Hornsea Project Four

Clarification Note: Justification of Offshore Maximum Design Scenarios

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Revision Summary

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Glossary

Term	Definition
Bedform Baseline (BFBL)	The level below which sediments are not deemed to be mobile, and therefore the level below which buried cables would not be predicted to become exposed.
Bedform Clearance	The clearance of mobile sediments.
Design Envelope	A description of the range of possible elements that make up the Hornsea Project Four design options under consideration, as set out in detail in the project description. This envelope is used to define Hornsea Project Four for Environmental Impact Assessment (EIA) purposes when the exact engineering parameters are not yet known. This is also often referred to as the "Rochdale Envelope" approach.
Maximum Design Scenario (MDS)	The maximum design parameters of each Hornsea Four asset (both on and offshore) considered to be a worst case for any given assessment.
Rochdale Envelope	Provides flexibility in design options where details of the whole project are not available when the application is submitted, while ensuring the impacts of the final development are fully assessed during the Environmental Impact Assessment (EIA).

Acronyms

Term	Definition
ALPACA	Axial-Lateral Pile Analysis for Chalk Applying multi-scale field and laboratory testing
BFBL	Bedform Baseline
CBRA	Cable Burial Risk Assessment
DCO	Development Consent Order
DML	Deemed Marine Licence
ECC	Export Cable Corridor
EIA	Environmental Impact Assessment
EPSRC	Engineering and Physical Sciences Research Council
ES	Environmental Statement
GBS	Gravity Base Structure
GIS	Geographical Information System
HDD	Horizontal Directional Drilling
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
KP	Kilometre Point
MDS	Maximum Design Scenario
NPS	National Policy Statement
OSS	Offshore Substation
PINS	Planning Inspectorate
RR	Relevant Representation
WTG	Wind Turbine Generator

1 Introduction

1.1.1.1 Orsted Hornsea Project Four Limited (hereafter the Applicant) has submitted a Development Consent Order (DCO) application to the Planning Inspectorate (PINS), supported by a range of plans and documents including an Environmental Statement (ES) which set out the results of the Environmental Impact Assessment (EIA) on the Hornsea Project Four Offshore Wind Farm (hereafter Hornsea Four) and its associated infrastructure.

1.1.1.2 In accordance with the accepted industry approach, the Hornsea Four ES provides details of maximum design scenarios (MDS) based on the project design envelope or Rochdale Envelope approach. Further detail on this approach is presented in **Section 2** of this note and in **A1.5 Environmental Impact Assessment Methodology (AS-007)**. The MDS approach is used to establish the maximum extent to which Hornsea Four could impact on the environment. The detailed design of Hornsea Four would lie within the maximum extent of the consent and could then vary within this 'envelope' without rendering the assessment inadequate. In line with this approach, the Hornsea Four impact assessments have been undertaken based on a MDS of predicted impacts, which are set out within each topic chapter.

1.1.1.3 This note has been produced to provide clarification of and justification for several offshore MDS (as set out in **Section 1.1.1.7**), as presented in the offshore chapters of the Hornsea Four ES (**Volume A2: APP-013 – APP-023**).

1.1.1.4 The Relevant Representation (RR) from Natural England (**RR-029**) has made comments regarding the precautionary and conservative nature of some of the offshore maximum design scenarios for Hornsea Four, requesting that some MDS should be refined based on latest available survey data (that wasn't available at the time of DCO Application). These comments are summarised in paragraphs 5.40 and 6.1-6.5 of the Natural England RR, with topic specific MDS comments provided in the following appendices to the Natural England Relevant Representation:

- Appendix E Marine Geology, Oceanography and Physical Processes;
- Appendix F Benthic and Intertidal Ecology; and
- Appendix G Fish and Shellfish Ecology.

1.1.1.5 It is important to note that the Applicant disagrees with Natural England and considers that the MDS are suitably precautionary or conservative, to ensure maximum impacts are identified, but not overly or excessively so. The Applicant considers that sufficient and proportionate data has been collected on ground conditions comparable to that obtained for other offshore wind projects at the application stage, and that this data, alongside the Applicant's experience in the construction of offshore wind farms in the UK and Europe, has been used to define the MDS which have then been assessed in line with the Rochdale Envelope approach to assessment in order to understand the potential maximum impacts on relevant receptors. This is considered to be appropriate.

1.1.1.6 Applicant responses to the MDS points raised in the Natural England RR are presented in **G1.9 Applicant's comments on Relevant Representations (REP1-038)**.

1.1.1.7 Based on the Relevant Representation points outlined above, the scope of this clarification note includes details of:

- Clarification of the MDS for bedform clearance for cable installation in **Section 3**;
- Clarification of the MDS for bedform clearance volumes for foundation installation in **Section 4**;

- Clarification of the MDS for foundation drilling in **Section 5**; and
- Clarification for MDS for cable protection for all cables, with specific focus on cable protection in the vicinity of Smithic Bank in **Section 6**.

1.1.1.8 Natural England have requested justification for the requirement for up to eight Horizontal Directional Drilling (HDD) exit pits for a maximum of six cables. The Applicant notes that the eight exit pits relates to 4 pairs of HVDC circuits). As such, the Applicant considers no further justification required and this MDS is not considered further in this note.

2 The Project Design Envelope and Maximum Design Scenarios

2.1.1.1 The Hornsea Four EIA is based on a project envelope approach, also known as a 'Rochdale Envelope' approach. Paragraph 2.6.43 of National Policy Statement (NPS) EN-3 (DECC, 2011) and PINS Advice Note Nine (PINS, 2018) recognise that, at the time of submitting an application, offshore wind developers may not know the precise nature and arrangement of turbines, infrastructure and associated infrastructure that make up the proposed development, nor the precise installation methodologies and tools that may be employed to construct the different elements of the project. This is due to several factors such as the evolution of technology, the need for flexibility in key commercial project decisions and the need for more detailed preconstruction engineering surveys which are required before a final design and layout can be determined. It is therefore important that a design envelope approach is used to provide flexibility to maximise the potential for Hornsea Four to proceed and be successful whilst providing sufficient detail to enable a robust EIA to be carried out. A degree of necessary flexibility has, therefore, been built into the Hornsea Four design by applying the design envelope approach, consistent with EN-3 and the PINS advice note.

2.1.1.2 To inform the assessments, a range of parameters for each aspect of the project has been defined (the design envelope) with a MDS identified for each potential effect that has been assessed. So, whilst the design envelope allows for some potential variations in detailed design and other aspects of Hornsea Four, the MDS ensures that assessment is based on a worst-case approach, specific to the effect being assessed. For each aspect of the project, a range of parameters has been defined and subsequently, the worst-case scenario associated with each parameter dependent on the receptor has been used in each impact assessment. This provides confidence that the EIA process robustly considers the likely worst-case impact of the project on each aspect of the environment, whilst also allowing the project to be optimised and refined at the time of construction noting that this may be several years after the final DCO submission is made. The project design envelope therefore provides the maximum extent of the consent sought. The detailed design of the project can then be developed, refined and procured within this consented envelope prior to construction. The technical chapters contain MDSs for each of the potential effects assessed, with MDSs for each effect considered during the EIA process presented in **Volume A4, Annex 5.1: Impacts Register (APP-049)**.

2.1.1.3 Further details on the Project Design Envelope and Maximum Design Scenarios approach is presented in Section 5.6 of **A1.5: Environmental Impact Assessment Methodology (AS-007)**.

3 Maximum Design Scenario for Bedform Clearance (Cables)

3.1 Maximum Design Scenario for Bedform Clearance Volumes (Cables) as Presented in ES

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

3.1.1.2 **Table 1** presents the MDS for bedform clearance volumes (cables) at DCO Application, as summarised from **A1.4 Project Description (REP1-004)**.

Table 1: Maximum design parameters for bedform clearance volume (cables).

Parameter	**Maximum design parameters**		
	Array cables	*Offshore interconnector cables*	*Offshore export cables*
Total length of cable (km)	600	90	654
Bedform Clearance - Material Volumes (m^3)	769,000	115,000	834,000

3.2 Reduction in the Maximum Design Scenario for Bedform Clearance Volumes (Cables)

3.2.1.1 As part of the analysis of the latest site-specific geophysical data, the Applicant has been considering the bedform clearance volumes required for cable installation. Following this consideration, the Applicant proposes to reduce the bedform clearance volumes for cable installation. The following sections set out the methodology associated with establishing this reduction, as well as confirmation of what this reduction will comprise.

3.2.2 Methodology for Bedform Clearance (Cables) Volume Analysis and Calculations

3.2.2.1 The methodology seeks to sum the total volume of mobile bedform sediment that would need to be cleared before a cable burial tool can bury the cable to the required depth. The amount of mobile bedform to be cleared is calculated by means of a morphological seabed assessment which compares the seabed level dataset to a Bedform Baseline (BFBL) dataset that is created using Geographical Information System (GIS) analysis modelling, which represents the level below which sediments are not deemed to be mobile, and therefore the level below which buried cables would not be predicted to become exposed. Both of these datasets are informed by survey data from all the Hornsea Four campaigns (including the 2021 geophysical data) which constitutes full coverage (2 m resolution) of the Hornsea Four offshore Order Limits). **Figure 1** presents an illustration of the BFBL in relation to the seabed level and the cable burial depth which is the depth that the cable burial tool will need to lay the cable at to achieve optimal burial. In relation to the Hornsea Four bedform clearance calculations, the cable burial depth is a constant value below the BFBL.

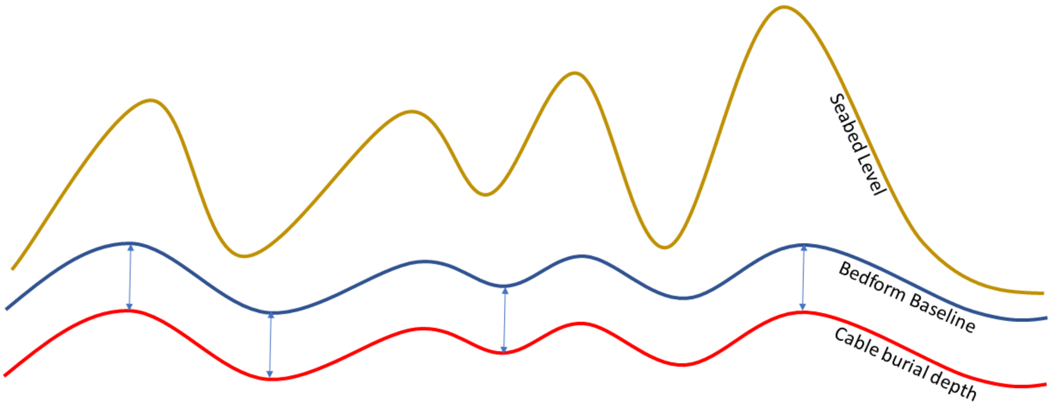


Figure 1: Illustration of seabed level, Bedform Baseline (BFBL), and the cable burial depth.

3.2.2.2 As presented in **Figure 2**, the performance (or reach) of the cable burial tool is fundamental to the volume of mobile bedforms that would require clearance prior to cable burial. A longer reach of cable burial tool will equate to a reduced requirement for mobile bedform clearance, with a shallower or deeper depth of burial equating to lesser or greater requirements for mobile bedform clearance.

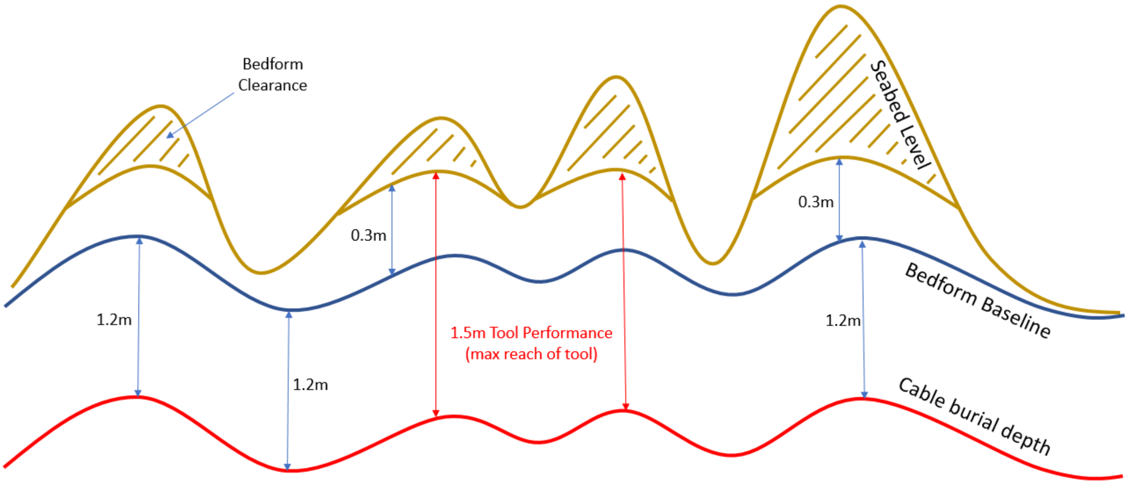


Figure 2: Illustration of cable burial tool performance in relation to the residual bedform requiring clearance.

3.2.2.3 As illustrated in **Figure 3**, given the wave-like shape of mobile bedforms, as the difference between the cable burial tool performance and the depth of burial is increased, there is an exponential drop off in the volume of mobile bedforms that would require clearance.

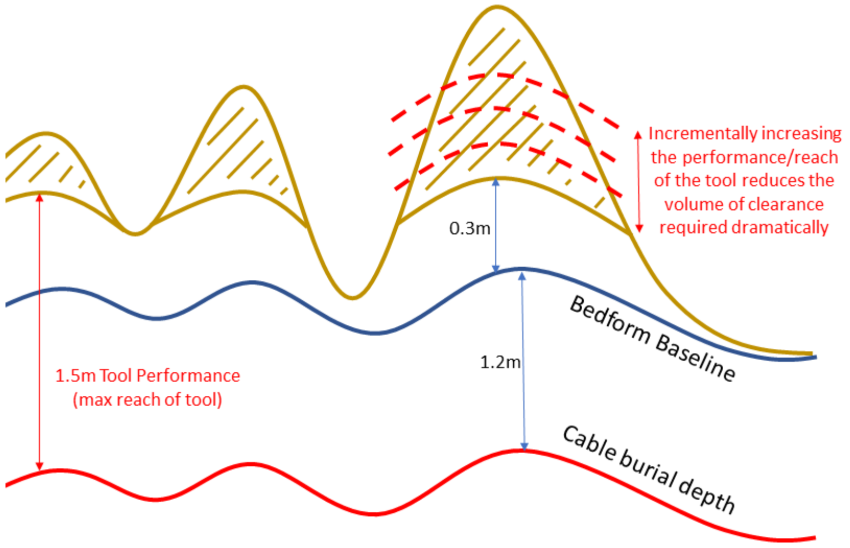


Figure 3: Illustration of the effect of varying cable burial tool performance (or reach).

3.2.2.4 Survey data from all the Hornsea Four campaigns (including the 2021 geophysical data) has been analysed by the Applicant to create the BFBL dataset. This dataset constitutes full coverage (2 m resolution) of the Hornsea Four offshore Order Limits. The BFBL dataset has been compared to a cable burial depth and tool performance value that are considered appropriate and acceptable to the Applicant for Hornsea Four, with comparisons made with the seabed level dataset to calculate the volumes of bedform clearance required.

3.2.3 Proposed Reduced Volumes for Bedform Clearance (Cables)

3.2.3.1 **Table 2** presents the results of the bedform clearance analysis and calculations, utilising all survey data collected for Hornsea Four. Volumes of bedform clearance set out in the DCO Application are also presented in the table to provide context and a comparison.

Table 2: Proposed reduced volumes for bedform clearance compared to MDS from DCO Application.

Parameter	**Maximum design parameters**				
	Array cables	*Offshore interconnector cables*	*Offshore export cables*		***Total***
			Within array area	*Export Cable Corridor (ECC)*	
Total length of cable (km)	600	90	654		**1,344**
DCO Application Volumes					
Bedform Clearance - Material Volumes (m^3)	769,000	115,000	834,000		**1,718,000**
Proposed Reduced Volumes					
Bedform Clearance - Material Volumes (m^3)	726,995	109,049	438,774		**1,274,818**
Percentage Reduction	*5.46%*	*5.17%*	*47.39%*		***25.80%***

3.2.3.2 There are several reasons for the reductions in the calculations for the volumes of bedform clearance. As noted above, the BFBL and seabed level datasets has been created using the latest high-resolution bathymetry data that was not available when the calculations for the DCO Application volumes were calculated. In addition, as illustrated in **Figure 3**, small changes in the vertical component of the analysis have a large impact on the volume of clearance required due to the lengths of the cable corridors. This relates to the differences between the BFBL/seabed level datasets used prior to DCO Application and the latest BFBL/seabed datasets (higher resolution and greater coverage), as well as differences between the tool performance and the depth of burial.

3.3 Materiality

3.3.1.1 The Applicant can confirm that the reduction in bedform clearance volumes does not affect the outcomes of the ES as this will just represent a reduction in the MDS that is already considered within the detailed assessments and as such, with the reduction in bedform clearance volumes, all effects will be equal to or less than as assessed in the ES.

3.3.1.2 The Applicant has been mindful of the examination timetable in making this decision at Deadline 3, such that sufficient time is available for interested parties to comment on the reduced calculations during Examination.

3.3.1.3 In order to capture this change, the Applicant proposes that this note is added to Schedule 15 of **C1.1 Draft DCO including Draft Deemed Marine Licences (DML) (REP2-061)** as a document to be certified, with volumes stated in **C1.1 Draft DCO including Draft DML (REP2-061)**, **A1.4 Project Description (REP1-004)** and **A4.4.8 Pro rata Annex (REP1-006)** updated accordingly.

3.4 Maximum Design Scenario for Bedform Clearance Areas (Bedform and Boulder Clearance - Cables)

3.4.1.1 **Table 3** presents the MDS for bedform clearance areas (bedform and boulder clearance - cables) at DCO Application, as summarised from **A1.4 Project Description (REP1-004)** and **A4.4.8 Pro rata Annex (REP1-006)**.

Table 3: Maximum design parameters for bedform clearance areas (bedform and boulder clearance - cables).

Parameter	Array Cables	Offshore Interconnector Cables	Offshore Export Cables
Bedform clearance width (m)	40		
Bedform clearance area (km^2)	18	2.7	19.5
Boulder clearance width (m)	30		
Boulder clearance area (km^2)	18	2.7	19.5

3.5 Justification for Maximum Design Scenario for Bedform Clearance Areas (Sandwave and Boulder Clearance)

3.5.1.1 As explained in **Section 3.2** and illustrated in **Figure 2**, mobile sediments have to be cleared across the entire extent of the cable routes in order to lay the cable at the required burial depth below the BFBL. The Applicant has undertaken further analysis of the volumes of bedform clearance required for cables in order to refine the MDS volumes, as detailed in Section 3.2, however due to the need to clear mobile sediments along the extent of the cable routes rather than across discrete sections, it is not possible to reduce bedform and boulder clearance areas. Additionally, a corridor of up to 40 m for bedforms and 30 m for boulders must be cleared per cable circuit as this width is sufficient for the operation of the cable burial tools under consideration.

4 Maximum Design Scenario for Bedform Clearance Volumes (Foundations)

4.1 Maximum Design Scenario for Bedform Clearance Volumes (Foundations) as Presented in ES

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

4.1.1.2 Gravity base, suction bucket jacket and mono-suction bucket foundations need to be placed in pre-prepared areas of seabed. Seabed preparation would involve levelling and dredging of the soft mobile sediments as required, as well as any boulder and obstruction removal.

4.1.1.3 It is likely that dredging would be required if using the Gravity Base Structure (GBS) foundations. If dredging is required it would be carried out by dredging vessels using suction hoppers or similar, and the spoil would be deposited on site adjacent to the turbine locations.

4.1.1.4 Table 4 and Table 5 present the MDS for bedform clearance volumes (foundations) at DCO Application, as summarised from A1.4 Project Description (REP1-004) and A4.4.8 Pro rata Annex (REP1-006).

Table 4: Maximum design parameters for bedform clearance volumes (Wind Turbine Generator (WTG) foundations).

	Maximum Design Parameters	Maximum Related Foundation Type	Maximum Design Parameters	Maximum Related Foundation Type	Total
Total number	70	Where GBS cannot be used	110	GBS	**180**
Seabed Preparation (Spoil) Volume (m^3)	359,427	Suction Caisson Jacket (WTG-type)	685,794	GBS (WTG-type)	**1,045,221**

Table 5: Maximum design parameters for bedform clearance volumes (substation foundations).

	Total Number	Maximum Seabed Preparation (Spoil) Volume (m^3)	Maximum Related Foundation Type
Offshore transformer substations	6 small OSS in array area	343,470 m^3	Suction Caisson Jacket (Small OSS)
Offshore High Voltage Direct Current (HVDC) converter substation (HVDC only)	3 large OSS in array area	393,660 m^3	GBS (Large OSS)
Offshore accommodation platform	1 in array area	57,245 m^3	Suction Caisson Jacket (Small OSS)
Offshore High Voltage Alternating Current (HVAC) booster station (HVAC only)	3 small OSS in HVAC Booster Station Search Area	171,735 m^3	Suction Caisson Jacket (Small OSS)

Offshore HVDC converter substation(s) are mutually exclusive with HVAC booster station(s) in a single transmission system. Therefore, these two figures should not be combined in the total number. The maximum number of structures within the Hornsea Four array area is 190 (i.e. 180 turbines, one accommodation platform, 6 offshore transformer substations and 3 offshore HVDC converter substations)

4.2 Justification for Maximum Design Scenario for Bedform Clearance Volumes (Foundations)

4.2.1.1 Prior to installation of GBS and suction caisson jacket foundations, the seabed will be levelled to the BFBL (as defined in **Section 3.2.2**). The levelling is required to avoid exposure of the foundation structure subsequent to installation, which could undermine the foundation and potentially lead to foundation failure.

4.2.1.2 The Applicant has revisited the bedform clearance volumes for WTG foundations, using the BFBL dataset which has been informed by survey data from all the Hornsea Four campaigns (including the 2021 geophysical data) which constitutes full coverage (2 m resolution) of the Hornsea Four offshore Order Limits). The outcome of this analysis has concluded that the depths of dredging that informed the MDS at DCO Application were not overly conservative and as such, no reduction in bedform clearance volumes is feasible.

4.2.1.3 It is important to note that although reductions have been made to bedform clearance volumes for cables as a result of analysing the 2021 geophysical data, the additional analysis for foundations concluded that previous assessments of required volumes for foundation bedform clearance remain valid. The implications of not clearing to BFBL for foundations are more serious for foundations as the consequence of a foundation being undermined and becoming unstable is a more severe consequence than a cable becoming exposed. As such, the MDS for bedform clearance for foundations must be adequately conservative. That said, the Applicant is confident that the bedform clearance volumes for cables is sufficient (with built-in contingencies) to ensure that cables will not become exposed.

4.2.1.4 The Applicant has reduced the maximum number of GBS WTG foundations that may be used for Hornsea Four, from 180 to a maximum of 110. This change was made to reduce the impact on physical environment and the seabed and as such, the Applicant considers that considerable efforts have been made prior to DCO Application in order to minimise impacts from bedform clearance for WTG foundations.

5 Maximum Design Scenario for Foundation Drilling

5.1 Maximum Design Scenario for Foundation Drilling as Presented in ES

5.1.1.1 Spoil created by drilling will normally be disposed of adjacent to the foundation location (i.e. the drilling location) and will be discharged at the sea surface settling rapidly to the seabed. Drill arisings typically comprise inert sub-bottom geological material; as a result, it will not result in the introduction of contaminants of anthropogenic origin to the marine environment.

5.1.1.2 Table 6 presents the MDS for foundation drilling at DCO Application, as summarised from **A1.4 Project Description (REP1-004)**.

Table 6: Maximum design parameters for foundation drilling.

Foundation Type	Drilling MDS
WTG Foundations (180)	10% of sites require drilling to full pile depth - Monopiles
OSS Foundations (six small offshore transformer substations and three large offshore converter substations)	Drilling of all piles to 10% of pile depth - Piled Jacket (Small OSS)
Offshore Accommodation Platform (one small OSS)	Drilling of all piles to 10% of pile depth - Piled Jacket (Small OSS)

5.2 Justification for Maximum Design Scenario for Foundation Drilling

5.2.1.1 The Hornsea Four Order Limits have soil conditions that differ from the rest of the Hornsea area, with a chalk and a pre-chalk layer outcropping at certain parts of the site. In relation to how the piles will interact with the chalk layer, the Applicant notes that the requirement to drill into chalk depends on the hardness of the substrate. Survey works conducted to date have informed and refined the ground model for Hornsea Four. This has contributed to the understanding of the hardness, driveability potential of and thickness of the chalk layer, with further geotechnical and geophysical investigations required in the pre-construction phase of Hornsea Four in order to create the final layout and design.

5.2.1.2 As detailed in Jardine (2020), while procedures exist to optimise pile design at Quaternary clay and sand sites, greater uncertainty arises for piles bearing into the older geomaterials encountered around north-west European coastlines. Drilled rock socket or drill–drive solutions are being adopted for harder rocks where driving cannot be considered, sometimes supported by trials and tests at onshore analogue sites. However, even when driving is feasible, it is often difficult to predict pile installation behaviour, pile capacities and load–displacement characteristics accurately. One of the most commonly encountered older strata is the Chalk where is noted that pile refusals have been reported on driving through hard high-density chalk.

5.2.1.3 As noted by Jardine (2020) and Buckley *et al.* (2020), there is no method currently available to predict the driving behaviour of piles driven into chalk, with Jardine (2020) noting the need for further research to refine pile driveability assessment into chalk. The Applicant is keen to further the industry knowledge base in relation to the installation of piles in chalk sites and is an part of the ALPACA project (Axial-Lateral Pile Analysis for Chalk Applying Multi-Scale Field and Laboratory Testing). This research project was started in 2017 with funding from Engineering and Physical Sciences Research Council (EPSRC) and Industry (including Orsted) aiming to develop new driven pile design guidance for chalk sites through a comprehensive programme of high quality field tests, advanced laboratory testing, rigorous analysis and synthesis with other case history data. The Academic Work Group comprises academics and researchers from Imperial College London (project lead) and Oxford University, with the key aim to develop design procedures that overcome, for chalk, the current shortfalls in knowledge regarding pile driving, ageing, static and cyclic response under axial and lateral loading. The research has applications with offshore wind turbines and oil platforms as well as port, bridge and other works.

5.2.1.4 In light of the uncertainty outlined above that often cannot not be predicted from survey data and will not become apparent until the commencement of pile driving, the Applicant has assumed a realistic worst case in relation to drilling requirements (10%). This value has been derived from the Applicant's experience, drilling requirements for other offshore wind farm projects, operational installation limits and programme implications.

5.2.1.5 Notably, Sheringham Shoal, 90 km to the south of Hornsea Four, encountered Cretaceous Chalk but was still able to drive all piles into the seabed without the need of drilling (Carotenuto *et al.* 2018), and at Lynn & Inner Dowsing Offshore Wind Farms, sites even further to the south, drilling was required through patches of hard chalk at six of 54 monopile installations. This variability further highlights the uncertainty inherent in piling in chalk environments. The Applicant considers that with the ongoing research that Orsted is contributing to into this area will add to the knowledge base on this topic and ultimately help to develop new drive pile design guidelines through chalk sites.

6 Maximum Design Scenario for Cable Protection

6.1 General

6.1.1 Maximum Design Scenario for Cable Protection as Presented in ES

6.1.1.1 As detailed in **A1.4 Project Description (REP1-004)**, cable protection will be required at cable crossings, as well as areas where cable burial is not possible. The MDS for cable protection at DCO Application is up to 10% of the total cable length (including export, array and interconnector cables and excluding cable crossings) requiring protection due to unforeseen ground conditions and tool failure. Cable protection pro-rata values (10%) are provided in **A4.4.8 Pro-Rata Annex (REP1-006)**.

6.1.2 Justification for Maximum Design Scenario for Cable Protection

6.1.2.1 The preference is always to bury cables as this offers the best protection for cables. The Applicant will endeavour to maximise the chance of burial success through a number of measures including:

i. extending the understanding of the site through further geophysical and geotechnical investigations;

ii. establishing the risk to the cable through the Cable Burial Risk Assessment (CBRA);

iii. preparing the site (i.e. clearing boulders and sandwaves); and

iv. using the right tool for the soil type.

6.1.2.2 The inclusion of cable protection parameters in **A1.4 Project Description (REP1-004)** is, however, necessary to cover those areas where burial may fail (e.g. because of subsurface boulders, tool breakdown, harder/softer soil than expected etc.).

6.1.2.3 The MDS of up to 10% missed burial is based on the Applicant's experience of the previous projects outlined in **Table 7**. These projects have been selected for inclusion in this note on the basis that data relating to extents of export cable protection installed at these projects is readily available to the Applicant and that these projects are considered to be suitably representative of the Applicant's experience across all of its previous projects. On this basis of the values presented in **Table 7**, together with the current knowledge of ground conditions across the Hornsea Four Order Limits, the prediction that up to 10% of Hornsea Four cables could potentially require cable protection is considered to be realistically conservative.

Table 7: Comparison of the total length of export cables requiring cable protection measures (and the corresponding percentage of the total length of cables) for relevant Orsted projects, at the time of installation.

Offshore wind farm project	Array cables		Offshore export cables	
	Total length (km)	Total length requiring cable protection (km) and percentage of total (%), at the time of installation	Total length (km)	Total length requiring cable protection (km) and percentage of total (%), at the time of installation
Anholt	139.54	6.32 (4.5%)	50.13	0.00 (0%)
Gunfleet Sands	15.28	0.00 (0%)	9.36	0.04 (0.4%)
West of Duddon Sands	102.97	0.00 (0%)	78.07	3.13 (4.0%)
Westermost Rough	42.61	4.60 (10.8%)	10.99	0.00 (0%)
Burbo Bank Extension	48.13	0.00 (0%)	23.91	0.00 (0%)
Race Bank	94.99	0.00 (0%)	146.32	9.17 (6.3%)
Walney Inter-Link	0	0.00 (0%)	23.00	0.91 (4.0%)
Hornsea Project One	Verified 'as built' values not yet available		378.96	17.83 (4.7%)
Hornsea Project Two			380.48	21.06 5.53%)

6.1.2.4 It is important to note that the values in **Table 7** represent 'as built' figures and making direct comparisons with MDS figures for Hornsea Four is not appropriate. The purpose of the MDS is to define the maximum values that may be required. As such, contingency must be built into design envelopes to allow the Applicant to deal with unforeseen situations and past performance is not a guarantee of future requirements for rock protection at different sites. The Applicant is also minded to avoid a scenario where a DCO and DML would require a variation during the construction phase to account for such an unforeseen situation where additional cable protection is required. Therefore, the Applicant considers that the MDS for cable protection is realistic.

6.1.2.5 It should be noted that, whilst additional surveys would inform the detailed design of burial and tool selection, the residual risk of burial failure would always remain.

6.1.2.6 It should also be noted that in the event that Hornsea Four requires fewer than six offshore export cables, the potential for cable protection measures to be used would also be accordingly reduced in line with **A4.4.8 Pro-Rata Annex (REP1-006)**.

6.2 Smithic Bank

6.2.1 Maximum Design Scenario for Smithic Bank Cable Protection as Presented in ES

6.2.1.1 At DCO Application, the MDS for cable protection across Smithic Bank is the same as for all Hornsea Four cables, with up to 10% of the total cable length across Smithic Bank requiring protection (**A1.4 Project Description (REP1-004)**).

6.2.2 Reduction in the Maximum Design Scenario for Smithic Bank Cable Protection

6.2.2.1 In response to Natural England's comments (as set out in **Section 1**), and the specific request from Natural England to avoid the placement of rock protection on Smithic Bank as a minimum (approximately 16 m depth contour), and as part of the analysis of the latest site-specific geophysical data, the Applicant has been seeking to reduce the MDS for cable protection across Smithic Bank, where feasible, in order to address concerns. With these considerations in mind, the Applicant proposes to reduce the MDS for cable protection across Smithic Bank. The following sections set out the methodology associated with establishing this reduction, as well as confirmation of what this reduction will comprise.

6.2.3 Methodology for Smithic Bank Cable Protection Assessment

6.2.3.1 The focus of this assessment is the shallow sandbank feature known as Smithic Bank. The Hornsea Four offshore ECC crosses this feature from Kilometre Point (KP) 4.11 to KP 9.21.

6.2.3.2 In practice, when a cable does not meet the target burial depth, there are several options available prior to the requirement for cable protection as a risk mitigation measure, for example:

- Assessment of the as-built survey data to understand if an acceptable burial depth had been achieved and therefore the cable can be considered protected from the natural and anthropogenic hazards;
- Assessment of the likelihood of natural reinstatement and therefore possible additional sediment accumulation on top of the cable which will provide protection; and
- Assessment of the ground conditions and as-built data, to establish the suitability of the soil conditions in the relevant area for remedial burial.

6.2.3.3 The following assessment focuses on the final option in the above list - the suitability of the soils for remedial burial.

6.2.3.4 Site-specific parameters have fed into the assessment including the soil conditions (i.e. how difficult will the soils be to trench in), the water depth, the target burial depths, the seabed morphology and the potential cable burial tool(s). To understand the soil conditions, site-specific geophysical and geotechnical data informed by all the Hornsea Four survey campaigns (including the 2021 geophysical and geotechnical data) which constitutes full coverage (2 m resolution) of the Hornsea Four offshore Order Limits, as well as extensive laboratory testing of soil samples has been considered. Using these parameters and information, cable burial success can be predicted and areas that have an increased risk of requiring cable protection can be determined. It is important to note that it is not always possible to determine where cable protection is required due to events that are not possible to predict as outlined in **paragraph 6.1.2.2** above.

6.2.3.5 Confidence levels have been developed based on the expected soil conditions and the Applicant's experience of cable installation remedial works in similar ground conditions. **Table 8** defines the cable burial success levels and outlines the estimated percentage of cables that may require protection. The baseline confidence level is defined as 90% for all soil units. Depending on the confidence level of successful remedial trenching in the particular soil unit, an additional percentage is added to the baseline. The additional confidence levels of remedial trenching equate to the following values:

- +0% if the soil unit is deemed to have a low likelihood of success;
- +5% for medium likelihood of success; and
- +8% for high likelihood of success.

6.2.3.6 For example, if the likelihood of success in a particular soil unit is deemed low then the overall confidence level of achieving target depth of lowering in that soil unit remains at 90%.

Table 8: Confidence levels used to assess the likelihood of remedial burial success.

Definition	Description	Estimated Percentage of Cable where Protection may be Required (%)
Low likelihood of success	The cable is unlikely to reach the target depth of lowering based on the expected soil conditions. Any remedial works may take multiple passes or show limited improvement in burial with additional passes.	10
Medium likelihood of success	The cable is likely to achieve the target depth of lowering in some sections although more than one pass will likely be required.	5
High likelihood of success	The cable is likely to reach the target depth of lowering and the risk to the cable is considered low. Burial will most likely be achieved in one pass.	2

6.2.3.7 Based on the analysis undertaken using the parameters and information set out in **paragraph 6.2.3.4**, the confidence level assigned to the soil units (superficial sands overlying medium to dense sands) across Smithic Bank is deemed to be medium (**Figure 4** and **Figure 5**). This equates to a 95% overall confidence level in relation to achieving target depth of lowering and a requirement for cable protection along 5% of the cables in that area. The assessment concluded that the sediments across Smithic Bank would be suitable for various trenching tools such as jet trenching or ploughing. However, operational constraints due to the limited water depths in the area may impact the type of trenching equipment and vessels that can be used to install the cable. As a result, the likelihood of success of trenching the cable in this area is considered to be medium.

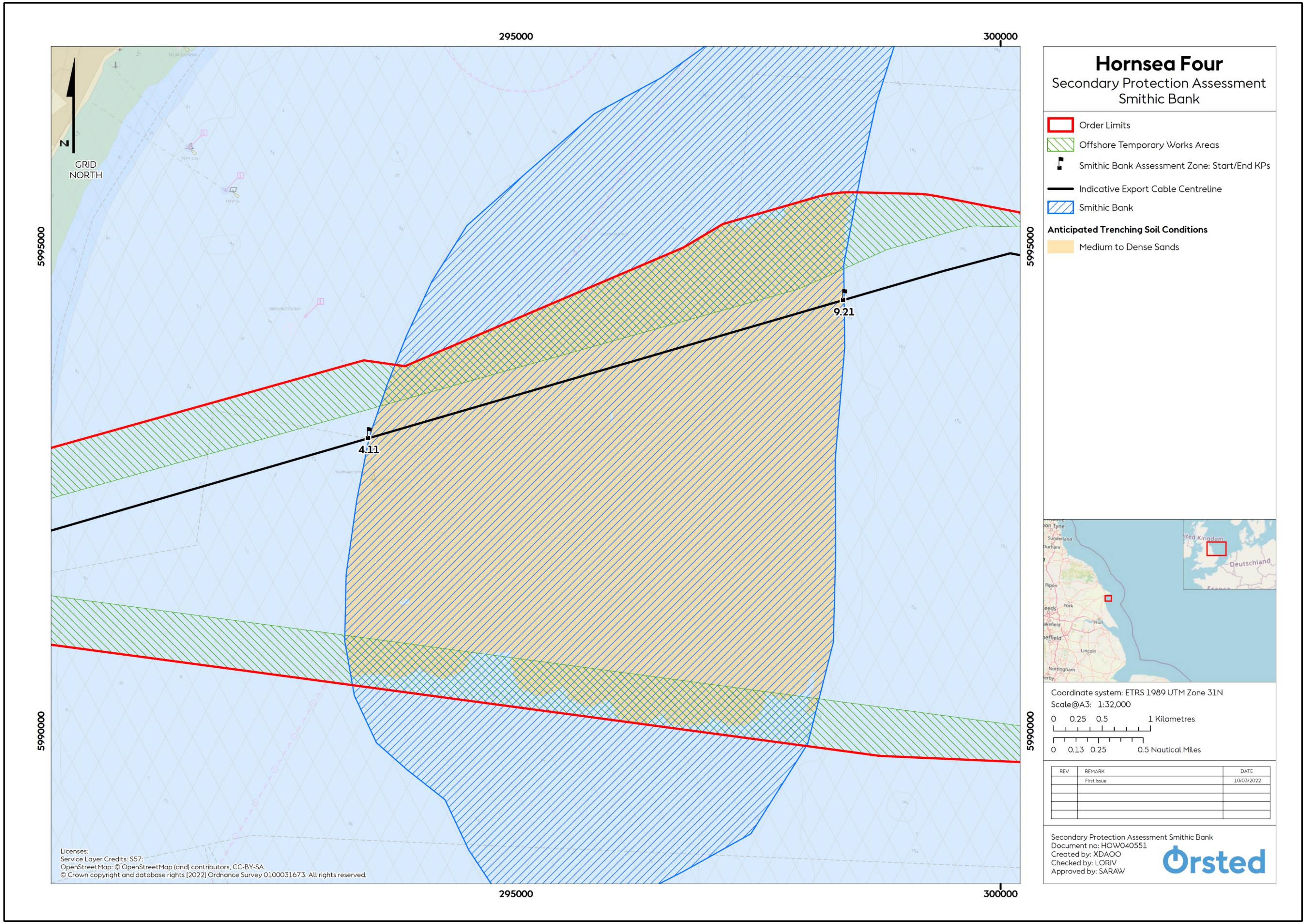
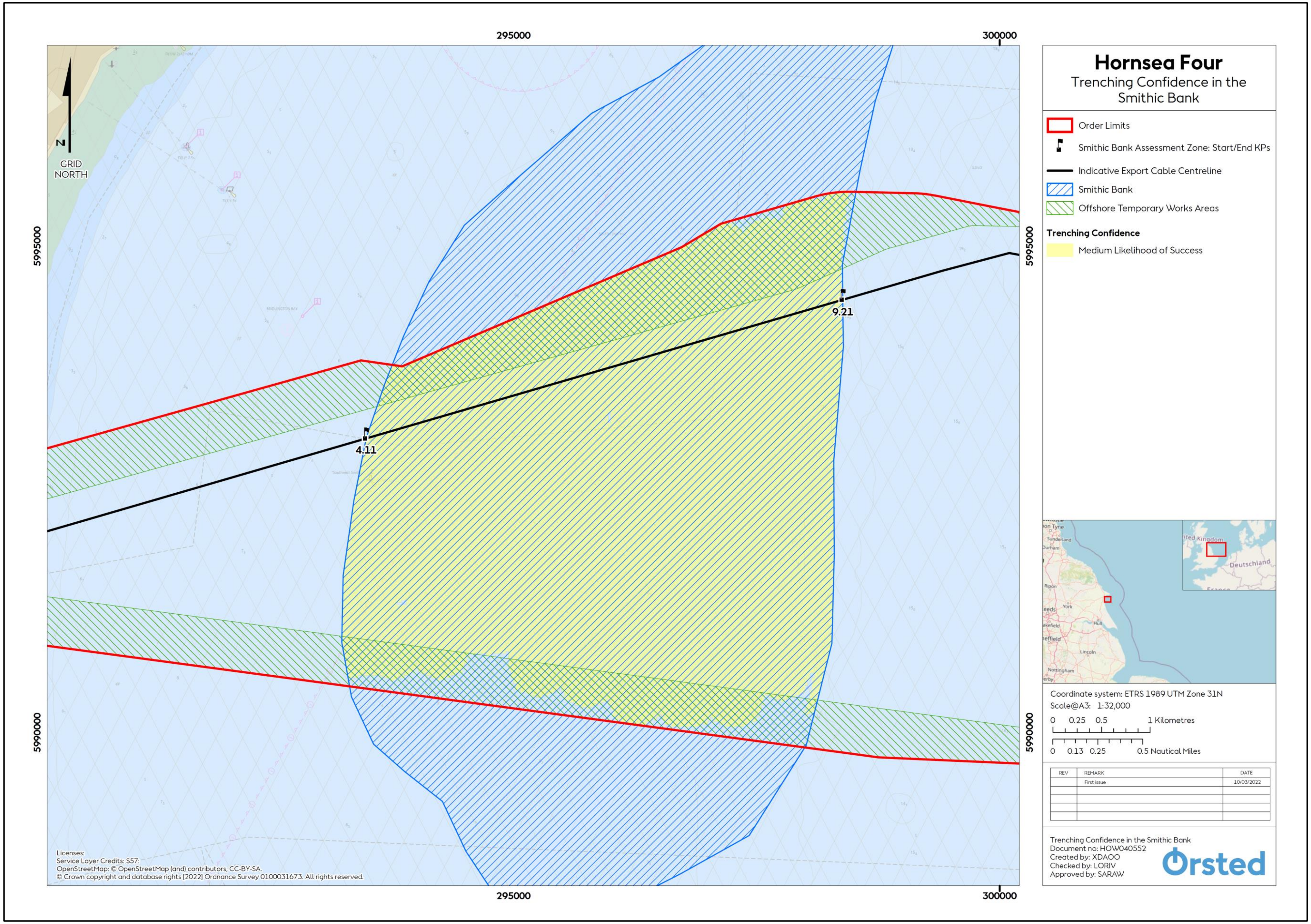


Figure 4: Trenching Soil Conditions Heat Map Analysis at Smithic Bank.



REV	REMARK	DATE
	First issue	10/03/2022

Trenching Confidence in the Smithic Bank
Document no: HOW040552
Created by: XDAOO
Checked by: LORIV
Approved by: SARAW

Figure 5: Trenching Confidence Heat Map Analysis at Smithic Bank.

6.2.4 Proposed Reduced Smithic Bank Cable Protection Requirement

6.2.4.1 Following the analysis detailed in **Section 6.2.3**, the Applicant proposes that a maximum of 5% of the cable lengths that cross Smithic Bank will require cable protection, compared to the 10% requirement stated at DCO Application.

6.2.5 Materiality

6.2.5.1 The Applicant can confirm that the reduction in Smithic Bank cable protection requirements does not affect the outcomes of the ES as this will just represent a reduction in the MDS that is already considered within the detailed assessments and as such, with the reduction in Smithic Bank cable protection requirements, all effects will be equal to or less than as assessed in the ES.

6.2.5.2 The Applicant has been mindful of the examination timetable in making this decision at Deadline 3, such that sufficient time is available for interested parties to comment on the reduced calculations during Examination.

6.2.5.3 In order to capture this change, the Applicant proposes that this note is added to Schedule 15 of **C1.1 Draft DCO including Draft DML (REP2-061)** as a document to be certified, with **A1.4 Project Description (REP1-004)** and **A4.4.8 Pro rata Annex (REP1-006)** updated accordingly.

7 References

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