From: Dominika Phillips <DOMPH@orsted.co.uk>
Sent: 08 February 2019 21:11
To: KJ Johansson <KJ.JOHANSSON@planninginspectorate.gov.uk>; Kay Sully <Kay.Sully@pins.gsi.gov.uk>; Hornsea Project Three <HornseaProjectThree@pins.gsi.gov.uk>
Cc: Andrew Guyton <ANGUY@orsted.co.uk>; Stuart Livesey <STLIV@orsted.co.uk>
Subject: Hornsea Project Three (UK) Ltd response to Deadline 6 (Part 4)

Dear Kay, K-J

Please find attached the 4th instalment of documents.

Best regards,

Dr Dominika Chalder PIEMA
Environment and Consent Manager

[redacted]

Environmental Management UK¦ Wind Power
5 Howick Place ¦ London ¦ SW1P 1WG

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Appendix 12 to Deadline 6 submission - Preliminary Trenching Assessment

Date: 8th February 2019

Hornsea 3
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Ørsted

5 Howick Place,

London, SW1P 1WG

Front cover picture: Kite surfer near a UK offshore wind farm © Ørsted Hornsea Project Three (UK) Ltd., 2019.

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1. Introduction

Purpose

1.1 Natural England (NE) and The Wildlife Trusts (TWT) have raised concerns regarding the Applicant's confidence in their ability to bury offshore export cables to the target burial depths and (in the event an export cable is not buried) their wish to minimise cable protection in marine protected areas. In their examination submissions (e.g. REP3-076 and RR-047), both parties stated that, cable burial difficulties for other offshore wind farms within the Wash and North Norfolk Coast Special Area of Conservation (SAC) have increased their concerns regarding cabling within this area and that further information is required from the Applicant to evidence their position.

1.2 To provide additional confidence on cable burial, the Applicant has undertaken a Preliminary Trenching Assessment which draws on the Applicant's detailed knowledge of the site conditions and target burial depths to assess the feasibility of cable burial within the marine protected areas along the Hornsea Three offshore cable corridor, utilising the tools referenced in the Volume 1, Chapter 3: Project Description of the Environmental Statement (APP-058). Where applicable the Applicant has also drawn on lessons learnt from other projects installed in comparable ground conditions, and where site conditions may be seen as different.

2. Project Information

Background

2.1 Hornsea Project Three Offshore Wind Farm (from hereon in referred to as 'Hornsea Three') is the third project to be developed in the former Hornsea Zone; it is located to the east of Hornsea Project One and Hornsea Project Two Offshore Wind Farms. The project has submitted a development consent application for offshore infrastructure (including 300 turbines) and onshore electrical cabling and associated infrastructure.

The proposed offshore cable corridor for Hornsea Three is illustrated in Figure 2.1. The offshore cable corridor is approximately 156.5 km long and enters the array area at approximately Kilometre Point (KP) 151.200. The export cable route corridor than makes landfall just west of Weybourne on the North Norfolk coast. The export cables will then make landfall by either horizontal directional drilling or open cut trench. The export cable corridor has an average width of approximately 1500m.

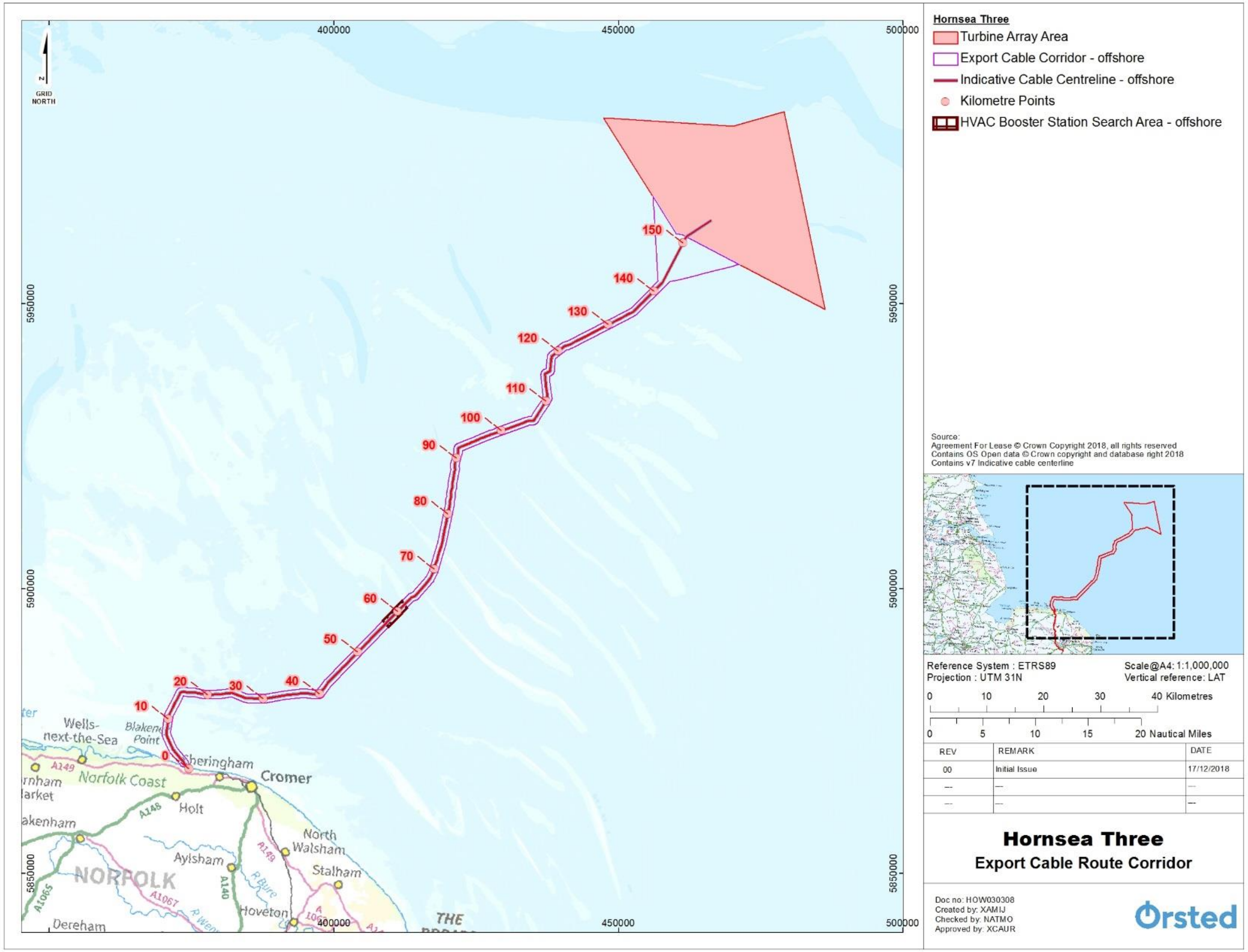


Figure 2.1: Hornsea Three offshore cable corridor

3. Offshore Cable Corridor Description

3.1 For the purpose of this assessment the route has been divided into four zones corresponding to where it interacts with different marine protected areas. Zones 1, 2, 3a and 3b (shown in Figure 3.1) are the areas in which the export cables pass through Marine Conservation Zones (MCZ) and/or Special Areas of Conservation (SACs) along the route. Zone 1 enters the Cromer Shoal Chalk Beds MCZ between Kilometre Point (KP) 0.43 – KP1.34 and Zone 2 enters The Wash and North Norfolk Coast SAC between KP1.34 – KP12.27. Zone 3 is split into two sections as it enters North Norfolk Sandbanks and Saturn Reef SAC at 3a between KP63.09 – KP87.75 and at 3b between KP95.56 and 117.22. This preliminary trenching assessment applies to these specific zones where concern has been focused from NE in particular, the remainder of the offshore export cable route is not considered further in this report.

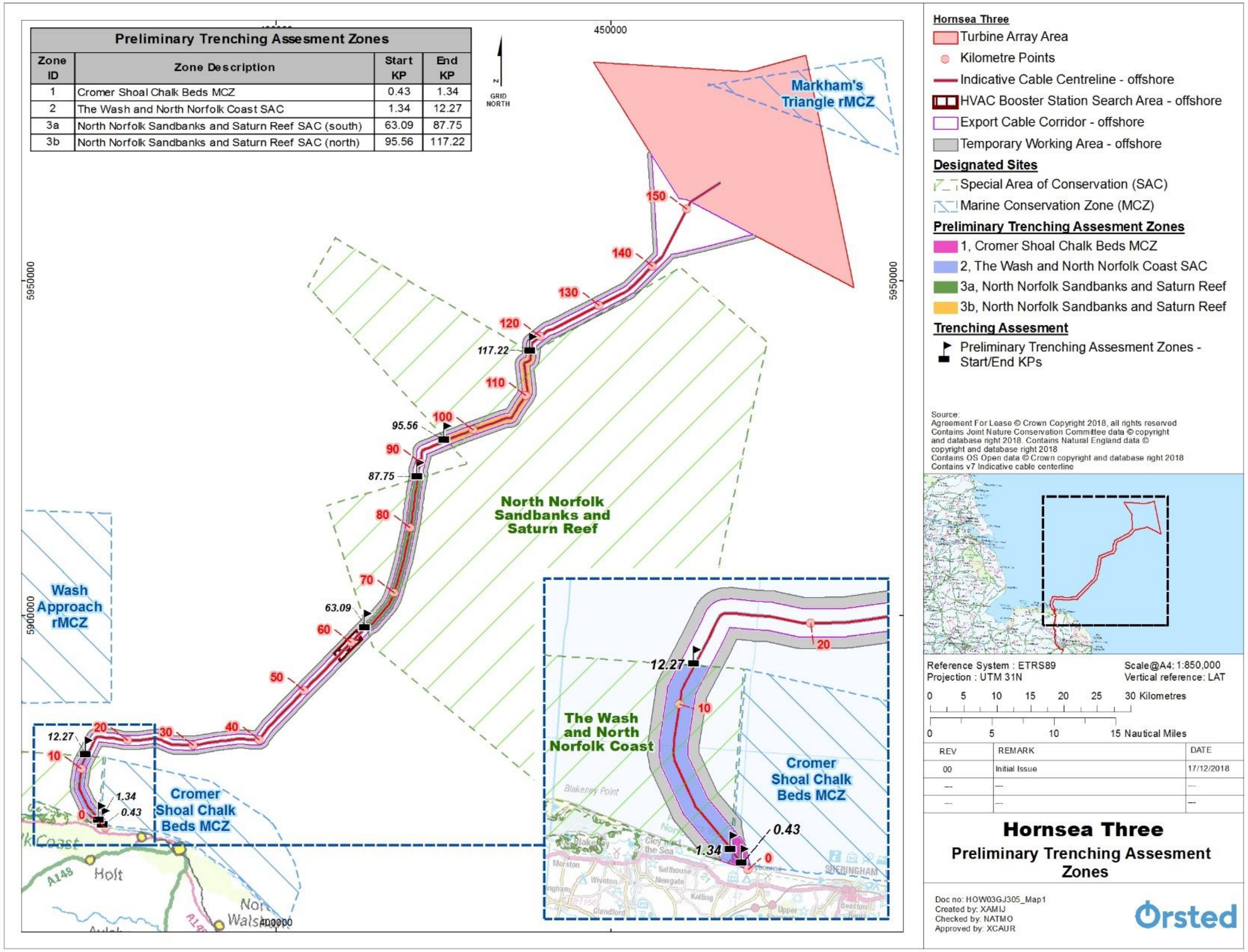


Figure 3.1: Preliminary Trenching Assessment Zones

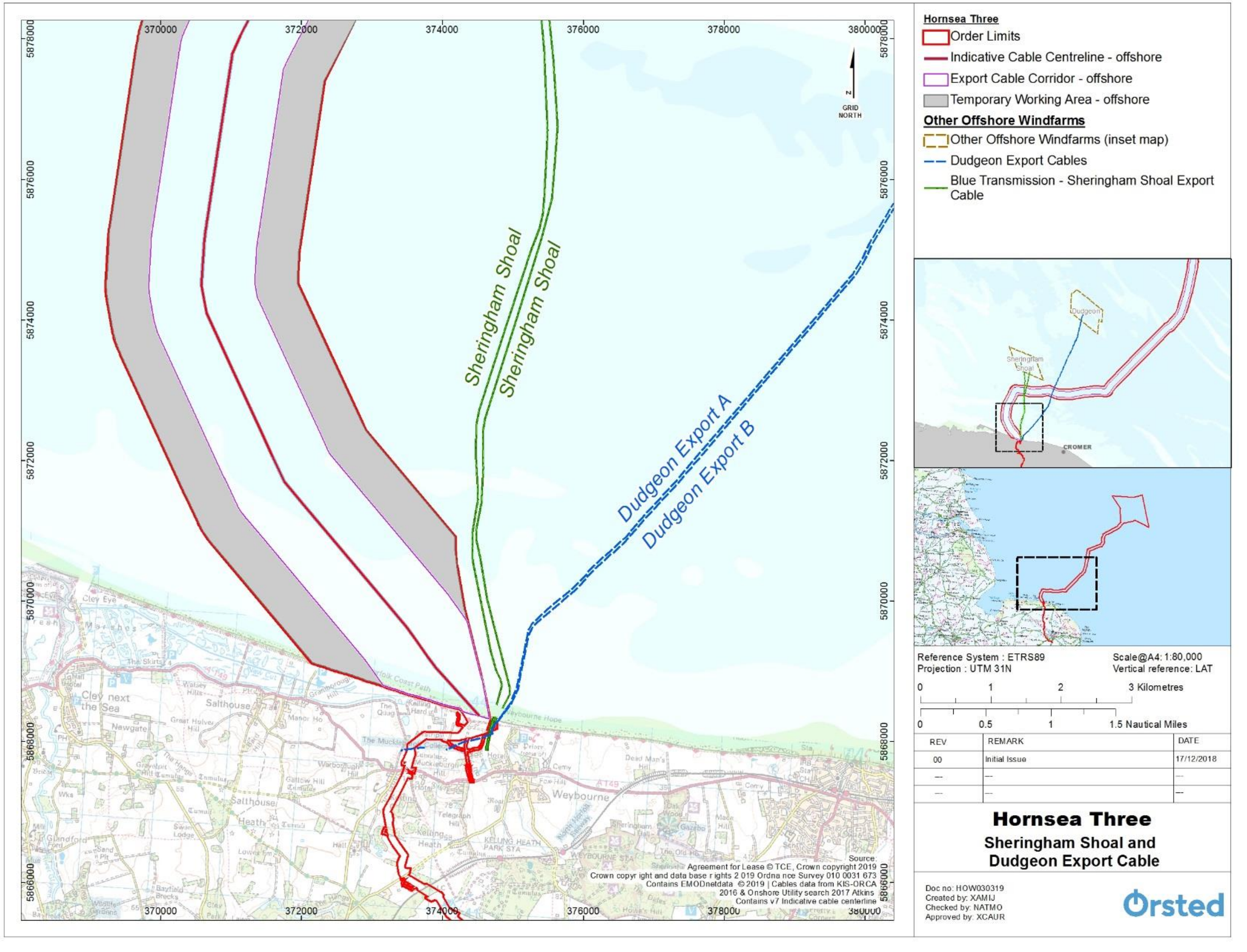


Figure 3.2: Proposed Hornsea Three offshore cable corridor and Dudgeon and Sheringham Shoal Export Cables

4. Ground Model

Summary of available data

4.1 Hornsea Three have identified a range of soil conditions from Chalk to Sand and Glacial Till within the four zones relevant to this assessment. NE are concerned with the ability to adequately bury export cables within these ground conditions, particularly within marine protected areas such as the Wash and North Norfolk Coast SAC and North Norfolk Sandbanks and Saturn Reef SAC, and they wish to minimise the installation of cable protection in these marine protected areas where target burial depths may not be achieved. To understand trenchability of these soil conditions a robust ground model has been developed for the site such that ground based risks associated with cable installation are understood. This model is based on both geophysical and geotechnical investigations in and around the project area, in addition to cross-referencing historic data sets such as British Geological Survey (BGS) maps. It is the Applicant's view that this approach is also aligned with the recommendations made by NE (Natural England, 2018[1]) where they advise:

4.2 *"Every effort should be made to use (or gain where there is no concern) pre-application geotechnical information to inform a realistic assessment of the cable burial tools and options and their impacts as part of the consenting process…"*

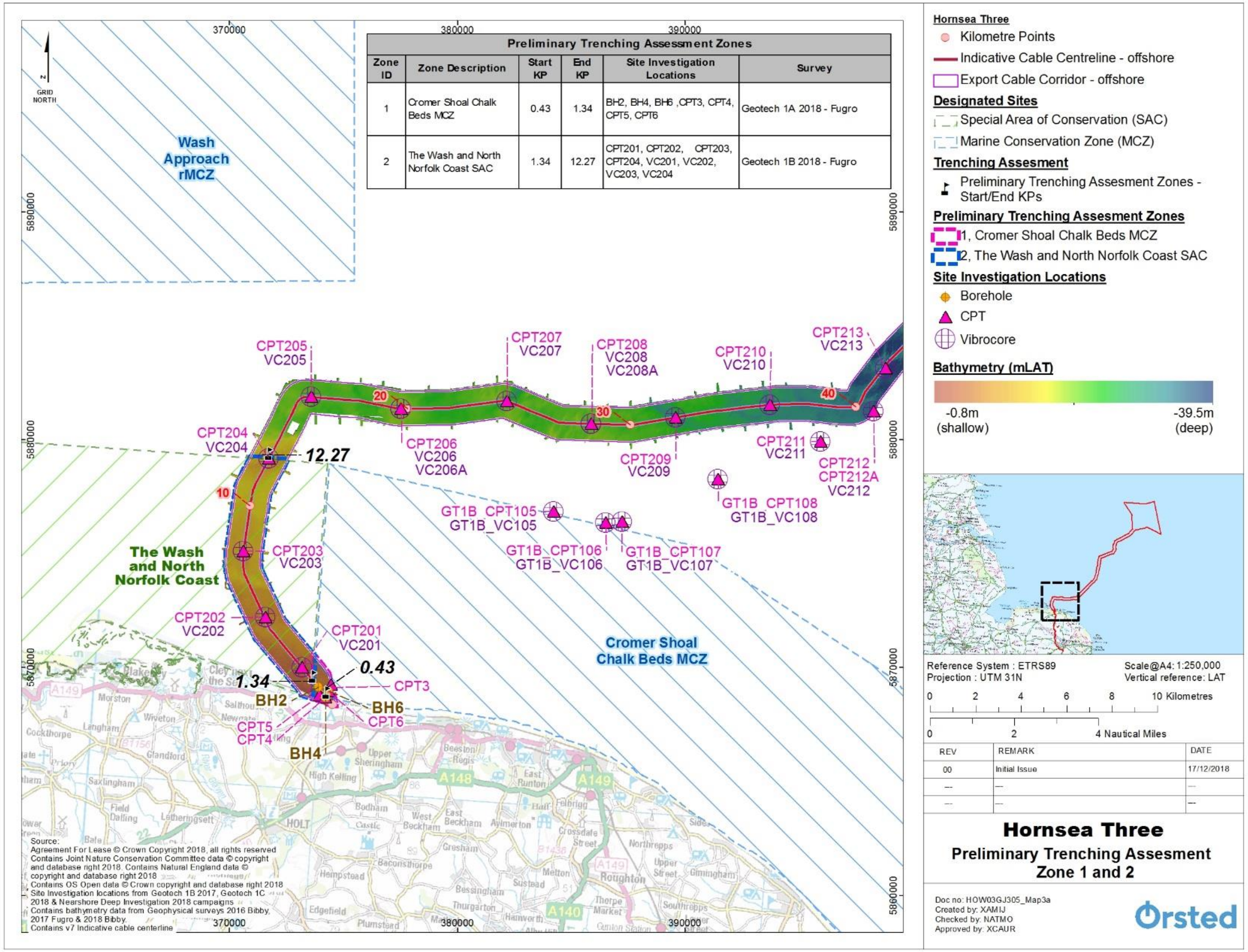
4.3 Ørsted have commissioned several geophysical and geotechnical site investigation campaigns. A summary of the information relevant to each of the MCZ and SAC zones is detailed below in Table 4.1 along with Figure 4.1 and Figure 4.2. It should be noted that development of the ground model is an iterative process, with the current document providing a robust ground model based on the data currently available. This will be updated and refined as further geophysical and geotechnical data across the Hornsea Three offshore cable corridor become available prior to construction.

Table 4.1: Summary of site investigation information for each zone.

Zone ID	Zone Description	Start KP	End KP	Geotechnical Site Investigation Locations	Geophysical Survey Reference
1	Cromer Shoal Chalk Beds MCZ	0.43	1.34	BH2, BH4, BH6, CPT3, CPT4, CPT5, CPT6	**Fugro 2017**: GP1b NS survey: MBES, SSS, MAG and SBP
2	The Wash and North Norfolk Coast SAC	1.34	12.27	CPT201, CPT202, CPT203, CPT204, VC201, VC202, VC203, VC204	**Bibby 2018/2019:** GP1b reroute survey: MBES, SSS, MAG and SBP

[1] Natural England (2018) Offshore wind cabling: ten years experience and recommendations. (REP1-208)

Zone ID	Zone Description	Start KP	End KP	Geotechnical Site Investigation Locations	Geophysical Survey Reference
3a	North Norfolk Sandbanks and Saturn Reef SAC (South)	63.09	87.75	CPT115, CPT116, CPT117, CPT119, CPT120, CPT121, CPT122, CPT214, CPT215, VC115, VC115a, VC116, VC117, VC119, VC120, VC121, VC122, VC214, VC215	**Bibby 2016**: GP1b survey: MBES, SSS, MAG and SBP
3b	North Norfolk Sandbanks and Saturn Reef SAC (North)	95.56	117.22	CPT124, CPT216, VC124, VC126	**Bibby 2016:** GP1b survey: MBES, SSS, MAG and SBP **Bibby 2018/2019**: GP1b reroute survey: MBES, SSS, MAG and SBP



Zone ID	Zone Description	Start KP	End KP	Site Investigation Locations	Survey
1	Cromer Shoal Chalk Beds MCZ	0.43	1.34	BH2, BH4, BH6 ,CPT3, CPT4, CPT5, CPT6	Geotech 1A 2018 - Fugro
2	The Wash and North Norfolk Coast SAC	1.34	12.27	CPT201, CPT202, CPT203, CPT204, VC201, VC202, VC203, VC204	Geotech 1B 2018 - Fugro

Figure 4.1: Zone 1 and Zone 2 – Available data

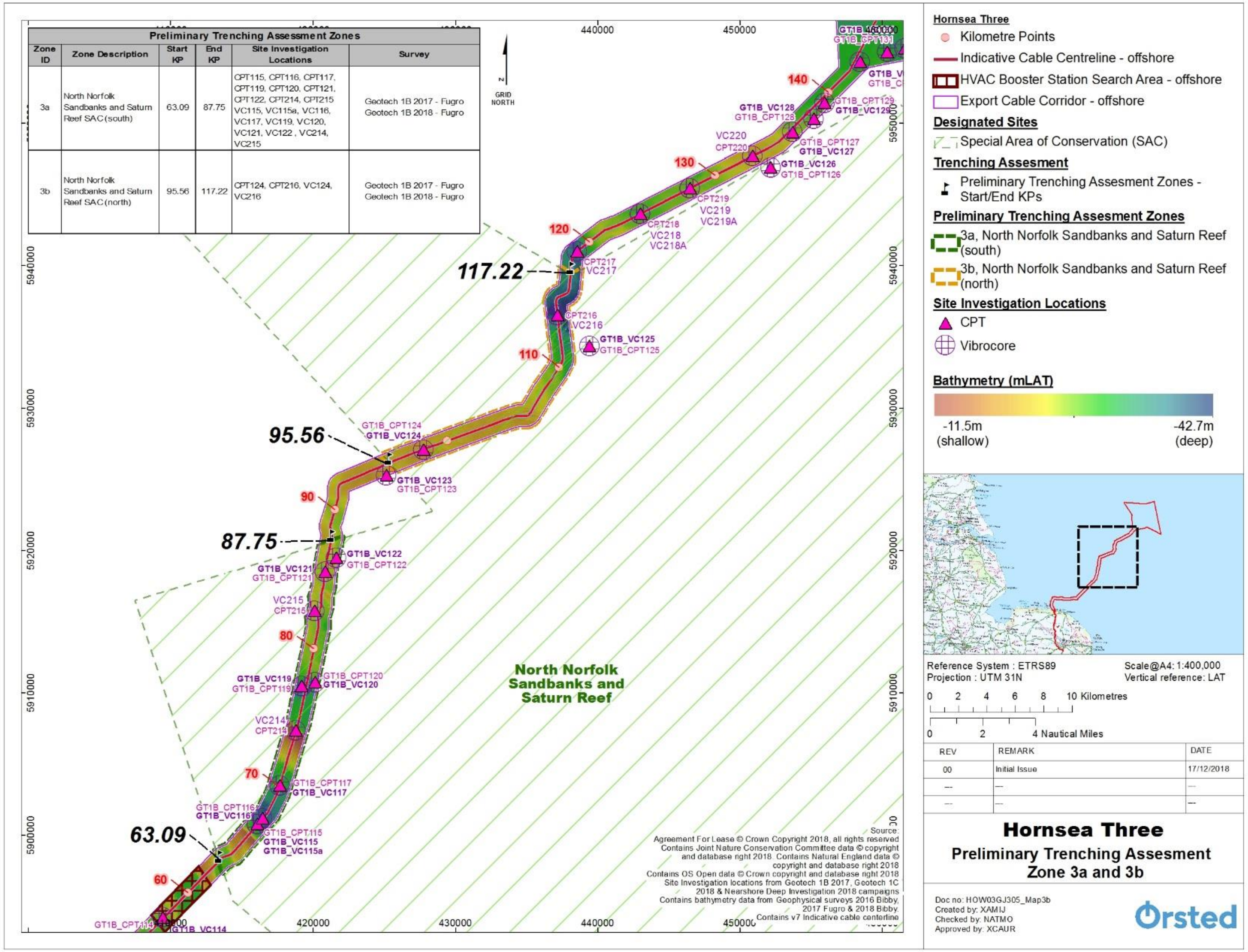


Figure 4.2: Zone 3a and 3b – Available data.

4.4 As part of the investigations to date, the Applicant has ensured that industry best practice is applied in the acquisition of site data. The following recommendations made by Det Norske Veritas (DNV) within RP-J301 (Subsea Power Cables in Shallow Water Renewable Energy Applications) have been adhered to in regard to specification of offshore surveys:

- Geophysical investigations of the bathymetry of the seabed using multi-beam echo-sounder, of the sea floor texture using side scan sonar and of objects on the seabed using side scan sonar and magnetometer;
- Geophysical investigation of the shallow geology using sub-bottom profiling;
- Geotechnical investigations, e.g. CPT; and
- Soil sampling, e.g. by vibrocoring or grab-sampling, with subsequent laboratory testing for ground truthing.

Ground conditions summary

Summary

4.5 Closer inshore within the Cromer Shoal Chalk Beds MCZ and The Wash and North Norfolk Coast SAC protected areas the geology comprises a thin to absent veneer of Holocene sand overlying stiff glacial tills of the Bolders Bank Formation with localised channels infilled with the Botney Cut Formation. The superficial soils overlie Chalk which occasionally outcrops at or near to the seabed. The Chalk in this area is categorised by Fugro in accordance with CIRIA (Construction Industry Research and Information Association) guidelines as Grade Dm or Dc, corresponding to a structureless coarse or fine grained material similar to an engineering soil rather than a competent rock.

4.6 Further offshore within the North Norfolk sandbanks and Saturn Reef SAC the shallow superficial geology is similar comprising a variable thickness of Holocene sand overlying the Bolders Bank and localised channels infilled with the Botney Cut Formation. The Chalk is present at depth in these areas; however not expected to be encounter during cable installation. The ground conditions are summarised in Table 4.2.

Table 4.2: Geological Unit Description.

Unit	Description	Distribution
Holocene	Variable lithology, primarily loose sand	Thin to absent closer inshore within the Cromer Shoal Chalk Beds MCZ and The Wash and North Norfolk Coast SAC. Thicker further offshore within the North Norfolk sandbanks and the Saturn Reef SAC

Unit	Description	Distribution
Botney Cut Formation	A system of partially or completely infilled glacial valleys occurring mostly within the outcrop limits of the Bolders Bank Formation. Consists of sands, silts, and clays	Consistently present in both SACs
Bolders Bank Formation	Glacial till, primarily stiff clay	Consistently present in both SACs
Chalk Group	Chalk, with or without flint and discrete limestone, marl (calcareous mudstone), sponge, calcarenite, phosphatic, hardground and fossil-rich beds	Outcrops at seabed or shallow depth closer inshore within the Cromer Shoal Chalk Beds MCZ and The Wash and North Norfolk Coast SAC. Present at depth further offshore. CIRIA grade Dc and Dm encountered.
Edmond Ground	Egmond Ground Formation comprises very fine- and medium-grained, sparsely shelly Hoxnian (Holsteinien) marine sands with thin bands of silt and clay.	Occasionally seen as an underlying layer in the North Norfolk Sandbanks and Saturn Reef SAC (Zone 3a).

4.7 The ground conditions relevant to each section are discussed in the following sections.

4.8 Please note: Some of the data in the following sections is currently not available. This is due to the base layer of the unit not being visible in the geophysical data. This is usually a result of the upper layer reflecting all the energy from the shallow seismic (Sub Bottom Profiler) and therefore the reflection being too weak for the lower layers. Where data is missing from the profile, consideration has been given in the summary text as to most likely ground type based on the available geophysical evidence. As outlined in paragraph 4.3 above, this is an iterative process with the ground model being further developed and refined as more data become available.

Zone 1 and 2

4.9 Figure 4.3 to Figure 4.6 are cross-sectional representations within The Cromer Shoal Chalk Beds MCZ (Zone 1; KP0.43 - 1.34) and The Wash and North Norfolk Coast SAC (Zone 2; KP1.34 – 12.27). Summary descriptions for each section are written underneath the figures.

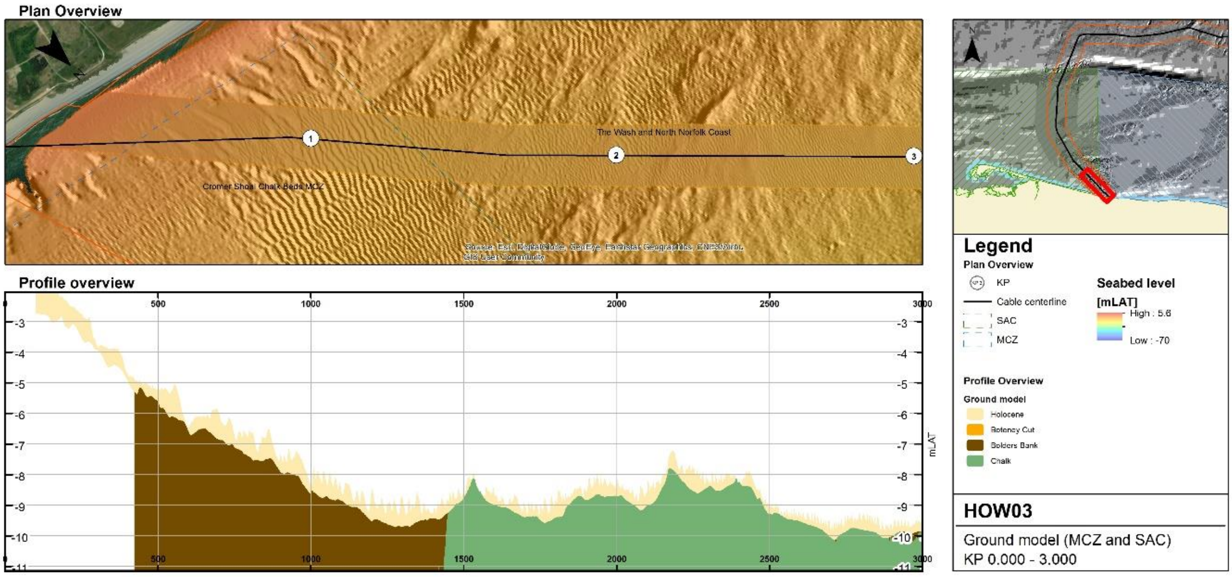


Figure 4.3: Ground Model; Cromer Shoal Chalk Beds MCZ KP0.43 – 1.34 and The Wash and North Norfolk Coast SAC KP1.34 – 3.0.

4.10 The Cromer Shoal Chalk Beds MCZ (Zone 1, Figure 4.3) is showing Bolders Bank with a layer of Holocene on top. There are small sandwaves seen in the Holocene layer. The route then enters The Wash and North Norfolk Coast SAC (Zone 2) where the underlying layer of Bolders Bank changes to Chalk from KP1.40.

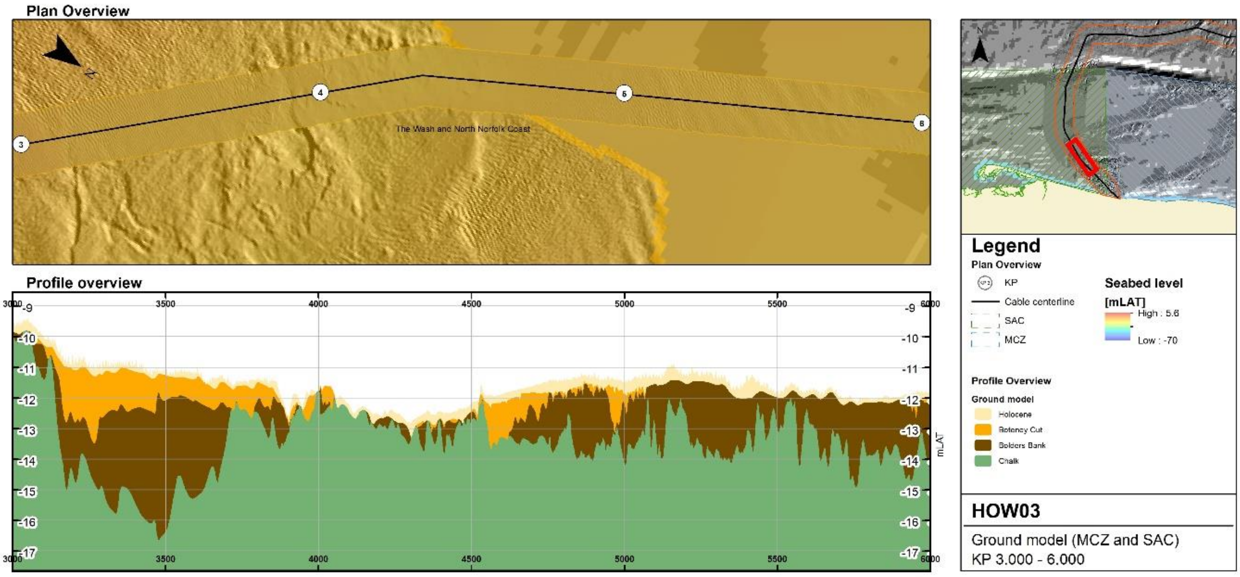


Figure 4.4: Ground Model; The Wash and North Norfolk Coast SAC KP3.0 – 6.0.

4.11 An underlying layer of Chalk is overlain by Bolders Bank. A top layer of Holocene is shown throughout with a layer of Botney Cut observed between the Holocene and Bolders Bank between KP3.1 – 4.1 and again between KP4.3 – 5.1 (Figure 4.4).

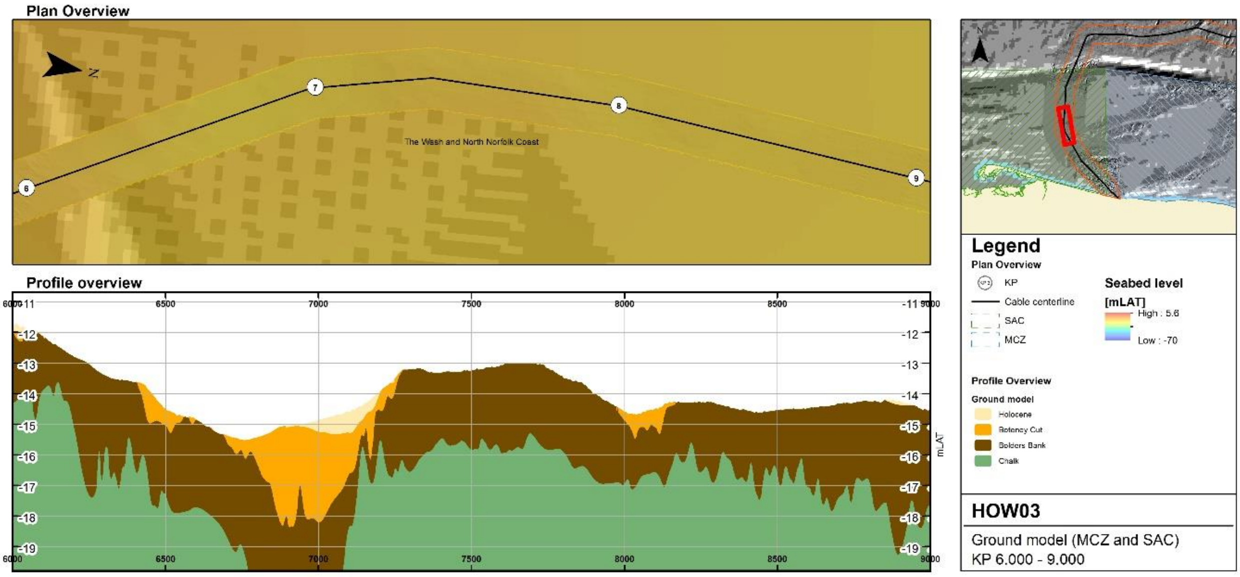


Figure 4.5: Ground Model; The Wash and North Norfolk Coast SAC KP6.0 – 9.0.

4.12 An underlying layer of Chalk is overlain by Bolders Bank. Areas of Botney Cut are overlaying the Bolders Bank between KP6.4 – 6.6, KP6.7 – 7.25 and KP7.95 – 8.2. A top layer Holocene is seen between KP6.8 – 7.2 (Figure 4.5).

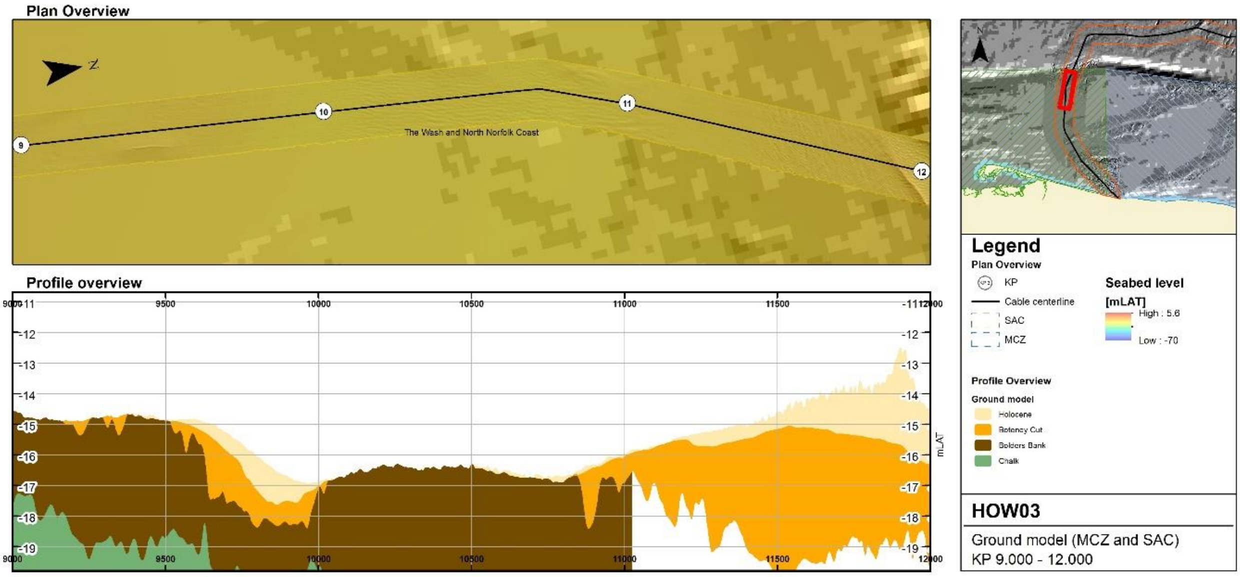


Figure 4.6: Ground Model; The Wash and North Norfolk Coast SAC KP 9.0 – 12.0.

4.13 An underlying layer of Chalk is overlain by Bolders Bank. Areas of Botney Cut are overlaying the Bolders Bank between KP9.2 – 10.1 and KP10.8 – 12.0. A top layer of Holocene is seen on most of this section with varying depths (Figure 4.6).

Zone 3a

4.14 Figure 4.7 to Figure 4.14 are cross-sectional representations within the North Norfolk Sandbanks and Saturn Reef SAC (South) (Zone 3a; KP63.09– KP87.75). Summary descriptions for each section are written underneath the figures.

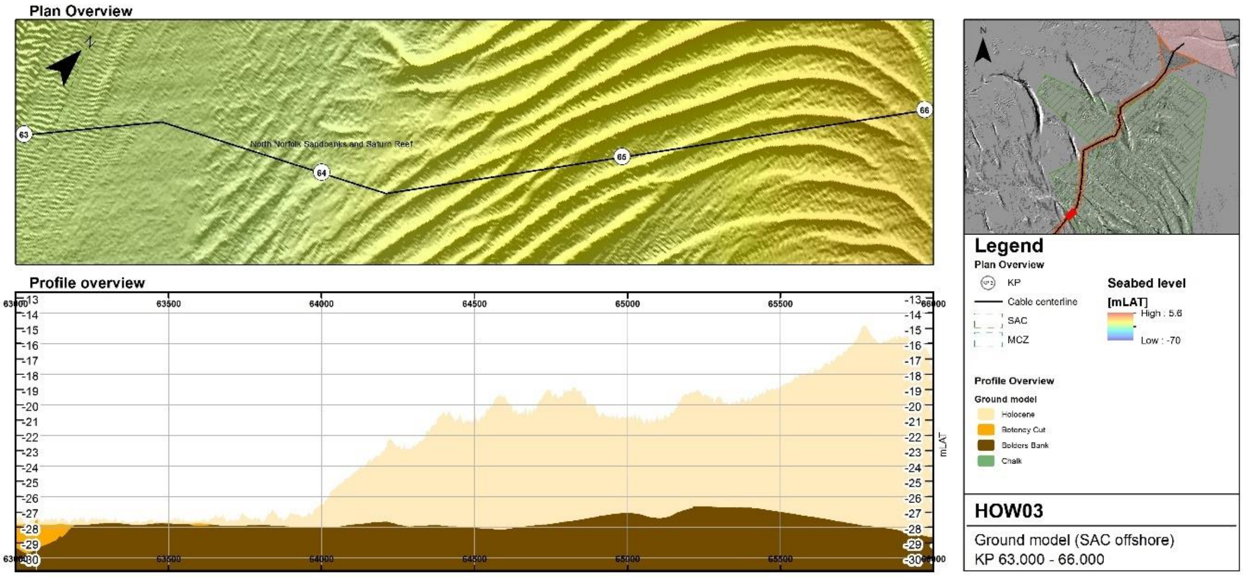


Figure 4.7: Ground Model; North Norfolk Sandbanks and Saturn Reef SAC (South) KP 63.0 – 66.0.

4.15 The top of layer in this section is Holocene and is seen to increase greatly in height towards the east and forming sandwaves on the upper section of the layer. There is an underlying layer of Bolders Bank underneath the Holocene (Figure 4.7).

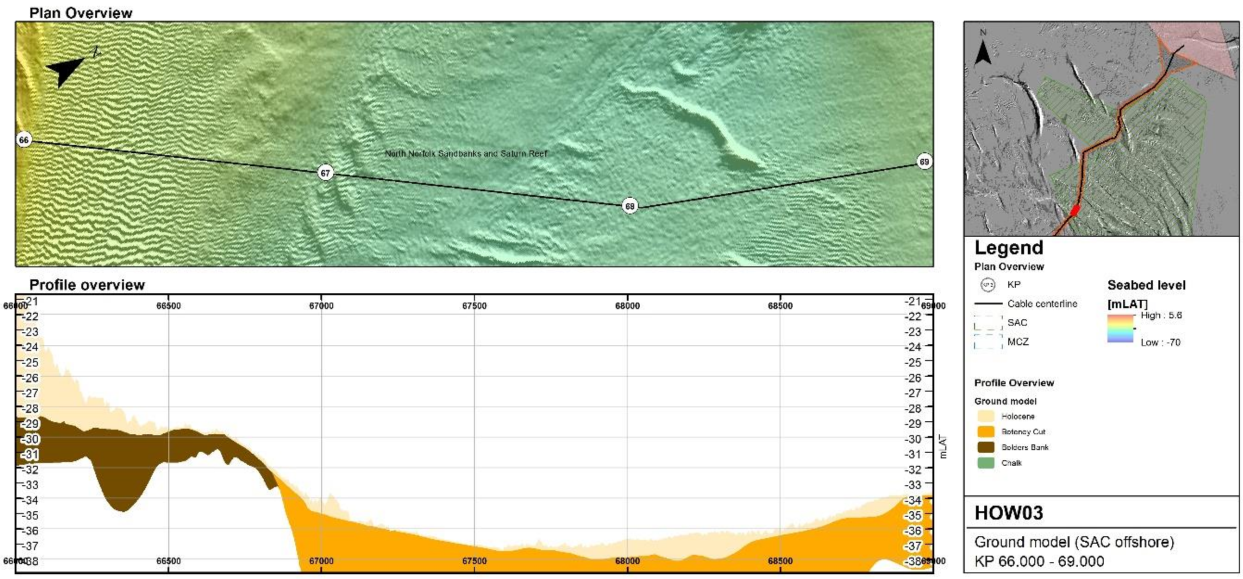


Figure 4.8: Ground Model; North Norfolk Sandbanks and Saturn Reef SAC (South) KP 66.0 – 69.0.

4.16 Most of this section is Botney Cut overlain by a thin layer of Holocene. To the west side of the section (up to KP66.8), Bolders Bank is the underlying layer with a decreasing layer of Holocene on top. The missing underlying layer is assumed to be Egmond Ground based on strong evidence from the geophysical data (Figure 4.8).

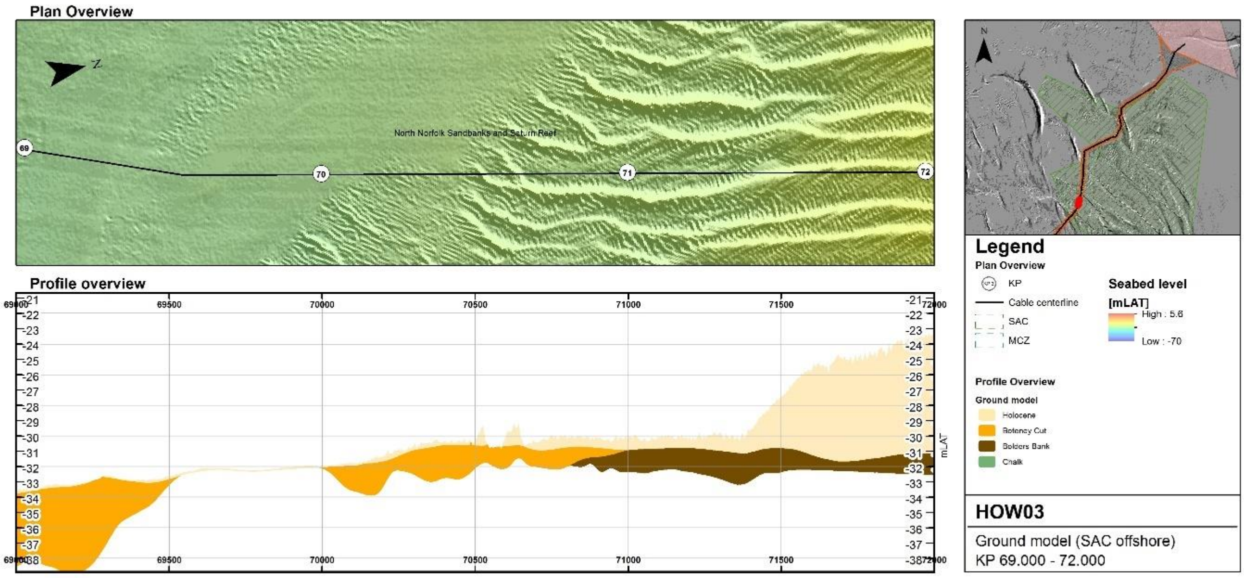


Figure 4.9: Ground Model; North Norfolk Sandbanks and Saturn Reef SAC (South) KP 69.0 – 72.0.

4.17 This section starts with Botney Cut overlain by a thin layer of Holocene. To the east side of the section Bolders Bank is underneath the Holocene with an increasing layer of Holocene on top. The missing underlying layer is assumed to be early Botney Cut based on strong evidence from the geophysical data (Figure 4.9). Earlier placed Botney Cut Units are stiffer and usually sand or re-worked till.

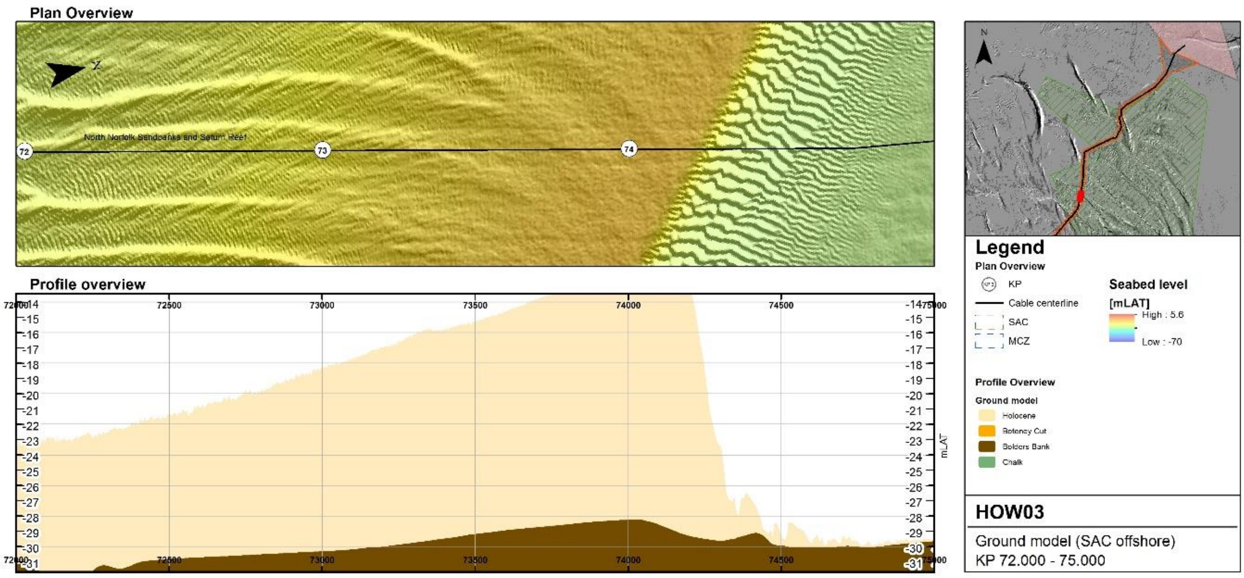


Figure 4.10: Ground Model; North Norfolk Sandbanks and Saturn Reef SAC (South) KP 72.0 – 75.0.

4.18 A depth top layer of Holocene is shown in Figure 4.10 above. As can be seen from the bathymetry, there is a major drop in water depth drop at KP74.2 with a very steep slope where the layer becomes a very thin veneer on the top of the underlying Bolders Bank layer (Figure 4.10).

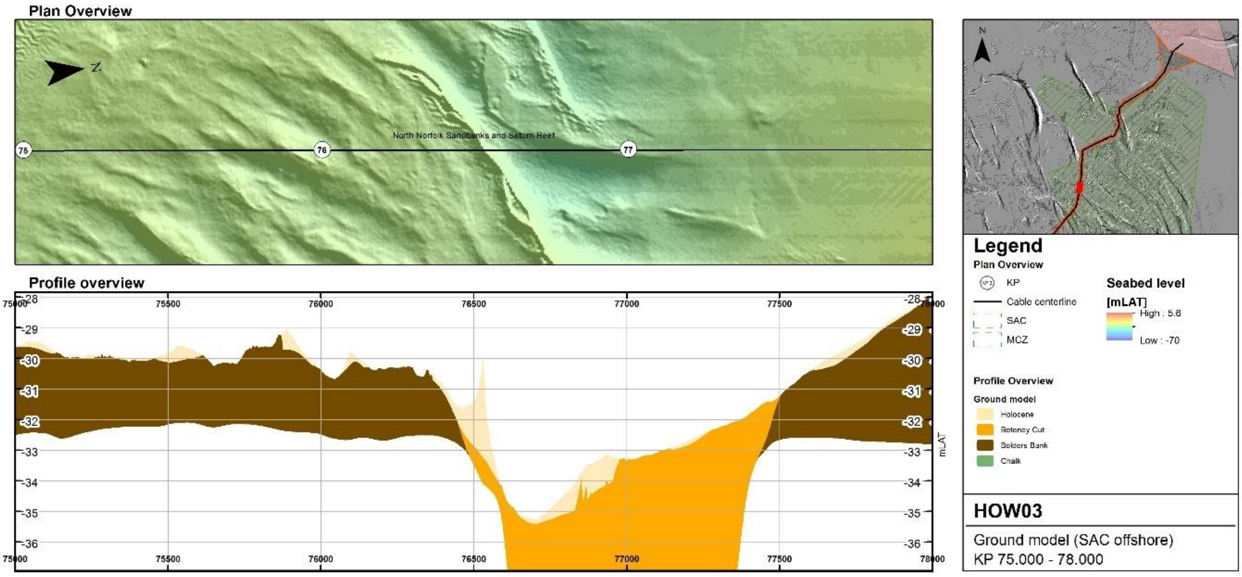


Figure 4.11: Ground Model; North Norfolk Sandbanks and Saturn Reef SAC (South) KP 75.0 – 78.0.

4.19 The top layer for this section is a thin veneer of Holocene with intermittent peaks. Bolders Bank is underneath this Holocene layer changing to Botney Cut between KP76.4 – 77.5. The Botney Cut layer deepens greatly at KP77.6. The missing underlying layer is assumed to be Egmond Ground based on strong evidence from the geophysical data (Figure 4.11).

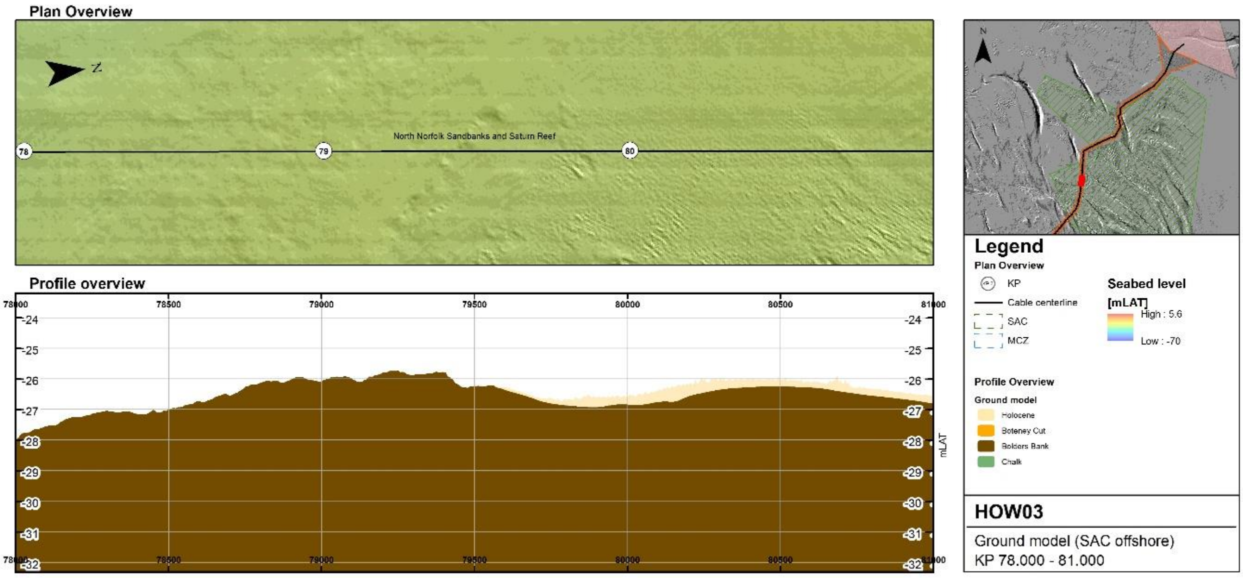


Figure 4.12: Ground Model; North Norfolk Sandbanks and Saturn Reef SAC (South) KP 78.0 – 81.0.

4.20 The majority of this section is Bolders Bank with a thin veneer of Holocene overlaying it (Figure 4.12).

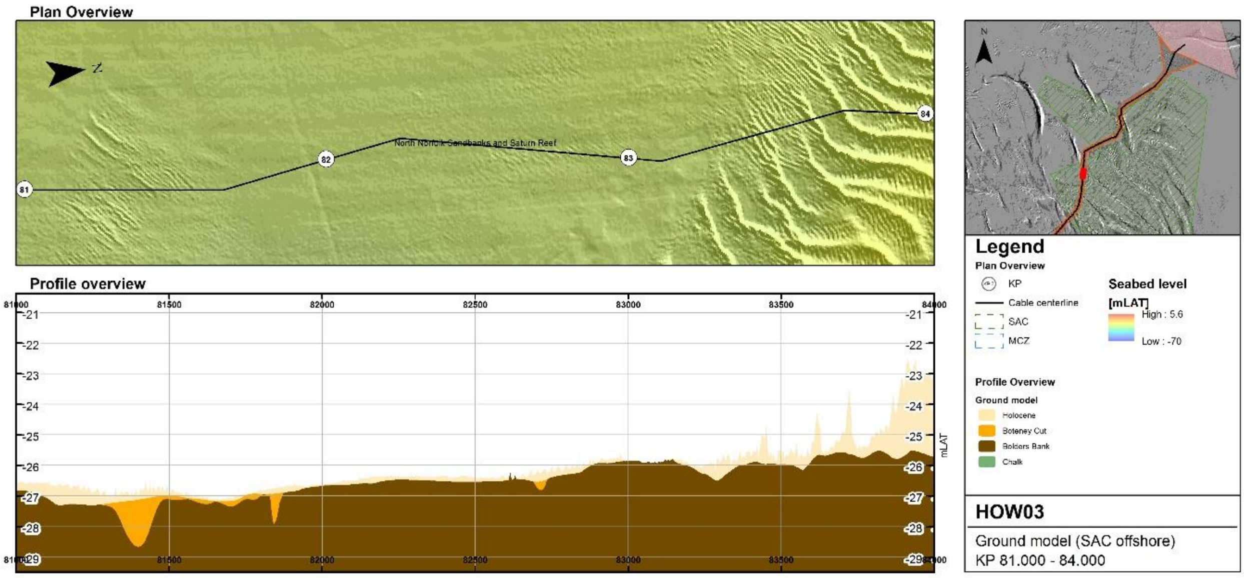


Figure 4.13: Ground Model; North Norfolk Sandbanks and Saturn Reef SAC (South) KP 81.0 – 84.0.

4.21 The majority of this section is Bolders Bank with a thin veneer of Holocene overlaying it. There are occasional intrusion channels of Botney Cut. The top layer of Holocene starts to increase in depth (forming sandwaves) towards to east of the section (Figure 4.13).

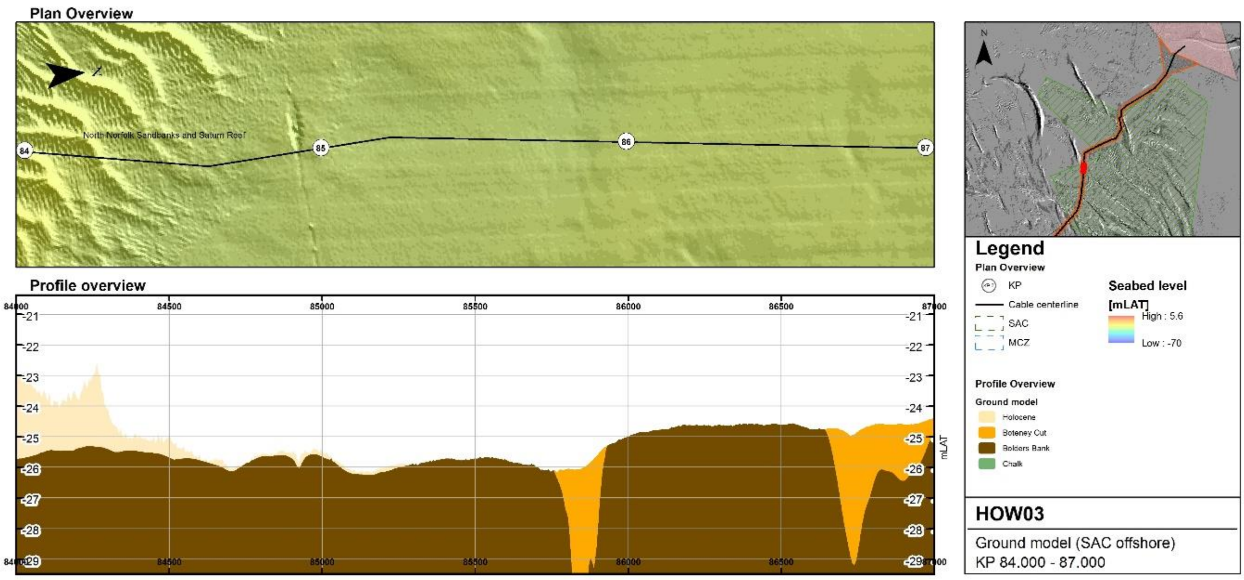


Figure 4.14: Ground Model; North Norfolk Sandbanks and Saturn Reef SAC (South) KP 84.0 – 87.0.

4.22 The majority of this section is Bolders Bank with a thin veneer of Holocene overlaying it. There are occasional intrusion channels of Botney Cut (Figure 4.14).

Zone 3b

4.23 Figure 4.15 to Figure 4.22 are cross-sectional representations within the North Norfolk Sandbanks and Saturn Reef SAC (North) (Zone 3b; KP95.56– KP117.22). Summary descriptions for each section are written underneath the figures.

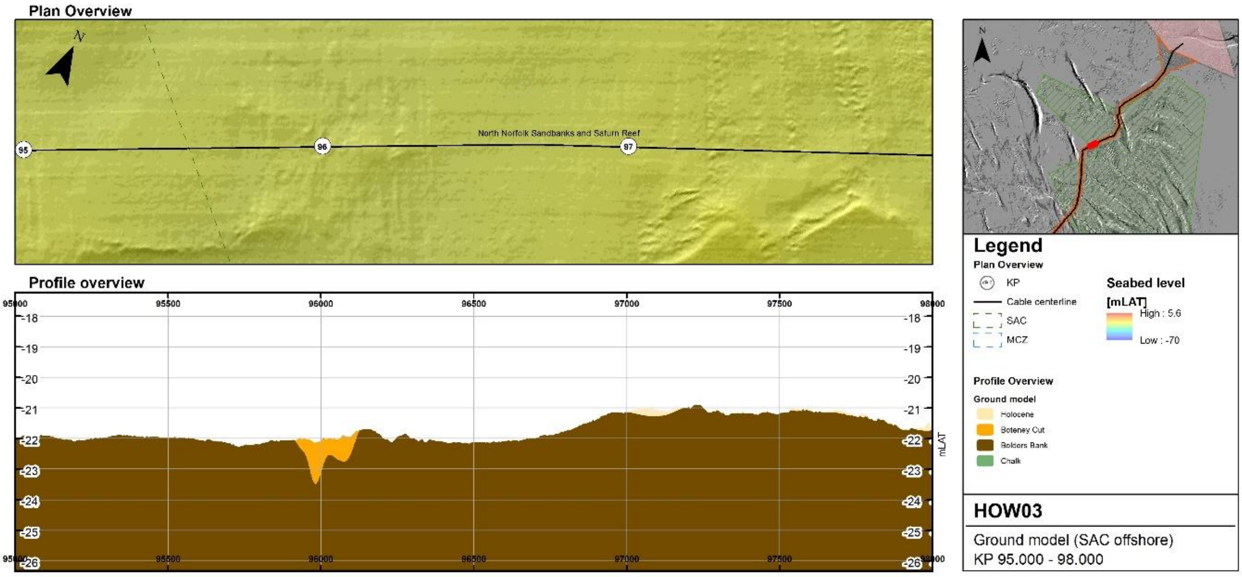


Figure 4.15: Ground Model; North Norfolk Sandbanks and Saturn Reef SAC (North) KP 95.0 – 98.0.

4.24 This section is Bolders Bank with a very thin veneer of Holocene overlaying it. There is an intrusion channel of Botney Cut between KP95.85 – 96.2 (Figure 4.15).

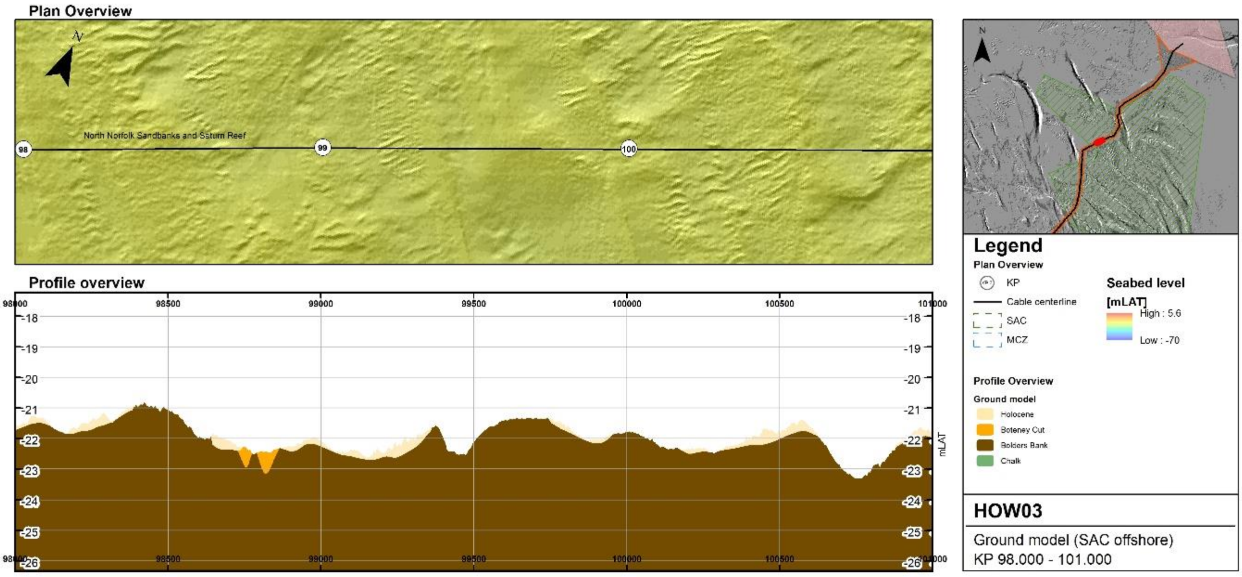


Figure 4.16: Ground Model; North Norfolk Sandbanks and Saturn Reef SAC (North) KP 98.0 – 101.0.

4.25 This section is Bolders Bank with a thin veneer of Holocene overlaying it. There are two small intrusion channels of Botney Cut between KP98.75 – 98.8 (Figure 4.16).

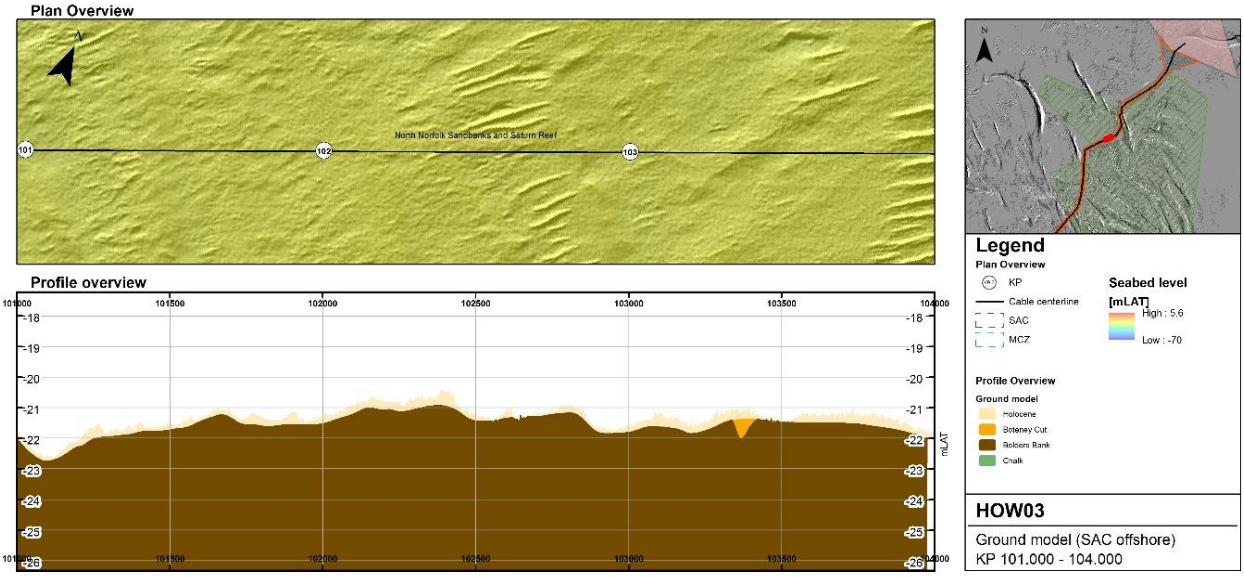


Figure 4.17: Ground Model; North Norfolk Sandbanks and Saturn Reef SAC (North) KP 101.0 – 104.0.

4.26 This section is Bolders Bank with a thin veneer of Holocene overlaying it. There is an intrusion channel of Botney Cut between KP103.3 – 103.4 (Figure 4.17).

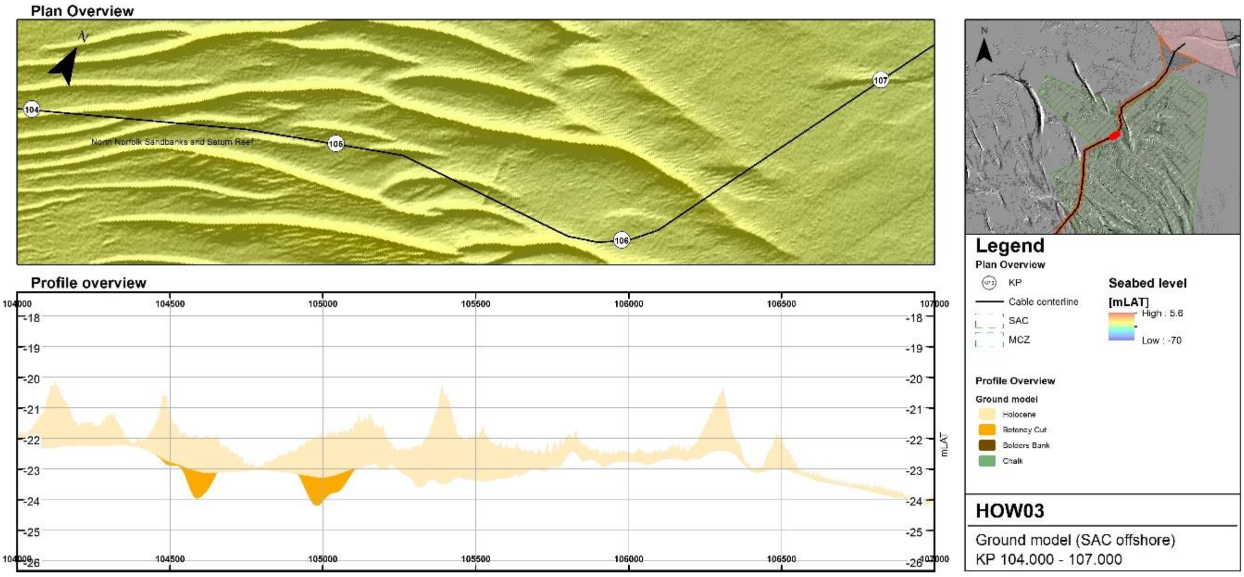


Figure 4.18: Ground Model; North Norfolk Sandbanks and Saturn Reef SAC (North) KP 104.0 – 107.0.

4.27 The top layer in this section is Holocene which form sandwaves. There are two intrusion channels of Botney Cut. The missing underlying layer is assumed to be a depth layer of Botney Cut based on strong evidence from the geophysical data (Figure 4.18).

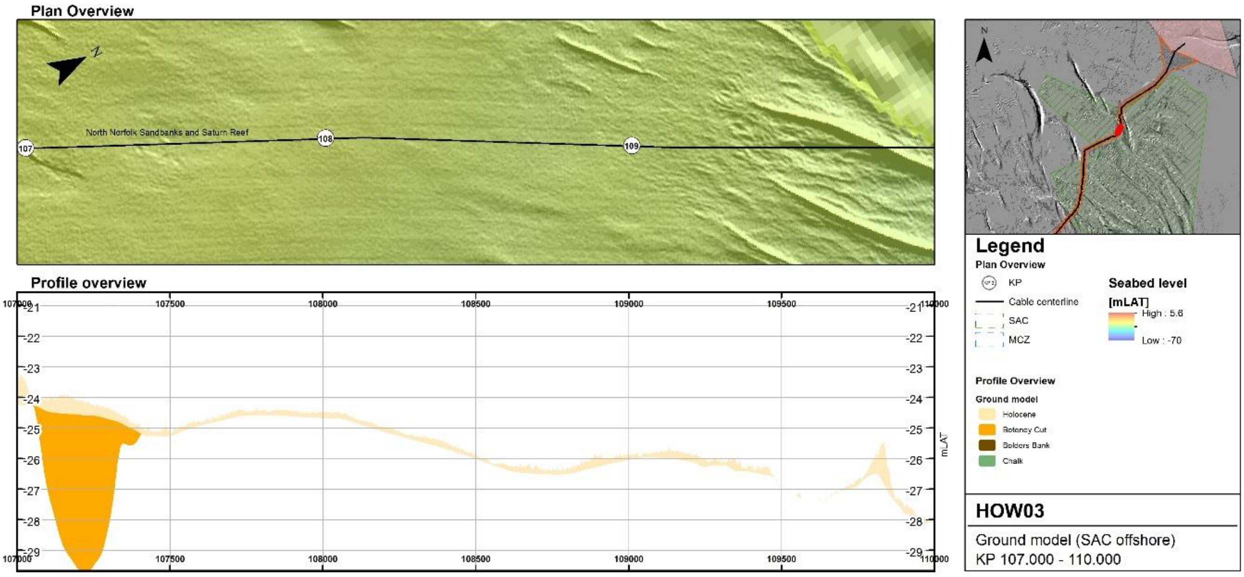


Figure 4.19: Ground Model; North Norfolk Sandbanks and Saturn Reef SAC (North) KP 107.0 – 110.0

4.28 The top layer in this section is a thin layer of Holocene. There is a deep intrusion channel of Botney Cut between KP107.1 – 107.35. The missing underlying layer is assumed to be a depth layer of Botney Cut based on strong evidence from the geophysical data (Figure 4.19).

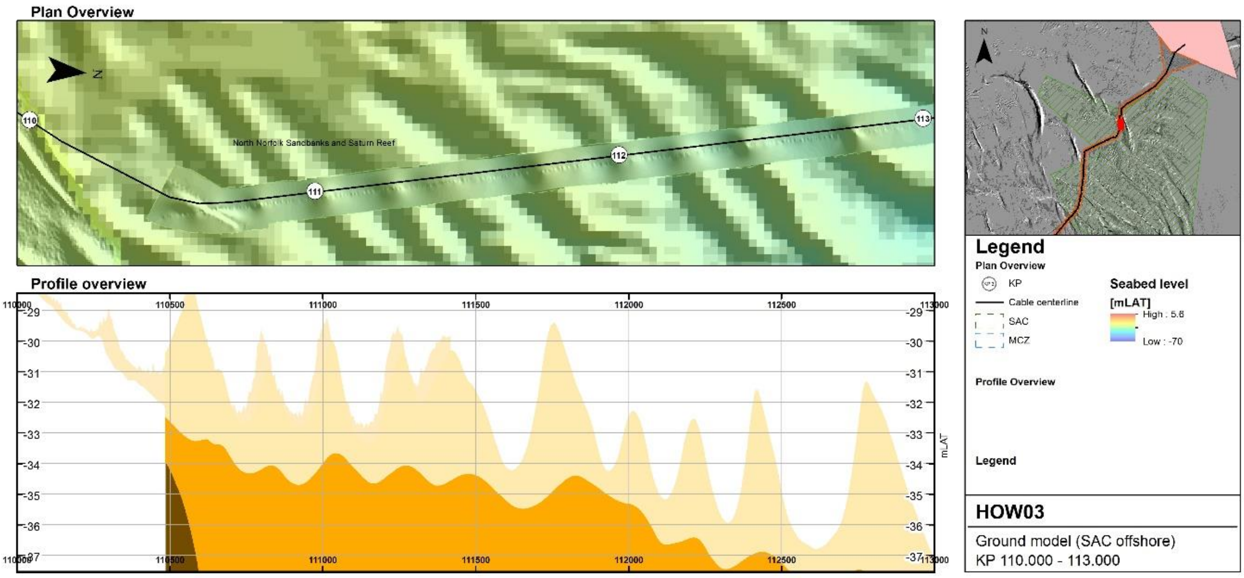


Figure 4.20: Ground Model; North Norfolk Sandbanks and Saturn Reef SAC (North) KP 110.0 – 113.0.

4.29 The top layer in this section is Holocene which forms large sandwaves. There appears to be a thick layer of Botney Cut between the top Holocene layer and the underlying layer of Bolders Bank (Figure 4.20).

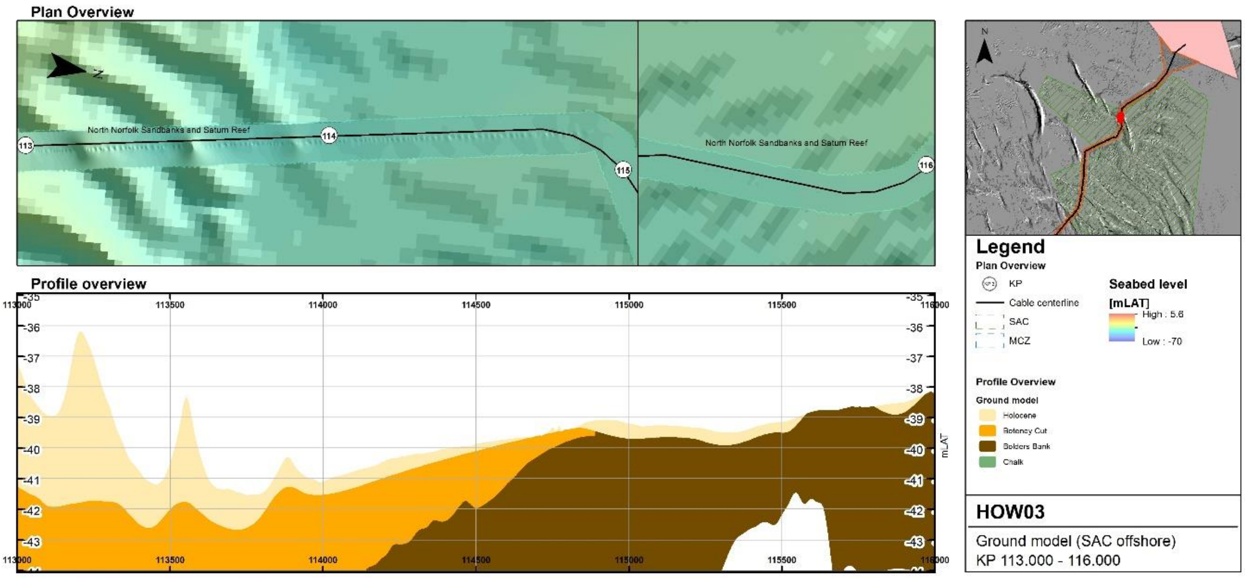


Figure 4.21: Ground Model; North Norfolk Sandbanks and Saturn Reef SAC (North) KP 113.0 – 116.0.

4.30 The top layer in this section is Holocene which starts off in the west as large sandwaves and decreases moving eastwards to a thin layer. Underneath the Holocene, the Botney Cut layer decreases in depth moving eastwards eventually disappearing at KP114.8. The underlying layer is Bolders Bank (Figure 4.21).

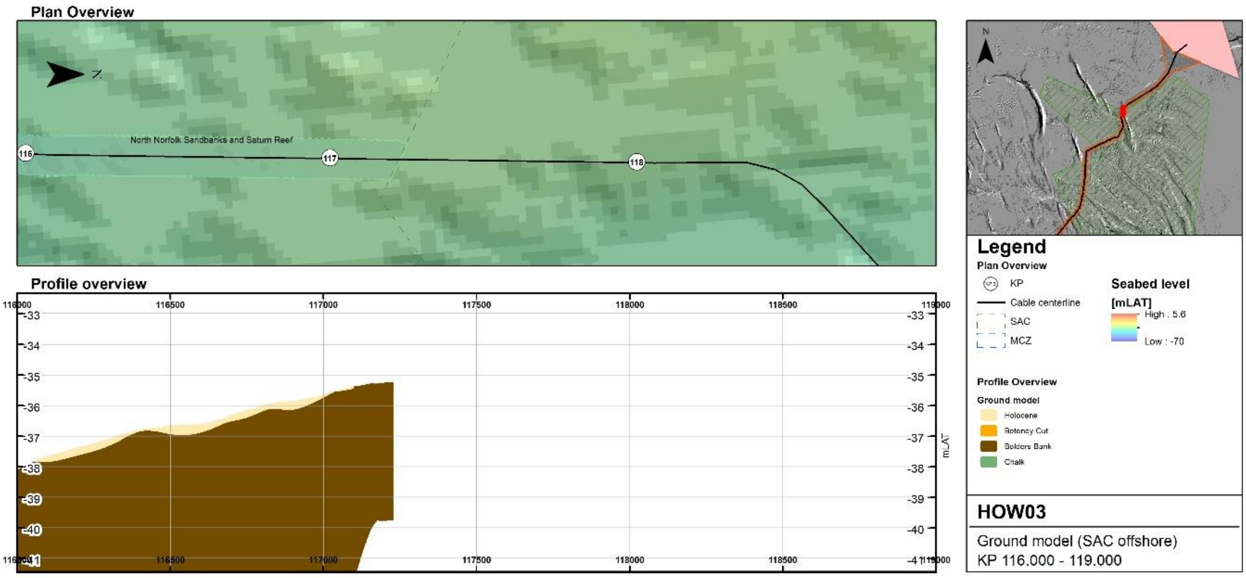


Figure 4.22: Ground Model; North Norfolk Sandbanks and Saturn Reef SAC (North) KP113.0 – 117.2.

4.31 This is a short section of Bolders Bank with a thin veneer of Holocene overlaying it (Figure 4.22).

Preliminary trenching parameters

4.32 The shallow geology along the proposed offshore cable corridor is presented in Table 4.3. Preliminary geotechnical parameters relevant to trenching have been included based on the available geotechnical data. For jet trenching this includes Particle Size Distribution and Relative Density; and for cohesive soils and the chalk – undrained shear strength and for the latter the CIRIA grading are key.

Table 4.3: Shallow geological formations with preliminary geotechnical parameters for trenching.

Epoch	Geological Formation	Description	Particle size distribution				Relative density, D_r (%)	Undrained shear strength, s_u (kPa)
			Clay/silt, %	Fine to medium grained sand, %	Coarse sand and gravel, %	d_{10}, d_{50} and d_{90}		
Holocene	Bligh Bank	Mainly fine to medium grained locally coarse silty slightly gravelly SAND	< 5	60 to 80	< 5 to 20	d_{10}, 0.04 to 0.03 d_{50}, 0.12 to 0.25 d_{90}, 0.2 to 0.3	20 to 80	NA
Late Pleistocene	Botney Cut	Fine sandy locally gravelly silt grading to soft to firm laminated clays	< 5 to 25	50 to 80	< 10	d_{10}, 0.06 to 0.025 d_{50}, 0.04 to 0.08 d_{90}, 0.06 to 0.6	10 to 40	10 to 65
Pleistocene	Bolders Bank	Stiff, locally firm to very stiff silty gravelly sandy clay	25 to 50	30 to 20	20 to 30	d_{10}, < 0.02 to 0.006 d_{50}, 0.006 to 0.25 d_{90}, 0.06 to 0.15	NA	100 to 150 (loc, 50)
Pleistocene	Egmont Ground	Dense to very dense silty muddy sand	< 5 to 20	60 to 90	< 5	No data	80 to > 100	NA
Pleistocene	Swarte Bank	Stiff to hard gravelly clay	20 to 50	20 to 30	10 to 15	No data	NA	150 to 250
Cretaceous	Chalk	Weathered structureless chalk, grade Dm or Dc	NA	NA	NA	NA	NA	100, locally up to 500

4.33 All the geotechnical samples including the vibrocores penetrate the chalk with CPTs penetrating to almost 6m. This suggests that the chalk is relatively weak. Fugro has adopted the CIRIA method to assess the chalk which is categorised as Grade Dc or Dm. These grades apply to a structureless coarse sediment (Dc); or a structureless fine grained sediment (Dm). In both cases the chalk is expected to behave as an engineering soil rather than a rock.

5. Tool Assessment

5.1 The export cables must be buried to protect them from natural (seabed mobility) and anthropogenic (shipping anchors) threats.

5.2 As per recommendations made by NE (Natural England, 2018[1]) they advise:

5.3 "*Where there is any doubt as to the feasibility of installation this should be clearly communicated, particularly where there is interaction with a Marine Protected Area*."

5.4 To conform with this recommendation, the Applicant has undertaken a Zone-specific trenching assessment (paragraph 5.21 *et seq*.) which, based on the tools available on the market (and in alignment for those installation methods listed in Table 3.32 of Volume 1, Chapter 3: Project Description of the Environmental Statement; APP-058), recommends which are considered to be feasible for the site conditions encountered at Hornsea Three.

Burial tool options

5.5 Figure 5.1 is an extract from DNV-RP-0360 which provides a basis to define which tools should be considered for installation in a range of soil conditions. As discussed in Section 4, the Applicant expects to primarily encounter loose sands (Holocene and Botney Cut), stiff clays (Bolders Bank) and structureless chalk which is according to its classification will behave as a loose to medium dense granular soil. On this basis the burial tool suitability curves suggest that for the site conditions, all three tools will be feasible if utilised in the correct soil conditions. The results from a detailed tool assessment is detailed in paragraph 5.21 *et seq*.

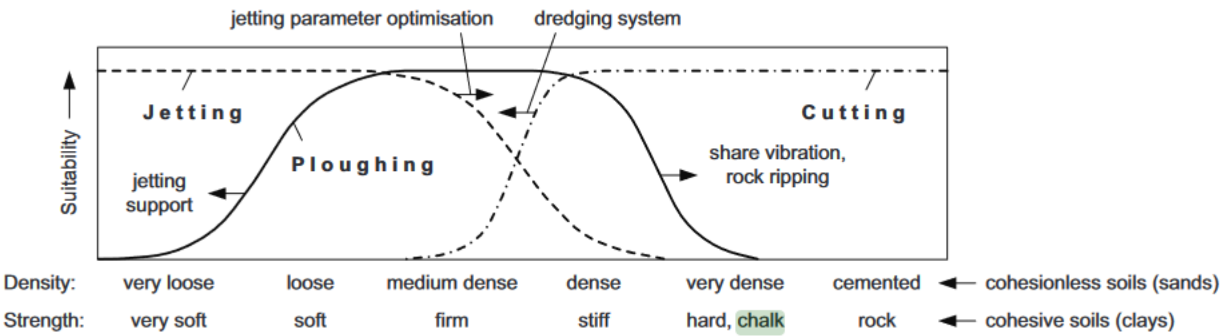


Figure 5.1: Indicative burial tool suitability in different ground conditions

5.6 The following paragraphs present an overview of the operating methodologies for each tool.

Jet trenching

5.7 Jet trenchers fluidise the soils by pumping seawater at high pressure through a series of small diameter nozzles arranged on opposing jet legs which locate either side of the product. The legs are slowly lowered into the seabed until near vertical and the trencher (which is usually track based) moves forwards forming a trench. The product (cable in this case) lies on the seabed and falls into the trench as the trencher progresses. Backwash nozzles are often located at the base of the legs to mobilise sediment along the trench and prevent it from settling out of suspension before the product touches down.

5.8 Jet trenchers are best suited to fine to medium grained sands and soft clays, with the more powerful jet trenchers able to jet firm clays as well. They are not suited to very stiff clays or areas of coarse sand and gravel although it is possible to achieve some lowering in the latter case by carrying out multiple passes.

5.9 Jet trenchers are a very popular tool particularly for cables as most do not actually engage with the product meaning that the risk of damage to cables is low and they can carry out multiple passes. They are always used in a simultaneous or post lay and burial application.

Mechanical trenchers

5.10 Mechanical trenchers physically cut a trench usually with a series of conical picks mounted on either a wheel or as a chain on a mechanical digging boom. The typical process is for the trencher to engage with and raise the product (the cable in this case) whilst deploying the wheel or chain below and then progress forwards digging a trench.

5.11 Mechanical trenchers are best suited for hard ground conditions i.e. stiff clay. They do not perform well in granular soils as the silica causes high wear on the picks and the trench tends to collapse before the cable touches down, although there are trenchers on the market which include jetting systems and cable depressors which keep the trench open until the cable touches down.

5.12 Most if not all mechanical trenchers engage with the product so there is a greater risk of damage to the cable, and it is essential that cable slack is closely monitored during lay and trenching operations. Mechanical trenchers are not able to carry out more than one pass, and like a jet trencher they are typically used for post lay burial.

Cable Ploughs

5.13 Cable ploughs come in a variety of shapes and sizes and are designed specifically for different soil types and burial depths. All ploughs are towed from a vessel or barge which must be able to provide adequate tow force, or in the case of landfall approaches pulled in from a fixed anchor point.

5.14 Ploughs can be either non-displacement or displacement. The former trench and bury the cable in a single pass leaving less disturbance on the seabed and are used for simultaneous or post lay and burial. They are often fitted with additional features to improve performance in certain soils for example water jets for burying in sand.

5.15 Displacement ploughs are typically large heavy-duty ploughs used to pre-cut a trench – typically in hard ground conditions where the trench remains open. The product is then laid into the trench and a secondary backfill pass carried out to bury it.

5.16 Ploughs cover a range of soil types and are well suited to long relatively straight routes. It is essential that the correct type of plough is selected for the prevailing soil and seabed conditions and the required burial depth.

Jet sleds

5.17 Jet sleds are a hybrid of a jet trencher and a cable plough. They are not usually self-propelling requiring to be towed or pulled but they often include a pumping system and jet legs.

Vertical injectors and Mass flow Excavator

5.18 These are typically specialised tools and they work on the same principal as jet trenchers with high pressure water jets fluidising the soils. As such they work best in granular soils and soft clays.

5.19 Vertical injectors can be mounted on sleds or tracks or suspended vertically over the side of a vessel. They are used mainly for very deep burial and are unlikely to be required for Hornsea Three.

5.20 Mass flow excavator or MFE is lowered towards the seabed from a vessel and jets the seabed soils creating a large open excavation. It is typically used to remove superficial cover similar to dredging to facilitate trenching operations.

Burial Tool Assessment

5.21 Given the concerns raised regarding trenching through the marine protected areas, a preliminary burial tool assessment has been carried out based on current knowledge of the site conditions in each Zone. The tool assessment will be refined as additional information is received and is intended at this stage to present a "first look" at the potential methods available.

5.22 The results are presented in Table 5.2 to Table 5.4. Note for reference, the BGS shorthand outlined in Table 5.1 has been used in the tables.

Table 5.1: BGS Shorthand for geological units.

BGS Shorthand	Unit
HOL	Holocene
BCT	Botney Cut Formation
BDK	Bolders Bank Formation
EG	Egmond Ground
Chalk	Weathered structureless chalk, grade Dm or Dc

Presentation of results

5.23 This section describes the results from the tool assessment for sections of the offshore cable corridor which coincide with marine protected areas. In almost all cases there is likely to be at least two viable options for burying the cables, providing a degree of flexibility going forwards.

5.24 The following definitions have been applied to the assessment:

- **Viable:** Based on current understanding of the site conditions this would be the preferred installation tool to meet the required burial depths.
- **Alternative:** Based on current understanding of the site conditions, whilst this would not be the preferred tool it would still have the ability to meet the target burial depth subject to further engineering and/or tool optimization e.g. additional buoyancy in soft soils. Subject to this, the tool may be considered Viable at a later date.
- **Limited feasibility:** Based on current understanding of the site conditions, this would have limited feasibility and areas which do not meet the target burial depth may be expected.

Cromer Shoal Chalk Beds MCZ (Zone 1) and The Wash and North Norfolk Coast SAC (Zone 2)

Table 5.2: Trenching feasibility assessment for Zone 1 and 2

General Area	Zone 1 and Zone 2; The Cromer Shoal Chalk Beds MCZ and The Wash and North Norfolk Coast SAC (KP0.0 to KP12.27)						
Section No.	1	2	3	4	5	6	7
KP Range	UK landfall to KP0.5	KP0.5 to 1.4	KP1.4 to 3.1	KP3.1 to 3.7	KP3.7 to 4.5	KP4.5 to 11	KP11 to 12.27
Section length (m)	500	900	1700	600	800	6500	1270
Geology	BDK	BDK	Chalk	BCT over BDK	Chalk	BDK loc. BCT	HOL
Burial Spec.	1 to 2m	1 to 2m	1 to 2m	1 to 2m	1 to 2m	1 to 2m	1 to 2m
Trenching asset assessment							
Shallow water jet trencher	Limited feasibility	Limited feasibility	Limited feasibility	Viable	Limited feasibility	Limited feasibility	Limited feasibility
Shallow water mechanical cutter	Viable	Viable	Viable	Alternative	Viable	Viable	Alternative
Jet Trencher	Limited feasibility	Limited feasibility	Limited feasibility	Limited feasibility	Limited feasibility	Limited feasibility	Viable
Mechanical cutter	Limited feasibility	Limited feasibility	Limited feasibility	Limited feasibility	Viable	Viable	Limited feasibility
Jet sled	Limited feasibility	Limited feasibility	Limited feasibility	Limited feasibility	Limited feasibility	Limited feasibility	Viable
Hydro assisted cable plough (non-displacement)	Viable	Viable	Viable	Viable	Viable	Viable	Viable

General Area	Zone 1 and Zone 2; The Cromer Shoal Chalk Beds MCZ and The Wash and North Norfolk Coast SAC (KP0.0 to KP12.27)						
Cable Plough (non-displacement)	Viable	Viable	Viable	Viable	Viable	Viable	Viable
Displacement plough (pre-cut)	Viable	Viable	Viable	Alternative	Viable	Viable	Alternative

* It is likely based on previous experience that the BCT can be jetted or mechanically cut

North Norfolk Sandbanks and Saturn Reef SAC (Zone 3a and Zone 3b).

Table 5.3: Trenching feasibility assessment for Zone 3a

General Area	Zone 3a; North Norfolk Sandbanks and Saturn Reef (KP63.09 to KP87.75)							
Section No.	1	2	3	4	5	6	7	8
KP Range	KP63 to KP63.9	KP63.9 to 66.5	KP66.5 to 66.9	KP66.9 to 71.5	KP71.5 to 74.5	KP74.5 to 76.5	KP76.5 to 77.5	KP77.5 to 87.5
Section length (m)	900	2.600	400	4.600	3.000	2.000	1.000	10.000
Geology	BDK	HOL	BDK	BCT loc.BDK	HOL	BDK	BCT	BDK
Burial Spec.	1 to 2m	1 to 2m	1 to 2m	1 to 2m	1 to 2m	1 to 2m	1 to 2m	1 to 2m
Trenching asset assessment								
Jet Trencher	Limited feasibility	Viable	Limited feasibility	Viable	Viable	Limited feasibility	Viable	Limited feasibility
Mechanical cutter	Viable	Alternative	Viable	Alternative	Alternative	Preferred	Alternative	Viable
Jet sled	Limited feasibility	Viable	Limited feasibility	Limited feasibility	Viable	Limited feasibility	Limited feasibility	Limited feasibility
Hydro assisted cable plough (non-displacement)	Viable	Viable	Viable	Viable	Viable	Viable	Viable	Viable
Cable Plough (non-displacement)	Viable	Viable	Viable	Viable	Viable	Viable	Viable	Viable

General Area	Zone 3a; North Norfolk Sandbanks and Saturn Reef (KP63.09 to KP87.75)							
Displacement plough (pre-cut)	Viable	Alternative	Viable	Alternative	Alternative	Viable	Alternative	Viable

* It is likely based on previous experience that the BCT can be jetted or mechanically cut

Table 5.4: Trenching feasibility assessment for Zone 3b

General Area	Section 3b; North Norfolk Sandbanks (KP95.58 to KP117.22)			
Section No.	1	2	3	4
KP Range	KP95.58 to 110.5*	KP110.5 to 113.5	KP113.5 to 114.5	KP113.5 to 117.25
Section length (m)	14,92	3000	1000	3750
Geology	BDK	HOL over BCT	BCT	BDK
Burial Spec.	1 to 2m	1 to 2m	1 to 2m	1 to 2m
Trenching asset assessment				
Jet Trencher	Limited feasibility	Viable	Viable	Limited feasibility
Mechanical cutter	Viable	Alternative	Alternative	Viable
Jet sled	Limited feasibility	Viable	Limited feasibility	Limited feasibility
Hydro assisted cable plough (non-displacement)	Viable	Viable	Viable	Viable
Cable Plough (non-displacement)	Viable	Viable	Viable	Viable
Displacement plough (pre-cut)	Viable	Alternative	Alternative	Viable

* It is likely based on previous experience that the BCT can be jetted or mechanically cut

5.25 It should be noted that the decision on burial tools will consider all technical, commercial and environmental constraints with the final methodology likely to favour a single or at most a dual approach suitable for burying the cable along the entire offshore cable corridor.

5.26 As more data is collected from the site and the understanding of the ground conditions improves, this tool assessment will be updated and a reassessment of the tool feasibility undertaken.

6. Lesson learnt from similar projects

6.1 The aim of this section is to identify key lessons learnt from industry experience in installing cable in similar ground conditions and also to identify potential risks to cable burial and provide recommendations as to how these will be managed up to and during cable installation.

General Lessons Learnt from adjacent sites

6.2 Ørsted have completed many successful cable installation projects and are confident in their ability to achieve the target burial depths for export cables and to minimise cable protection in marine protected areas. The Applicant also gains a lot of confidence from both Dudgeon and Sheringham Shoal both of which are projects adjacent to some extent to sections of the proposed Hornsea Three offshore cable corridor, where minimal to no cable protection was required following trenching. The Applicant understands that Sheringham has no cable protection at all and Dudgeon has a stretch of approximately 70m of rock bags from the HDD punch out point, but this was ultimately not driven by the trenching performance. These examples represent the most directly relevant case studies for the nearshore area of Hornsea Three and demonstrate that cable burial within this nearshore area is imminently achievable without the need for remedial cable protection.

Race Bank Lessons Learnt

6.3 This section outlines the main lessons learned on the Race Bank Offshore Wind Farm Project, which is further northwest of the proposed Hornsea Three offshore cable corridor. The Applicant has aimed to use this to help identify potential risks and provide recommendations as to how similar risks will be managed on Hornsea Three. Along the Race Bank export cable route, the Deep Ocean T3200 trencher was used which is a tracked mechanical trencher with simultaneous jetting functionality. The lessons learnt were as follows:

6.4 In areas where soft soils exist, the T3200 encountered traction issues resulting in areas where manoeuvrability was restricted. In these areas a lightweight trencher was mobilised; however, the operation left areas of reduced cable burial and a requirement for remedial works. It is recommended on Hornsea Three that areas where soft soils exist are characterised and bearing capacity analysis performed prior to mobilisation of installation tools to ensure the risk is managed.

6.5 There were observations of the T3200 depressor deflecting up locally which was an indication of larger item(s) that fell inside the trench or local collapsing of trench between cutter and jet legs/depressor. The cause of this could have been one or a combination of sub-surface boulders, gravels or chalk debris. It is important that the extent of these conditions at Hornsea Three is understood prior to trenching and high quality geotechnical and geophysical data acquisition is recommended.

6.6 Coarse material in gravelly areas can increase wear of the chain cutter on mechanical trencher as witnessed with the T3200. To quantify the chain wear (and the requirement for chain replacement), where possible the coarse sediments should be mapped along the Hornsea Three cable route through soil sampling and / or geophysical survey data. Similarly, to managing tool changeover operations, the cable lay operation should, where practical, account for areas where chain wear is expected to be high and chain replacement may be required.

6.7 When switching between tools in areas of complex geology the operation needs to be carefully planned. If this is not planned then excessive tension in the cable can reduce the ability for trenchers to pick up, engage and bury the cable. If tool changes are planned, then a sufficient pick-up bight should be accounted for during cable lay.

6.8 The risks and lessons learnt from Race Bank will be considered in the context of Hornsea Three, discussed with relevant stakeholders (i.e. MMO and Statutory Nature Conservation Bodies; SNCBs) and set out within the Cable Specification and Installation Plan (see paragraph 7.2 below).

Rampion Lessons Learnt

6.9 This section outlines lessons learned that Ørsted has acquired from the Rampion Offshore Wind Farm Project export cable installation, which aims to help identify potential risks and provide recommendations as to how similar risks will be managed on Hornsea Three.

6.10 Rampion Offshore Wind Farm export cables were installed in 2017 and there are many lessons learnt from this project relevant for Hornsea Three. The ground conditions were the biggest challenge on this project. The offshore export cables along the 16km route were predominately installed in chalk.

6.11 Rampion also had to dredge a number of floatation pits using back-hoe excavators in the nearshore section. The lessons learnt from these pits are not discussed here as they are not relevant to Hornsea Three.

6.12 VBMS/Boskalis successfully installed the export cables to the required burial depths. The Sea Stallion plough was successful in achieving the ~1m burial requirement, except for two occasions where boulders were encountered along the route. However, the cables were still adequately protected to a depth of ~0.5m which was sufficient considering the strength of the seabed in those areas and no rock protection was required.

6.13 During the first replacement export cable (Cable 3) installation, there was a malfunction with the cable lay pull ahead winch and the cables had to be surface laid onto the seabed. A combination of the Canyon I-trencher and Canyon T1200 was subsequently used for burial of this cable. The combination of jetting (T1200) and cutting (I-trencher) meant that even with changing seabed conditions the cable could be buried by a one vessel solution. There were no problems with standing bights witnessed, as the I-trencher does not lift the cable too high and an overlap was included past the competent material, so the bight could be buried by jet trencher.

6.14 The second replacement export cable (Cable 4) was buried using a wheel-cutter by Assodivers. During the cutting there was an issue with trench walls collapsing prior to the cable being lowered. A jet trencher was subsequently successful used to lower the cable to the required depth within the trench.

6.15 One of the major concerns on the Rampion export cable burial was the strength of the chalk in some of the nearshore sections. Nearby maintenance vessels were not able to use anchors in the area as they would not penetrate the seabed. The CPT values in the area fell mainly in the partially cemented and cemented chalk zones, ranging from Grades A1 to C5 from the CIRIA grading which is described as a structured chalk, a higher grade than expected to be encountered on Hornsea Three (see paragraph 4.5). However, the grade of the chalk did not prove to be an issue for the Sea Stallion plough to meet the target burial depths. The Applicant is therefore confident that lessons learnt from Rampion can be used to the benefit of Hornsea Three and provide further confidence in installation preparations, both by the Applicant and the contractor eventually employed for work.

7. Next Steps

7.1 The second geotechnical campaign for Hornsea Three is currently envisaged (consent and CfD award notwithstanding) to take place in 2021/2022. The purpose of this site investigation campaign will be to investigate areas along the route where residual risk exists with respect to the trenching operations to ensure that they are appropriately managed prior to site operations. During the scoping of the investigation particular focus will be given to The Cromer Shoal Chalk Beds MCZ, The Wash and North Norfolk Coast SAC and North Norfolk Sandbanks and Saturn Reef SAC to ensure that ground-based risks are characterised.

Compliance

7.2 One of the key messages that the Applicant has taken from submissions made into the examination to date, and the feedback on these, is the need to provide NE with as much clarity as possible as to how and when detailed information relating to the cable installation process (inclusive of any site preparation and/or protection works) will come forward and how the specific activities are controlled within the DCO. This is needed so that they can have greater confidence in the Applicant's assumptions relating to site preparation, cable burial and deployment of cable protection measures. For Deadline 5, the Applicant has submitted an Outline CSIP (Appendix 3 to the Applicant's response to Deadline 5) and at Deadline 4 amended the Deemed Marine Licence (REP4-004) to include the requirement for Sandwave Clearance and Cable Protection Plans to form part of the CSIP.

7.3 The Applicant acknowledges that it will be important, particularly within the areas where the cables intersect with marine protected areas, for there to be ongoing dialogue between the Project and the relevant SNCBs as the CSIP is developed. It is proposed that an Ecological Clerk of Works (ECoW) will be responsible for ensuring this coordinated approach to the development of the plan. The ECoW will be to be the main point of contact for SNCBs throughout the pre-construction, construction and post-construction phases of the project. The ECoW will form an interface between the Hornsea Three engineering and consents teams, as well as briefing contractors to ensure compliance with the DCO and any further measures agreed through this plan.

8. Conclusions

8.1 Through acquisition of detailed geotechnical and geophysical data along the length of the Hornsea Three offshore cable corridor, a detailed ground model has been developed which highlights the primary ground conditions (and their engineering properties) that the cable will be installed within. This is expected to comprise a range of soil conditions from loose sands, stiff clay and weathered chalk. Based on these conditions a preliminary tool assessment has been undertaken to assess the feasibility of achieving the target burial depth. The analysis demonstrates that for each zone, a range of burial options are 'Viable' with ploughing and mechanical cutting the most suitable. Furthermore, some trenching technologies have been identified as 'Alternative' which subject to further optimisation and/or engineering could also be utilised for the works. An example of this could be addition of buoyancy of a tool to make it more suitable in softer soils such as the Botney Cut Formation.

8.2 The ground model has been developed and preliminary tool assessment undertaken based on the information available at the time of writing. The Applicant would note that this is an iterative process, with further development of these as more data are collected across the Hornsea Three offshore cable corridor.

8.3 It must be understood that whilst sections of the offshore cable corridor have been identified as 'Viable' for cable installation, this does not mean that cable burial can be guaranteed and negate the requirement for remedial burial and/or cable protection. External factors outside the Applicant's control should be considered such as adverse weather conditions, unforeseen ground conditions and mechanical breakdown.

8.4 To support this assessment, a number of lessons have been learned from both Ørsted projects and other projects installed in similar ground conditions. These past experiences will ensure that risk of remedial action is reduced through incorporating improved cable lay and trenching practices into the CSIP, with early engagement with and feedback from NE and JNCC prior to cable installation.