.04	-1.93	-1.63	5.67	0.00	5.67	56	73
60.00	4.50		4.50	-2.83	-2.53	7.03	0.00	7.03	69	85
70.00	5.64		5.64	-3.59	-3.29	8.93	0.00	8.93	88	94
80.00	6.52		6.52	-4.23	-3.93	10.45	0.00	10.45	102	102
90.00	5.03		5.03	-4.73	-4.43	9.46	0.00	9.46	93	109
100.00	3.60		3.60	-5.10	-4.80	8.39	0.00	8.39	82	114
110.00	3.16		3.16	-5.33	-5.03	8.19	0.00	8.19	80	117
120.00	1.58		1.58	-5.43	-5.13	6.71	0.00	6.71	66	118
130.00	0.00		0.00	-5.49	-5.19	5.19	0.00	5.19	51	119
140.00	0.01		0.01	-5.55	-5.25	5.26	0.00	5.26	52	119
150.00	0.08		0.08	-5.61	-5.31	5.39	0.00	5.39	53	120
160.00	0.15		0.15	-5.66	-5.36	5.51	0.00	5.51	54	121
170.00	0.22		0.22	-5.72	-5.42	5.63	0.00	5.63	55	121
180.00	0.29		0.29	-5.78	-5.48	5.76	0.00	5.76	57	122
190.00	0.36		0.36	-5.84	-5.54	5.89	0.00	5.89	58	123
200.00	0.43		0.43	-5.89	-5.59	6.01	0.00	6.01	59	124
210.00	0.49		0.49	-5.95	-5.65	6.14	0.00	6.14	60	124
220.00	0.51		0.51	-6.01	-5.71	6.21	0.00	6.21	61	125
230.00	0.51		0.51	-6.07	-5.77	6.28	0.00	6.28	62	126
240.00	0.52		0.52	-6.12	-5.82	6.33	0.00	6.33	62	127
250.00	0.52		0.52	-6.18	-5.88	6.40	0.00	6.40	63	127
260.00	0.53		0.53	-6.24	-5.94	6.46	0.00	6.46	63	128
270.00	0.53		0.53	-6.30	-6.00	6.53	0.00	6.53	64	129
280.00	0.54		0.54	-6.35	-6.05	6.58	0.00	6.58	65	130
290.00	0.54		0.54	-6.41	-6.11	6.64	0.00	6.64	65	130
300.00	0.54		0.54	-6.47	-6.17	6.71	0.00	6.71	66	131
310.00	0.55		0.55	-6.53	-6.23	6.77	0.00	6.77	66	132
320.00	0.55		0.55	-6.58	-6.28	6.83	0.00	6.83	67	132
330.00	0.56		0.56	-6.64	-6.34	6.89	0.00	6.89	68	133
340.00	0.56		0.56	-6.70	-6.40	6.96	0.00	6.96	68	134
350.00	0.57		0.57	-6.76	-6.46	7.02	0.00	7.02	69	135
360.00	0.57		0.57	-6.81	-6.51	7.08	0.00	7.08	69	135
370.00	0.58		0.58	-6.87	-6.57	7.14	0.00	7.14	70	136
380.00	0.58		0.58	-6.93	-6.63	7.21	0.00	7.21	71	137
390.00	0.59		0.59	-6.99	-6.69	7.27	0.00	7.27	71	138
400.00	0.59		0.59	-7.04	-6.74	7.33	0.00	7.33	72	138
410.00	0.60		0.60	-7.10	-6.80	7.39	0.00	7.39	72	139
420.00	0.60		0.60	-7.16	-6.86	7.45	0.00	7.45	73	140
430.00	0.58		0.58	-7.22	-6.92	7.49	0.00	7.49	74	141
440.00	0.56		0.56	-7.27	-6.97	7.53	0.00	7.53	74	141
450.00	0.54		0.54	-7.33	-7.03	7.57	0.00	7.57	74	142
460.00	0.52		0.52	-7.39	-7.09	7.61	0.00	7.61	75	143
470.00	0.50		0.50	-7.44	-7.14	7.64	0.00	7.64	75	143
480.00	0.48		0.48	-7.50	-7.20	7.68	0.00	7.68	75	144
490.00	0.46		0.46	-7.56	-7.26	7.72	0.00	7.72	76	145
500.00	0.45		0.45	-7.62	-7.32	7.76	0.00	7.76	76	146
510.00	0.43		0.43	-7.67	-7.37	7.79	0.00	7.79	76	146
520.00	0.41		0.41	-7.73	-7.43	7.83	0.00	7.83	77	147

530.00	0.39	0.39	-7.79	-7.49	7.87	0.00	7.87	77	148
540.00	0.37	0.37	-7.85	-7.55	7.91	0.00	7.91	78	149
550.00	0.35	0.35	-7.90	-7.60	7.94	0.00	7.94	78	149
560.00	0.33	0.33	-7.96	-7.66	7.99	0.00	7.99	78	150
570.00	0.32	0.32	-8.02	-7.72	8.03	0.00	8.03	79	151
580.00	0.31	0.31	-8.08	-7.78	8.08	0.00	8.08	79	152
590.00	0.29	0.29	-8.13	-7.83	8.12	0.00	8.12	80	152
600.00	0.28	0.28	-8.19	-7.89	8.16	0.00	8.16	80	153
610.00	0.27	0.27	-8.25	-7.95	8.21	0.00	8.21	81	154
620.00	0.25	0.25	-8.31	-8.01	8.26	0.00	8.26	81	155
630.00	0.24	0.24	-8.36	-8.06	8.30	0.00	8.30	81	155
640.00	0.23	0.23	-8.42	-8.12	8.34	0.00	8.34	82	156
650.00	0.22	0.22	-8.48	-8.18	8.39	0.00	8.39	82	157
660.00	0.20	0.20	-8.54	-8.24	8.44	0.00	8.44	83	157
670.00	0.19	0.19	-8.59	-8.29	8.47	0.00	8.47	83	158
680.00	0.18	0.18	-8.65	-8.35	8.52	0.00	8.52	84	159
690.00	0.17	0.17	-8.71	-8.41	8.57	0.00	8.57	84	160
700.00	0.16	0.16	-8.77	-8.47	8.62	0.00	8.62	85	160
710.00	0.15	0.15	-8.82	-8.52	8.66	0.00	8.66	85	161
720.00	0.14	0.14	-8.88	-8.58	8.71	0.00	8.71	85	162
730.00	0.13	0.13	-8.94	-8.64	8.77	0.00	8.77	86	163
740.00	0.12	0.12	-9.00	-8.70	8.82	0.00	8.82	87	163
750.00	0.10	0.10	-9.05	-8.75	8.85	0.00	8.85	87	164
760.00	0.09	0.09	-9.11	-8.81	8.89	0.00	8.89	87	165
770.00	0.09	0.09	-9.17	-8.87	8.95	0.00	8.95	88	165
780.00	0.09	0.09	-9.23	-8.93	9.02	0.00	9.02	88	166
790.00	0.09	0.09	-9.28	-8.98	9.07	0.00	9.07	89	167
800.00	0.10	0.10	-9.34	-9.04	9.13	0.00	9.13	90	168
810.00	0.10	0.10	-9.40	-9.10	9.19	0.00	9.19	90	168
820.00	0.10	0.10	-9.46	-9.16	9.26	0.00	9.26	91	169
830.00	0.10	0.10	-9.51	-9.21	9.31	0.00	9.31	91	170
840.00	0.10	0.10	-9.57	-9.27	9.37	0.00	9.37	92	171
850.00	0.11	0.11	-9.63	-9.33	9.43	0.00	9.43	93	171
860.00	0.11	0.11	-9.69	-9.39	9.49	0.00	9.49	93	172
870.00	0.11	0.11	-9.74	-9.44	9.55	0.00	9.55	94	173
880.00	0.11	0.11	-9.80	-9.50	9.61	0.00	9.61	94	174
890.00	0.12	0.12	-9.86	-9.56	9.67	0.00	9.67	95	174
900.00	0.12	0.12	-9.91	-9.61	9.72	0.00	9.72	95	175
910.00	0.12	0.12	-9.97	-9.67	9.79	0.00	9.79	96	176
920.00	0.12	0.12	-10.03	-9.73	9.85	0.00	9.85	97	176
930.00	0.13	0.13	-10.09	-9.79	9.91	0.00	9.91	97	177
940.00	0.13	0.13	-10.14	-9.84	9.96	0.00	9.96	98	178
950.00	0.13	0.13	-10.20	-9.90	10.03	0.00	10.03	98	179
960.00	0.13	0.13	-10.26	-9.96	10.09	0.00	10.09	99	179
970.00	0.14	0.14	-10.32	-10.02	10.15	0.00	10.15	100	180
980.00	0.14	0.14	-10.37	-10.07	10.20	0.00	10.20	100	181
990.00	-4.86	-4.86	-10.43	-10.13	5.27	0.00	5.27	52	182
1000.00	-4.86	-4.86	-10.49	-10.19	5.33	0.00	5.33	52	182
1010.00	-4.86	-4.86	-10.55	-10.25	5.39	0.00	5.39	53	183
1020.00	-4.85	-4.85	-10.60	-10.30	5.45	0.00	5.45	53	184
1030.00	-4.85	-4.85	-10.66	-10.36	5.51	0.00	5.51	54	184
1040.00	-4.85	-4.85	-10.61	-10.31	5.46	0.00	5.46	54	184
1050.00	-4.85	-4.85	-10.43	-10.13	5.28	0.00	5.28	52	182
1060.00	0.16	0.16	-10.12	-9.82	9.97	0.00	9.97	98	178
1070.00	0.16	0.16	-9.68	-9.38	9.53	0.00	9.53	94	172
1080.00	0.16	0.16	-9.10	-8.80	8.96	0.00	8.96	88	165
1090.00	0.16	0.16	-8.44	-8.14	8.30	0.00	8.30	81	156
1100.00	0.17	0.17	-7.79	-7.49	7.65	0.00	7.65	75	148
1110.00	0.17	0.17	-7.14	-6.84	7.00	0.00	7.00	69	140
1120.00	0.17	0.17	-6.48	-6.18	6.34	0.00	6.34	62	131
1130.00	0.17	0.17	-5.83	-5.53	5.70	0.00	5.70	56	123
1140.00	0.17	0.17	-5.17	-4.87	5.04	0.00	5.04	49	114
1150.00	2.13	2.13	-4.52	-4.22	6.35	0.00	6.35	62	106
1160.00	4.42	4.42	-3.86	-3.56	7.98	0.00	7.98	78	98
1170.00	6.94	6.94	-3.21	-2.91	9.85	0.00	9.85	97	89
1180.00	7.82	7.82	-2.55	-2.25	10.06	0.00	10.06	99	81
1190.00	6.90	6.90	-1.90	-1.60	8.50	0.00	8.50	83	73

1200.00	4.75	4.75	-1.24	-0.94	5.69	0.00	5.69	***56***	***64***
1210.00	3.38	3.38	-0.59	-0.29	3.67	0.00	3.67	***36***	***56***
1220.00	3.74	3.74	0.06	0.36	3.38	0.00	3.38	***33***	***48***
1230.00	3.53	3.53	0.72	1.02	2.51	0.00	2.51	***25***	***39***
1240.00	3.47	3.47	1.37	1.67	1.79	0.00	1.79	***18***	***31***
1250.00	3.71	3.71	2.03	2.33	1.37	0.00	1.37	***13***	***23***
1260.00	3.53	3.53	2.68	2.98	0.54	0.00	0.54	***5***	***14***
1270.00	3.43	3.43	3.34	3.64	0.00	0.00	0.00	***0***	***6***
1272.00	3.44	3.44	3.44	3.74	0.00	0.00	0.00	***0***	***5***

HDD borehole profile graph based on the above table



*The pressure calculations are set out in this table. Note that **Rpmax** varies as it is set to be a proportion of the cover depth.*

Hf is a rough estimate of the drilling mud pressure in the return annular flow.

*The total head **H** is the static head **Hs** (table above) and **Hf**.*

Dist (m)	σv (kN/m²)	σh (kN/m²)	σo (kN/m²)	Pf (kN/m²)	Q	Rpmax (m)	Pemax (kN/m²)	Pmax (kN/m²)	Hf (kN/m²)	H (kN/m²)
0.0	0.0	0.0	0.0	1.8	0.00012	0.3	2	2	0	0
10.0	8.3	0.0	8.3	13.7	0.00035	0.4	18	27	0	13
20.0	20.6	0.0	20.6	31.0	0.00068	1.1	71	93	1	30
30.0	24.7	0.0	24.7	37.0	0.00080	1.3	94	120	1	46
40.0	42.2	0.0	42.2	61.8	0.00128	2.3	209	253	2	62
50.0	52.8	0.0	52.8	77.0	0.00157	2.8	290	346	2	75
60.0	65.5	0.0	65.5	95.0	0.00192	3.5	392	461	3	87
70.0	83.2	0.0	83.2	120.1	0.00240	4.5	538	625	3	97
80.0	97.3	0.0	97.3	140.3	0.00279	5.2	650	753	3	106
90.0	88.1	0.0	88.1	127.2	0.00254	4.7	577	670	4	113
100.0	78.2	0.0	78.2	113.1	0.00227	4.2	497	579	4	118
110.0	76.3	0.0	76.3	110.4	0.00221	4.1	481	562	5	121
120.0	62.5	0.0	62.5	90.7	0.00183	3.4	368	434	5	123
130.0	48.3	0.0	48.3	70.6	0.00145	2.6	255	306	5	124
140.0	49.0	0.0	49.0	71.5	0.00146	2.6	260	312	6	125
150.0	50.2	0.0	50.2	73.2	0.00150	2.7	270	322	6	126
160.0	51.3	0.0	51.3	74.8	0.00153	2.8	278	332	7	127
170.0	52.5	0.0	52.5	76.5	0.00156	2.8	288	343	7	129
180.0	53.7	0.0	53.7	78.2	0.00159	2.9	297	354	8	130
190.0	54.9	0.0	54.9	79.9	0.00163	2.9	306	364	8	131
210.0	57.2	0.0	57.2	83.2	0.00169	3.1	325	385	9	133
220.0	57.9	0.0	57.9	84.2	0.00171	3.1	330	391	9	134
230.0	58.5	0.0	58.5	85.0	0.00172	3.1	335	397	10	136
240.0	59.0	0.0	59.0	85.8	0.00174	3.2	339	402	10	137
250.0	59.6	0.0	59.6	86.6	0.00176	3.2	344	407	10	138
260.0	60.2	0.0	60.2	87.5	0.00177	3.2	349	413	11	139
270.0	60.8	0.0	60.8	88.3	0.00179	3.3	354	418	11	140
280.0	61.3	0.0	61.3	89.1	0.00180	3.3	358	423	12	141
290.0	61.9	0.0	61.9	89.9	0.00182	3.3	363	428	12	142
300.0	62.5	0.0	62.5	90.8	0.00184	3.4	368	434	13	144
310.0	63.1	0.0	63.1	91.6	0.00185	3.4	373	439	13	145
320.0	63.6	0.0	63.6	92.3	0.00187	3.4	377	444	13	146
330.0	64.2	0.0	64.2	93.2	0.00188	3.4	382	450	14	147
340.0	64.8	0.0	64.8	94.1	0.00190	3.5	387	455	14	148
350.0	65.4	0.0	65.4	94.9	0.00192	3.5	392	461	15	149
360.0	66.0	0.0	66.0	95.6	0.00193	3.5	396	466	15	150
370.0	66.6	0.0	66.6	96.5	0.00195	3.6	401	471	15	152
380.0	67.2	0.0	67.2	97.4	0.00196	3.6	406	477	16	153
390.0	67.8	0.0	67.8	98.2	0.00198	3.6	411	482	16	154
400.0	68.3	0.0	68.3	98.9	0.00199	3.7	415	487	17	155
410.0	68.9	0.0	68.9	99.8	0.00201	3.7	420	493	17	156
420.0	69.5	0.0	69.5	100.6	0.00203	3.7	425	498	18	157
430.0	69.8	0.0	69.8	101.2	0.00204	3.7	428	502	18	159
440.0	70.1	0.0	70.1	101.6	0.00204	3.8	431	504	18	160
450.0	70.5	0.0	70.5	102.1	0.00205	3.8	434	508	19	161
460.0	70.9	0.0	70.9	102.7	0.00207	3.8	437	511	19	162
470.0	71.2	0.0	71.2	103.1	0.00207	3.8	439	514	20	163
480.0	71.6	0.0	71.6	103.6	0.00208	3.8	442	518	20	164
490.0	71.9	0.0	71.9	104.2	0.00209	3.9	445	521	20	165
500.0	72.3	0.0	72.3	104.7	0.00210	3.9	449	525	21	167
510.0	72.6	0.0	72.6	105.1	0.00211	3.9	451	527	21	168
520.0	73.0	0.0	73.0	105.6	0.00212	3.9	454	531	22	169

530.0	73.4	0.0	73.4	106.2	0.00213	3.9	457	534	22	170
540.0	73.7	0.0	73.7	106.7	0.00214	4.0	460	538	23	171
550.0	74.0	0.0	74.0	107.1	0.00215	4.0	463	541	23	172
560.0	74.4	0.0	74.4	107.7	0.00216	4.0	466	544	23	173
570.0	74.9	0.0	74.9	108.3	0.00217	4.0	469	548	24	175
580.0	75.3	0.0	75.3	108.9	0.00219	4.0	473	552	24	176
590.0	75.6	0.0	75.6	109.4	0.00220	4.1	476	556	25	177
600.0	76.1	0.0	76.1	110.1	0.00221	4.1	480	560	25	178
610.0	76.5	0.0	76.5	110.7	0.00222	4.1	483	564	26	179
620.0	77.0	0.0	77.0	111.3	0.00223	4.1	487	568	26	180
630.0	77.3	0.0	77.3	111.8	0.00224	4.1	490	571	26	181
640.0	77.7	0.0	77.7	112.4	0.00225	4.2	493	575	27	183
650.0	78.2	0.0	78.2	113.1	0.00227	4.2	497	579	27	184
660.0	78.6	0.0	78.6	113.7	0.00228	4.2	500	583	28	185
670.0	79.0	0.0	79.0	114.2	0.00229	4.2	503	586	28	186
680.0	79.4	0.0	79.4	114.8	0.00230	4.3	507	591	28	187
690.0	79.9	0.0	79.9	115.5	0.00231	4.3	511	595	29	188
700.0	80.3	0.0	80.3	116.1	0.00232	4.3	514	599	29	190
710.0	80.7	0.0	80.7	116.7	0.00234	4.3	518	603	30	191
720.0	81.2	0.0	81.2	117.3	0.00235	4.4	521	607	30	192
730.0	81.7	0.0	81.7	118.1	0.00236	4.4	526	612	31	193
740.0	82.2	0.0	82.2	118.7	0.00238	4.4	529	616	31	194
750.0	82.5	0.0	82.5	119.1	0.00238	4.4	532	618	31	195
760.0	82.9	0.0	82.9	119.7	0.00239	4.4	535	622	32	196
770.0	83.4	0.0	83.4	120.5	0.00241	4.5	540	627	32	198
780.0	84.0	0.0	84.0	121.3	0.00243	4.5	544	633	33	199
790.0	84.5	0.0	84.5	122.0	0.00244	4.5	548	637	33	200
800.0	85.1	0.0	85.1	122.9	0.00246	4.6	553	643	33	201
810.0	85.7	0.0	85.7	123.7	0.00247	4.6	558	648	34	202
820.0	86.3	0.0	86.3	124.5	0.00249	4.6	562	653	34	203
830.0	86.7	0.0	86.7	125.2	0.00250	4.7	566	658	35	205
840.0	87.3	0.0	87.3	126.0	0.00252	4.7	571	663	35	206
850.0	87.9	0.0	87.9	126.9	0.00253	4.7	576	668	36	207
860.0	88.5	0.0	88.5	127.7	0.00255	4.7	580	673	36	208
870.0	89.0	0.0	89.0	128.4	0.00256	4.8	584	678	36	209
880.0	89.6	0.0	89.6	129.2	0.00258	4.8	589	683	37	210
890.0	90.1	0.0	90.1	130.0	0.00259	4.8	594	688	37	211
900.0	90.6	0.0	90.6	130.7	0.00261	4.9	597	693	38	213
910.0	91.2	0.0	91.2	131.6	0.00262	4.9	602	698	38	214
920.0	91.8	0.0	91.8	132.4	0.00264	4.9	607	703	38	215
930.0	92.4	0.0	92.4	133.2	0.00265	5.0	611	708	39	216
940.0	92.9	0.0	92.9	133.9	0.00267	5.0	615	713	39	217
950.0	93.4	0.0	93.4	134.7	0.00268	5.0	620	718	40	218
960.0	94.0	0.0	94.0	135.5	0.00270	5.0	624	723	40	220
970.0	94.6	0.0	94.6	136.4	0.00272	5.1	629	728	41	221
980.0	95.1	0.0	95.1	137.1	0.00273	5.1	633	733	41	222
990.0	49.1	0.0	49.1	71.6	0.00147	2.6	261	312	41	223
1000.0	49.6	0.0	49.6	72.4	0.00148	2.7	265	317	42	224
1010.0	50.2	0.0	50.2	73.2	0.00150	2.7	269	322	42	225
1020.0	50.7	0.0	50.7	74.0	0.00151	2.7	274	327	43	226
1030.0	51.3	0.0	51.3	74.8	0.00153	2.8	278	332	43	228
1040.0	50.8	0.0	50.8	74.1	0.00151	2.7	274	328	43	227
1050.0	49.2	0.0	49.2	71.8	0.00147	2.6	261	313	44	225
1060.0	92.9	0.0	92.9	134.0	0.00267	5.0	616	713	44	222
1070.0	88.8	0.0	88.8	128.2	0.00256	4.8	583	677	45	217
1080.0	83.5	0.0	83.5	120.5	0.00241	4.5	540	628	45	210
1090.0	77.3	0.0	77.3	111.8	0.00224	4.1	490	571	46	202
1100.0	71.3	0.0	71.3	103.2	0.00208	3.8	440	515	46	194
1110.0	65.3	0.0	65.3	94.6	0.00191	3.5	390	459	46	186
1120.0	59.1	0.0	59.1	85.9	0.00174	3.2	340	403	47	178
1130.0	53.1	0.0	53.1	77.3	0.00158	2.8	292	348	47	170
1140.0	47.0	0.0	47.0	68.6	0.00141	2.5	245	294	48	162
1150.0	59.1	0.0	59.1	85.9	0.00174	3.2	340	403	48	154
1160.0	74.4	0.0	74.4	107.6	0.00216	4.0	465	544	48	146
1170.0	91.8	0.0	91.8	132.4	0.00264	4.9	607	703	49	138
1180.0	93.8	0.0	93.8	135.2	0.00269	5.0	622	721	49	130
1190.0	79.2	0.0	79.2	114.5	0.00229	4.2	505	588	50	123
1200.0	53.0	0.0	53.0	77.2	0.00157	2.8	291	347	50	115
1210.0	34.2	0.0	34.2	50.4	0.00106	1.8	153	189	51	107
1220.0	31.5	0.0	31.5	46.6	0.00098	1.7	135	168	51	99
1230.0	23.3	0.0	23.3	35.0	0.00076	1.3	86	111	51	91
1240.0	16.7	0.0	16.7	25.5	0.00058	0.9	52	70	52	83
1250.0	12.8	0.0	12.8	20.0	0.00047	0.7	35	49	52	75
1260.0	5.1	0.0	5.1	9.0	0.00026	0.3	8	13	53	67
1270.0	0.0	0.0	0.0	1.8	0.00012	0.3	2	2	53	59
1272.0	0.0	0.0	0.0	1.8	0.00012	0.3	2	2	53	58

Comments

Hydrofracture - Longitudinal Profile Check

[redacted]

$$Pmax = Pemax + U$$ ***Eqn(1)***

$$Pemax = (Pf + c.\cot\emptyset).\left\{\left(\frac{Ro}{Rpmax}\right)^2 + Q\right\}^{\frac{-\sin\emptyset}{1+\sin\emptyset}} - c.\cot\emptyset$$ ***Eqn(2)***

$$Q = \frac{(\sigma o.\sin\emptyset + c.\cos\emptyset)}{G}$$ ***Eqn(3)***

$$Pf = \sigma o\,(1 + \sin\emptyset) + c.\cos\emptyset$$ ***Eqn(4)***

$$G = \frac{E}{2}\,(1 + \vartheta)$$ ***Eqn(5)***

Where:

Pmax	maximum allowable mud pressure
U	initial in-situ pore pressure
Pemax	maximum allowable effective mud pressure
σ_o	initial effective stress
ϕ	internal angle of friction
c	cohesion
Ro	internal radius of borehole
Rpmax	maximum allowable radius of plastic zone
G	shear modulus
E	elasticity modulus
N	Poisson's ratio

[redacted]

General variables

Gravity (m/s/s):	**g**	9.81		
Density of water (kg/m3):	**ɣw**	1000		
Density of drilling mud (kg/m3):	**ɣm**	1300		
Soil density (kg/m^3):	**ɣs**	1950		
Cohesion (kN/m^2):	**Coh**	2		
Friction angle (deg):	**Φ**	25	Radians Φr =	0.4363
Poission's ratio :	**v**	0.3		
Elasticity modulus (kPa):	**Emod**	40000		
Shear modulus (kPa):	Gmod =	15385		

Soil characteristic values are all assumed and should be confirmed by Intrusive Ground Investigation.

Product pipe OD (m):			
Drill bit diameter (inch):	24.00 inch	**Do**	0.610 m
Drill pipe OD (inch):	12.00 inch	**Di**	0.305 m

Diameters assumed at feasibility stage.

Initial radius of borehole (m):	**Ro**	0.305	*Equal half drill bit diameter*
Allowable plastic radius factor	**Rpmax**	0.50	

Rpmax usually assumed between 1/2 and 2/3 depth, assumed 1/2 as worst case scenario

Consider lateral soil pressure: **No** ***Use drop-down to select Y/N***

Passive coefficient **ko** = IF(Y_N = "Yes", 1 - SIN(Φr), 0)
= IF(= "Yes", 1 - SIN(0.43633), 0)
= **0**

Conservative to not consider lateral soil pressures

Annular pressure calculations

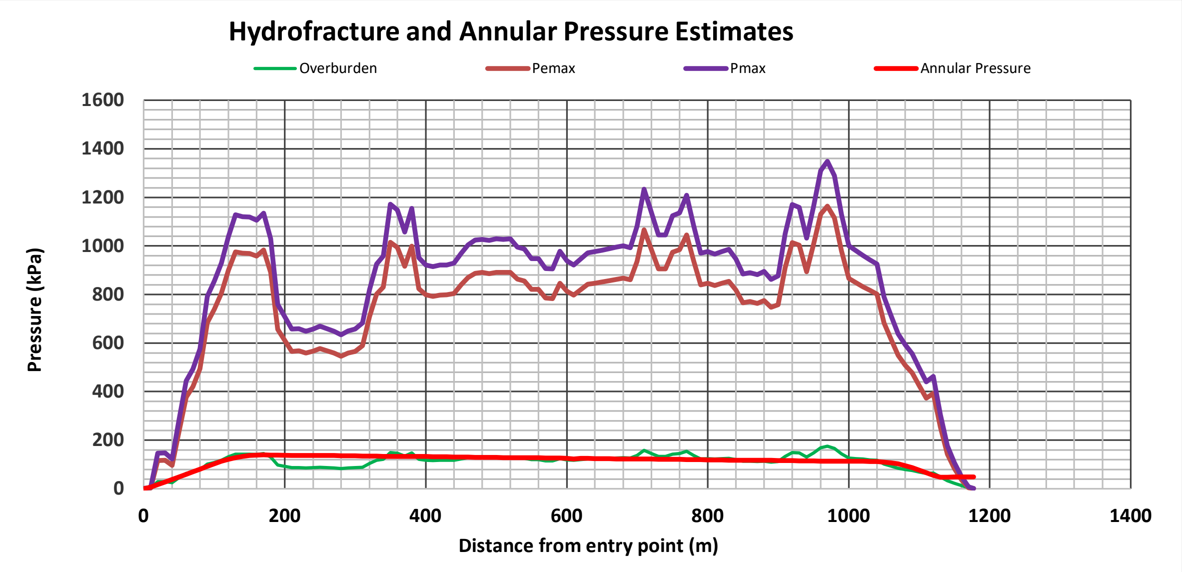
Darcy Weisbach equation for flow in an annulus is: H = f(L/Dh)(V^2/2g), where Dh is the hydraulic diameter, V the flow velocity, L flow pipe length and f is a friction factor. In the case of co-centered circular pipes Dh = Do - Di. The exact drilling operational parameters, such as flow rate are unknown, but some estimated values have been applied - but require verification. The total head is the flow head plus the static head.

Assumed flow velocity (m/s):	V	0.50
Assumed friction coefficient:	f	1.00

The calculations at each chainage location are performed in the frac-out table

Summary Figures

Elevation of entrance hole mOD =	**8.74**	**mOD**		
Elevation of exit hole mOD =	**12.74**	**mOD**	***Diff =***	***-4.00*** m
Maximum cover to HDD borehole =	**18.8**	**m**		
Maximum overburden pressure =	**175.2**	**kN/m^2**		***1.8 Bar***
Maximum safe effective stress **Pemax** =	**1164**	**kN/m^2**		***11.6 Bar***
Maximum safe stress **Pmax** =	**1348**	**kN/m^3**		***13.5 Bar***



Expressions used in hydrofracture calculations

In the tabulation below the following functions are applied

Saturated Layer **Sat'd**: IF (WTL<=HDD, Elevn-HDD, Max(Elevn-WTL, 0))

Bouyant Layer **Bou't**: IF (WTL<=HDD, 0, Min(WTL-HDD, Elevn-HDD))

σv = (ɣs*Satd+(ɣs-ɣw)*Bout)*g/1000

σo = SQRT((ɣs*Satd+(ɣs-ɣw)*Bout)^2 + (ko * (ɣs*Satd + (ɣs-ɣw)*Bout))^2))

Q = (σo*SIN(Φr) + Coh*COS(Φr)) / Gmod

Pf = (σo * (1+SIN(Φr))) + (Coh * COS(Φr))

Pemax = (Pf + Coh*COT(Φr)) * (((Ro/Rpmax)^2 + Q)^(-SIN(Φr)/(1+SIN(Φr)))) - Coh*COT(Φr)

Pelim = (Pf + Coh*COT(Φr)) * (Q^(-SIN(Φr)/(1+SIN(Φr)))) - Coh*COT(Φr)

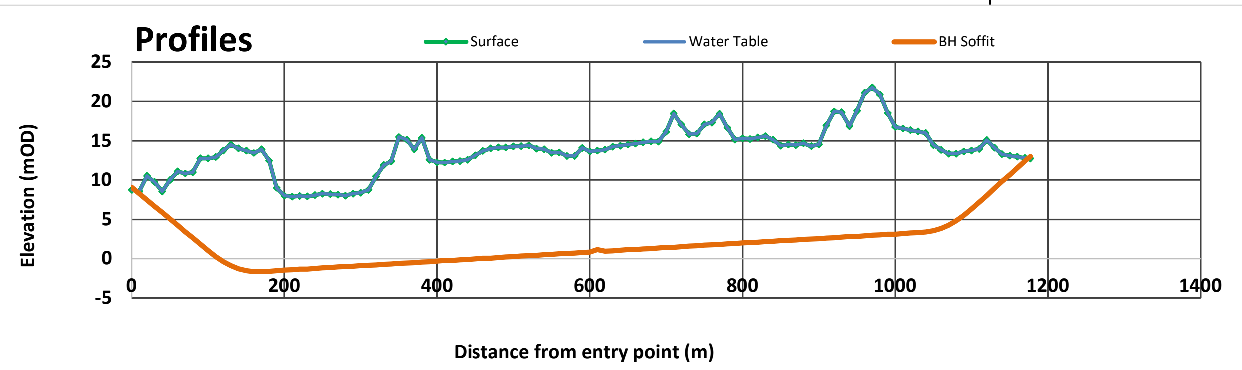
LAT

WT controls: 0 -4.89

Dist (m)	Elev'n (mOD)	Loc'n	WTL (mOD)	C-Line (mOD)	Soffit (mOD)	Cover (m)	Sat'd (m)	Bou't (m)	U kN/m2	Hs kN/m3
0.00	8.74		8.74	8.76	9.06	0.00	0.00	0.00	0	0
10.00	8.57		8.57	7.96	8.26	0.31	0.00	0.31	3	6
20.00	10.51		10.51	7.15	7.46	3.06	0.00	3.06	30	16
30.00	9.75		9.75	6.35	6.66	3.09	0.00	3.09	30	27
40.00	8.54		8.54	5.55	5.85	2.69	0.00	2.69	26	37
50.00	10.02		10.02	4.75	5.05	4.97	0.00	4.97	49	47
60.00	11.08		11.08	3.94	4.25	6.83	0.00	6.83	67	57
70.00	10.85		10.85	3.14	3.45	7.40	0.00	7.40	73	68
80.00	11.00		11.00	2.34	2.64	8.35	0.00	8.35	82	78
90.00	12.77		12.77	1.54	1.84	10.93	0.00	10.93	107	88
100.00	12.76		12.76	0.74	1.04	11.72	0.00	11.72	115	98
110.00	12.94		12.94	-0.04	0.26	12.68	0.00	12.68	124	108
120.00	13.76		13.76	-0.69	-0.39	14.15	0.00	14.15	139	116
130.00	14.51		14.51	-1.21	-0.91	15.42	0.00	15.42	151	123
140.00	14.02		14.02	-1.60	-1.29	15.32	0.00	15.32	150	128
150.00	13.74		13.74	-1.85	-1.54	15.28	0.00	15.28	150	131
160.00	13.45		13.45	-1.97	-1.66	15.12	0.00	15.12	148	133
170.00	13.89		13.89	-1.96	-1.65	15.54	0.00	15.54	152	133
180.00	12.44		12.44	-1.90	-1.59	14.03	0.00	14.03	138	132
190.00	9.00		9.00	-1.84	-1.53	10.53	0.00	10.53	103	131
200.00	8.00		8.00	-1.78	-1.48	9.47	0.00	9.47	93	130
210.00	7.88		7.88	-1.72	-1.42	9.30	0.00	9.30	91	130
220.00	7.98		7.98	-1.67	-1.36	9.34	0.00	9.34	92	129
230.00	7.91		7.91	-1.61	-1.30	9.21	0.00	9.21	90	128
240.00	8.07		8.07	-1.55	-1.25	9.31	0.00	9.31	91	127
250.00	8.26		8.26	-1.49	-1.19	9.45	0.00	9.45	93	127
260.00	8.20		8.20	-1.44	-1.13	9.33	0.00	9.33	92	126
270.00	8.14		8.14	-1.38	-1.07	9.21	0.00	9.21	90	125
280.00	8.02		8.02	-1.32	-1.02	9.04	0.00	9.04	89	124
290.00	8.26		8.26	-1.26	-0.96	9.22	0.00	9.22	90	124
300.00	8.41		8.41	-1.21	-0.90	9.31	0.00	9.31	91	123
310.00	8.76		8.76	-1.15	-0.84	9.60	0.00	9.60	94	122
320.00	10.49		10.49	-1.09	-0.79	11.27	0.00	11.27	111	122
330.00	11.90		11.90	-1.03	-0.73	12.63	0.00	12.63	124	121
340.00	12.39		12.39	-0.97	-0.67	13.05	0.00	13.05	128	120
350.00	15.46		15.46	-0.92	-0.61	16.07	0.00	16.07	158	119
360.00	15.16		15.16	-0.86	-0.55	15.72	0.00	15.72	154	119
370.00	13.92		13.92	-0.80	-0.50	14.42	0.00	14.42	141	118
380.00	15.37		15.37	-0.74	-0.44	15.80	0.00	15.80	155	117
390.00	12.59		12.59	-0.69	-0.38	12.97	0.00	12.97	127	116
400.00	12.26		12.26	-0.63	-0.32	12.58	0.00	12.58	123	116
410.00	12.22		12.22	-0.57	-0.27	12.49	0.00	12.49	122	115
420.00	12.36		12.36	-0.51	-0.21	12.57	0.00	12.57	123	114
430.00	12.43		12.43	-0.46	-0.15	12.58	0.00	12.58	123	113
440.00	12.58		12.58	-0.40	-0.09	12.67	0.00	12.67	124	113
450.00	13.17		13.17	-0.34	-0.04	13.20	0.00	13.20	129	112
460.00	13.70		13.70	-0.28	0.02	13.67	0.00	13.67	134	111
470.00	14.03		14.03	-0.23	0.08	13.95	0.00	13.95	137	110
480.00	14.14		14.14	-0.17	0.14	14.00	0.00	14.00	137	110
490.00	14.14		14.14	-0.11	0.20	13.94	0.00	13.94	137	109
500.00	14.27		14.27	-0.05	0.25	14.02	0.00	14.02	137	108
510.00	14.31		14.31	0.01	0.31	14.00	0.00	14.00	137	108
520.00	14.39		14.39	0.06	0.37	14.02	0.00	14.02	138	107

530.00	14.00	14.00	0.12	0.43	13.57	0.00	13.57	*133*	*106*
540.00	13.94	13.94	0.18	0.48	13.45	0.00	13.45	*132*	*105*
550.00	13.46	13.46	0.24	0.54	12.92	0.00	12.92	*127*	*105*
560.00	13.52	13.52	0.29	0.60	12.92	0.00	12.92	*127*	*104*
570.00	13.05	13.05	0.35	0.66	12.39	0.00	12.39	*122*	*103*
580.00	13.07	13.07	0.41	0.71	12.36	0.00	12.36	*121*	*102*
590.00	14.10	14.10	0.47	0.77	13.33	0.00	13.33	*131*	*102*
600.00	13.63	13.63	0.53	0.83	12.80	0.00	12.80	*126*	*101*
610.00	13.74	13.74	0.85	1.16	12.58	0.00	12.58	*123*	*97*
620.00	13.85	13.85	0.64	0.94	12.91	0.00	12.91	*127*	*99*
630.00	14.25	14.25	0.70	1.00	13.25	0.00	13.25	*130*	*99*
640.00	14.37	14.37	0.76	1.06	13.31	0.00	13.31	*131*	*98*
650.00	14.49	14.49	0.81	1.12	13.38	0.00	13.38	*131*	*97*
660.00	14.65	14.65	0.87	1.18	13.47	0.00	13.47	*132*	*97*
670.00	14.80	14.80	0.93	1.23	13.56	0.00	13.56	*133*	*96*
680.00	14.93	14.93	0.99	1.29	13.64	0.00	13.64	*134*	*95*
690.00	14.88	14.88	1.04	1.35	13.53	0.00	13.53	*133*	*94*
700.00	16.15	16.15	1.10	1.41	14.75	0.00	14.75	*145*	*94*
710.00	18.46	18.46	1.16	1.46	16.99	0.00	16.99	*167*	*93*
720.00	17.08	17.08	1.22	1.52	15.56	0.00	15.56	*153*	*92*
730.00	15.81	15.81	1.28	1.58	14.23	0.00	14.23	*140*	*91*
740.00	15.87	15.87	1.33	1.64	14.24	0.00	14.24	*140*	*91*
750.00	17.07	17.07	1.39	1.69	15.37	0.00	15.37	*151*	*90*
760.00	17.30	17.30	1.45	1.75	15.55	0.00	15.55	*153*	*89*
770.00	18.43	18.43	1.51	1.81	16.62	0.00	16.62	*163*	*88*
780.00	16.65	16.65	1.56	1.87	14.78	0.00	14.78	*145*	*88*
790.00	15.13	15.13	1.62	1.93	13.21	0.00	13.21	*130*	*87*
800.00	15.30	15.30	1.68	1.98	13.32	0.00	13.32	*131*	*86*
810.00	15.21	15.21	1.74	2.04	13.17	0.00	13.17	*129*	*85*
820.00	15.41	15.41	1.79	2.10	13.31	0.00	13.31	*131*	*85*
830.00	15.58	15.58	1.85	2.16	13.43	0.00	13.43	*132*	*84*
840.00	15.10	15.10	1.91	2.21	12.89	0.00	12.89	*126*	*83*
850.00	14.36	14.36	1.97	2.27	12.09	0.00	12.09	*119*	*83*
860.00	14.49	14.49	2.02	2.33	12.16	0.00	12.16	*119*	*82*
870.00	14.44	14.44	2.08	2.39	12.05	0.00	12.05	*118*	*81*
880.00	14.67	14.67	2.14	2.44	12.23	0.00	12.23	*120*	*80*
890.00	14.32	14.32	2.20	2.50	11.82	0.00	11.82	*116*	*80*
900.00	14.55	14.55	2.26	2.56	11.99	0.00	11.99	*118*	*79*
910.00	16.95	16.95	2.31	2.62	14.33	0.00	14.33	*141*	*78*
920.00	18.73	18.73	2.37	2.67	16.06	0.00	16.06	*158*	*77*
930.00	18.61	18.61	2.43	2.73	15.88	0.00	15.88	*156*	*77*
940.00	16.85	16.85	2.49	2.79	14.06	0.00	14.06	*138*	*76*
950.00	18.81	18.81	2.54	2.85	15.96	0.00	15.96	*157*	*75*
960.00	21.09	21.09	2.60	2.91	18.18	0.00	18.18	*178*	*74*
970.00	21.76	21.76	2.66	2.96	18.80	0.00	18.80	*184*	*74*
980.00	20.88	20.88	2.72	3.02	17.86	0.00	17.86	*175*	*73*
990.00	18.54	18.54	2.77	3.08	15.46	0.00	15.46	*152*	*72*
1000.00	16.76	16.76	2.83	3.14	13.62	0.00	13.62	*134*	*71*
1010.00	16.55	16.55	2.89	3.19	13.36	0.00	13.36	*131*	*71*
1020.00	16.34	16.34	2.95	3.25	13.08	0.00	13.08	*128*	*70*
1030.00	16.16	16.16	3.01	3.31	12.85	0.00	12.85	*126*	*69*
1040.00	15.99	15.99	3.07	3.37	12.62	0.00	12.62	*124*	*68*
1050.00	14.43	14.43	3.22	3.53	10.90	0.00	10.90	*107*	*66*
1060.00	13.82	13.82	3.52	3.82	10.00	0.00	10.00	*98*	*63*
1070.00	13.33	13.33	3.94	4.24	9.09	0.00	9.09	*89*	*57*
1080.00	13.35	13.35	4.50	4.80	8.55	0.00	8.55	*84*	*50*
1090.00	13.62	13.62	5.19	5.49	8.13	0.00	8.13	*80*	*41*
1100.00	13.76	13.76	6.01	6.31	7.45	0.00	7.45	*73*	*31*
1110.00	13.96	13.96	6.88	7.18	6.78	0.00	6.78	*66*	*20*
1120.00	15.10	15.10	7.75	8.05	7.04	0.00	7.04	*69*	*9*
1130.00	14.11	14.11	8.62	8.93	5.19	0.00	5.19	*51*	*0*
1140.00	13.30	13.30	9.49	9.80	3.50	0.00	3.50	*34*	*0*
1150.00	13.10	13.10	10.36	10.67	2.43	0.00	2.43	*24*	*0*
1160.00	12.95	12.95	11.23	11.54	1.41	0.00	1.41	*14*	*0*
1170.00	12.80	12.80	12.10	12.41	0.39	0.00	0.39	*4*	*0*
1177.00	12.74	12.74	12.69	13.00	0.00	0.00	0.00	*0*	*0*

HDD borehole profile graph based on the above table



Dist (m)	σv (kN/m²)	σh (kN/m²)	σo (kN/m²)	Pf (kN/m²)	Q	Rpmax (m)	Pemax (kN/m²)	Pmax (kN/m²)	Hf (kN/m²)	H (kN/m²)
0.0	0.0	0.0	0.0	1.8	0.00012	0.3	2	2	*0*	*0*
10.0	2.9	0.0	2.9	5.9	0.00020	0.2	3	6	*0*	*7*
20.0	28.5	0.0	28.5	42.3	0.00090	1.5	116	146	*1*	*17*
30.0	28.8	0.0	28.8	42.8	0.00091	1.5	118	149	*1*	*28*
40.0	25.1	0.0	25.1	37.5	0.00081	1.3	96	122	*2*	*39*
50.0	46.3	0.0	46.3	67.7	0.00139	2.5	239	288	*2*	*49*
60.0	63.7	0.0	63.7	92.4	0.00187	3.4	377	444	*3*	*60*
70.0	69.0	0.0	69.0	99.9	0.00201	3.7	421	494	*3*	*70*
80.0	77.8	0.0	77.8	112.6	0.00226	4.2	494	576	*3*	*81*
90.0	101.8	0.0	101.8	146.7	0.00292	5.5	685	792	*4*	*92*
100.0	109.2	0.0	109.2	157.1	0.00312	5.9	740	855	*4*	*102*
110.0	118.2	0.0	118.2	169.9	0.00336	6.3	805	930	*5*	*113*
120.0	131.9	0.0	131.9	189.4	0.00374	7.1	900	1039	*5*	*121*
130.0	143.7	0.0	143.7	206.2	0.00406	7.7	977	1128	*5*	*128*
140.0	142.7	0.0	142.7	204.9	0.00404	7.7	970	1121	*6*	*134*
150.0	142.4	0.0	142.4	204.4	0.00403	7.6	969	1118	*6*	*137*
160.0	140.9	0.0	140.9	202.2	0.00399	7.6	959	1107	*7*	*139*
170.0	144.8	0.0	144.8	207.8	0.00410	7.8	984	1136	*7*	*140*
180.0	130.7	0.0	130.7	187.8	0.00371	7.0	892	1030	*8*	*139*
190.0	98.1	0.0	98.1	141.4	0.00281	5.3	656	760	*8*	*139*
210.0	86.7	0.0	86.7	125.1	0.00250	4.7	566	657	*9*	*138*
220.0	87.0	0.0	87.0	125.6	0.00251	4.7	568	660	*9*	*138*
230.0	85.8	0.0	85.8	123.9	0.00248	4.6	559	649	*10*	*138*
240.0	86.8	0.0	86.8	125.3	0.00250	4.7	567	658	*10*	*137*
250.0	88.1	0.0	88.1	127.1	0.00254	4.7	577	670	*10*	*137*
260.0	86.9	0.0	86.9	125.5	0.00251	4.7	568	659	*11*	*137*
270.0	85.8	0.0	85.8	123.9	0.00248	4.6	559	649	*11*	*136*
280.0	84.2	0.0	84.2	121.6	0.00243	4.5	546	635	*12*	*136*
290.0	85.9	0.0	85.9	124.0	0.00248	4.6	559	650	*12*	*136*
300.0	86.7	0.0	86.7	125.2	0.00250	4.7	566	657	*13*	*136*
310.0	89.5	0.0	89.5	129.1	0.00258	4.8	588	683	*13*	*135*
320.0	105.0	0.0	105.0	151.2	0.00300	5.6	709	820	*13*	*135*
330.0	117.7	0.0	117.7	169.2	0.00335	6.3	802	926	*14*	*135*
340.0	121.7	0.0	121.7	174.9	0.00346	6.5	830	958	*14*	*134*
350.0	149.8	0.0	149.8	214.9	0.00423	8.0	1015	1172	*15*	*134*
360.0	146.5	0.0	146.5	210.2	0.00414	7.9	994	1148	*15*	*134*
370.0	134.4	0.0	134.4	193.0	0.00381	7.2	916	1058	*15*	*133*
380.0	147.3	0.0	147.3	211.3	0.00416	7.9	999	1154	*16*	*133*
390.0	120.9	0.0	120.9	173.8	0.00344	6.5	825	952	*16*	*133*
400.0	117.3	0.0	117.3	168.6	0.00334	6.3	799	922	*17*	*132*
410.0	116.4	0.0	116.4	167.4	0.00331	6.2	792	915	*17*	*132*
420.0	117.1	0.0	117.1	168.5	0.00334	6.3	798	921	*18*	*132*
430.0	117.2	0.0	117.2	168.6	0.00334	6.3	799	922	*18*	*131*
440.0	118.1	0.0	118.1	169.8	0.00336	6.3	805	929	*18*	*131*
450.0	123.0	0.0	123.0	176.8	0.00350	6.6	839	969	*19*	*131*
460.0	127.4	0.0	127.4	183.1	0.00362	6.8	870	1004	*19*	*130*
470.0	130.0	0.0	130.0	186.8	0.00369	7.0	887	1024	*20*	*130*
480.0	130.5	0.0	130.5	187.4	0.00370	7.0	890	1028	*20*	*130*
490.0	129.9	0.0	129.9	186.6	0.00369	7.0	887	1023	*20*	*129*
500.0	130.6	0.0	130.6	187.6	0.00371	7.0	891	1029	*21*	*129*
510.0	130.5	0.0	130.5	187.4	0.00370	7.0	890	1028	*21*	*129*
520.0	130.7	0.0	130.7	187.7	0.00371	7.0	892	1029	*22*	*129*

The pressure calculations are set out in this table. Note that ***Rpmax*** *varies as it is set to be a proportion of the cover depth.*

Hf is a rough estimate of the drilling mud pressure in the return annular flow.

The total head ***H*** *is the static head* ***Hs*** *(table above) and* ***Hf****.*

530.0	126.5	0.0	126.5	181.7	0.00359	6.8	863	996	*22*	*128*
540.0	125.4	0.0	125.4	180.1	0.00356	6.7	856	988	*23*	*128*
550.0	120.4	0.0	120.4	173.1	0.00342	6.5	821	948	*23*	*128*
560.0	120.4	0.0	120.4	173.1	0.00343	6.5	821	948	*23*	*127*
570.0	115.5	0.0	115.5	166.1	0.00329	6.2	786	908	*24*	*127*
580.0	115.2	0.0	115.2	165.7	0.00328	6.2	784	905	*24*	*127*
590.0	124.2	0.0	124.2	178.5	0.00353	6.7	848	978	*25*	*126*
600.0	119.3	0.0	119.3	171.5	0.00339	6.4	813	939	*25*	*126*
610.0	117.2	0.0	117.2	168.6	0.00334	6.3	799	922	*26*	*122*
620.0	120.3	0.0	120.3	173.0	0.00342	6.5	820	947	*26*	*125*
630.0	123.4	0.0	123.4	177.4	0.00351	6.6	842	972	*26*	*125*
640.0	124.0	0.0	124.0	178.2	0.00352	6.7	846	977	*27*	*125*
650.0	124.7	0.0	124.7	179.1	0.00354	6.7	851	982	*27*	*124*
660.0	125.5	0.0	125.5	180.4	0.00357	6.7	857	989	*28*	*124*
670.0	126.4	0.0	126.4	181.6	0.00359	6.8	863	996	*28*	*124*
680.0	127.1	0.0	127.1	182.6	0.00361	6.8	868	1001	*28*	*123*
690.0	126.1	0.0	126.1	181.2	0.00358	6.8	861	993	*29*	*123*
700.0	137.4	0.0	137.4	197.3	0.00389	7.4	936	1081	*29*	*123*
710.0	158.4	0.0	158.4	227.1	0.00447	8.5	1067	1233	*30*	*123*
720.0	145.0	0.0	145.0	208.1	0.00410	7.8	985	1137	*30*	*122*
730.0	132.6	0.0	132.6	190.5	0.00376	7.1	905	1045	*31*	*122*
740.0	132.7	0.0	132.7	190.6	0.00376	7.1	905	1045	*31*	*122*
750.0	143.3	0.0	143.3	205.6	0.00405	7.7	974	1125	*31*	*121*
760.0	144.9	0.0	144.9	208.0	0.00410	7.8	984	1137	*32*	*121*
770.0	154.9	0.0	154.9	222.2	0.00437	8.3	1046	1209	*32*	*121*
780.0	137.7	0.0	137.7	197.7	0.00390	7.4	938	1083	*33*	*120*
790.0	123.1	0.0	123.1	176.9	0.00350	6.6	840	969	*33*	*120*
800.0	124.1	0.0	124.1	178.4	0.00353	6.7	847	978	*33*	*120*
810.0	122.7	0.0	122.7	176.4	0.00349	6.6	837	966	*34*	*119*
820.0	124.0	0.0	124.0	178.2	0.00352	6.7	846	977	*34*	*119*
830.0	125.1	0.0	125.1	179.8	0.00356	6.7	854	986	*35*	*119*
840.0	120.1	0.0	120.1	172.7	0.00342	6.4	819	946	*35*	*118*
850.0	112.7	0.0	112.7	162.1	0.00321	6.0	766	884	*36*	*118*
860.0	113.3	0.0	113.3	163.1	0.00323	6.1	771	890	*36*	*118*
870.0	112.3	0.0	112.3	161.6	0.00320	6.0	763	882	*36*	*117*
880.0	114.0	0.0	114.0	163.9	0.00325	6.1	775	895	*37*	*117*
890.0	110.1	0.0	110.1	158.5	0.00314	5.9	747	863	*37*	*117*
900.0	111.7	0.0	111.7	160.8	0.00319	6.0	759	877	*38*	*116*
910.0	133.6	0.0	133.6	191.8	0.00379	7.2	911	1052	*38*	*116*
920.0	149.6	0.0	149.6	214.7	0.00423	8.0	1014	1171	*38*	*116*
930.0	148.0	0.0	148.0	212.3	0.00418	7.9	1003	1159	*39*	*116*
940.0	131.0	0.0	131.0	188.2	0.00372	7.0	894	1032	*39*	*115*
950.0	148.8	0.0	148.8	213.5	0.00420	8.0	1008	1165	*40*	*115*
960.0	169.5	0.0	169.5	242.9	0.00477	9.1	1132	1310	*40*	*115*
970.0	175.2	0.0	175.2	251.0	0.00493	9.4	1164	1348	*41*	*114*
980.0	166.5	0.0	166.5	238.6	0.00469	8.9	1114	1289	*41*	*114*
990.0	144.1	0.0	144.1	206.8	0.00408	7.7	979	1131	*41*	*114*
1000.0	127.0	0.0	127.0	182.4	0.00361	6.8	867	1000	*42*	*113*
1010.0	124.5	0.0	124.5	178.9	0.00354	6.7	850	981	*42*	*113*
1020.0	121.9	0.0	121.9	175.3	0.00347	6.5	832	960	*43*	*113*
1030.0	119.8	0.0	119.8	172.2	0.00341	6.4	817	943	*43*	*112*
1040.0	117.6	0.0	117.6	169.1	0.00335	6.3	801	925	*43*	*112*
1050.0	101.6	0.0	101.6	146.3	0.00291	5.5	683	790	*44*	*110*
1060.0	93.2	0.0	93.2	134.4	0.00268	5.0	618	716	*44*	*107*
1070.0	84.7	0.0	84.7	122.3	0.00244	4.5	550	639	*45*	*102*
1080.0	79.7	0.0	79.7	115.2	0.00231	4.3	509	593	*45*	*95*
1090.0	75.8	0.0	75.8	109.6	0.00220	4.1	477	557	*46*	*87*
1100.0	69.4	0.0	69.4	100.5	0.00202	3.7	424	497	*46*	*77*
1110.0	63.2	0.0	63.2	91.7	0.00185	3.4	373	440	*46*	*66*
1120.0	65.6	0.0	65.6	95.2	0.00192	3.5	393	462	*47*	*56*
1130.0	48.3	0.0	48.3	70.6	0.00145	2.6	255	306	*47*	*47*
1140.0	32.6	0.0	32.6	48.2	0.00101	1.8	143	177	*48*	*48*
1150.0	22.6	0.0	22.6	34.0	0.00074	1.2	83	106	*48*	*48*
1160.0	13.2	0.0	13.2	20.5	0.00048	0.7	37	50	*48*	*48*
1170.0	3.6	0.0	3.6	6.9	0.00022	0.2	4	8	*49*	*49*
1177.0	0.0	0.0	0.0	1.8	0.00012	0.3	2	2	*49*	*49*

Comments

Hydrofracture - Longitudinal Profile Check

[redacted]

$$Pmax = Pemax + U$$ *Eqn(1)*

$$Pemax = (Pf + c.cot\emptyset).\left\{\left(\frac{Ro}{Rpmax}\right)^2 + Q\right\}^{\frac{-sin\emptyset}{1+sin\emptyset}} - c.cot\emptyset$$ *Eqn(2)*

$$Q = \frac{(\sigma o.sin\emptyset + c.cos\emptyset)}{G}$$ *Eqn(3)*

$$Pf = \sigma o\,(1 + sin\emptyset) + c.cos\emptyset$$ *Eqn(4)*

$$G = \frac{E}{2}\,(1 + \vartheta)$$ *Eqn(5)*

Where:

Pmax	maximum allowable mud pressure
U	initial in-situ pore pressure
Pemax	maximum allowable effective mud pressure
σ_o	initial effective stress
ϕ	internal angle of friction
c	cohesion
Ro	internal radius of borehole
Rpmax	maximum allowable radius of plastic zone
G	shear modulus
E	elasticity modulus
N	Poisson's ratio

Only enter data into green highlight cells. Other cells may contain calculations and editing them will over-write the formula.

General variables

Gravity (m/s/s):	**g**	9.81			
Density of water (kg/m3):	**ɣw**	1000			
Density of drilling mud (kg/m3):	**ɣm**	1300			
Soil density (kg/m^3):	**ɣs**	1950			
Cohesion (kN/m^2):	**Coh**	2			
Friction angle (deg):	**Φ**	25	Radians Φr =	0.4363	
Poission's ratio :	**v**	0.3			
Elasticity modulus (kPa):	**Emod**	40000			
Shear modulus (kPa):	Gmod =	15385			

Soil characteristic values are all assumed and should be confirmed by Intrusive Ground Investigation.

Product pipe OD (m):					
Drill bit diameter (inch):	44.00	inch	**Do**	1.118	m
Drill pipe OD (inch):	12.00	inch	**Di**	0.305	m

Diameters assumed at feasibility stage.

Initial radius of borehole (m):	**Ro**	0.559	*Equal half drill bit diameter*
Allowable plastic radius factor	**Rpmax**	0.50	

Rpmax usually assumed between 1/2 and 2/3 depth, assumed 1/2 as worst case scenario

Consider lateral soil pressure: **No** ***Use drop-down to select Y/N***

Passive coefficient **ko** = IF(Y_N = "Yes", 1 - SIN(Φr), 0)
= IF(= "Yes", 1 - SIN(0.43633), 0)
= **0**

Conservative to not consider lateral soil pressures

Annular pressure calculations

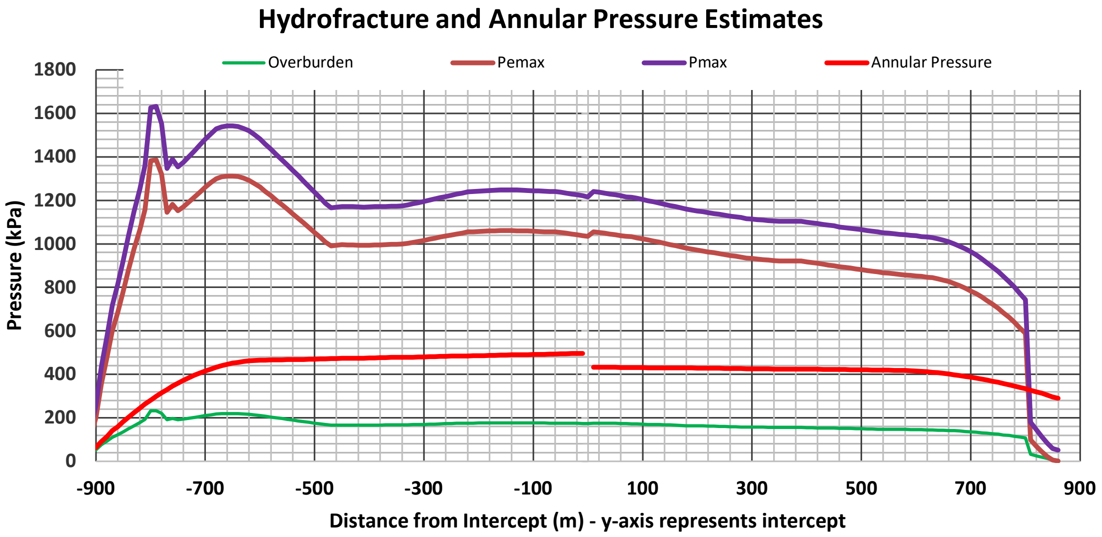
Darcy Weisbach equation for flow in an annulus is: H = f(L/Dh)(V^2/2g), where Dh is the hydraulic diameter, V the flow velocity, L flow pipe length and f is a friction factor. In the case of co-centered circular pipes Dh = Do - Di. The exact drilling operational parameters, such as flow rate are unknown, but some estimated values have been applied - but require verification. The total head is the flow head plus the static head.

Assumed flow velocity (m/s):	V	0.50
Assumed friction coefficient:	f	2.50

The calculations at each chainage location are performed in the frac-out table

Summary Figures

Elevation of entrance hole mOD =	**12.97**	**mOD**			
Elevation of exit hole mOD =	**-9.89**	**mOD**	***Diff =***	***22.86***	m
Maximum cover to HDD borehole =	**25.0**	**m**			
Maximum overburden pressure =	**233.1**	**kN/m^2**		***2.3***	***Bar***
Maximum safe effective stress **Pemax** =	**1387**	**kN/m^2**		***13.9***	***Bar***
Maximum safe stress **Pmax** =	**1632**	**kN/m^3**		***16.3***	***Bar***



Expressions used in hydrofracture calculations

In the tabulation below the following functions are applied

Saturated Layer **Sat'd**: IF (WTL<=HDD, Elevn-HDD, Max(Elevn-WTL, 0))

Bouyant Layer **Bou't**: IF (WTL<=HDD, 0, Min(WTL-HDD, Elevn-HDD))

σv = (γs*Satd+(γs-γw)*Bout)*g/1000

σo = SQRT((γs*Satd+(γs-γw)*Bout)^2 + (ko * (γs*Satd + (γs-γw)*Bout))^2))

Q = (σo*SIN(Φr) + Coh*COS(Φr)) / Gmod

Pf = (σo * (1+SIN(Φr))) + (Coh * COS(Φr))

Pemax = (Pf + Coh*COT(Φr)) * (((Ro/Rpmax)^2 + Q)^(-SIN(Φr)/(1+SIN(Φr)))) - Coh*COT(Φr)

Pelim = (Pf + Coh*COT(Φr)) * (Q^(-SIN(Φr)/(1+SIN(Φr)))) - Coh*COT(Φr)

LAT

WT controls: 0 -4.89

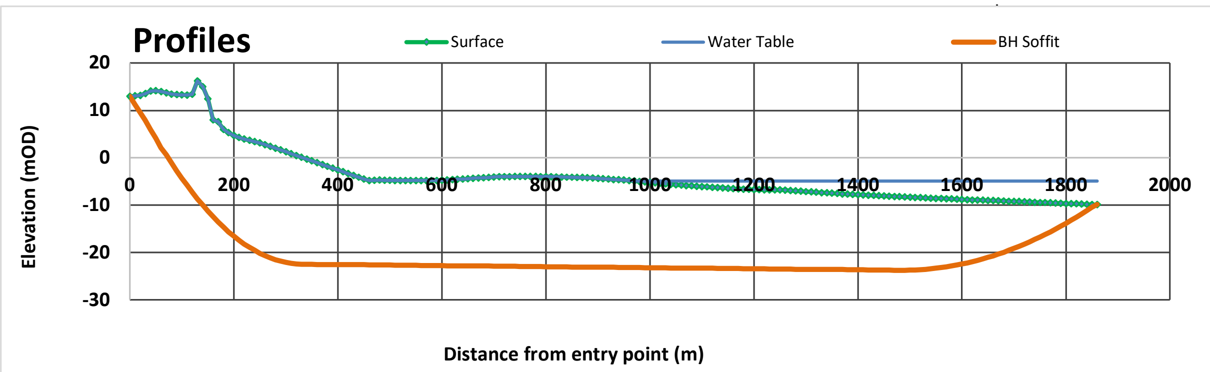
Dist (m)	Elev'n (mOD)	Loc'n	WTL (mOD)	C-Line (mOD)	Soffit (mOD)	Cover (m)	Sat'd (m)	Bou't (m)	U kN/m2	Hs kN/m3
0.00	12.97		12.97		12.97	0.00	0.00	0.00	0	0
10.00	13.08		13.08		11.21	1.87	0.00	1.87	18	22
20.00	13.18		13.18		9.45	3.73	0.00	3.73	37	45
30.00	13.58		13.58		7.96	5.62	0.00	5.62	55	64
40.00	14.12		14.12		5.94	8.18	0.00	8.18	80	90
50.00	14.15		14.15		4.18	9.97	0.00	9.97	98	112
60.00	13.98		13.98		2.15	11.84	0.00	11.84	116	138
70.00	13.74		13.74		0.66	13.08	0.00	13.08	128	157
80.00	13.45		13.45		-1.06	14.51	0.00	14.51	142	179
90.00	13.36		13.36		-2.72	16.08	0.00	16.08	158	200
100.00	13.28		13.28		-4.31	17.58	0.00	17.58	172	220
110.00	13.22		13.22		-5.83	19.05	0.00	19.05	187	240
120.00	13.37		13.37		-7.28	20.66	0.00	20.66	203	258
130.00	16.25		16.25		-8.67	24.92	0.00	24.92	244	276
140.00	15.01		15.01		-10.00	25.01	0.00	25.01	245	293
150.00	12.46		12.46		-11.25	23.71	0.00	23.71	233	309
160.00	8.02		8.02		-12.44	20.46	0.00	20.46	201	324
170.00	7.56		7.56		-13.56	21.12	0.00	21.12	207	338
180.00	5.96		5.96		-14.62	20.58	0.00	20.58	202	352
190.00	5.29		5.29		-15.61	20.89	0.00	20.89	205	364
200.00	4.72		4.72		-16.53	21.25	0.00	21.25	208	376
210.00	4.30		4.30		-17.39	21.69	0.00	21.69	213	387
220.00	3.97		3.97		-18.18	22.15	0.00	22.15	217	397
230.00	3.66		3.66		-18.90	22.56	0.00	22.56	221	406
240.00	3.39		3.39		-19.55	22.95	0.00	22.95	225	415
250.00	3.17		3.17		-20.14	23.32	0.00	23.32	229	422
260.00	2.79		2.79		-20.67	23.46	0.00	23.46	230	429
270.00	2.41		2.41		-21.12	23.53	0.00	23.53	231	435
280.00	2.03		2.03		-21.51	23.54	0.00	23.54	231	440
290.00	1.64		1.64		-21.83	23.48	0.00	23.48	230	444
300.00	1.26		1.26		-22.09	23.35	0.00	23.35	229	447
310.00	0.88		0.88		-22.28	23.16	0.00	23.16	227	449
320.00	0.50		0.50		-22.40	22.90	0.00	22.90	225	451
330.00	0.11		0.11		-22.46	22.57	0.00	22.57	221	452
340.00	-0.27		-0.27		-22.47	22.20	0.00	22.20	218	452
350.00	-0.65		-0.65		-22.48	21.83	0.00	21.83	214	452
360.00	-1.04		-1.04		-22.49	21.46	0.00	21.46	210	452
370.00	-1.42		-1.42		-22.50	21.08	0.00	21.08	207	452
380.00	-1.80		-1.80		-22.51	20.71	0.00	20.71	203	452
390.00	-2.18		-2.18		-22.52	20.34	0.00	20.34	200	453
400.00	-2.57		-2.57		-22.54	19.97	0.00	19.97	196	453
410.00	-2.95		-2.95		-22.55	19.60	0.00	19.60	192	453
420.00	-3.33		-3.33		-22.56	19.23	0.00	19.23	189	453
430.00	-3.72		-3.72		-22.57	18.85	0.00	18.85	185	453
440.00	-4.10		-4.10		-22.58	18.48	0.00	18.48	181	453
450.00	-4.48		-4.48		-22.59	18.11	0.00	18.11	178	453
460.00	-4.79		-4.79		-22.60	17.81	0.00	17.81	175	454
470.00	-4.75		-4.75		-22.61	17.87	0.00	17.87	175	454
480.00	-4.72		-4.72		-22.62	17.91	0.00	17.91	176	454
490.00	-4.74		-4.74		-22.64	17.90	0.00	17.90	176	454
500.00	-4.76		-4.76		-22.65	17.89	0.00	17.89	175	454
510.00	-4.78		-4.78		-22.66	17.88	0.00	17.88	175	454
520.00	-4.80		-4.80		-22.67	17.87	0.00	17.87	175	454

530.00	-4.80		-4.80	-22.68	17.88	0.00	17.88	*175*	*455*	
540.00	-4.80		-4.80	-22.69	17.89	0.00	17.89	*176*	*455*	
550.00	-4.80		-4.80	-22.70	17.90	0.00	17.90	*176*	*455*	
560.00	-4.80		-4.80	-22.71	17.91	0.00	17.91	*176*	*455*	
570.00	-4.80		-4.80	-22.72	17.92	0.00	17.92	*176*	*455*	
580.00	-4.80		-4.80	-22.73	17.93	0.00	17.93	*176*	*455*	
590.00	-4.80		-4.80	-22.75	17.95	0.00	17.95	*176*	*455*	
600.00	-4.75		-4.75	-22.76	18.01	0.00	18.01	*177*	*456*	
610.00	-4.68		-4.68	-22.77	18.09	0.00	18.09	*177*	*456*	
620.00	-4.61		-4.61	-22.78	18.17	0.00	18.17	*178*	*456*	
630.00	-4.54		-4.54	-22.79	18.25	0.00	18.25	*179*	*456*	
640.00	-4.48		-4.48	-22.80	18.33	0.00	18.33	*180*	*456*	
650.00	-4.41		-4.41	-22.81	18.41	0.00	18.41	*181*	*456*	
660.00	-4.34		-4.34	-22.82	18.48	0.00	18.48	*181*	*456*	
670.00	-4.27		-4.27	-22.83	18.56	0.00	18.56	*182*	*457*	
680.00	-4.20		-4.20	-22.85	18.64	0.00	18.64	*183*	*457*	
690.00	-4.13		-4.13	-22.86	18.72	0.00	18.72	*184*	*457*	
700.00	-4.07		-4.07	-22.87	18.80	0.00	18.80	*184*	*457*	
710.00	-4.00		-4.00	-22.88	18.88	0.00	18.88	*185*	*457*	
720.00	-3.99		-3.99	-22.89	18.90	0.00	18.90	*185*	*457*	
730.00	-3.98		-3.98	-22.90	18.92	0.00	18.92	*186*	*457*	
740.00	-3.97		-3.97	-22.91	18.94	0.00	18.94	*186*	*458*	
750.00	-3.96		-3.96	-22.92	18.96	0.00	18.96	*186*	*458*	
760.00	-3.95		-3.95	-22.93	18.99	0.00	18.99	*186*	*458*	
770.00	-3.94		-3.94	-22.95	19.01	0.00	19.01	*186*	*458*	
780.00	-3.96		-3.96	-22.96	19.00	0.00	19.00	*186*	*458*	
790.00	-3.97		-3.97	-22.97	18.99	0.00	18.99	*186*	*458*	
800.00	-3.99		-3.99	-22.98	18.99	0.00	18.99	*186*	*458*	
810.00	-4.01		-4.01	-22.99	18.98	0.00	18.98	*186*	*459*	
820.00	-4.04		-4.04	-23.00	18.96	0.00	18.96	*186*	*459*	
830.00	-4.07		-4.07	-23.01	18.94	0.00	18.94	*186*	*459*	
840.00	-4.10		-4.10	-23.02	18.92	0.00	18.92	*186*	*459*	
850.00	-4.12		-4.12	-23.03	18.91	0.00	18.91	*185*	*459*	
860.00	-4.15		-4.15	-23.04	18.90	0.00	18.90	*185*	*459*	
870.00	-4.17		-4.17	-23.06	18.89	0.00	18.89	*185*	*459*	
880.00	-4.22		-4.22	-23.07	18.85	0.00	18.85	*185*	*460*	
890.00	-4.29		-4.29	-23.08	18.79	0.00	18.79	*184*	*460*	
900.00	-4.36		-4.36	-23.09	18.73	0.00	18.73	*184*	*460*	
910.00	-4.43		-4.43	-23.10	18.67	0.00	18.67	*183*	*460*	
920.00	-4.50		-4.50	-23.11	18.61	0.00	18.61	*183*	*460*	
930.00	-4.58		-4.58	-23.12	18.55	0.00	18.55	*182*	*460*	INTERCEPT
940.00	-4.63		-4.63	-23.13	18.51	0.00	18.51	*182*	*397*	
950.00	-4.71		-4.71	-23.14	18.44	0.00	18.44	*181*	*397*	
960.00	-4.79		-4.79	-23.16	18.37	0.00	18.37	*180*	*397*	
970.00	-4.89	sea	-4.89	-23.17	18.28	0.00	18.28	*179*	*397*	
980.00	-4.99	sea	-4.89	-23.18	18.19	0.00	18.19	*179*	*398*	
990.00	-5.09	sea	-4.89	-23.19	18.10	0.00	18.10	*180*	*398*	
1000.00	-5.19	sea	-4.89	-23.20	18.01	0.00	18.01	*180*	*398*	
1010.00	-5.29	sea	-4.89	-23.21	17.92	0.00	17.92	*180*	*398*	
1020.00	-5.39	sea	-4.89	-23.22	17.83	0.00	17.83	*180*	*398*	
1030.00	-5.49	sea	-4.89	-23.23	17.74	0.00	17.74	*180*	*398*	
1040.00	-5.59	sea	-4.89	-23.24	17.65	0.00	17.65	*180*	*398*	
1050.00	-5.69	sea	-4.89	-23.26	17.56	0.00	17.56	*180*	*399*	
1060.00	-5.78	sea	-4.89	-23.27	17.49	0.00	17.49	*180*	*399*	
1070.00	-5.85	sea	-4.89	-23.28	17.43	0.00	17.43	*180*	*399*	
1080.00	-5.93	sea	-4.89	-23.29	17.36	0.00	17.36	*180*	*399*	
1090.00	-6.00	sea	-4.89	-23.30	17.30	0.00	17.30	*181*	*399*	
1100.00	-6.08	sea	-4.89	-23.31	17.23	0.00	17.23	*181*	*399*	
1110.00	-6.16	sea	-4.89	-23.32	17.17	0.00	17.17	*181*	*399*	
1120.00	-6.23	sea	-4.89	-23.33	17.10	0.00	17.10	*181*	*400*	
1130.00	-6.30	sea	-4.89	-23.34	17.04	0.00	17.04	*181*	*400*	
1140.00	-6.37	sea	-4.89	-23.36	16.99	0.00	16.99	*181*	*400*	
1150.00	-6.45	sea	-4.89	-23.37	16.92	0.00	16.92	*181*	*400*	
1160.00	-6.50	sea	-4.89	-23.38	16.88	0.00	16.88	*181*	*400*	
1170.00	-6.55	sea	-4.89	-23.39	16.84	0.00	16.84	*181*	*400*	
1180.00	-6.60	sea	-4.89	-23.40	16.80	0.00	16.80	*182*	*400*	
1190.00	-6.65	sea	-4.89	-23.41	16.76	0.00	16.76	*182*	*401*	

1200.00	-6.70	sea	-4.89	-23.42	16.73	0.00	16.73	182	401
1210.00	-6.74	sea	-4.89	-23.43	16.69	0.00	16.69	182	401
1220.00	-6.75	sea	-4.89	-23.44	16.70	0.00	16.70	182	401
1230.00	-6.75	sea	-4.89	-23.45	16.70	0.00	16.70	182	401
1240.00	-6.77	sea	-4.89	-23.47	16.70	0.00	16.70	182	401
1250.00	-6.79	sea	-4.89	-23.48	16.68	0.00	16.68	182	401
1260.00	-6.85	sea	-4.89	-23.49	16.64	0.00	16.64	182	402
1270.00	-6.92	sea	-4.89	-23.50	16.58	0.00	16.58	183	402
1280.00	-6.99	sea	-4.89	-23.51	16.52	0.00	16.52	183	402
1290.00	-7.06	sea	-4.89	-23.52	16.46	0.00	16.46	183	402
1300.00	-7.13	sea	-4.89	-23.53	16.40	0.00	16.40	183	402
1310.00	-7.20	sea	-4.89	-23.54	16.34	0.00	16.34	183	402
1320.00	-7.27	sea	-4.89	-23.55	16.28	0.00	16.28	183	402
1330.00	-7.34	sea	-4.89	-23.57	16.23	0.00	16.23	183	403
1340.00	-7.41	sea	-4.89	-23.58	16.17	0.00	16.17	183	403
1350.00	-7.47	sea	-4.89	-23.59	16.11	0.00	16.11	183	403
1360.00	-7.54	sea	-4.89	-23.60	16.06	0.00	16.06	184	403
1370.00	-7.61	sea	-4.89	-23.61	16.00	0.00	16.00	184	403
1380.00	-7.67	sea	-4.89	-23.62	15.95	0.00	15.95	184	403
1390.00	-7.74	sea	-4.89	-23.63	15.90	0.00	15.90	184	403
1400.00	-7.80	sea	-4.89	-23.64	15.84	0.00	15.84	184	404
1410.00	-7.85	sea	-4.89	-23.65	15.80	0.00	15.80	184	404
1420.00	-7.90	sea	-4.89	-23.67	15.76	0.00	15.76	184	404
1430.00	-7.95	sea	-4.89	-23.68	15.72	0.00	15.72	184	404
1440.00	-8.00	sea	-4.89	-23.69	15.68	0.00	15.68	184	404
1450.00	-8.06	sea	-4.89	-23.70	15.64	0.00	15.64	185	404
1460.00	-8.11	sea	-4.89	-23.71	15.60	0.00	15.60	185	404
1470.00	-8.16	sea	-4.89	-23.72	15.56	0.00	15.56	185	405
1480.00	-8.21	sea	-4.89	-23.73	15.52	0.00	15.52	185	405
1490.00	-8.26	sea	-4.89	-23.73	15.47	0.00	15.47	185	405
1500.00	-8.31	sea	-4.89	-23.71	15.40	0.00	15.40	185	404
1510.00	-8.36	sea	-4.89	-23.67	15.31	0.00	15.31	184	404
1520.00	-8.41	sea	-4.89	-23.61	15.20	0.00	15.20	184	403
1530.00	-8.46	sea	-4.89	-23.53	15.07	0.00	15.07	183	402
1540.00	-8.51	sea	-4.89	-23.44	14.92	0.00	14.92	182	401
1550.00	-8.56	sea	-4.89	-23.32	14.75	0.00	14.75	181	399
1560.00	-8.61	sea	-4.89	-23.18	14.56	0.00	14.56	179	398
1570.00	-8.67	sea	-4.89	-23.02	14.35	0.00	14.35	178	396
1580.00	-8.71	sea	-4.89	-22.84	14.12	0.00	14.12	176	393
1590.00	-8.76	sea	-4.89	-22.64	13.88	0.00	13.88	174	391
1600.00	-8.80	sea	-4.89	-22.42	13.62	0.00	13.62	172	388
1610.00	-8.84	sea	-4.89	-22.18	13.34	0.00	13.34	170	385
1620.00	-8.88	sea	-4.89	-21.92	13.04	0.00	13.04	167	382
1630.00	-8.92	sea	-4.89	-21.64	12.72	0.00	12.72	164	378
1640.00	-8.96	sea	-4.89	-21.34	12.38	0.00	12.38	161	374
1650.00	-9.00	sea	-4.89	-21.02	12.03	0.00	12.03	158	370
1660.00	-9.03	sea	-4.89	-20.68	11.65	0.00	11.65	155	366
1670.00	-9.07	sea	-4.89	-20.32	11.25	0.00	11.25	151	361
1680.00	-9.12	sea	-4.89	-19.94	10.83	0.00	10.83	148	356
1690.00	-9.16	sea	-4.89	-19.55	10.39	0.00	10.39	144	351
1700.00	-9.20	sea	-4.89	-19.13	9.92	0.00	9.92	140	346
1710.00	-9.25	sea	-4.89	-18.69	9.44	0.00	9.44	135	340
1720.00	-9.29	sea	-4.89	-18.23	8.94	0.00	8.94	131	334
1730.00	-9.34	sea	-4.89	-17.75	8.41	0.00	8.41	126	328
1740.00	-9.38	sea	-4.89	-17.25	7.87	0.00	7.87	121	322
1750.00	-9.42	sea	-4.89	-16.73	7.30	0.00	7.30	116	315
1760.00	-9.47	sea	-4.89	-16.19	6.72	0.00	6.72	111	308
1770.00	-9.51	sea	-4.89	-15.63	6.12	0.00	6.12	105	301
1780.00	-9.56	sea	-4.89	-15.05	5.49	0.00	5.49	100	294
1790.00	-9.60	sea	-4.89	-14.45	4.85	0.00	4.85	94	286
1800.00	-9.64	sea	-4.89	-13.83	4.19	0.00	4.19	88	278
1810.00	-9.69	sea	-4.89	-13.19	3.51	0.00	3.51	81	270
1820.00	-9.73	sea	-4.89	-12.53	2.80	0.00	2.80	75	262
1830.00	-9.77	sea	-4.89	-11.85	2.08	0.00	2.08	68	253
1840.00	-9.82	sea	-4.89	-11.16	1.34	0.00	1.34	61	244
1850.00	-9.86	sea	-4.89	-10.45	0.59	0.00	0.59	55	235
1860.00	-9.89	sea	-4.89	-9.89	0.00	0.00	0.00	49	228

HDD borehole profile graph based on the above table

JUB	8.00	8.00	8.00	0.00	



Dist (m)	σv (kN/m²)	σh (kN/m²)	σo (kN/m²)	Pf (kN/m²)	Q	Rpmax (m)	Pemax (kN/m²)	Pmax (kN/m²)	Hf (kN/m²)	H (kN/m²)
0.0	0.0	0.0	0.0	1.8	0.00012	0.6	2	2	*0*	*0*
10.0	17.4	0.0	17.4	26.6	0.00060	0.9	38	56	*0*	*23*
20.0	34.8	0.0	34.8	51.3	0.00107	1.9	109	146	*1*	*46*
30.0	52.4	0.0	52.4	76.3	0.00156	2.8	204	259	*1*	*65*
40.0	76.3	0.0	76.3	110.3	0.00221	4.1	357	438	*2*	*91*
50.0	92.9	0.0	92.9	134.0	0.00267	5.0	475	573	*2*	*114*
60.0	110.3	0.0	110.3	158.7	0.00315	5.9	601	717	*2*	*140*
70.0	121.9	0.0	121.9	175.2	0.00347	6.5	685	814	*3*	*160*
80.0	135.3	0.0	135.3	194.2	0.00383	7.3	781	923	*3*	*182*
90.0	149.8	0.0	149.8	215.0	0.00423	8.0	882	1040	*4*	*204*
100.0	163.9	0.0	163.9	234.9	0.00462	8.8	976	1149	*4*	*224*
110.0	177.6	0.0	177.6	254.4	0.00500	9.5	1064	1251	*4*	*244*
120.0	192.5	0.0	192.5	275.7	0.00541	10.3	1157	1359	*5*	*263*
130.0	232.2	0.0	232.2	332.2	0.00650	12.5	1382	1627	*5*	*281*
140.0	233.1	0.0	233.1	333.4	0.00652	12.5	1387	1632	*5*	*298*
150.0	221.0	0.0	221.0	316.2	0.00619	11.9	1321	1554	*6*	*315*
160.0	190.7	0.0	190.7	273.1	0.00536	10.2	1146	1346	*6*	*330*
170.0	196.8	0.0	196.8	281.8	0.00552	10.6	1182	1390	*7*	*345*
180.0	191.8	0.0	191.8	274.7	0.00539	10.3	1152	1354	*7*	*359*
190.0	194.7	0.0	194.7	278.8	0.00547	10.4	1170	1375	*7*	*372*
210.0	202.1	0.0	202.1	289.3	0.00567	10.8	1213	1426	*8*	*395*
220.0	206.4	0.0	206.4	295.5	0.00579	11.1	1239	1456	*9*	*406*
230.0	210.2	0.0	210.2	300.9	0.00589	11.3	1261	1482	*9*	*415*
240.0	213.9	0.0	213.9	306.0	0.00599	11.5	1281	1506	*9*	*424*
250.0	217.3	0.0	217.3	311.0	0.00609	11.7	1300	1529	*10*	*432*
260.0	218.6	0.0	218.6	312.8	0.00612	11.7	1308	1538	*10*	*439*
270.0	219.3	0.0	219.3	313.8	0.00614	11.8	1312	1542	*11*	*445*
280.0	219.4	0.0	219.4	313.9	0.00614	11.8	1312	1543	*11*	*451*
290.0	218.8	0.0	218.8	313.1	0.00613	11.7	1309	1539	*11*	*455*
300.0	217.6	0.0	217.6	311.4	0.00610	11.7	1302	1531	*12*	*459*
310.0	215.8	0.0	215.8	308.8	0.00605	11.6	1292	1519	*12*	*462*
320.0	213.4	0.0	213.4	305.4	0.00598	11.4	1278	1503	*13*	*464*
330.0	210.3	0.0	210.3	301.0	0.00590	11.3	1261	1482	*13*	*465*
340.0	206.9	0.0	206.9	296.1	0.00580	11.1	1241	1459	*13*	*465*
350.0	203.4	0.0	203.4	291.2	0.00571	10.9	1221	1435	*14*	*466*
360.0	199.9	0.0	199.9	286.3	0.00561	10.7	1201	1411	*14*	*466*
370.0	196.5	0.0	196.5	281.3	0.00552	10.5	1180	1387	*15*	*467*
380.0	193.0	0.0	193.0	276.4	0.00542	10.4	1160	1363	*15*	*467*
390.0	189.6	0.0	189.6	271.5	0.00532	10.2	1139	1338	*15*	*468*
400.0	186.1	0.0	186.1	266.6	0.00523	10.0	1118	1313	*16*	*468*
410.0	182.6	0.0	182.6	261.6	0.00513	9.8	1096	1288	*16*	*469*
420.0	179.2	0.0	179.2	256.7	0.00504	9.6	1075	1263	*16*	*469*
430.0	175.7	0.0	175.7	251.8	0.00494	9.4	1053	1238	*17*	*470*
440.0	172.2	0.0	172.2	246.8	0.00485	9.2	1031	1212	*17*	*471*
450.0	168.8	0.0	168.8	241.9	0.00475	9.1	1008	1186	*18*	*471*
460.0	166.0	0.0	166.0	237.9	0.00468	8.9	990	1165	*18*	*472*
470.0	166.5	0.0	166.5	238.7	0.00469	8.9	994	1169	*18*	*472*
480.0	166.9	0.0	166.9	239.2	0.00470	9.0	996	1172	*19*	*473*
490.0	166.8	0.0	166.8	239.1	0.00470	8.9	995	1171	*19*	*473*
500.0	166.7	0.0	166.7	238.9	0.00470	8.9	995	1170	*20*	*474*
510.0	166.6	0.0	166.6	238.8	0.00469	8.9	994	1170	*20*	*474*
520.0	166.5	0.0	166.5	238.7	0.00469	8.9	994	1169	*20*	*475*
530.0	166.6	0.0	166.6	238.9	0.00469	8.9	994	1170	*21*	*475*
540.0	166.7	0.0	166.7	239.0	0.00470	8.9	995	1171	*21*	*476*

*The pressure calculations are set out in this table. Note that **Rpmax** varies as it is set to be a proportion of the cover depth.*

Hf is a rough estimate of the drilling mud pressure in the return annular flow.

*The total head **H** is the static head **Hs** (table above) and **Hf**.*

550.0	166.8	0.0	166.8	239.1	0.00470	9.0	996	1171	22	476
560.0	166.9	0.0	166.9	239.3	0.00470	9.0	996	1172	22	477
570.0	167.0	0.0	167.0	239.4	0.00471	9.0	997	1173	22	477
580.0	167.1	0.0	167.1	239.6	0.00471	9.0	998	1174	23	478
590.0	167.2	0.0	167.2	239.7	0.00471	9.0	998	1174	23	479
600.0	167.8	0.0	167.8	240.6	0.00473	9.0	1002	1179	24	479
610.0	168.6	0.0	168.6	241.6	0.00475	9.0	1007	1184	24	480
620.0	169.3	0.0	169.3	242.7	0.00477	9.1	1012	1190	24	480
630.0	170.0	0.0	170.0	243.7	0.00479	9.1	1017	1196	25	481
640.0	170.8	0.0	170.8	244.8	0.00481	9.2	1021	1201	25	481
650.0	171.5	0.0	171.5	245.8	0.00483	9.2	1026	1207	25	482
660.0	172.3	0.0	172.3	246.9	0.00485	9.2	1031	1212	26	482
670.0	173.0	0.0	173.0	247.9	0.00487	9.3	1036	1218	26	483
680.0	173.7	0.0	173.7	249.0	0.00489	9.3	1040	1223	27	483
690.0	174.5	0.0	174.5	250.0	0.00491	9.4	1045	1229	27	484
700.0	175.2	0.0	175.2	251.1	0.00493	9.4	1050	1234	27	484
710.0	175.9	0.0	175.9	252.1	0.00495	9.4	1054	1239	28	485
720.0	176.1	0.0	176.1	252.4	0.00496	9.4	1055	1241	28	485
730.0	176.3	0.0	176.3	252.6	0.00496	9.5	1057	1242	29	486
740.0	176.5	0.0	176.5	252.9	0.00497	9.5	1058	1244	29	487
750.0	176.7	0.0	176.7	253.2	0.00497	9.5	1059	1245	29	487
760.0	176.9	0.0	176.9	253.5	0.00498	9.5	1061	1247	30	488
770.0	177.1	0.0	177.1	253.8	0.00498	9.5	1062	1248	30	488
780.0	177.1	0.0	177.1	253.7	0.00498	9.5	1061	1248	31	489
790.0	177.0	0.0	177.0	253.6	0.00498	9.5	1061	1247	31	489
800.0	177.0	0.0	177.0	253.6	0.00498	9.5	1061	1247	31	490
810.0	176.9	0.0	176.9	253.4	0.00498	9.5	1060	1246	32	490
820.0	176.7	0.0	176.7	253.2	0.00497	9.5	1059	1245	32	491
830.0	176.5	0.0	176.5	252.9	0.00497	9.5	1058	1244	33	491
840.0	176.3	0.0	176.3	252.7	0.00496	9.5	1057	1242	33	492
850.0	176.2	0.0	176.2	252.5	0.00496	9.5	1056	1242	33	492
860.0	176.1	0.0	176.1	252.4	0.00496	9.4	1055	1241	34	493
870.0	176.0	0.0	176.0	252.2	0.00495	9.4	1055	1240	34	493
880.0	175.7	0.0	175.7	251.8	0.00494	9.4	1053	1238	34	494
890.0	175.1	0.0	175.1	250.9	0.00493	9.4	1049	1233	35	495
900.0	174.6	0.0	174.6	250.1	0.00491	9.4	1045	1229	35	495
910.0	174.0	0.0	174.0	249.3	0.00490	9.3	1042	1225	36	496
920.0	173.4	0.0	173.4	248.5	0.00488	9.3	1038	1221	36	496
930.0	172.8	0.0	172.8	247.7	0.00487	9.3	1035	1217	36	
920.0	176.0	0.0	176.0	252.2	0.00495	9.4	1055	1240	36	433
910.0	175.7	0.0	175.7	251.8	0.00494	9.4	1053	1238	36	433
900.0	175.1	0.0	175.1	250.9	0.00493	9.4	1049	1233	35	433
890.0	174.6	0.0	174.6	250.1	0.00491	9.4	1045	1229	35	432
880.0	174.0	0.0	174.0	249.3	0.00490	9.3	1042	1225	34	432
870.0	173.4	0.0	173.4	248.5	0.00488	9.3	1038	1221	34	432
860.0	172.8	0.0	172.8	247.7	0.00487	9.3	1035	1217	34	432
850.0	172.5	0.0	172.5	247.2	0.00486	9.3	1032	1214	33	431
840.0	171.8	0.0	171.8	246.3	0.00484	9.2	1028	1209	33	431
830.0	171.2	0.0	171.2	245.3	0.00482	9.2	1024	1204	33	431
820.0	170.4	0.0	170.4	244.2	0.00480	9.1	1019	1198	32	431
810.0	169.5	0.0	169.5	243.0	0.00477	9.1	1013	1192	32	430
800.0	168.7	0.0	168.7	241.8	0.00475	9.0	1008	1187	31	430
790.0	167.9	0.0	167.9	240.6	0.00473	9.0	1002	1182	31	430
780.0	167.0	0.0	167.0	239.4	0.00471	9.0	997	1177	31	430
770.0	166.2	0.0	166.2	238.2	0.00468	8.9	992	1171	30	429
760.0	165.4	0.0	165.4	237.1	0.00466	8.9	986	1166	30	429
750.0	164.5	0.0	164.5	235.9	0.00464	8.8	981	1161	29	429
740.0	163.7	0.0	163.7	234.7	0.00461	8.8	975	1155	29	429
730.0	163.0	0.0	163.0	233.7	0.00459	8.7	971	1151	29	428
720.0	162.4	0.0	162.4	232.8	0.00458	8.7	967	1147	28	428
710.0	161.8	0.0	161.8	232.0	0.00456	8.7	963	1143	28	428
700.0	161.2	0.0	161.2	231.1	0.00455	8.6	959	1139	27	428
690.0	160.6	0.0	160.6	230.3	0.00453	8.6	955	1135	27	427
680.0	160.0	0.0	160.0	229.4	0.00451	8.6	951	1131	27	427
670.0	159.4	0.0	159.4	228.6	0.00450	8.6	947	1128	26	427
660.0	158.8	0.0	158.8	227.7	0.00448	8.5	943	1124	26	427
650.0	158.3	0.0	158.3	227.0	0.00447	8.5	940	1121	25	426
640.0	157.6	0.0	157.6	226.1	0.00445	8.5	935	1116	25	426
630.0	157.3	0.0	157.3	225.6	0.00444	8.4	933	1114	25	426
620.0	156.9	0.0	156.9	225.1	0.00443	8.4	930	1112	24	426
610.0	156.6	0.0	156.6	224.6	0.00442	8.4	928	1110	24	425
600.0	156.2	0.0	156.2	224.1	0.00441	8.4	926	1107	24	425
590.0	155.9	0.0	155.9	223.6	0.00440	8.4	923	1105	23	425
580.0	155.5	0.0	155.5	223.1	0.00439	8.3	921	1103	23	425
570.0	155.6	0.0	155.6	223.2	0.00439	8.3	921	1103	22	424
560.0	155.7	0.0	155.7	223.3	0.00439	8.4	922	1104	22	424
550.0	155.6	0.0	155.6	223.2	0.00439	8.3	921	1104	22	424

540.0	155.5	0.0	155.5	223.0	0.00439	8.3	921	1103	*21*	*424*
530.0	155.0	0.0	155.0	222.4	0.00438	8.3	918	1100	*21*	*423*
520.0	154.5	0.0	154.5	221.6	0.00436	8.3	914	1097	*20*	*423*
510.0	153.9	0.0	153.9	220.8	0.00435	8.3	910	1093	*20*	*423*
500.0	153.4	0.0	153.4	220.0	0.00433	8.2	907	1089	*20*	*423*
490.0	152.8	0.0	152.8	219.2	0.00432	8.2	903	1086	*19*	*422*
480.0	152.3	0.0	152.3	218.4	0.00430	8.2	899	1082	*19*	*422*
470.0	151.7	0.0	151.7	217.7	0.00429	8.1	895	1078	*18*	*422*
460.0	151.2	0.0	151.2	216.9	0.00427	8.1	892	1075	*18*	*422*
450.0	150.7	0.0	150.7	216.2	0.00426	8.1	888	1071	*18*	*421*
440.0	150.2	0.0	150.2	215.4	0.00424	8.1	885	1068	*17*	*421*
430.0	149.7	0.0	149.7	214.7	0.00423	8.0	881	1065	*17*	*421*
420.0	149.1	0.0	149.1	214.0	0.00421	8.0	878	1061	*16*	*421*
410.0	148.6	0.0	148.6	213.3	0.00420	8.0	874	1058	*16*	*420*
400.0	148.1	0.0	148.1	212.6	0.00419	7.9	871	1055	*16*	*420*
390.0	147.6	0.0	147.6	211.8	0.00417	7.9	867	1051	*15*	*420*
380.0	147.3	0.0	147.3	211.3	0.00416	7.9	865	1049	*15*	*420*
370.0	146.9	0.0	146.9	210.8	0.00415	7.9	862	1046	*15*	*419*
360.0	146.5	0.0	146.5	210.3	0.00414	7.9	860	1044	*14*	*419*
350.0	146.2	0.0	146.2	209.7	0.00413	7.8	857	1042	*14*	*418*
340.0	145.8	0.0	145.8	209.2	0.00412	7.8	855	1039	*13*	*416*
330.0	145.4	0.0	145.4	208.7	0.00411	7.8	852	1037	*13*	*415*
320.0	145.0	0.0	145.0	208.1	0.00410	7.8	849	1034	*13*	*413*
310.0	144.7	0.0	144.7	207.6	0.00409	7.8	847	1032	*12*	*412*
300.0	144.2	0.0	144.2	207.0	0.00408	7.7	844	1028	*12*	*409*
290.0	143.5	0.0	143.5	206.0	0.00406	7.7	839	1024	*11*	*407*
280.0	142.7	0.0	142.7	204.8	0.00404	7.7	833	1018	*11*	*404*
270.0	141.7	0.0	141.7	203.4	0.00401	7.6	826	1010	*11*	*401*
260.0	140.5	0.0	140.5	201.6	0.00398	7.5	818	1001	*10*	*398*
250.0	139.1	0.0	139.1	199.6	0.00394	7.5	808	990	*10*	*395*
240.0	137.5	0.0	137.5	197.4	0.00389	7.4	797	977	*9*	*391*
230.0	135.7	0.0	135.7	194.9	0.00385	7.3	784	964	*9*	*387*
220.0	133.8	0.0	133.8	192.1	0.00379	7.2	770	948	*9*	*383*
210.0	131.6	0.0	131.6	189.1	0.00373	7.1	755	931	*8*	*378*
200.0	129.3	0.0	129.3	185.8	0.00367	6.9	739	913	*8*	*374*
190.0	126.9	0.0	126.9	182.3	0.00360	6.8	722	893	*7*	*369*
180.0	124.3	0.0	124.3	178.7	0.00353	6.7	703	873	*7*	*363*
170.0	121.5	0.0	121.5	174.7	0.00346	6.5	683	850	*7*	*358*
160.0	118.5	0.0	118.5	170.4	0.00337	6.4	661	825	*6*	*352*
150.0	115.4	0.0	115.4	166.0	0.00329	6.2	638	800	*6*	*346*
140.0	112.1	0.0	112.1	161.2	0.00320	6.0	614	772	*5*	*340*
130.0	108.6	0.0	108.6	156.3	0.00310	5.8	589	744	*5*	*333*
120.0	32.7	0.0	32.7	48.3	0.00102	1.8	99	181	*5*	*327*
110.0	26.1	0.0	26.1	39.0	0.00084	1.4	70	145	*4*	*320*
100.0	19.4	0.0	19.4	29.4	0.00065	1.0	44	113	*4*	*312*
90.0	12.5	0.0	12.5	19.6	0.00046	0.7	22	84	*4*	*305*
80.0	5.5	0.0	5.5	9.7	0.00027	0.3	5	60	*3*	*297*
70.0	0.0	0.0	0.0	1.8	0.00012	0.6	2	51	*3*	*289*
60.0	153.0	0.0	153.0	219.5	0.00432	4.0	675	675	*2*	*281*
50.0	0.0	0.0	0.0	1.8	0.00012	0.6	2	2	*2*	*272*
40.0	0.0	0.0	0.0	1.8	0.00012	0.6	2	2	*2*	*263*
30.0	0.0	0.0	0.0	1.8	0.00012	0.6	2	2	*1*	*254*
20.0	0.0	0.0	0.0	1.8	0.00012	0.6	2	2	*1*	*245*
10.0	0.0	0.0	0.0	1.8	0.00012	0.6	2	2	*0*	*236*
0.0	0.0	0.0	0.0	1.8	0.00012	0.6	2	2	*0*	*228*

Comments