NorthConnect

Cable Protection Analysis Report

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SUMMARY

NorthConnect is an EU Project of Common Interest being jointly developed by Agder Energi, E-CO, Lyse Produksjon and Vattenfall ('NorthConnect KS') to build, own and operate an electrical interconnector between Scotland and Norway. The 665km long, 1400 megawatt (MW) interconnector will provide an electricity transmission link allowing the two nations to exchange power and increase use of renewable energy.

Under instruction from the Client, Cathie Associates has undertaken this Cable Protection Analysis Report (CPAR) for the survey corridor. This report builds on the findings of the Cable Burial Risk Assessment (C831 R01) and covers the UK nearshore, North Sea, and Norwegian fjords sections and incorporates information gathered from the final geophysical and geotechnical reports. A separate document (C831 R03) provides a more detailed assessment of the route corridor from the UK Landfall to where the corridor crosses the 12NM UK limit (found at KP 27.7 on RPL09).

The main body of this report provides a summary of seabed conditions and installation risks identified along the cable route.

A Risk Register, analysing the main cable installation and protection risks and mitigation measures to reduce these risks is presented as Appendix A.

A comprehensive assessment of the route, encompassing a preliminary burial tool assessment is presented in the detailed table in Appendix B.

Alignment Charts depicting the findings of the assessment are presented as Appendix C.

Information on cable burial techniques and tools is presented as Appendix D with additional examples of specific equipment included in Appendix E.

Finally, rock placement volume estimates to account for possible sections of reduced burial, trench backfill and crossing designs are presented as Appendix F. Conceptual berm designs provided by the Client have been utilised for this purpose, for which initial hydrodynamic stability and trawl/anchor impact resistance assessments have been performed.

The shallow geology of the survey corridor varies considerably across the entire route length: from loose to dense sands and extremely low to high strength clays; through to gravels, glacial Tills, boulder areas and outcropping bedrock.

The North Sea section mainly comprises of sands and lower strength clays. However, glacial Tills are expected to be subcropping at varying depth within the surveyed corridor between KP 1.35 and KP 5.1 in the UK nearshore, with some localised bedrock outcrops. High strength clays are also found within the first 5km of the UK landfall, generally overlying the Till, and in localised areas of the eastern slope of the Norwegian Trench (KP 447.5 to KP 456.2). Boulders are common within the first 62.5km of the route and within the Fjord.

Localised bedrock outcrops are noted on the approach to the Norwegian coastline, in particular between KP 470 and KP 474, and within the Hardangerfjord. Bedrock/Till is interpreted periodically in raised areas across the width of the Hardangerfjord. These may

represent terminal moraine features; however the presence of bedrock has not been ruled out by the survey contractor. In the bottom of the Fjord, the sides of which are steep and rocky, clays of very low to extremely low strength are found. In many areas, these sediments are interpreted as being mass-transport deposits. Historic slip-scarp features occur regularly perpendicular to the Fjord length.

Despite the variable geological conditions, jet trenching is deemed generally suitable for the majority of the cable route, with pre-lay ploughing better suited in areas of sub surface boulders (estimated at <3% of the total route).

The indicative volumes of rock placement presented in this report (upper estimate of 124334m^3 per cable) are intended to inform the Marine Licence application however it is anticipated that more detailed burial assessment, berm design and sediment dynamics studies will be performed as part of detailed engineering, and enable refinement of these estimates.

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1.1 Background

NorthConnect is a project set up to develop, consent, build, own and operate an HVDC electrical interconnector between Peterhead in Scotland and Simadalen in Norway. The 665km long, 1400MW interconnector will provide an electricity transmission link allowing the two nations to exchange power and increase use of renewable energy. The intention is for the HVDC interconnector to be operational by 2023.

NorthConnect KS is a Joint Venture (JV) project company owned by four community and state-owned partners from Norway and Sweden: Agder Energi AS, E-CO Energi AS, Lyse Produksjon AS, and Vattenfall AB. The partnership was established on 1st February 2011.

A 550m corridor has been surveyed by MMT and the cable routes will be optimised within this corridor based on the results of the survey. Within the UK 12NM limit, a 60m wide “Conceptual Installation Corridor” is defined for the purposes of environmental consenting (Ref. 20).

Under instruction from the Client, Cathie Associates undertook a Cable Burial Risk Assessment Report (CBRA) (Ref. 19) for the whole route in which the seabed conditions along the survey corridor were assessed, and the main risks to the cable over the operational lifetime of the project were identified and analysed.

This report builds on the findings of the CBRA and presents an appraisal of cable protection methods that may be suitable for the NorthConnect project, considering the seabed conditions along the survey corridor and lifetime risks to the cable as determined in the CBRA. The report also considers risks, advantages and disadvantages of different cable installation methodologies that could be employed on this project. A review of burial tool types and examples of tools currently available in the market are also presented within this Cable Protection Analysis Report (CPAR), along with preliminary estimates for total rock placement lengths/volumes to account for crossings and areas where burial may be problematic.

1.2 Objectives and Purpose of Document

The objectives of this study are to summarise the seabed conditions along the survey corridor from an installation perspective and to assess suitable cable protection methods for the NorthConnect Interconnector cables.

The purpose of this document is to provide preliminary recommendations for the cable protection design and inform the environmental consenting process for the project.

It should be noted that whilst in general the cable route description has been based on the Survey Centre Line (SCL) data, the possibility of route optimisation away from potentially problematic seabed conditions has been considered throughout.

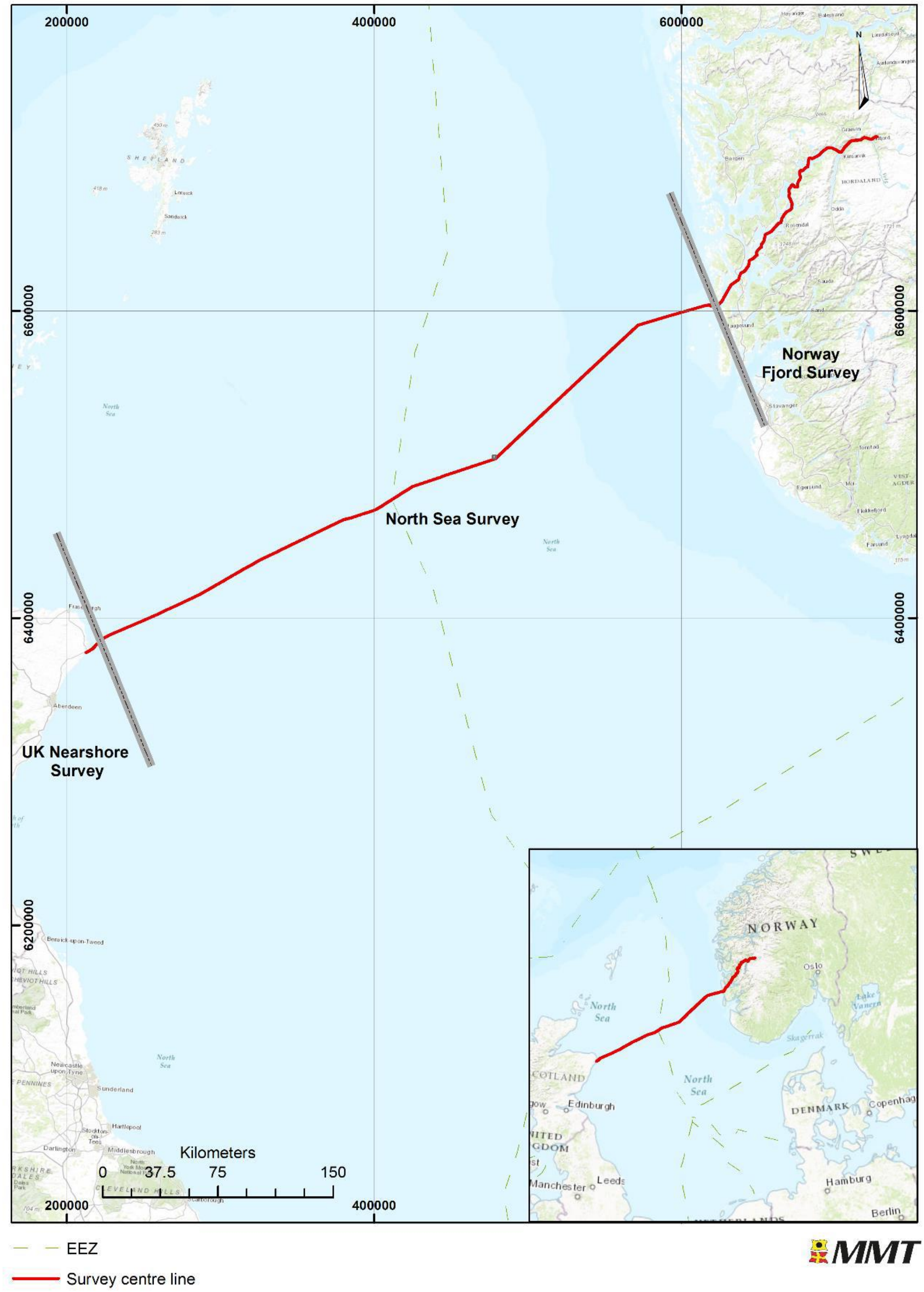

Figure 1: Overview of the NorthConnect survey corridor and survey sections (Ref. 1)

1.3 Scope of Work

The detailed Scope of Work completed and reported in this document is as follows:

- Review of the draft Cable Protection Strategy provided by Client.
- Characterisation of the seabed and sub seabed conditions covering the entire subsea survey corridor highlighting potential installation risks.
- Identification and analysis of factors that may influence the installation; and assessment of the attainable protection levels and their adequacy to satisfy marine licensing and hazard protection requirements for the lifetime of the cable system.
- Review of all available burial methods and/or alternative protection options available on the market that are suitable for the conditions of the seabed along the survey corridor.
- Comparative assessment of different burial tool types on a section-by-section basis. The assessment only considers the ability of different tool types to achieve the required burial depth. Other issues such as progress rates and risks posed by the tools to the product are also discussed in brief.

1.4 Abbreviations

A list of the abbreviations used in this report is provided in Table 1

Table 1: List of abbreviations

Abbreviation	Description
AIS	Automatic Identification System
ALARP	As Low as Reasonably Practicable
bsbl	Below Sea bed level
CC	Consenting Corridor
CBRA	Cable Burial Risk Assessment
Client	NorthConnect KS
CPAR	Cable Protection Analysis Report
DOL	Depth of Lowering (to top of product)
DTS	Desk Top Study

Abbreviation	Description
EIA	Environmental Impact Assessment
FEED	Front End Engineering Design
HDD	Horizontal Directional Drilling
IMR	Inspection Maintenance Repair
KP	Kilometre Post
LAT	Lowest Astronomical Tide
MAG	Magnetometer
MBES	Multi-beam Echo Sounder
mbsbl	Metres Below Sea Bed Level
MDAC	Methane-derived Authigenic Carbonate
MSL	Mean Sea Level
N/A	Not Applicable
NM	Nautical Mile
PCPT	Piezo-cone Penetration Test
RSBL	Reference Sea Bed Level
SBP	Sub Bottom Profiler
SCL	Survey Centre Line
SSS	Side Scan Sonar
(p)UXO	(Potential) Unexploded Ordnance
VC	Vibrocore

2. Data Adequacy Review

2.1 Data Sources

Several Front-End Engineering Design reports have been undertaken for the project including a Desk Top Study (DTS), incorporating a preliminary hazard assessment and cable route engineering; and an initial Cable Protection Study comprising risk assessment and trenchability assessment. In addition, a geophysical, benthic and geotechnical investigation of the proposed route corridor has been performed in 2017.

The Client supplied the following documents for use in the assessment:

1. MMT, Geotechnical Report: 102273-NOC-MMT-SUR-REP-GEOTECH (Feb 18)
2. MMT, Geophysical, Benthic and Geotechnical Route Survey: Final Survey Report, Ref: 102273-NOC-MMT-SUR-REP-SURVEYRE (May 18)
3. MMT, Geophysical, Benthic and Geotechnical Route Survey: Field Operations Report, Crossing and Inspection Survey, Ref: 102273-NOC-MMT-SUR-REP-CIFREPLB (Nov 17)
4. MMT, Geophysical, Benthic and Geotechnical Route Survey: Field Archaeological Report, Ref: 102273-NOC-MMT-SUR-REP-FIELDALB (Apr 17)
5. MMT, Geophysical, Benthic and Geotechnical Route Survey: Geophysical and Geotechnical Alignment Chart(s), RPL-R09, Route B
6. NorthConnect, RPL-RouteB-R09
7. MMT, Contact and Anomaly lists, UK Nearshore and North Sea, project 102273 (Survey Report Appendix)
8. NorthConnect, Attachment E01.10 – Requirements to Submarine Cable Protection (April '18)
9. Xodus, Desk Top Survey and Route Engineering Study: Route Option Analysis Report, Ref: A-30722-S04-REPT-002 (Sep 12)
10. MMT, GIS data, WebGIS portal data
11. Riggall & Associates, Conceptual HDD Design Norther / Southern Alignment, Drawing No. 20160401RA-C/01 and 04 (May 16)
12. NorthConnect, HVDC Cable Route Scoping Report, Ref.: 2016.04.25_NorthConnect_PER-REP_HVDC Scoping Report_Rev A
13. 6 Alpha Associates, Unexploded Ordnance (UXO) Threat & Risk Assessment with Risk Mitigation Strategy for Cable Installation, Ref.: P5530 V2.0 (May 17)
14. Intertek, NorthConnect Metocean Data Study, Ref.: P2152A_R4323_Rev1 (Sep 17)
15. NorthConnect, Environmental Statement, Chapter 1: Introduction
16. NorthConnect Project, Appendix E03.01- Design Basis – Cable and Pipeline Crossings, Document I.D: 1384225

17. NGI, Hardangerfjord Geohazard Assessment, Document number 20180094-01-R (Mar 18)
18. NorthConnect, Attachment E02.02.01 Annex 1: List of Crossings (25/04/18)

Cathie Associates has undertaken a detailed CBRA for the cable survey corridor, a detailed assessment of the routed alignment within the 12NM limit, and a preliminary assessment of rock berm stability:

19. Cathie Associates, UK-Norway HVDC Interconnector Cable Burial Risk Assessment, Ref. C831R01.
20. Cathie Associates, UK 12 NM Detailed Burial Assessment, Ref. C831 R03
21. Cathie Associates, Rock Berm Assessment Ref. C831T02

The following additional non-project specific references have been used:

22. BGS, 1990. The geology of the Moray Firth, UK Offshore Regional Report. London: HMSO for the BGS
23. Carbon Trust, Cable Burial Risk Assessment Methodology, Guidance for the Preparation of Cable Burial Depth of Lowering Specification, CTC835, February 2015
24. Carbon Trust, Application Guide for the Specification of the Depth of Lowering using the Cable Burial Risk Assessment (CBRA) methodology, Dec 2015
25. DNV-RP-F107, Recommended Practice, Risk Assessment of Pipeline Protection, October 2010
26. Deltares, 2013. Anchor Tests German Bight. Document Number 1207052-002-GEO-0003
27. Eigaard, O.R. et al, 2015. Estimating seabed pressure from demersal trawls, seines and dredges based on gear design and dimensions. *ICES Journal of Marine Science*.
28. Marine Management Organisation, UK Sea Fisheries Statistics 2015, 2015.
29. Marine Traffic, AIS Traffic Data, whole NorthConnect route – two full calendar years 10/2015 to 09/2017 © marinetraffic.com 2015/2017
30. Shapiro S., Murray J., Gleason R., Barnes S., Eales B., and Woodward P., (1997) Threats to Submarine Cable, SubOptic '07, San Francisco.
31. DNV, Subsea Power Cables in Shallow Water, DNV-RP-J301, 2014.
32. Vryhof Anchors, Anchor Manual 2010 – The Guide to Anchoring, 2010
33. MAIB, 1997. Report of the Inspector's Inquiry into the loss of the Fishing Vessel Westhaven AH 190 with four lives on 10 March 1997 in the North Sea.
34. Marine Scotland, WebGIS portal data, https://marinescotland.atkinsgeospatial.com/nmpi/
35. BERR - Review of Cabling Techniques and Environmental Effects Applicable to the Offshore Wind Farm Industry

36. Tentative reconstruction of ice margins at the maximum stage of the second major expansion of the Main Late Devensian ice sheet (after Hall and Bent, 1990 and Sejrup et al., 1987). This stage is correlated with the maximum of the 'Dimlington Advance', 18.5–15.1 ka BP (Sejrup et al., 1994). From: Figure 44 in MERRITT, J W, AUTON, C A, CONNELL, E R, HALL, A M, and PEACOCK, J D. 2003. Cainozoic geology and landscape evolution of north-east Scotland.

2.2 Data Adequacies and Gaps

An appraisal of the available information is presented in Table 2.

Table 2: Data appraisal

Data Requirement	Data Adequacy	Comments
Geophysical Data	✓	
Bathymetry	✓	
Seabed Features	✓	
Shallow Geology	✓	
Geotechnical Data	✓	
GIS	✓	
Metocean Data	✓	
Sediment Mobility	✓	Characteristics of the bedforms identified during the geophysical surveys have been recorded in the survey report, however a dedicated sediment mobility study has not been undertaken.
UXO	✓	UXO DTS available for the survey corridor
Fishing	✓	Location of fish farms (with associated anchors) indicated in WebGIS however a detailed fishing study is not yet available (will be completed as part of the EIA)
Existing Infrastructure	✓	

Data Requirement	Data Adequacy	Comments
Cable Specification	×	Not yet available. NorthConnect has indicated that the cables will be mass-impregnated paper insulated HVDC cables of ~120mm diameter. Single cable per trench is preferred but bundling is not ruled out. The fibre-optic (FO) cable will be bundled to one of the power cables until branching off at the Norwegian coastline.
RPL	✓	References to KPs are based on the SCL (Route revision 09) however reference to co-ordinates is also provided in the CPA table.

The available data supplied by the Client and gathered by Cathie Associates during the assessment from third party sources has been deemed generally acceptable to undertake this CPAR. It is recommended to update the report once further route engineering has been completed.

3. Assessment of Seabed Conditions

3.1 Bathymetry and Seabed Features

Detailed assessment of the bathymetry and seabed features observed during the MMT surveys (Ref's. 1,2) is provided in the CBRA report (Ref. 18), and detailed information along the survey corridor is also presented in the CPA table in Appendix B.

The main seabed features observed are:

- Surface boulders: Surface boulders of varying density are found mostly within the first 50km from the UK landfall, and in parts of the Fjord.
- Mobile sediments: Found mostly within the first 62.5km of the UK landfall
- Iceberg plough marks: The base of icebergs during the previous ice age have carved marks into the seabed between KP 415 and KP 456. Clay strength is variable in parts of this area depending upon the level of reworking and soft clay infill.
- Trawl marks: Evidence of demersal fishing, found across most of the North Sea.
- Pockmarks: Naturally occurring depressions in the seabed found regularly between KP 80 and KP 415. These should be avoided by the final route as they are generally steep-sided and their formation is associated with potentially corrosive gas.
- Potential slip scarps across the cable route and landslides from the Fjord sides.
- Areas of outcropping bedrock and Till at both the UK and Norwegian ends of the route, and also within the Handangerfjord

Water depths increase rapidly from the UK end of the route into the North Sea. The route then crosses the northern extent of the Norwegian Trench, before entering the very deep water found within Handangerfjord.

3.2 Environmental Habitats

The environmental aspects of the NorthConnect project are to be reviewed in detail in an Environmental Impact Assessment (EIA). This is being finalised at the time of writing and any additional constraints identified in the EIA not reported below must also be considered.

The proposed corridor on the UK side is subject to a PAC (pre-application consultation). Marine Licence is required under the Marine (Scotland) Act 2010 for cables and all associated objects (including cable protection within 12NM of the shore) and under the Marine and Coastal Access Act 2009 for cable protection (12-200NM).

The proposed cable corridor crosses the Buchan Ness to Collieston Coast Special Protection Area (SPA) and thus requires a Habitats Regulation Appraisal (HRA). This site is designated for breeding bird seabird assemblages, and further identified habitats within the SPA are vegetated sea cliffs, home to multiple seabird species, and rocky reef communities. Horizontal Directional Drilling (HDD) will bypass these cliffs and it should be possible to re-route around the rock outcrops in the nearshore, thus these habitats should be avoided.

JNCC ANNEX I habitats and OSPAR threatened species were also noted along the route corridor: locations on the SCL are given in the table in Appendix B.

The route also crosses the location of a Southern Trench proposed Marine Protection Area (pMPA). This pMPA is to be designated for: burrowed mud, minke whale, fronts and shelf deeps.

The survey corridor passes adjacent to the Scanner Pockmark SAC (Special Area of Conservation), a large example of a seabed pockmark. The impacts of cable installation/operation should be considered on this neighbouring protected site.

At the Norwegian end of the offshore cable section, areas of coral reefs lie in proximity/within the survey corridor which are being considered by NorthConnect when routing the cable.

A consenting corridor (CC) will be provided to the contractor which excludes hard constraints such as Annex I reefs which limits the final cable route to outside of these areas. At present, the cable layout is envisaged by a "conceptual installation corridor" of 60m width, with a minimum of 20m separation between the two cables, however the final separation may be forced to be wider should UXO be found and require avoidance. The cable layout is discussed in detail in C831R03 (Ref. 20)

3.3 Existing Infrastructure

A large number of cables and pipelines (both in service and decommissioned) are indicated to cross the cable route. A comprehensive list is provided in Ref. 18, and crossing locations, infrastructure type and burial status (North Sea only) are also detailed in Appendix B (note this includes some repeat crossings). Not all of this infrastructure will be crossed using a designed crossing, e.g. disused cables will be cut and cleared from the route.

The presence of multiple fish-farms in the fjords is of relevance for this project. The seabed anchors of five of these farms will be removed prior to cable installation and later re-instated. Enhanced burial protection is required in the vicinity of fish farm anchors for which the burial tools will have to increase the trenching depth. These locations are outlined in Appendix B.

3.4 Archaeological Exclusion Areas/Wrecks/UXO

Numerous wrecks are found along the survey corridor however these should be avoided during micro-routing. This applies particularly to military wrecks, which may be associated with UXO risks. The MMT survey report discusses these wrecks in detail.

The level of UXO risk reported in the 6 Alpha UXO desk study route charts has been transferred to the CPA table and alignment charts. Detailed UXO survey and possible clearance will occur on the final route. Avoidance is the preferred strategy rather than removal.

3.5 Regional Geology

Publicly available information from the BGS (Ref. 19) and the Desk Top Study (Ref. 10) has been consulted to inform the assessment of regional geology. The principal formations within the uppermost 3m of the seabed are described in detail in section 3.3 of the CBRA report (Ref. 18). Further discussion of the geology within the 12NM area can be found in C831R03 (Ref. 20).

3.6 Shallow Geology

Assessment of the geology using CPT and Vibrocore samples in addition to sub-bottom interpretation allowed the route to be divided according to expected geological/geotechnical conditions. Clay strengths are outlined in Table 4. The CBRA table provides an assessment of the geology on a section-by section basis, and the description of each section is reproduced below in Table 3. The expected geological conditions were used to assess the expected performance of different burial tools in each route section.

Table 3: Route Section Geology

KP From	KP To	Brief Description of Geology expected in section
0	0.1	BEDROCK (HDD)
0.1	1.35	SAND over dense SAND
1.35	3.7	Veneer of SAND/GRAVEL over 0.5-4m CLAY over TILL. SAND present under clay in some areas. (Clay medium to high strength)
3.7	4.47	Veneer of SAND/GRAVEL over 1-2m CLAY over TILL, BEDROCK outcrops. (Expect Clay medium to high strength)
4.47	4.60	Veneer of SAND/GRAVEL over 0.5-1m CLAY over TILL (Expect clay of medium to high strength)
4.60	5.10	Veneer of SAND/GRAVEL over TILL (Expect Till/Clay to be medium to high strength)
5.1	5.75	0.4-0.7m GRAVEL or very gravelly SAND, over CLAY (Clay low-medium strength)
5.75	14.20	0.4-0.7m GRAVEL or very gravelly SAND, over CLAY (Clay low-medium strength)
14.20	15.00	0.4-0.7m GRAVEL or very gravelly SAND, over CLAY (Clay low-medium strength)
15.00	20.00	0.5m gravelly SAND over CLAY (Clay borderline medium/low strength)
20.00	24.00	Areas of CLAY and areas of SAND to depth
24.00	27.70	0.2-0.6m SAND over CLAY (Low Strength)
27.70	32.50	0.2-0.6m SAND over CLAY (Low Strength)
32.50	40.00	0.2-0.6m SAND over CLAY (Low Strength)
40.00	44.50	2m SAND over CLAY (Low strength)
44.50	49.75	CLAY (Very low strength) Variable thickness of loose SAND cover, up to 1.2m
49.75	60	CLAY (Very low strength) Variable thickness of loose SAND cover, up to 1.2m
60.00	72.75	CLAY (Very low strength) Variable thickness of SAND cover (Samples suggest 0.75-2m)
72.75	79.50	CLAY (Extremely low strength) Variable thickness of SAND / SILT cover (Sample suggest 0.8-2m.
79.50	102.00	0.6-1m SAND/SILT over extremely/very low strength CLAY
102.00	107.50	CLAY (Extremely low strength)

107.50	119.60	CLAY (Extremely / very low strength)
119.60	126.00	CLAY (Extremely low strength)
126.00	200.00	CLAY (Extremely low strength)
200.00	224.00	CLAY (Extremely low strength)
224.00	240.50	SAND and CLAY (Extremely low strength)
240.50	276.00	SAND to depth
276.00	290.50	SAND to depth
290.50	341.50	Areas of SAND and CLAY (Extremely/Very Low Strength)
341.50	348.50	CLAY (Extremely/Very Low Strength)
348.50	363.50	CLAY (Extremely Low Strength)
363.50	390	CLAY (Extremely/Very Low Strength)
390	409.50	CLAY (Extremely Low Strength)
409.50	413.00	CLAY (Extremely Low Strength)
413.00	415.00	CLAY (Extremely Low Strength)
415.00	427.75	CLAY (Extremely Low Strength)
427.75	430.00	CLAY (Extremely Low Strength)
430.00	447.50	CLAY (Extremely Low Strength)
447.50	456.25	CLAY (Very low to high strength)
456.25	460.75	CLAY (Extremely low strength)
460.75	470.00	CLAY (Extremely low strength), highly localised sub-cropping BEDROCK/TILL
470.00	480.65	Sub-cropping/exposed BEDROCK, BEDROCK/TILL interspersed with areas of CLAY and SAND BEDROCK outcrops are particularly prevalent between KP 470 and KP474, although found locally across the full section
480.65	482.25	BEDROCK/TILL
482.25	502.30	CLAY (Extremely/Very Low Strength)
502.30	505.75	CLAY (Extremely/Very Low Strength), some areas of BEDROCK/TILL with veneer of CLAY
505.75	508.75	BEDROCK/TILL with veneer of CLAY, and CLAY (Extremely/Very Low Strength)
508.75	509.80	BEDROCK/TILL with veneer of CLAY, and CLAY (Extremely/Very Low Strength)
509.8	520.6	CLAY (Extremely/Very Low Strength)
520.60	524.65	TILL with veneer of CLAY (Veneer thickness unknown, TILL not sampled)
524.65	531.50	CLAY (Extremely/Very Low Strength)
531.50	548.25	CLAY (Extremely/Very Low Strength)
548.25	549.00	BEDROCK or TILL with veneer of CLAY
549.00	557.50	CLAY (Extremely/Very Low Strength)
557.50	592.60	CLAY (Extremely/Very Low Strength)

592.60	594.60	BEDROCK or TILL with veneer of CLAY or SAND/GRAVEL
594.60	610.00	CLAY (Extremely/Very Low Strength)
610.00	634.75	CLAY (Extremely/Very Low Strength)
634.75	658.70	CLAY (Extremely/Very Low Strength)
658.70	661.40	CLAY (Extremely/Very Low Strength). Outcrops of BEDROCK KP 660.5 - 661.3
661.40	664.66	CLAY (Very Low Strength)

For reference, strength descriptions are defined as follows:

Table 4: Undrained Shear Strength Definitions

Description	Undrained Shear strength (kPa)
Extremely Low	<10
Very Low	10-20
Low	20-40
Medium	40-75
High	75-150

Complete descriptions of CPT and VC samples at each location are provided in the MMT geotechnical report (Ref. 1), This contains a further level of shallow sediment classification that is applied across the whole depth of the sample, and thus may not be representative of the upper 1-3m of sediment. It should thus only be used as guide to general conditions along the route. Many of the Fjord ridges are not covered by samples, and are thus not represented in the list of seabed indices.

4. Cable Protection Measures

The CBRA (Ref. 18) provides a more detailed assessment of the shallow geology and the potential operational risks to the NorthConnect cables and includes recommendations to lower the cables below the seabed to appropriate depths in order to provide sufficient protection against the hazards identified. NorthConnect has formulated protection levels in a front-end engineering design (FEED) document, which determines the absolute minimum depth of lowering acceptable across short distances for a given protection level. It also provides target depths of lowering (to top of product) for the same protection levels. This target depth (plus an allowance for product outside diameter and variation in survey data) has been used as the basis of the tool assessment in the CPA table.

Where subsea hazards are unavoidable through routing alone, burial beneath the seabed is generally accepted as the primary method to mitigate risk of cable damage. However, when cable protection cannot be achieved by cable burial, or for operational reasons cable burial is not the preferred method for protection (for example due to prohibitive costs or steep slopes inaccessible for tooling), there are a number of alternative cable protection methodologies available to ensure subsea cables are protected.

A brief review of potential cable protection methods that could be employed for protection of the NorthConnect cables is provided below, followed by a comparison of the advantages and disadvantages of the various options.

4.1 Summary of Cable Burial Methods

Subsea cable installation can be achieved in three main ways:

- Ploughing an open trench and subsequently laying a cable into it (*Separate lay and burial, e.g. pre-lay trenching)* optionally followed by a backfill pass/rock placement.
- Laying the cable on the seabed and subsequently trenching it into the seabed (*Separate lay and (post-lay) burial, e.g. Jetting, Mechanical Trenching, Combined tool*)
- Simultaneously laying and burying a cable through the trenching tool (*Simultaneous lay and burial, e.g. Ploughing, Jetting, Mechanical Trenching, Combined tool*)

In the case of jet trenchers, mechanical trenchers and simultaneous lay/burial systems, many tools can be equipped with the means to provide some backfill cover behind the tool to infill the trench, cover the cable and provide immediate protection. This can either be done immediately following a trenching pass or as a separate subsequent burial pass. Pre-cut trenches require a burial pass unless natural backfill is relied upon to cover the product or rock placement is used to backfill the trench.

As variants on the above, it is also possible to plough-in a surface-laid cable or indeed subsequently lay into a jetted open trench. The methods outlined above are described in more detail in Appendix D but the main benefits and risks of each method are summarized in Table 5.

Table 5: Summary of main cable-laying methods.

Burial Method	Benefits	Drawbacks and risks
Separate lay & burial (cable laid into pre-cut ploughed trench)	-Reduced risk of cable damage by burial equipment. -Multiple passes possible. -Can be performed using cheaper vessel in advance of arrival of more expensive cable-lay vessel. -Separate lay and burial operations increase the number of available, (shorter) weather windows.	-Potential for collapse of trench sides or sediment infill before cable laying phase. -Requires accurate cable positioning during laying due to risk of cable being placed on side of trench (can be damaged if using a backfill plough). Trench backfill (if required) may be preferred over backfill plough -Larger more powerful vessel required for ploughing (compared to jet/mechanical trencher). -Ploughing limits turn radius for micro-routing (e.g. SCAR plough is 50m). -Spoil heaps can be an issue for fishermen
Separate lay & burial (Jet/mechanical trenching of pre-laid cable)	-Smaller, lower powered vessel sufficient (Tracked ROV tool). -Multiple passes can be used to remediate in the event of areas of reduced burial or stronger soils. -Avoids contact between trencher and cable (jetting only). -Separate (shorter) lay and burial operations increases number of available weather windows.	-Risk of external damage to exposed surface-laid cable prior to trenching. -Contact with cable increases risk of damage (mechanical trenchers). -Care must be taken not to damage the cable while landing or removing the tool from the seabed. -Cable tension ahead and behind the tool requires careful control of the burial tool feed-through to avoid damage through kinks ahead of the tool or free-spans behind.
Simultaneous lay & burial (Plough, Jet or Mechanical)	-Efficient operation (single pass, single vessel). -Multiple passes can be performed if backfill	-Contact of tools with cable increases damage risk.

Burial Method	Benefits	Drawbacks and risks
	pumps/ploughs not engaged on first pass.	-Typically limited to single pass - may be a problem if adequate depth of burial is not achieved. -If ploughing, limits turn radius for micro-routing. -Very highly co-ordinated operation required to ensure correct cable tension ahead in the water column and behind the tool to avoid damage.

4.2 Cable Burial Tools

The CPA table (Appendix B) reviews 5 tool types on their ability to penetrate the seabed.

- **Jet Trencher:** Suitable for sands and low to medium strength clays. Coarse gravels and high strength clays are likely to limit performance., however many high-powered tools with variable pump/jetting configurations are available to increase the envelope of suitable operating conditions. Tracked and skid (including free lying) modes also available for soils of variable bearing capacity. Multiple passes possible in order to meet depth of lowering/depth of cover requirements.
- **Chain Cutter:** Suitable for cohesive sediments (clays) and weak/fractured rock. Numerous cutting boom and chain/pick configurations are available, with varying levels of power. Significant thicknesses of sand and gravel are likely to hinder performance as the tool relies on the action of ripping cohesive soils. Chain cutting may require a subsequent backfill pass dependent on depth of cover requirements. Requires contact with cable.
- **Combined Jet/Chain Cutting tool:** Combined abilities of both tools to increase envelope of suitable operating conditions. Some tools may deploy both functions simultaneously, or only one at a time. Whilst overall trenching ability is improved, the combined tooling can lead to heavy machines and slower progress rates. May require contact with cable.
- **Pre-lay Plough:** Suitable for variable soil conditions with multiple passes possible although ride-out may occur in very dense sands of very high strength clays. A towed plough creates an open v-shaped trench into which the cable is subsequently laid. After the cable is laid in the trench it will be back-filled with rock
- **Cable Burial Plough:** Suitable for low to medium strength clays which can be sheared. Addition of fluidizing jets on the plough share can assist passage in non-cohesive sediments. A towed plough opens a narrow slot in the seabed into which the cable is

inserted simultaneously. Slumping of the narrow trench reduces the need for a separate backfill pass, however contact with cable increases the risk profile during installation.

These tools are discussed in greater detail in Appendix D.1.2. Appendix E.1.1 provides a summary of different contractors suitable for interconnector installation and the tools that they can mobilise along with brief specifications for a variety of different trenching tools.

4.3 Rock Placement

As an alternative means of cable protection (see Appendix D.1.3), rock placement can be employed in deep water using fall pipe vessels (FPV's). Sections of pipe are connected downwards from the vessel to reach the required depth above the target. Dynamic positioning keeps the vessel in place at the surface and the end of the fall pipe can be controlled either using pipe mounted thrusters or a separate dedicated ROV, to provide accurate placement. Crushed, well graded rock is fed into the fall pipe at controlled rate. The anticipated rock grading to be used is 1"-5" (CP45/125mm), with D_{10} 45mm, D_{50} 80mm, D_{90} 125mm, with an installed bulk density of 1.5 – 1.7 tons/ m^3. A detailed estimate of rock placement volumes is given in section 6 and the figures tabulated in Appendix F.

Further details and examples of rock placement contractors are provided in Appendix E.

4.4 Preliminary Burial Assessment

4.4.1 General

Tools have been assessed against the target Protection Levels (Ref. 8) that have been defined by the Client with consideration for the findings of the CBRA (Ref. 19). These target burial requirements are listed in Appendix B.

4.4.2 Tool suitability grading for conditions within survey corridor

The accompanying CPA table provides an A-C rating of the suitability of 5 different trenching tool types as listed in section 4.2.

The rating for each tool for each section was reached by considering only the ability of the tool to penetrate the seabed to the required depth, based upon the available information. Aspects such as cost, speed and resourcing have not been considered as part of the ranking. It is noted that contact with the cable product in the case of cable ploughs and chain cutters is considered to increase the risk of cable damage during installation.

The grading system is as follows, for each given section of the SCL:

- **A**: Required burial depth should be achieved across the section within the limits of the tool.
- **A/B**: Burial should be achieved but may be reduced in some localised areas requiring reduced speed, further tool passes or external remediation (i.e. rock placement).

- **B**: Burial should be achieved albeit potentially at a reduced depth in significant parts of the section. Multiple passes or slower forward progress may be required to achieve desired results, otherwise external rock placement protection.
- **B/C**: Performance is expected to be generally poor, although may improve in localised areas dependent on tool capabilities.
- **C**: Inappropriate tool for the expected soil conditions. Required burial depth is unlikely to be achieved or within reasonable timescales.

Appendix B.1.1 provides an expanded explanation of all the comments found in the CPA table, Appendix D.1.3 provides details of alternative, external cable protection methods, that may be applicable when the above tools are not suitable e.g. at crossings.

Information to reach these conclusions is based upon a combination of in-house experience of cable installation activities and the information provided in Appendix D.

4.4.3 Preliminary Recommendations

It is anticipated that for the majority of the cable route (~97%), jet trenching will be suitable and enable the target protection levels to be achieved.

At the UK end of the route, in areas of dense boulders (and potentially dense subsurface boulders), Tills and coarse surficial sediments, pre-lay ploughing may offer a lower risk solution with greater potential for achieving the necessary target trench depths.

Towards the Norwegian coastline and within the Hardangerfjorden, areas of Till may be encountered (pending further route optimisation) and reduced burial may result from jet trenching, however these are anticipated in localised sections only.

Between KP 470 and KP 474, rock outcrop at seabed is also noted and could significantly affect tool performance and cable burial in this area. An estimate is made of the rock placement requirements across this area in section 6.1.4.

4.4.4 Rock placement estimates

Estimates of rock placement for the route are addressed in detail in section 6, with the table detailing these volumes found in Appendix F.

4.5 Indicative Costs

Table 6 provides indicative costs for the cable protection measures discussed in this document. This information is intended only as a rough guideline and is based on Cathie Associates previous experience. It is recommended that a more detailed cost analysis be undertaken once the cable protection strategy has been advanced.

Table 6: Indicative costs of cable protection methods

Protection Method	Indicative Cost
Cable lay vessel	Daily charter rates 810 000kr – 1 350 000kr (£75k - £125k). Simultaneous lay/burial equipped vessels are likely to comprise the higher end of this estimate and represent a cost efficiency over separate campaigns.
Trenching vessel Indicative vessel size 12 000 tons (GT) / 7000 tons (DWT)	Daily charter rates 810 000kr – 1 000 000kr (£75K - £90K). Will require cable lay vessel hire in conjunction if separate lay/burial campaigns are used.
Rock Placement Indicative vessel rock capacity 30 000 tons Indicative vessel size 35 000 tons GT/DWT	Daily charter rates for DP vessels with rock placement capabilities are likely to be in the order of 1 080 000kr (£100k) upwards, plus cost of rock (to be determined)

5. Cable Installation Risks/Considerations

The available survey information has been reviewed in conjunction with knowledge of potential installation and trenching tools, and potential risks that could impact upon cable installation/burial have been identified. The risks (pre- and post- mitigation) have been assessed and are summarised in the Risk Register found in Appendix A. The most significant threats are further discussed in the following section.

5.1 Metocean Conditions

Excessive wave height poses a risk to installation vessels and the deployment and recovery of installation equipment. Dangerous waves and confused seas are noted close to the entry of Hardangerfjorden (see Figure 2), and further offshore cable installation operations will also be highly vulnerable to storm events.

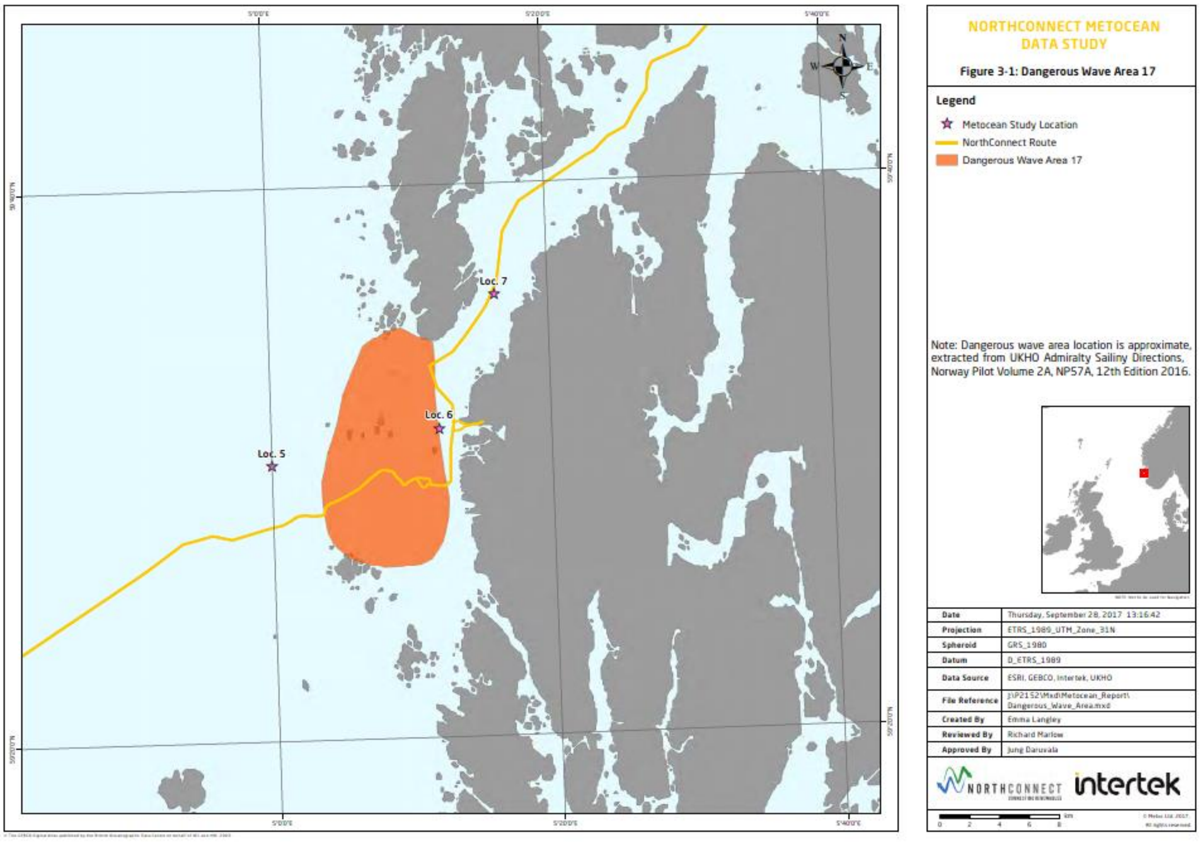

Figure 2: Area of dangerous waves (Ref. 14)

Significant seabed currents were found near the UK end of the cable route (Ref. 14). Metocean conditions in this area are discussed at length in the detailed 12NM report, C831R03 (Ref. 20), however data for 1m above seabed is given for the examples of location 2 and location 3 (see Figure 3) in Table 7.

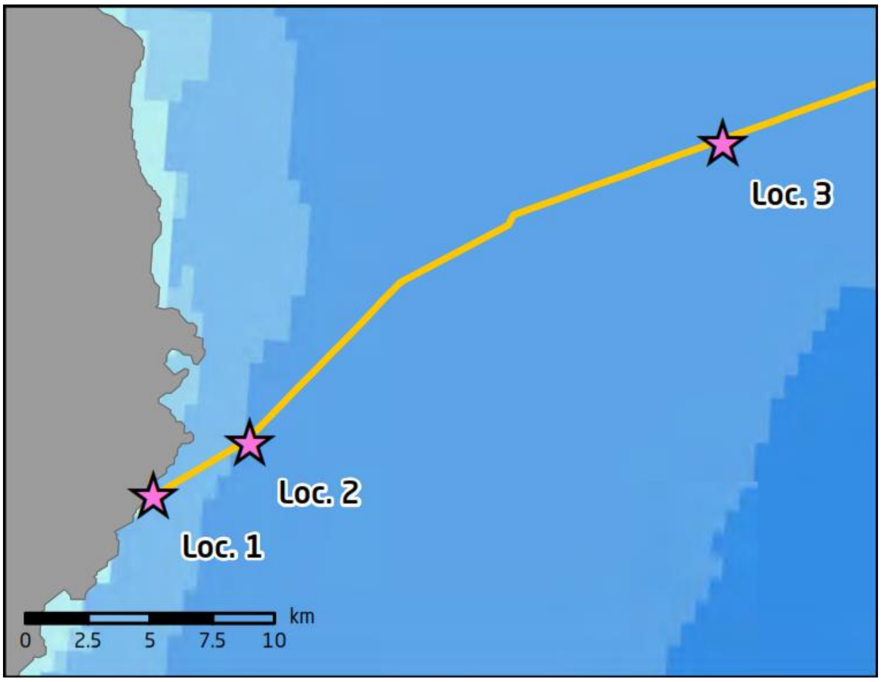

Figure 3: Metocean data locations near UK landfall (Ref. 14)

Table 7: Example metocean data for locations 2 and 3

Metocean data location	100-year return period event		1-year return period event		Summer, storm-free	
	Tidal current + Storm Surge (100-year, m/s) (SB + 1m)	Hs (100-year) (m)	Tidal current + Storm Surge (100-year, m/s) (SB + 1m)	Hs (1-year, m)	Tidal current (m/s) (SB + 1m)	Hs (summer average, m)
Location 2	1.39	8.5	1.22	5	0.77	1.02
Location 3	0.99	10	0.88	6	0.45	1.23

Strong currents present two main risks:

- Instability in the deployment and recovery of ROV type equipment to/from the seabed, which poses a risk to the product and/or the equipment itself.
- Movement of the cable prior to trenching (if separate lay and subsequent burial operations is adopted). Current directions appear to be almost in-line with the survey corridor bearing thus this may not present severe problem, but should be further assessed by the cable installation contractor.

To mitigate the challenging metocean conditions, the installation operations should be planned and executed in consideration of a dedicated weather analysis/operability study that should be undertaken by the installation contractor.

Metocean conditions in Hardangerfjorden are expected to be calm due to the extreme water depths and shelter from waves.

5.2 Seabed Slopes

For the majority of the survey corridor, seabed slopes are relatively gentle. In localised areas, steeper gradients are noted, and these have been identified in the CPA table in Appendix B. Steeper gradients are typically associated with:

- **Pockmark flanks** – Up to 8m deep and 100m across. Should be avoidable through routing.
- **Bedrock/Till** – Bedrock is encountered in the UK nearshore area and potentially Bedrock and/or Till approaching the Norwegian Coast and in local areas in Hardangerfjorden. Outcropping bedrock or Till can result in steep gradients (up to 35°, see CPA table), which impose strains and point loads upon the cable and prove problematic for cable burial. Micro-routing is recommended to avoid such areas where possible to reduce the gradient.
- **Iceberg plough marks** – Found in the eastern slope of the Norwegian Trench, close to the Norwegian coast. Icebergs in the previous Ice-Age have grounded and penetrated the seabed and ploughed a furrow 0.5m to 2m deep and 100m to 200m across into the sediment. Low background sedimentation rates preserve these steep-sided marks on the seabed. Avoidance, or increased burial should be used to mitigate steep cable gradients and reduce the likelihood of excessive cable bend radii or free-spans.
- **Slip scarps** – Many of these features are noted along the fjords comprising very steep back-scarps at the back of the failed material. Stability of these features is discussed in detail in the CBRA (Ref. 19), with reference to the NGI report (Ref. 17)

The most practical solution is to route the cable away from steep slopes, however, where this is not possible further, more detailed route assessment may be necessary e.g. slope stability analysis, free span analysis, assessment of remedial options (rock placement, pre-sweeping) etc.

5.3 Pockmarks, Gas Seeps

Parts of the survey corridor pass through areas that are densely pockmarked. Pockmarks are understood to form when unstable methane hydrates rapidly decompose, and gas is forcefully expelled through seabed sediments. The bathymetric survey data suggests that some pockmarks are on the order of 100m across and 8m deep relative to the surrounding seabed. These pockmarks represent a variety of risks:

- Steep slopes (as discussed above) which also pose a stability risk if trenching close to the top of a steep pockmark slope that could collapse

- Seepage of gas may lead to the presence of methane-derived authigenic carbonate (MDAC): seafloor concretions formed by microbial oxidation of methane and sulphur reduction. Cemented sediments can impede trenching equipment and result in localised reduced burial or cable point loads. No evidence of MDAC was found within the survey corridor during the 2017 survey.

Figure 3 below shows an individual pockmark example near KP391 with dimensions approximately 5m deep (compared to surrounding seabed) by 200m across (on survey line, right). Note the disturbance to the sub-bottom reflector (note, seismic units superseded) at depth (left), indicating the sub-seabed formation origins of this feature.

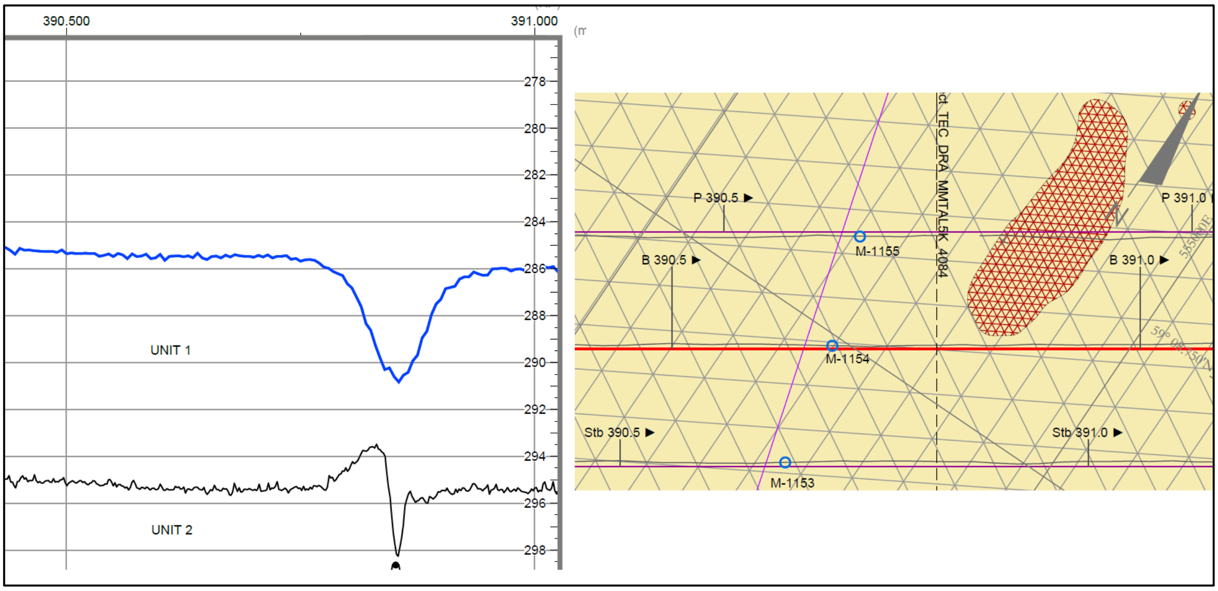

Figure 4: A seabed pockmark crossed by the northern survey line

The most practical solution is to route the cable around pockmarks and noted gas seeps.

5.4 Wrecks

Numerous wrecks are identified in the survey report (Ref. 2) as lying within the survey corridor, the location of each of these are noted for each section in the CPA table.

The archaeologist has recommended an exclusion zone around wrecks under the following assumptions:

- That the wrecks date from after 1913 and relate to fishing, ferrying or coastwise trade, or in the case of recent wrecks they have been assessed as having no archaeological or future historical interest.
- The focus is avoidance of risk, there may still be some change in sedimentation near the wreck but it would not generate a significant effect.

For the above, a minimum of a 50m exclusion zone has been recommended. Routing should also avoid any archaeological exclusion zones. The areas within the consented corridor will be marked as hard constraints to final routing.

5.5 Environmental Habitats

Several environmentally sensitive/protected areas are noted within the survey corridor (see section 3.2). Impacts of the cable installation upon the marine environment are discussed in the project Scoping Report (Ref. 12) and will be discussed in the EIA. EMF emissions from the cable may cause disruption to species, particularly spawning fish and seabed crustaceans, the impacts of this are mitigated by sufficient burial.

The presence of protected marine habitats/species pose the following risks to the cable installation:

- Work scheduling restrictions
- Route diversions
- Restrictions on particular tools and protection methods
- Costly environmental mitigations

The primary form of mitigation is to route around these habitats. Where this is not feasible, cable installation should be conducted in accordance with the consents/permits e.g. timing of construction, which will ensure the minimum environmental impact.

These areas within the consented corridor will be marked as hard constraints to final routing

5.6 Variable Ground Conditions

The shallow geology of the survey corridor is mostly characterised as loose to dense sands, soft-very soft clayey silt and silty clay, however localised bedrock (granite) is noted close to both the UK and approaching/within Hardangerfjorden. Iceberg reworked till deposits of very low to high strength are found between KP 447.5 and 456.25, and high strength clay is expected near UK landfall c. KP 1.35- KP 5.1. (See section 5.6.3 below).

5.6.1 Soft Sediments

Very soft sediment may pose a risk to burial tool stability during cable burial unless the tool features buoyancy systems and or skids to reduce bearing pressures and avoid bearing capacity failure. Soft sediments may also hinder a pre-lay trenching campaign if it is required in these areas, as a trench may not stay open long enough to lay the cable at the correct depth before the sides fail and the profile degrades.

5.6.2 Gravel

Gravelly sediments are found at numerous sample locations on the route. Gravel poses a risk of reduced burial where jetting is used, as the gravel component rapidly settles out of suspension back into the trench before the cable can catenary into the base of the trench. This can be accounted for by increasing trenching depth to maintain the required depth of lowering or using a depressor to guide the cable into the trench. Depressor use is considered undesirable by the client due to the risks of product damage thus is unlikely to be used on this project.

Within the UK 12NM limit, significant thicknesses (c.0.4 – 0.5m) of surficial coarse sediment are found. This appears to have severely affected burial by jetting for the Hywind export cable (Ref. 20). As such, pre-lay ploughing has been suggested as an alternative for this section, and is discussed in finer detail in the 12NM detailed assessment (Ref. 20)

5.6.3 High Strength Clays

High strength clays are found in the UK nearshore section, as well as in localised areas of the North Sea and Hardangerford, which may slow the progress of any jet trenching operation, depending on depth of burial and the tool used. Chain cutting may be better suited in such areas, although due to the relatively short lengths identified (aside from the UK section - where pre-lay ploughing is suggested due to the risk of subsurface boulders), chain cutting may not be practical.

5.6.4 Bedrock

Bedrock outcrops are found by the survey near the UK Landfall c. KP 4. (See Figure 5) Outcropping / shallow sub-cropping bedrock is also interpreted by the survey in parts of Hardangerfjord (KP 469.5 to KP 474, KP 660.5 – 661.3).

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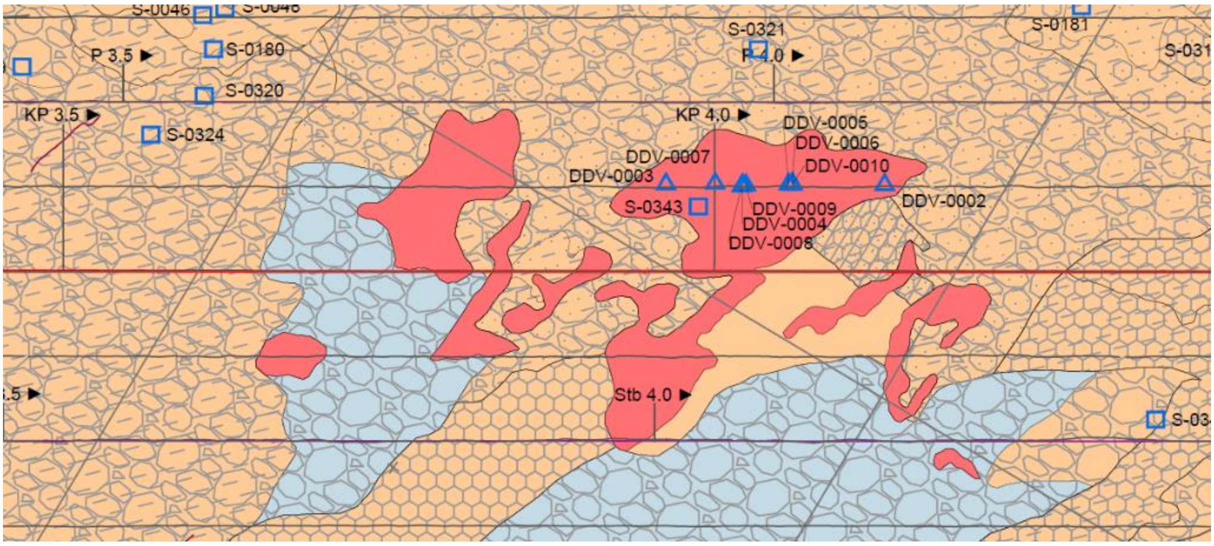


Figure 5: Rock outcrops in UK nearshore (c. KP4.0)

Within the Fjord, ridges across its width are mostly interpreted as either Bedrock or Till ("Bedrock/Till"), thus the presence of shallow bedrock should still be expected.

Burial ability in these areas will be strongly dependent upon the thickness of soft clay veneers (in many cases unknown) compared to the target DoL. If (crystalline) rock-head is encountered, then none of the assessed tools are deemed likely to achieve a significant depth of burial external rock placement will likely be required. At this stage, estimates for rock placement remediation for the above scenario have not been included in the volume estimates (Appendix F) as the veneer thickness is not fully known, and pending final route optimisation, such outcrops may be avoidable. Areas where potential bedrock may be avoided through routing have been noted in the CPA table (Appendix B).

Rock outcrops in c.KP 4 in the UK nearshore have already been avoided by the UK 12NM routed alignment "RPL12NM" (see 12NM detailed report, Ref. 20.)

5.6.5 Mobile Bedforms

Bedforms up to large ripple classification (up to 0.7m) have been recorded by the survey (The majority being in the first 75km) and the maximum bedform height in each section has been given in the CPA table (Appendix B). Deeper burial is recommended in these areas to maintain the target depth of lowering (DoL) below a non-mobile level.

Larger bedforms identified during the survey are understood to be relic features and are not anticipated to be mobile.

5.6.6 Moraine/Till

As previously mentioned and discussed in the CBRA (Ref. 19), crossing the Fjord are multiple features that could be moraine till deposits (although the survey retains the possibility of bedrock). These are generally unsampled to any significant depth, and may comprise a core of mixed glacial deposits, including boulders, however a soft sediment veneer is expected in most cases. The local composition of the till, thickness of this veneer and seabed slope will determine if the cable can be buried easily across these features, and this should be revisited during detailed route engineering.

Till is also interpreted at shallow depth/seabed (within expected trenching depth) in the UK nearshore between KP 3.5 and KP 5.1 with a gravelly surficial veneer. Again, this material area is unsampled as CPT_A_004_A terminated on an obstruction near the top of the interpreted till horizon (potentially a cobble/boulder), and VC 01-SS-01A was blocked by a cobble in the surficial sediments. This material may be an outcrop of the Wee Bankie formation, overlying the bedrock/older sediments.

The eastern slope in the Norwegian Trench from KP 447.45 – 456.15 is interpreted as CLAY (TILL), although samples show this material to be clay varying from low to high strength (See section 5.6.3 above).

5.7 Boulders

5.7.1 Surface Boulders

Boulders are noted in numerous areas in the nearshore, North Sea and Fjord sections, particularly between KP0 to KP49.75 and KP427.75 to KP524.4. The density of these boulders along some of these sections of the SCL is described as "Numerous": with a density of 20-40 boulders per 10 000m^2 of seafloor. Some areas of the nearshore have a higher density of boulders, with over 40/10 000m^2.

Figure 5 shows the appearance of boulder covered areas on the alignment charts. Figure 6 below shows the character of the seabed at KP455. Darker areas represent iceberg reworked

"Till" covered by boulders. Lighter areas represent more recent sediment covering iceberg plough marks.

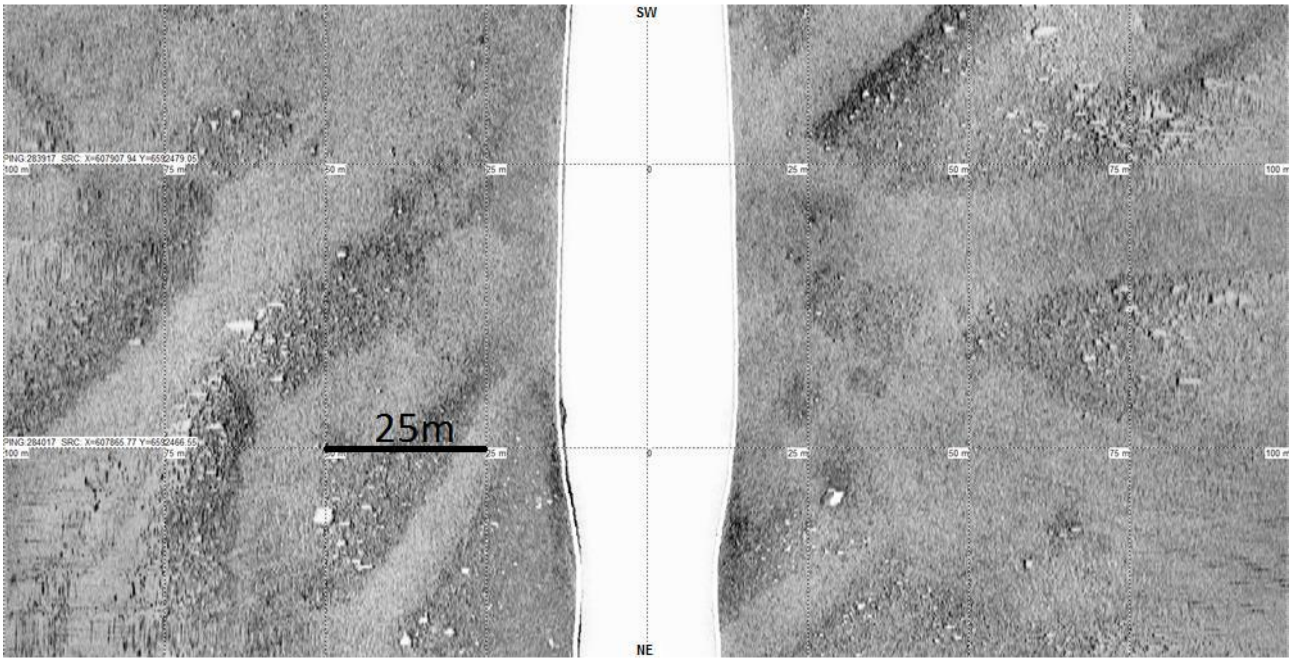


Figure 6: MMT (Ref. 1) seabed imagery from KP455 showing boulder-covered clay and iceberg plough marks.

The surveyed presence of boulders on the surface along the route are presented in the CPA table

Boulders at seabed may impede burial progress and pose a risk of damage or instability to the tool. Surface boulders (>0.3m) should be avoided through routing or cleared from the seabed in advance of any burial operation.

5.7.2 Sub-Surface Boulders

Wherever surface boulders are found, MMT identified the possibility of concealed subsea boulders. They pose a risk to trenching and can lead to localised areas of reduced burial. Jet trenching may be particularly susceptible to boulders forcing the retraction of jetting swords, whereas ploughing may potentially have more success in forcing obstructions aside. Whilst it is difficult to accurately determine the frequency of sub-surface boulders from the currently available survey data, understanding of the genesis of the formations provides further insight as to the level of risk posed by this hazard.

The boulder areas on the survey corridor are found in two main areas. KP1.35 to KP48.35 and KP427.75 to KP524.4.

The section KP1.35 to KP48.35 correlates well with the mapped Forth Formation as discussed in the CBRA report. The Forth Formation is part of the Reaper Glaciogenic group, described as being composed of tunnel valleys and channels, episodically incised and backfilled by subglacial and proglacial deposits. The Forth Formation is dated from the last glacial period (upper Weichselian - Scandinavia /late Devensian – Britain), and the maximum extent of the ice-front may be expected at approximately KP20 on the SCL from study of the BGS memoir (Ref. 19). The ice-front ran North-South, with the ice moving outward from the Moray Firth.

Figure 7 shows a reconstruction of the maximum ice advance of the late Devensian Dimlington stadial. As can be seen, the southern tip of the "Bosies Bank Moraine", the terminal moraine of Moray Firth ice, would be expected to be crossed by the NorthConnect route. This reconstruction suggests this terminal moraine would be expected c. KP40.

Alignment charts find raised seabed areas with surface boulders at KP 21 and KP 45. These may represent terminal or push moraines deposited in the last glacial period. Figure 8 shows the surveyed seabed character at KP 21, the feature at KP 45 being similar in character (note, seismic units now superseded).

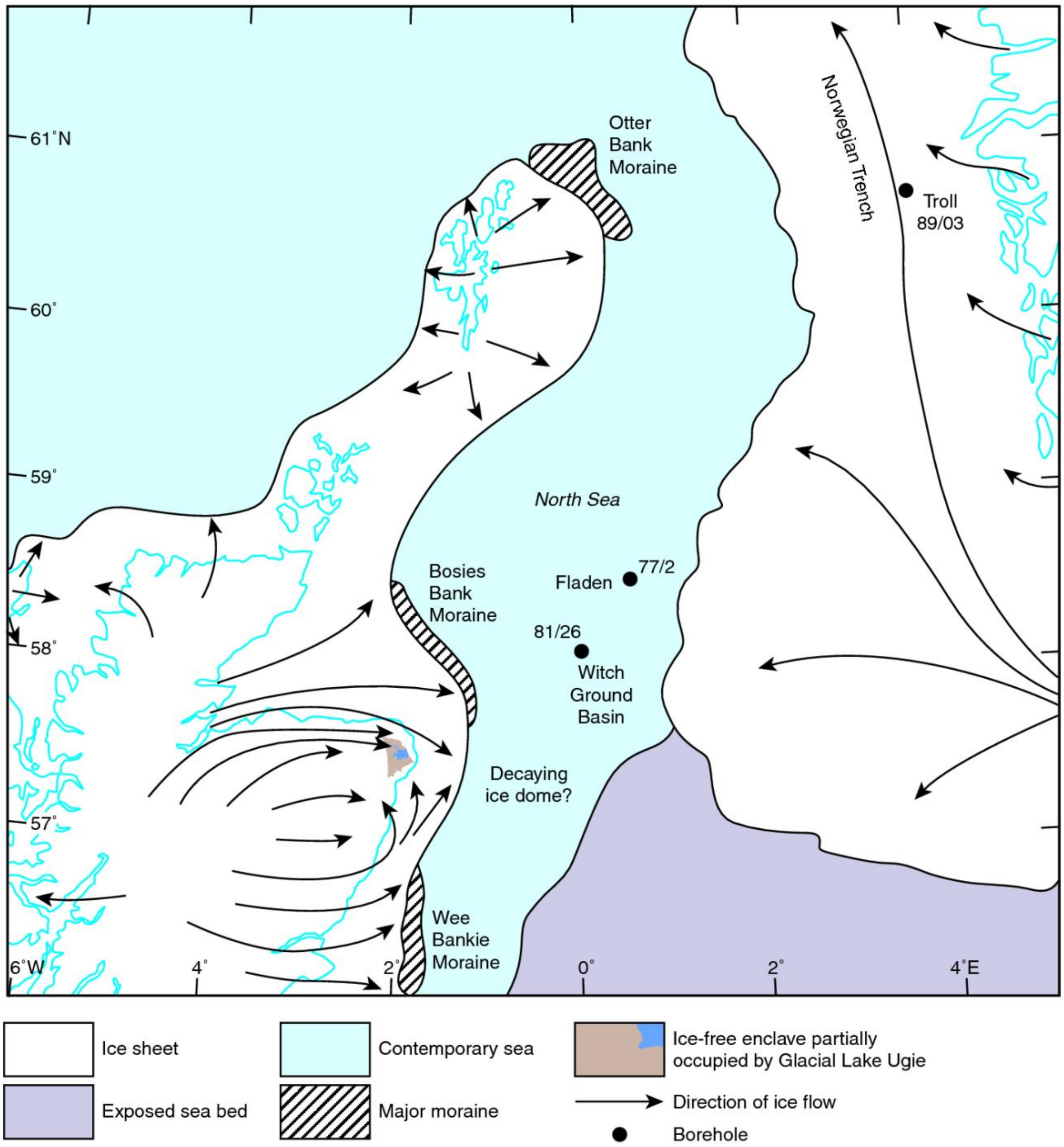


Figure 7: **Tentative reconstruction of ice margins at the maximum stage of the second major expansion of the Main Late Devensian ice sheet (Ref. 33)**

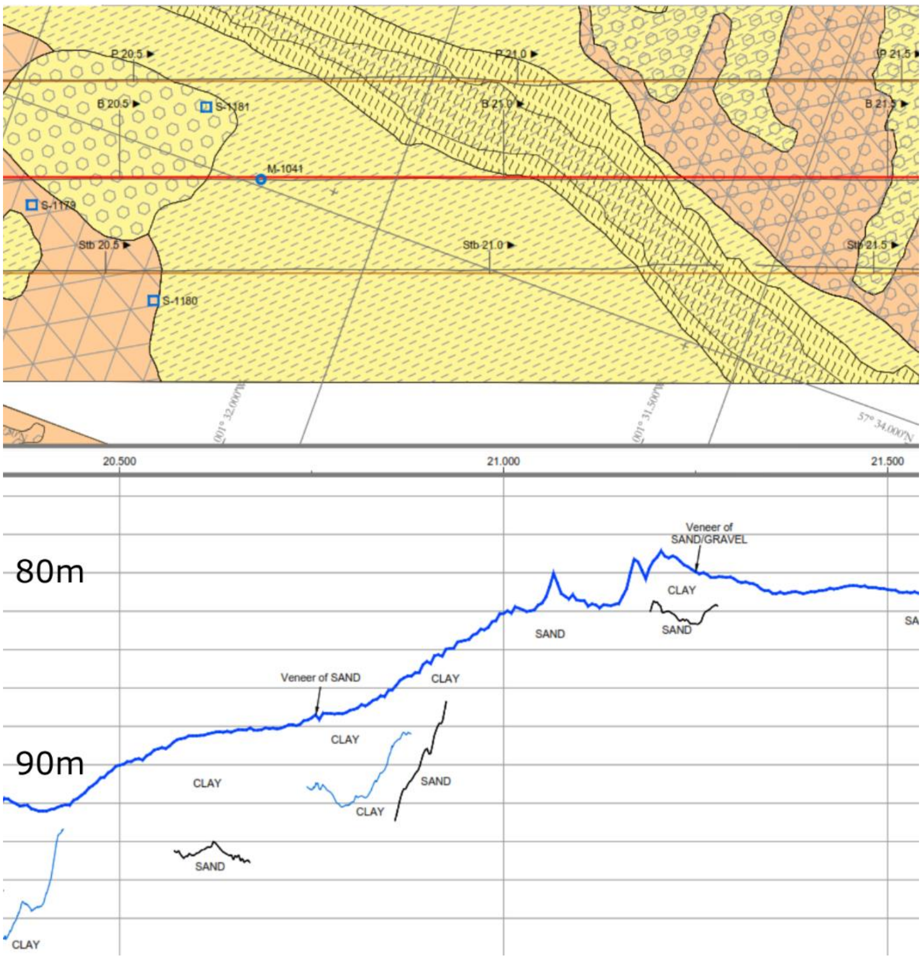


Figure 8: Possible moraine feature c. KP 21 (MMT chart 4004)

From KP 427.75 to KP 456.25 the boulders are associated with iceberg plough marked seabed areas. Boulders in this area may have originated as iceberg drop-stones or otherwise been deposited with the underlying Till, with outcropping reworked Till being found at approximately KP447.5 to KP456.25 and coinciding with higher density surface boulder fields. Within the Fjord itself, boulders are found in the areas of glacial moraine diamicton till, and some patches may originate from rockfalls from the Fjord sides.

It is deemed highly likely that boulders are present in the subsurface across much of KP1.35 and KP48.35 and between KP427.75 and KP 524.4. Thus, there is a risk of reduced burial in these areas as burial tools are forced over boulders, requiring rock placement as remediation. An uneven trench bottom may also place point loads on the installed cable.

The effect of subsurface boulders on burial tools has been modelled to assist prediction of the required volumes of rock placement used as remediation. This method (and any assumptions made) are discussed in detail in section 6.

5.8 Slope Stability and other Mass-movement Failures

All of the slip-scarp slopes identified in the NGI report (Ref. 17) as being most-critical have been shown to be stable under static and earthquake loadings, the exception being the scarp at KP 661.5 which under some scenarios exhibited an FOS of <1.

Installation activity across these areas, in particular loading slopes with placed rock could reduce factors of safety and cause failure of these scarps. Slope failure could result in significant cable damage or damage to equipment. Avoidance of existing scarps is advised where possible, and if rock placement is to be used in these areas, further stability analysis should be carried out.

Mass-movements (landslides, rockfalls) from the sides of the Fjord are noted along its length. These areas should be avoided in routing as a mass-movement landslide could laterally displace the cable or rockfall could pose a risk of boulder crushing impact to the cables.

5.9 Existing Infrastructure

Forty-one (41) existing and planned cables and pipelines are indicated to cross the corridor survey between KP 0 and KP 457 based upon the 2017 inspection survey (Ref. 2). A further 58 crossings of both active and disused cables are in the Fjord between KP505 - KP664, although many of these are repeated crossings of the same cable by the survey centre line, which may be reduced in the final route. Locations are given in the CPA table (Appendix B).

A protection strategy is already in place for known seabed infrastructure, with crossing designs employing external protection. A risk still exists that unrecorded infrastructure (old telegraph cables etc.) exists on the chosen route, which could impact installation operations. A route clearance operation will be conducted in advance of trenching and laying operations and a much-used approach is to perform a pre-lay grapnel run to remove long debris such wire ropes from the cable routes.

Within the Fjord there are multiple floating fish-farms which are anchored to the seabed in deep water. These anchors are to be temporarily removed, the cable installed, and then reinstalled. Deeper burial to increase protection is to be provided in these areas to mitigate the risk of storm conditions or third party impact potentially dragging one of these anchors across the cable alignment. Further areas of deeper burial have been specified in the vicinity of a yard and mobilisation area in the Fjord off Stord.

5.10 UXO

The 6Alpha desk based UXO study (Ref. 13) identifies large sections of the survey corridor as having a high risk of encountering UXO during operations. Multiple potential UXO risk sources are identified. Some, such as recorded sea-mine field lays or munitions dumps occur within known areas. In other areas, the risk of encountering UXO arises from less constrained sources such as torpedoes, bombs, naval battle debris, etc. Risks to vessels and operatives arising due to a subsea ordnance explosion are high in shallower water <100m, however the probability of encountering UXO is lower in the UK nearshore area.

Risks to subsea equipment are higher in the North Sea and Fjord areas due to the probable loss of equipment in the event of an explosion. Included in the CPA table is a transcription of the risk of encountering UXO on the seabed (Low, Medium and High), taken from the 6Alpha report. 6Alpha advise to avoid any UXOs by a distance of at least 15m. Only if re-routing is impractical should UXO clearance be considered.

Further potential UXO assessment and potentially survey will be required during detailed engineering.

6. Rock placement Estimates

For the purposes of planning, budgeting and environmental consenting, an estimate of required rock volume is required. This includes rock required for the purposes of remediation of insufficient burial, backfill of a pre-ploughed trench where this is suggested as an option, and for infrastructure crossings.

From the HDD exit to the UK 12 nautical mile limit (KP 27.7, RPL09), a new route alignment has been derived (RPL12NM). Rock placement has been assessed using this route in this section, which extends from the HDD seabed exit at KP-0.382 to KP27.7. Beyond KP 27.7, the route is assessed using the RPL09 survey centre line. See C831R03 (Ref. 20) for further information on this section.

In this detailed assessment, two tool options have been assessed.

- Jetting of the full route
- Pre-lay ploughing between KP 0.823 and KP 17.891 (RPL12NM), with jetting from the HDD exit KP -0.382 to KP 0.823 and from KP 17.891 to the end of the route (KP 664.66).

All estimates have been made on a *PER CABLE* basis, assuming a layout of two separate HVDC cables with the fibre-optic cable bundled to one of the cables.

6.1 Remedial Rock Placement

Estimation methods for remedial rock placement have been separated into the following two scenarios:

1. Coarse surficial sediments (e.g. gravels) restricting jet sword penetration in the 12NM zone.
2. Surface and subsurface boulders disrupting burial tools in otherwise trenchable sediments (jetting or pre-lay ploughing).

6.1.1 Remedial Berm Dimensions

Rock berms for remedial purposes have been modelled as being triangular in cross-section, with a side slope of 3:1. For example, a 1m high berm will have a footprint 6m wide. Berm height will be varied such that total cover over the cable (any partial burial plus rock) satisfies the cover requirements when using placed rock (see Ref. 8)

A description follows outlining how these situations have been modelled, further information is provided in the rock placement estimates in Appendix F.

6.1.2 Coarse Surficial Sediments

Using the evidence of the difficulties faced by the Hywind project, where coarse surficial sediments (gravels) appear to have prevented adequate trench formation, an estimate is made that across the RPL12NM route from KP 0.823 to KP 17.891, a jetting tool will on average manage to form a nominal 0.3m trench, giving a DoL of 0.1m, allowing 0.2m for the product. When using rock/ combined trench and rock, the cover requirement is 0.8m (Ref. 8), thus in order to achieve the required protection, a 0.7m high berm across the cable will be required, with a 3:1 slope.

For this assessment, pre-lay ploughing was assumed to be unaffected by coarse surficial sediments, although issues with grade-in in sands/gravels may require further assessment. For this tool, the subsurface boulder model of reduced burial was applied across the section.

6.1.3 Boulders

At present, there is no widely adopted method for surveying or predicting the presence of subsurface boulders. Therefore, an extrapolation of the number of boulders recorded at surface has been made to estimate the number of boulders lying beneath the surface.

A simple cellular model was generated to enable a prediction of the lengths of rock placement that may be required to remediate reduced burial where boulders have hindered it.

It is recognised that this model relies on a number of assumptions, some of which may be conservative (such as boulder size and distribution in 3D space). The output estimates should thus be regarded as highly theoretical, however the predicted volumes to remediate reduced burial caused by subsurface boulders are relatively small. Detailed contractor survey, routing around boulder fields where possible, and clearance of visible boulders may reduce these volumes further.

The assumptions are as follows:

- Simplified cube-shaped boulders of 0.5m x 0.5m x 0.5m, evenly distributed in “cells” of the same size.
- Boulder density of 15/10 000m^2 for occasional boulders, 30/10 000m^2 for numerous boulders, and 60/10 000m^2 for high density boulders, the latter which has no upper density bound in the survey results.
- 3 x 0.5m thick layers of boulders, with “cells” occupied at an assumed equal density to those observed at surface in the survey data, and distributed evenly. This is likely to be conservative, as boulders may be enriched in the uppermost layer, often being the remnant of an eroded deposit.
- A tool influence width of 1m for jetting tools (assuming swords are 0.5m apart and interact with a corridor two cells wide when considering the width of the swords themselves), extending to depth across all boulder model layers. Influence width of pre-lay plough assumes a 3m wide x 1m deep V-shape share, wider in upper layer than lower layer. (Only applied in this case to the upper two boulder model layers based upon DoL target)
- A re-grade in distance of reduced burial following boulder impact of 10m for jetting tools, 20m for pre-lay plough.
- A percentage of boulders within the influence width of the tool that remain unmoved (and thus disruptive to burial) after up to 3 burial passes have been performed. 75% for jetting and 25% for pre-lay ploughing, to reflect the potential for the high mass and towing momentum of a pre-lay plough and the potential for damage to jetting equipment.
- Assumption of the depth of reduction in burial that will occur based upon disruptive strikes of boulders within different layers of the cellular model, to be compensated for by remedial rock berms in order to satisfy the protection levels stipulated for rock cover

or combined trench and rock cover (Section 4.2.1 of Ref.8, Requirements to Submarine Cable Protection).

- Depth of reduced burial is assumed to extend across the whole re-grade in distance, which is likely to be conservative.

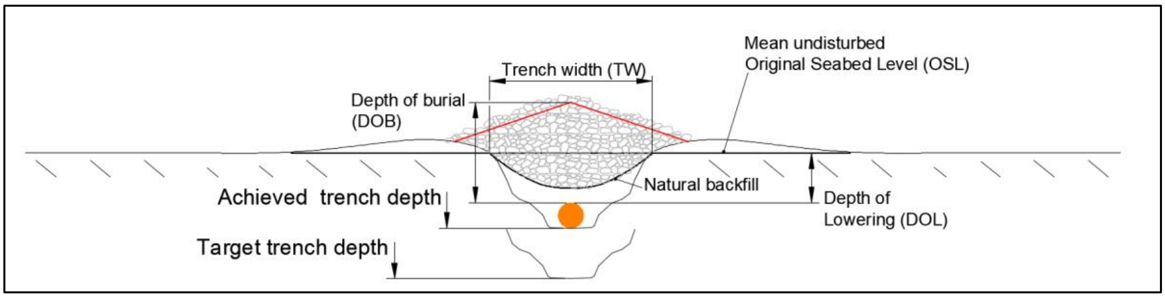


Figure 9; Remedial rock placement where trenching is insufficient (Ref. 8)

In all jetting scenarios (coarse sediments and boulders), trench sediment backfill over the partially lowered cable is assumed to be flush with original seabed level prior to any remedial rock placement being applied. Where this is not the case and the jetted trench remains partly open, an increased quantity of rock should be allowed for, depending on trench dimensions.

6.1.4 *Outcropping rock*

Across the section KP 470 to KP 474, outcropping rock is common. 1600m (40%) of this section has been estimated as likely to suffer from limited burial as a result. In cases where bedrock prevents burial, lowering is assumed to be 0m, and a 1m berm height has been used in the calculation (allowing 0.2m for product and 0.8m of rock cover to satisfy protection level C in this area). This results in an estimated 4800m^3 of remedial rock placement per cable for this section.

6.2 Backfill Rock Placement

Where pre-lay trenching using a plough is suggested as an option within the 12NM area, backfill with placed rock is expected, rather than the use of a subsequent burial pass. This has been calculated as the volume expected to refill a 3m wide by 1m deep trench back to original seabed surface level providing the requisite 0.8m of cover (protection level C) over a 0.2m product in the trench base where rock backfill is used. (the small volume occupied by the cable itself is ignored). Where reduced burial is expected due to boulders, this has been accounted for by reducing the quantity of backfill required, based upon shallower penetration of the same V-shape plough share. The remedial berm height that will be required in the corresponding length to achieve cover is accounted for separately in the remedial rock placement calculations.

6.3 Infrastructure Crossing Rock Placement

Where rock placement is planned to be utilised to cross existing infrastructure (active cable and both active/disused pipeline crossings), berms of placed rock are to be used. There is to be no trenching activity within 50m of infrastructure, with the cable to be graded out of the seabed either side of this restriction. When crossing pipelines, pre-lay rock is required prior to the laying of the NorthConnect cables, resulting in a raised mid-section of the final crossing profile as cover over the top of the NorthConnect cable is to be maintained to the required protection level specification. Drawings of the crossing designs are found in NorthConnect document Appendix E03.01 (Ref. 16). The dimensions used in the volume calculations for crossing berms are outlined in the accompanying spreadsheet in Appendix F.

Preliminary hydrodynamic stability and trawl gear/anchor impact resistance checks have been carried out for these conceptual designs (Ref. 21), with the designs found to be suitable for the purposes of these initial estimates of rock placement volumes.

The preliminary estimate of the total volume of rock placement per individual cable route (a bundled cable would be treated as one route) to protect crossings was calculated in this way as 27100m^3, of which 900m^3 volume is within the UK 12NM limit. Of this full-route total, 1600m^3 is expected to be pre-lay placement. Within the fjord, all cable crossings on the survey centre line are assumed to be unburied cables for the purposes of volume calculations, in the absence of ROV video survey.

6.4 Slip-Scarps

The potential effects of rock placement on slip scarp features was not included in the scope of the NGI report on slope stability (Ref. 17), discussed at length in the CBRA C831R01, (Ref. 19). The potential for rock placement in these areas has thus not been discussed, as it is pending further routing/assessment. Rock placement extending up from the toe of the slope to ease the gradient and minimise the risk of cable free-span may have a stabilizing effect, whereas loading of the slope crest is likely to reduce the slope stability factor of safety.

6.5 Contingency Factor

A global factor of safety of +40% has been applied to all theoretical rock placement volume estimates to cover for the following uncertainties.

- Uncertainty in the method. The method for predicting the effect of boulders upon burial is based upon a highly theoretical model. Similarly, the effect of coarse sediments on jetting within part of the 12NM area has been influenced by the performance evidence from the Hywind project, and different jetting tools are likely to deliver different results.
- Factor for over-dumping. This percentage factor is consistent with the over-dumping factor that may be applied by a typical rock placement contractor.

6.6 Volume Summaries

A summary of total estimated rock placement volumes for the full route is shown below in Table 8, reproduced from the spreadsheet in Appendix F. Included is a breakdown of estimates for the full route to KP 664.66, the UK12NM section, the section to the UK EEZ (KP 224) and estimates for approximate halves of the route, KP 0 to KP 330 and KP 330 to KP 664.66.

Table 8: Rock placement volume estimate summaries (per cable)

Assessed Length	Remedial rock placement estimate (m^3)	Backfill estimate (m^3)	Subtotal (m^3)	Crossings estimate (m^3)	Theoretical Total (m^3)	Total including 40% contingency /over-dumping factor (m^3)
Full Route: Option 1 - Jetting	33800	0	33800	27100	**60900**	**85300**
Full Route: Option 2 - Jetting with Pre-lay ploughing KP0.823 - 17.891	10900	24300	35200	27100	**62300**	**87200**
KP0 to 12NM limit: Option 1 - Jetting	25200	0	25200	900	**26000**	**36400**
KP0 to 12NM limit: Option 2 - Jetting with pre-lay ploughing KP 0.823 - 17.891	2200	24300	26500	900	**27400**	**38300**
KP0 to UK EEZ limit: Option 1 - Jetting	26200	0	26200	6900	**33100**	**46300**
KP0 to UK EEZ limit: Option 2 - Jetting with pre-lay ploughing KP0.823 - 17.891	3300	24300	27600	6900	**34400**	**48200**
KP0 to KP 330: Option 1 - Jetting	26200	0	26200	12700	**38900**	**54500**
KP0 to KP 330: Option 2 - Jetting + pre-lay ploughing KP 0.823 - KP 17.891	3300	24300	27600	12700	**40300**	**56400**
KP 330 to KP 664.66: - Jetting	7600	0	7600	14400	**22000**	**30800**

7. Conclusions and Recommendations

Under instruction from the Client, Cathie Associates has undertaken a Cable Protection Analysis Report (CPAR) for the subsea cable survey corridor of the NorthConnect project. This has drawn upon many of the findings from the CBRA (Cable Burial Risk Assessment) report.

Summarised in Table 5 are the main methods used to install a subsea cable and their respective advantages and disadvantages, followed by a summary of the main types of trenching tools used, expanded upon further in Appendix D.

The shallow geology along much of the survey corridor is dominated by loose to dense sands and very low to low strength clays, and locally extremely low strength clays and silty clays. In these areas the cable should be relatively easily buried using a jet trencher. It is noted however, that there is a risk of instability or sinkage of burial tools in significant sections of the route and skids and or buoyancy tanks may be to be required to reduce bearing pressure.

Within the UK12NM area, a significant part of the route has surficial sediments composed of gravelly material with some high strength clays and risk of boulders in the subsurface. In these areas, jetting tools are expected to face considerable difficulty and pre-lay ploughing has been suggested as a potential lower risk alternative. This has been discussed in detail in the 12NM detailed burial assessment, C831R03, (Ref. 20).

The presence of iceberg plough-marks, discussed in section 5.6, may warrant further investigation to establish their dimensions in more detail and the potential for soft sediment fills.

Within the Fjord, conditions comprise very soft clay for much of the route. This is punctuated occasionally by steep sided deposits across the width of the Fjord interpreted as Till or Bedrock. Burial of the cable in these areas will depend on the local thickness of soft clay veneers overlying likely till or bedrock. Where cover over bedrock is thinner than the proposed burial depth, achieving the target burial will not be possible due to the crystalline nature of the bedrock. Some slopes may be too steep for tools to remain stable, and free-flying modes of operation may present a solution. Furthermore, there are regular steep slip scarps in soft sediment running across the fjord. Analysis by NGI (Ref. 17) suggests these features are likely to remain stable (except at c. KP 661.5), this assessment did not account for external loadings such as placed rock. Should the ground fail underneath the cable it may be left in free span or excess tension. Historic mass-movements (rockfalls, landslides) impinging from the Fjord sides should be avoided to minimise the risk of future cable impact damage or lateral displacement, tension and kinking.

Subsurface boulders are likely to present a problem for most burial tools. Significant areas of surface boulders (suggesting subsurface boulders are likely) are found within the first 50km of the UK end of the cable route as well as in parts of the Fjord. The effects of subsurface boulders and the implications for remedial rock placement are discussed in section 6.

Appendix A – Risk Register

GEOTECHNICAL RISK REGISTER
Front Sheet

CA Client : NorthConnect KS
Project : NorthConnect
Project No : C831

Revision History

Revision	Purpose	Author(s)	Reviewed:	Approved:	Date
1	DRAFT for HAZID	EJO	EJO	JIR	06/11/2017
2	Interim DRAFT	PTH	EJO	EJO	01/12/2017
3	Issued	PTH	EJO	EJO	08/03/2018
4	Re-Issued	PTH	EJO	EJO	11/05/2018

Risk Rating

Probability	Definition
1	Never heard of in Industry
2	Heard of in Industry
3	Incident has occurred near the project area
4	Happens several times a year in Industry
5	Happens several times a year at project location

Consequence	Definition
1	Negligible Damage
2	Minor Damage / Exposure to other hazards
3	Localised Damage / No unplanned loss of capacity
4	Major Damage - replacement of small section / Unplanned loss of capacity
5	Extensive Damage - replacement of significant section of cable/ Unplanned loss of capacity

Geotechnical Risk Matrix		Consequence				
		1	2	3	4	5
Probability	1	1	2	3	4	5
	2	2	4	6	8	10
	3	3	6	9	12	15
	4	4	8	12	16	20
	5	5	10	15	20	25

CA Client : NorthConnect KS
Project : NorthConnect
Project No : C831

GEOTECHNICAL RISK REGISTER

GEOTECHNICAL RISK	Data Sources / Data Adequacy	Risks to Cable							
			Initial Risk				Residual Risk		
		Hazard Details	Freq	Cons	Rank	Quantification / Mitigation	Freq	Cons	Rank
Cable Installation / Protection Risks									
Metocean Conditions	Metocean Report	Noted dangerous waves and confused seas near the Norwegian coast pose a risk to installation vessels and the launch and recovery of equipment. Offshore installation operations are similarly vulnerable to storm events. High seabed currents noted near the UK end of the cable pose a risk to the stability of ROV equipment. This risk is particularly elevated during the landing/removal of tools onto a cable product, which may be damaged. High current in Blocks 9, 10 and 11 Possible unexpected and uncharted currents in fjords	5	2	10	Planning and execution of the project should give consideration to a dedicated weather analysis / operability study carried out by the chosen contractor. Exceedance probabilities arising from an analysis should be used by the contractor to estimate the anticipated duration of weather-related stoppage time.	2	2	4
Seabed Topography	WebGIS, Survey Report, DTS	Presence of localised slopes can impact on burial performance / achievable burial depths and slack requirements, particularly where associated with ridges or outcrops of material of increased strength or competence and areas of mobile bedforms. Reduced burial can lead to increased cable risk from external threats e.g. anchor strike, fishing gear etc. Steep gradients observed on the flanks of iceberg scars, pock marks, rock outcrops and slip-scarps.	5	2	10	Route engineering should be sympathetic to seabed features to be avoided where possible and mitigated through other means (e.g. pre-lay and post-lay rock where not feasible, in order to maximise cable protection. A more in depth analysis of slopes can be undertaken at installation stage. Theoretical slack requirements can be calculated at installation stage	2	2	4
Fjord Topography	WebGIS, Survey Report	High cliffs impact on vessel dynamic positioning placing operations at risk of DP run off.	5	1	5	Mobile base station for installation	5	1	5
Unstable sediments (Avalanches)	WebGIS, Survey Report, Academic Papers	Snow/ice avalanches could impact the cable. Fjord depth means any impact (if depth is reached) is likely to be gentle and not pose a risk of damage.	3	1	3	Routeing cable centrally in the Fjord will maximise distance from hazard.	2	1	2
Unstable sediments (Rockfall)	WebGIS, Survey Report, Academic Papers	Rockfall or other mass movement from the Fjord sides may cause impact damage to the cable, or lateral displacement inducing tensions or kinks. Rockfall is recorded all the way along the Fjord, and the survey provides evidence of these deposits on the Fjord bottom.	3 (survey data suggests historic falls, return period unknown)	3	9	Softness of sediment in the majority of the Fjord area means that protection from rockfall is unlikely to be gained by burial. The simplest way to reduce the risk will be to use routeing to avoid areas of historic mass transport/rockfall deposition originating from the side of the Fjord, as recorded by the survey. Keeping the cable route central to the Fjord where possible should reduce the likelihood that material will strike the cable from either side.	1	3	3
Unstable sediments (Fjord slide scarps)	WebGIS, Survey Report, Academic Papers	Numerous slip-scarp features cross the width of the Fjord, generally perpendicular to the survey centre line. The installed cable will have to traverse these features. Failure of the ground underneath the cable at the scarp-slope crest or impact by mass-movement material originating upslope could cause cable damage by inducing cable tension, creating freespans or causing slack areas of cable to become kinked.	3 (survey data shows historic slips, return period unknown)	4	12	Avoid slopes where possible. Transition of cable across existing slip-scarps or potential future scarps is in many cases unavoidable. Triggering of failure may be seismic, with a suggested return period of 1000 years (based upon dating mass-flow deposit sequences), however use of heavy tools across slip-scarps should be avoided to reduce the risk of artificially causing a failure. NGI have indicated that most critical slopes are stable, except that at c. KP 661.5. Slopes have not been asessed for additional loading of external material.	2	4	8
Pock Marks	WebGIS, Survey Report, DTS	Pock marks are usually associated with ancient or ongoing gas seepage/shallow gas, which can pose a risk to the cable integrity and potentially impact burial tool performance. Numerous pock marks identified along the survey corridor.	5	2	10	Route engineering should be sympathetic to seabed features such as pock marks and avoided where possible, especially where ongoing gas seepage is noted, and mitigated through other means (e.g. pre-lay and post-lay rock placement) where not feasible, in order to maximise cable protection. Cable armouring to account for risk of shallow gas.	2	2	4
Cemented hard ground (Pock marks)	WebGIS, Survey Report, DTS	Cemented hard ground can prove problematic for cable burial, exhibiting far higher strength than uncemented sands or lower strength clays, which may not be accounted for in the choice of installation tool. Preliminary information from the 2017 site investigation suggests the route corridor has generally avoided large areas of cemented sediments, however cemented hard ground is anticipated where pockmarks are present.	5	1	5	Route engineering should be sympathetic to seabed features such as pock marks and avoided where possible. Residual risk of encountering cemented hard ground should be further assessed by installation contractor and suitable contingency/redundancy built into design solution.	2	1	2
Seabed Obstructions / Boulders	WebGIS, Survey Report, DTS	Obstructions along routes can inhibit lay / burial increasing risk of cable damage from external threats. Numerous sidescan, sub bottom and magnetometer contacts have been identified along the cable route.	4	2	8	Adequate survey to identify obstructions e.g. cobbles and boulders accurately. Micro routing utilising appropriate buffer zones placed around targets. Clearance of obstructions e.g. boulders where necessary. Magnetometer contacts to be investigated to mitigate UXO risk to ALARP. UXO strategy is for avoidance through routing rather than removal. Additional survey prior to cable lay along the proposed cable route to confirm risks are suitably mitigated.	3	2	6
Archaeological Exclusion Zones	WebGIS, Survey Report, Wessex Report, DTS	Protected sites which require avoidance. Can impact on cable routing. Wrecks / protected archaeological areas identified in vicinity of the cable route within the offshore section and the Norwegian fjords.	3	2	6	Cable routing to avoid wrecks / archaeological exclusion zones.	2	2	4

CA Client : NorthConnect KS
Project : NorthConnect
Project No : C831

GEOTECHNICAL RISK REGISTER

GEOTECHNICAL RISK	Data Sources / Data Adequacy	Risks to Cable							
		Hazard Details	Initial Risk			Quantification / Mitigation	Residual Risk		
			Freq	Cons	Rank		Freq	Cons	Rank
Annex 1 Habitats / Protected areas	WebGIS, Survey Report, UK HVDC Scoping Report, DTS	Protected habitats where present require avoidance / mitigation. Can impact on cable routing and or protection requirements. Suspended sediments also to be considered. SPA at UK landfall (breeding seasons). Potential Annex 1 Habitats (cobble reefs / Sabellaria Spinulosa) identified in proximity to cable corridor. Corals at Norwegian end of route. Cable route also crosses the Southern Trench pMPA.	3	2	6	If protected habitats are confirmed to be present within corridor, ensure avoidance where practical through route engineering and seek further specialist support and consultation where unavoidable. Installation methods to comply with consents licenses e.g. suspended sediments.	2	2	4
Existing Seabed Infrastructure (oil and gas)	WebGIS, Survey Report, Crossings list, DTS	Existing infrastructure can impact on cable routing and cable protection methods. Several Fields and associated infrastructure present in the vicinity of/within the cable corridor.	2	5	10	Routing of cables should take into account existing infrastructure to avoid where possible. Where unavoidable, ensure that appropriate (crossing) protection measures are put in place. Use of crossing agreements / consultation with license holders and suitable guidelines, such as those provided by ICPC and Carbon Trust, to mitigate risk.	2	2	4
Existing Seabed Infrastructure (cables)	WebGIS, Survey Report, Crossings list, DTS	Existing infrastructure can impact on cable routing and cable protection methods. Several dis-used cables and live cables have been identified within the cable corridor. Unknown cables also identified during the 2017 survey	3	3	9	Routing of cables should take into account existing infrastructure to avoid where possible. Where unavoidable, ensure that appropriate (crossing) protection measures are put in place. Out-of-service cables to be removed prior to installation. Use of crossing agreements / consultation with license holders and suitable guidelines, such as those provided by ICPC and Carbon Trust, to mitigate risk.	3	2	6
Shallow Geology Spatial Variability: Channel Features, Subsurface Boulders etc.	WebGIS, Survey Report, DTS	Variable seabed conditions / shallow geology (incl. subsurface boulders) can hinder cable burial operations, leading to reduced burial depth and increased risk from external threats. Surveys indicate spatial variability in seabed strength and composition - especially in the glacial deposits which vary in shear strength considerably over short distances. (Iceberg ploughed area) Coarse surfical sediments within UK 12NM are expected to pose a significant impediment to jetting tools (based upon observed evidence of Hywind export cable burial difficulties. Features such as channels may present unexpected conditions.	5	2	10	Adequate survey and route engineering / sympathetic routing of cables where possible. Adequate burial assessment and selection of appropriate cable protection method(s) for the expected variations in ground conditions, in order to achieve target burial depths. Potential benefit in undertaking pre-trenching trial to gain knowledge of expected performance prior to cable installation operation.	4	2	8
Rock outcrops	WebGIS, Survey Report, DTS	Presence of hard sediments / strata at surface can lead to reduced burial, increasing risk to cables from external threats. Exposed bedrock identified at UK/Norwegian ends of cable.	4	2	8	Adequate mapping of hard sediments/rock outcrops, sympathetic routing of cables where possible. Adequate burial assessment and selection of appropriate protection method(s) for the expected variations in ground conditions, in order to mitigate identified risks (taking account of environmental considerations).	3	2	6
Peat	WebGIS, Survey Report	Presence of peat can result in geophysical survey blanking (increasing geological uncertainty). Peat can also contain biogenic gas which must be accounted for in cable design. Fibrous material can be difficult to trench through resulting in reduced burial / increased risk to cables from external threats. Can also pose risk of liquefaction. Preliminary information from the 2017 site investigation suggests the route corridor has largely avoided areas of peat.	2	2	4	Ensure adequate survey and integration of geotechnics with geophysics. Appropriate route engineering e.g. route around areas of peat if extents are well constrained, and where practical. Adequate burial assessment and selection of appropriate burial method(s) for the expected variations in ground conditions, in order to achieve target burial depths.	2	2	4
Unexploded Ordnance (UXO)	WebGIS, Survey Report, UXO reports, DTS	UXO can pose a risk to cables associated with the installation e.g. detonation by trenching equipment strike. Desk study indicates multiple sources of UXO threats in the area from both allied and axis WWII operations. Due to the presence of sand and migratory features such as sand waves on the site, it is possible that any UXO located on the seabed has subsequently become partially, or completely buried.	3	4	12	Consultation with UXO specialist has been undertaken. A UXO geophysical survey is to be undertaken to investigate any potential UXOs on site and depending on the results of this survey, further investigation and/or clearance campaign may be required. UXO clearance certificates should be obtained before any operations that interfere with the seabed commence. Additional micro-routing to be undertaken as necessary in preference to removal.	1	4	4
Fish Farms (moorings)	WebGIS	Anchor wires pose an obstruction to installation operations and are to be removed before, and replaced after the installation operation. A risk exists that in rough conditions or in the event of a third party vessel striking the fish farm, anchors may be dragged across the cable causing damage.	2	4	8	Anchors to be removed and replaced prior to and post completion of installation operations. Extra burial (Protection level D, NC FEED document) is planned to mitigate the risk of damage arising from Fish-Farm anchors.	1	4	4

Appendix B – Cable Protection Analysis Table

Project name: UK-Norway HVDC Interconnector
Project number: C831
Client name: NorthConnect
Location: Northern North Sea (Scotland / Norway)

Cable Protection Analysis

KP (RPL09 Corridor) From	KP To	From Easting	From Northing	To Easting	To Northing	Length [km]	Summary of Geology in upper 3m in section[9]	Additional notes on shallow geology	Bathymetry range in section [m below MSL]	Seabed features[2,3] alignment chart survey centre-line (SCL)	Surface and subsurface boulder risk (surface boulder density (per 10 000m²))[5] Green: 0-20/10 000m² Amber: 20-40/10 000m² Red: >40/10 000m²	UXO Encounter Probability Green: Low (Background theat items) Amber: Medium (Background threat items) Red: High (Minefields, munitions etc)	Maximum bedform height of potential mobile sediments found in section[4] [m] Green: <1m (Ripples & Large Ripples) Amber: 1-3m (Megaripples) Red: >3m (Sandwaves)	Maximum gradient Green <10° Amber ≤10° to <15° Red ≤15° (Max slope shown in brackets if >10°)	Slope Stability Risk	Rockfall and landslide risk from Fjord side *(Highlighted as potentially more critical)	Crossings on SCL Status (B - Buried, S - Surface laid) UK nearshore and North Sea survey: as-found location given. Fjord section: as-detected location. Burial status in Fjord unknown.	Environmental intersections, see GIS/Charts for 2D extents) 12NM routing avoids hard constraints incuding environmental areas	Wrecks/possible wrekcs (50m route buffer) Displayed perpendicular to KP, offset to wreck centre (offset in m, +ve = Port, -ve Starboard)	Protection Level	Target DOL (Increase across areas of bedforms to achieve lowering relative to non-mobile level.	Note	Samples in section
0	0.1 [1]	212349	6377615	212447	6377634	0.1	**BEDROCK (HDD)**		18 to 24.5		HDD												
0.1	0.85	212447	6377634	213135	6377906	0.75	**SAND over dense SAND**		24.5 to 28.5	Ripples KP: 0.1 - 0.222	0	LOW	<0.2 (limited area)					Special protection area		D	1.3		CPT/VC_A_001
0.85	1.35	212447	6377634	213564	6378161	0.5	**SAND over dense SAND**		28.5 to 40	Large Ripples KP: 1.338 - 1.368	0	LOW	0.7 (limited area)					Special protection area		C	0.8		CPT/VC_A_003
1.35	3.7	213564	6378161	215583	6379364	2.35	Veneer of **SAND/GRAVEL** over **0.5-4m CLAY** over **TILL**. **SAND** present under clay in some areas. (Clay medium to high strength)		40 to 51.5	High density boulders <50% are >0.75m in size Ripples KP: 1.685 - 2.180 2.518 - 2.603 3.169 - 3.652	0	LOW	<0.2					Special protection area KP1.35 - 1.47 ANNEX I Stony Reef Medium Grade 1170	3.463, 297m	C	0.8		CPT/VC_A_004
3.7	4.47	215583	6379364	216245	6379758	0.77	Veneer of **SAND/GRAVEL over 1-2m CLAY** over **TILL, BEDROCK** outcrops. (Expect Clay medium to high strength)		50 to 55	Mix of high density and numerous boulders. <50% are >0.75m in size. Ripples KP: 4.270 - 4.521 Megaripples KP: 4.096 - 4.169 Rock outcrops	≥40	LOW	0.5 (limited area)					Special protection area to KP3.79 KP3.77 - 3.8, 3.83 - 3.84, 3.89 - 3.92, 4.13 - 4.19 ANNEX I Possible Bedrock Reef 1170 KP3.94 - 3.97, 4.02 - 4.04 ANNEX I Bedrock Reef 1170 KP3.94 - 3.97, 4.02 - 4.04 ANNEX I Sabellaria Reef		C	0.8		
4.47	4.60	216245	6379758	216348	6379835	0.13	**Veneer of SAND/GRAVEL** over **0.5-1m CLAY** over **TILL** (Expect clay of medium to high strength)	Shallow bedrock KP 4.5	54 to 55	Numerous boulders <50% are >0.75m in size. Ripples and large ripples KP: 4.467 - 4.878	20-40	LOW	0.3							C	0.8		
4.60	5.10	216348	6379835	216697	6380193	0.50	Veneer of **SAND/GRAVEL** over **TILL**(Expect Til/Clay to be medium to high strength)		55 to 57	Numerous boulders <50% are >0.75m in size. Ripples and large ripples KP: 4.467 - 4.878	20-40	LOW	0.3							C	0.8		VC 01-SS-01
5.1	5.75	216697	6380193	217151	6380658	0.65	0.4-0.7m **GRAVEL** or very gravelly **SAND, over CLAY** (Clay low-medium strength)		57 to 59	Numerous boulders <50% are >0.75m in size.	20-40	LOW	0							C	0.8		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	Numerous boulders (patchy from KP 9.5) <50% are >0.75m in size. Ripples & Large Ripples KP: [illegible]	20-40	LOW 5.75-5.9 MEDIUM 5.9-8.6 HIGH 8.6 - 14.20	0.5				10.964 Active cable (**B in progress**)			C	0.8		CPT/VC 01-SS-02 CPT/VC 01-SS-03
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	5-20	HIGH	<0.2							C	0.8		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	5-20	HIGH	<0.2				16.597 Disused cable **B** (MMT not found) 18.558 Active pipeline **S**			C	0.8		CPT/VC 01-SS-04
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	5-20 *(Not easily avoidable)*	HIGH	0.2 (0.5 Limited area)						20.197, 507.1m (12NM routing will avoid)	C	0.8		CPT/VC 02-SS-01
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	20-40 (patch avoidable by routing to the north)	HIGH	0.7							C	1.0		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	20-40 *(small part of section, not avoidable)*	HIGH 27.70 -28.00 MEDIUM 28 - 32.50	0.7							C	1.0		CPT/VC 02-SS-02/A
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	20-40	MEDIUM 32.5- 33.7 HIGH 33.7 - 40	0.7							C	1.0		CPT/VC 02-SS-03/A/B
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	20-40 *(part of section, avoidable beyond KP 41.0)*	HIGH	0.7* (*Interpreted sandwave 4.5m, limited area). Potentially immobile relict feature.							C	1.0		CPT 02-SS-04/A
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	20-40	HIGH	0.4	12.1 (seabed ridge, likely glaciogenic feature, gradients >10 degrees avoidable by routing to north of corridor)				KP45.28 - 46.36 ANNEX I		C	1.0		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	HIGH	0.5				53.403 **S** Active pipeline			C	1.0		CPT/VC 02-SS-05 CPT 02-SS-06 CPT/VC 03-SS-01
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	HIGH	0.5				60.326 **B** Active pipeline			C	1.0		CPT/VC 03-SS-02/A/B CPT/VC 03-SS-03
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	HIGH	0							C	1.0		CPT/VC 03-SS-04
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	0	HIGH	0							C	1.0		CPT/VC 03-SS-05 CPT 03-SS-06 CPT/VC 03-SS-07
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	0	HIGH 102.00 -104.80 LOW 104.80 - 107.50	0							C	1.0		CPT03-SS-08
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	0	LOW	0	12.6 *(Pockmark Flanks, avoidable)*			115.131 **B** Disused cable (Found in unexpected position)			C	1.0		CPT/VC 03-SS-09 CPT 03-SS-10
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	0	LOW	0							C	1.0		CPT/VC 03-SS-11
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	0	LOW	0	12.5 *(Pockmark Flanks, avoidable)*			137.347 **B** Group 4 x Active pipelines 137.391 **B** - 137.391 **B** - 137.449 **B** - 140.250 **B** Group 2 x Active pipelines 140.288 **B** - 142.830 **B** Group 5 x Disused pipelines 142.861 **B** - 142.895 **B** - 142.926 **B** - 142.926 **B** - 156.395 **S** Active pipeline	KP128.32 - 200 OSPAR Seapen and burrowing megafauna communities	171.339, -239.7m 171.644, 237.4m	C	1.0		CPT/VC 03-SS-12 CPT 04-SS-01 CPT 04-SS-02
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	0	LOW	0				205.053 **S** Active pipeline 219.410 **S** Active pipeline	KP200 - 217.63, 217.64 - 217.65, 217.7 - 223.28, 223.41 - 224.0 OSPAR Seapen and burrowing megafauna communities		C	1.0		CPT/VC 04-SS-03 CPT/VC 04-SS-04 CPT/VC 04-SS-05

Project name: UK-Norway HVDC Interconnector
Project number: C831
Client name: NorthConnect
Location: Northern North Sea (Scotland / Norway)

Cable Protection Analysis

KP (RPL09 Corridor) From	KP To	Co-ordinates ETRS 1989 UTM Zone 31N From Easting	From Northing	To Easting	To Northing	Length [km]	Bathymetry and Seabed: Summary of Geology in upper 3m in section[9]	Additional notes on shallow geology	Bathymetry range in section [m below MSL]	Seabed features[2,3] alignment chart survey centre-line (SCL)
224 (EEZ boundary)	240.50	411413	6477119	425382	6485874	16.50	**SAND** and **CLAY** (Extremely low strength)	Clay/Sand boundary located in this section (Loose sand sampled at very end of section. Charts suggest change at c. KP 233, however reflectors don't show clear change. Consider section as low strength clay.	112 to 124	Trawlmarks across c.50% of section. Frequent possible gas seeps. MMT suggest that signal in water column unlikely to be caused fish.
240.50	276.00	425382	6485874	459805	6492945	35.50	**SAND** to depth		88 to 111	Occasional Trawl marks. Rare pockmarks
276.00	290.50	459805	6492945	472700	6499251	14.50	**SAND** to depth		96 to 103	Featureless
290.50	341.50	472700	6499251	513994	6528958	51.00	Areas of **SAND** and **CLAY** (Extremely/Very Low Strength)	*Loose clayey silty sand interpreted in vicinity of 06-SS-02 and 07-SS-01 not well defined by reflectors, section considered low strength clay for anchoring to remain conservative.	103 to 119	Trawl marks KP 294.5-324.1 Ripples KP: 309.048 - 309.882 Ripples & Large Ripples KP: 328.480 - 345.408
341.50	348.50	513994	6528958	519794	6532877	7.00	**CLAY** (Extremely/Very Low Strength)		123 to 152	Ripples KP: 328.480 - 345.408
348.50	363.50	519794	6532877	532223	6541275	15.00	**CLAY** (Extremely Low Strength)		152 to 238	Frequent small pockmarks. Trawl marks KP 348.5-351.5, 359.5-361.8
363.50	390	532223	6541275	554181	6556111	26.50	**CLAY** (Extremely/Very Low Strength)		103 to 285	Very frequent pockmarks up to 8m deep, c.100m across. Trawl marks across whole section.
390	409.50	554181	6556111	570338	6567028	19.50	**CLAY** (Extremely Low Strength)		274 to 290	Very frequent pockmarks up to 8m deep, c.100m across. Trawl marks across whole section.
409.50	413.00	570338	6567028	573239	6568987	3.50	**CLAY** (Extremely Low Strength)		269 to 274	Trawl marks across whole section.
413.00	415.00	573239	6568987	574896	6570107	2.00	**CLAY** (Extremely Low Strength)		267 to 271	Iceberg plough marks throughout section. Pockmark on centre line at KP 413.
415.00	427.75	574896	6570107	585460	6577245	12.75	**CLAY** (Extremely Low Strength)		256 to 267	Iceberg plough marks throughout section. Pockmark on centre line at KP 413.
427.75	430.00	585460	6577245	587325	6578505	2.25	**CLAY** (Extremely Low Strength)		266 to 272	Iceberg plough marks throughout section. Occasional boulders, <50% are >0.75m in size
430.00	447.50	587325	6578505	601825	6588302	17.50	**CLAY** (Extremely Low Strength)		231 to 274	Iceberg plough marks throughout section. Occasional boulders, <50% are >0.75m in size
447.50	456.25	601825	6588302	609264	6592719	8.75	**CLAY** (Very low to high strength*)	(*Variable degrees of iceberg reworking and soft sediment fill)	165 to 235	Iceberg plough marks throughout section. Numerous boulders, <50% are >0.75m in size
456.25	460.75	609264	6592719	613607	6593354	4.50	**CLAY** (Extremely low strength)		165 to 205	Featureless
460.75	470.00	613607	6593354	621415	6596941	9.25	**CLAY** (Extremely low strength), highly localised subcropping **BEDROCK/TILL**		190 to 270	Numerous boulders, <50% are >0.75m in size: KP 460.75 - 462.25 KP 464.1 - 466 Occasional boulders, <50% are >0.75m in size: KP 462.25 - 463.65
470.00	480.65	621415	6596941	624798	6602140	10.65	Subcropping/exposed **BEDROCK**, **BEDROCK/TILL** interspersed with areas of **CLAY** and **SAND** **BEDROCK** outcrops are particularly prevalent between KP 470 and KP474, although found across the section	Appears particularly rocky between KP 471.1 - KP472.8 Considered LOW STRENGTH CLAY for shipping assessment as this comprises the majority of this section.	140 to 372	Frequent areas of numerous/high density boulders <50% are >0.75m in size, Diamicton Till, Reefs. Where sampled, ,Till appears to comprise gravell and sand. Ripples KP: 473.393 - 473.4498 Extreme gradients, thin sediment cover over bedrock.
480.65	482.25	625174	6601722	624204	6602969	1.60	**BEDROCK/TILL**		282.5 to 352	High density boulders <50% are > 0.75m in size
482.25	502.30	624204	6602969	634429	6618436	20.05	**CLAY** (Extremely/Very Low Strength)		290 to 424	Occasional pinnacles of bedrock at seabed c.KP 487.5 -488.5, (avoidable) Occasional boulders KP 488.3-489.1 <50% are >0.75m in size Trawl marks KP 488.3 - 501.0
502.30	505.75	634429	6618436	637330	6621058	3.45	**CLAY** (Extremely/Very Low Strength), some areas of **BEDROCK/TILL** with veneer of **CLAY**		217 to 334	routing should be able to avoid rock/hard sediment and bury the cable in soft clay . Thus considered soft clay for anchoring assessment. Patches occasional/numerous boulders KP 502.5-505.6.
505.75	508.75	637330	6621058	638422	6623764	3.00	**BEDROCK/TILL** with veneer of **CLAY**, and **CLAY** (Extremely/Very Low Strength)		217 to 120	Route consistently on "bedrock" (MMT interpretation), KP 507.75 - 508.75 (unavoidable, clay veneer thickness unknown. "Bedrock" may be Till). Other 2km in section may be possible to route on soft material. High density boulders KP 505.75-507.75, <50% are >0.75m in size. Reef on or near centreline KP 506.5 - 508.0. Relict bedforms on centre-line KP 507.555 - 507.743

KP From	KP To	Surface and subsurface boulder risk [surface boulder density (per 10 000m²)][5] Green: 0-20/10 000m² Amber: 20-40/10 000m² Red: >40/10 000m²	UXO Encounter Probability[6] Green: Low (Background theat items) Amber: Medium (Background threat items) Red: High (Minefields, munitiions etc)	Maximum bedform height of potential mobile sediments found in section[4] [m] Green: <1m (Ripples & Large Ripples) Amber: 1-3m (Megaripples) Red: >3m (Sandwaves)	Maximum gradient (survey centre line) Green <10° Amber ≤10° to <15° Red ≤15° (Max slope shown in brackets if >10°)	Slope Stability Risk	Rockfall and landslide risk from Fjord side *(Highlighted as potentially more critical)	Crossings on SCL (KP as-found by MMT)[4] Status (B - Buried, S - Surface laid) UK nearshore and North Sea survey: as-found location given. Fjord section: as-detected location. Burial status in Fjord unknown.	Environmental Designated Habitats (Survey centre line intersections, see GIS/Charts for 2D extents) 12NM routing avoids hard constraints incuding environmental areas	Wrecks/possible wrekcs (50m route buffer) Displayed perpendicular to KP, offset to wreck centre (offset in m, +ve = Port, -ve Starboard)	Cable Protection levels: Protection Level	Target DOL (Increase across areas of bedforms to achieve lowering relative to non-mobile level.	Note
224 (EEZ boundary)	240.50	0	LOW	0				235.929 **B** Active cable	KP224.0-224.1, 224.1 - 233.09 OSPAR Seapen and burrowing megafauna communities	237.061, 161.7m	C	1.0	
240.50	276.00	0	LOW 240.50 - 274.2 HIGH 274.2 - 276.0	0				244.610 **S** Active pipeline 246.750 **S** Active pipeline 248.384 **B** Active cable 248.414 **S** 2 x Active pipelines 248.445 **S** - 259.413 **B** Active cable 264.888 **S** Active pipeline 268.635 **S** Active pipeline 280.857 **S** Active pipeline 287.657 **B** Active cable			C	1.0	
276.00	290.50	0	HIGH	0				298.564 **B** Disused cable			C	1.0	
290.50	341.50	0	HIGH	<0.2, some 0.6				304.477 **B** Active cable 326.208 **S** Active pipeline 338.965 ***Planned cable***			C	1.0	
341.50	348.50	0	HIGH	<0.2, some 0.6							C	1.0	
348.50	363.50	0	HIGH	0	12.5 *(Pockmark Flanks, avoidable)*			351.365 ***Planned cable***	KP359.63 - 363.50 OSPAR Possible Deep-sea sponge aggregations		C	1.0	
363.50	390	0	HIGH 363.50 - 380.5 MEDIUM 380.5 - 390.0	0	23.9 *(Pockmark Flanks, avoidable)*			374.606 ***Planned pipeline***	KP363.50 - 367.63 OSPAR Possible Deep-sea sponge aggregations KP367.63 - 390.0 OSPAR Seapen and burrowing megafauna communities		C	1.0	
390	409.50	0	MEDIUM 390 - 402.8 HIGH 402.8 - 409.50	0	22.8 *(Pockmark Flanks, avoidable)*			390.661 **B** Active cable 397.186 **B** Active cable	KP390 - 404.31 OSPAR Seapen and burrowing megafauna communities	398.829, 106.7m	C	1.0	
409.50	413.00	0	HIGH	0							C	1.0	
413.00	415.00	0	HIGH	0	11.6 *(Pockmark Flanks, avoidable)*						C	1.0	
415.00	427.75	0	HIGH	0							C	1.0	
427.75	430.00	5-20	HIGH	0							C	1.0	
430.00	447.50	5-20	HIGH	0				446.595 **S** Active pipeline	KP435.89 - 435.94, 436.02 - 436.08 OSPAR Deep-sea sponge aggregations		C	1.0	
447.50	456.25	20-40	HIGH	0	**20.5** ***(possible iceberg plough mark feature, steep gradient at KP 450.4 avoidable by routing to the north, as already marked on MMT chart)***						C	1.0	
456.25	460.75	0	HIGH	0				456.816 **S** Active pipeline			C	1.0	
460.75	470.00	*5-40 (To KP 466)*	HIGH	0	**17.1** ***(possible moraine feature, gradients at c.KP 464.15 and KP 465.25-465.5 unavoidable)***	Interpreted mass-transport deposit: KP 467.55 - 467.65			KP 464.67 - KP 464.74 ANNEX I KP 465.19 to 465.38 ANNEX I KP 467.37 to 467.74 ANNEX I		C	1.0	
470.00	480.65	**20->40**	HIGH	<0.2 (limited area)	**22.8** ***(Steep gradients KP 472.5 - 472.8 unavoidable, but may be eased by routing to the north)***				KP 469.84 to 474.12 ANNEX I KP 474.98 to 475.55 ANNEX I KP 478.00 to 478.07 ANNEX I KP 480.34 to 480.46 ANNEX I	477.841, -134.7m 477.844, -136m 479.084, 6.1m 479.883, 84.3m 479.902, 35m	C	1.0	
480.65	482.25	**≥40**	HIGH	0	**24.6** ***Moraine area, unavoidable gradients***				KP 480.80 to 482.22 ANNEX I		C	0.8	
482.25	502.30	Small areas of 5-20 *Avoidable through routing*	**HIGH (Low 493 - 498)**	0		Patches interpreted mass transport deposits KP 483.25-484				486.661, -105m 489.82, 176m	C	1.0	
502.30	505.75	Some small patches of density 5-40 *Avoidable apart from c. KP 504.5-504.75*	HIGH	0	**39.3 Unavoidable steep gradients, routing around rocky areas will reduce maximum**	Mass transport deposits across section (contains disturbed reflectors indicative of mass transport deposits.)		505.435 Active cable		503.546, 13.5m 504.34, -20.6m 504.405, -42.7m	C	1.0	
505.75	508.75	**>40**	HIGH	Bedforms are Relict <0.2, 3 (Megaripples)	**25 *Narrow pass, steep gradients unavoidable***					508.594, -20.7m	C	0.8	

KP From	KP To	Expected Geology within Trenching Depth: Samples in section	Sample route KP location	Easting	Northing	Trenching assessed depth (m) (Target DOL from protection level + 0.2m allowance for product OD and variation in survey data)	Summary of Geology expected within assessed depth (From VC samples) Description provides principal and major secondary soil type description for the anticipated trench depth. Consult logs for full detailed description. Where no VC present, CPT interpretation given. Note that there may be differences with the geology used for the CBRA shipping assessment as that summarises the top 3m for anchoring assessment purposes.	Indicative strenths/density (Lab / CPT data) of soils within assessed depth	Burial Tool Assessment (A - Depth likely to be achieved, B - Depth may be achieved with limitations, C - Depth unlikley to be achieved. Lower case letters indicate a tool-specific comment. Numbers indicate a comment which applies to all tools (although not necessarily affecting them equally). Tools rated only on their ability to penetrate the seabed to assessed depth. Other factors such as cost, speed etc should be considered separately.): Jet Trencher (simultaneous/ post-lay)	Pre-lay Plough	Chain Cutter[10] (simultaneous/ post-lay)	Combined Jet/Chain cutting tool[10] (simultaneous/ post-lay)	Jet Assisted Cable Burial Plough[10] (simultaneous/ post-lay)	Comments: Tool-specific comments (a-f)	Comments relevant to multiple tools (1-11)
224 (EEZ boundary)	240.50	CPT05-SS-01	239.305	424324	6485339	1.2	*No VC* CPT05-SS-01 0-0.61 silty SAND 0.61-1.08 SAND 1.08-1.2 very silty SAND	CPT05-SS-01 Sand 0-0.55 Dr 10-35%, 0.55-1.2 Dr 70%	A	A/B (a)	A/B (c)	A	A	(a)Sand/dense sand may cause ride-out with ploughs (unassisted). (c) Expect increased chain-wear and possibly reduced progress or burial in sandy areas	
240.50	276.00	CPT/VC 05-SS-02 CPT/VC 05-SS-03 CPT/VC 06-SS-01	247.138 261.600 275.730	431674 445792 459549	6487988 6490447 6492852	1.2	VC 05-SS-02 0-0.55 very silty SAND 0.55-1.2 very silty SAND VC 05-SS-03 0-0.67 silty SAND 0.67-1.0 very silty SAND 1.0-1.2 SAND VC 06-SS-01 0-0.35 very silty SAND 0.35-1.2 very silty SAND	CPT/VC 05-SS-02 Sand 0-0.55 Dr 25-75%, 0.55-1.2 Dr 75-90% CPT/VC 05-SS-03 0-0.25 Sand, Dr 0-75% 0.25-1.2 Sand Dr 65-90% CPT/VC 06-SS-01 Sand, 0-0.35 Dr 25-40% 0.35-1.2 65%	A (4,6)	B (a) (4,6)	B (c) (4,6)	A (4,6)	B (a) (4,6)	(a)Sand/dense sand may cause ride-out with ploughs. (c) Expect increased chain-wear and possibly reduced progress or burial in sandy areas	(4) Cross pipelines/cables using designed crossing (6) Rare pockmarks, avoid through micro-routing.
276.00	290.50					1.2	Expect dense sand	*Expect dense sand*	A (5)	B (a) (5)	B (c) (5)	A (5)	B (a) (5)	(a)Sand/dense sand may cause ride-out with ploughs. (c) Expect increased chain-wear and possibly reduced progress or burial in sandy areas	(5) Find, cut , move and weight disused cable
290.50	341.50	CPT06-SS-02 CPT/VC 06-SS-03 CPT/VC 06-SS-04 CPT/VC 07-SS-01	293.196 303.800 319.900 331.600	474850 483355 496197 505777	6500877 6507264 6516926 6523407	1.2	CPT06-SS-02 0-1.2 clayey SAND VC 06-SS-03 0-0.52 very clayey SAND 0.52-1.2 extremely low to very low strength sandy silty CLAY VC 06-SS-04 0-0.37 extremely low to very low strength very sandy CLAY 0.37-0.84 very low strength very sandy CLAY 0.84-1.0 very clayey SAND 1.0-1.2 extremely low to very low strength very sandy CLAY VC 07-SS-01 0-0.78 very silty SAND 0.78-1.2 silty SAND	CPT06-SS-02 Sand Dr 50% CPT/VC 06-SS-03 Sand Dr 40% 10kPa clay CPT/VC 06-SS-04 10kPa Clay CPT/VC 07-SS-01 Sand Dr 50% Majority section 10kPa clay	A (f) (3,4)	A/B (a) (3,4)	A/B (c) (3,4)	A (3,4)	A/B (a) (3,4)	(a)Sand/dense sand may cause ride-out with ploughs. (c) Expect increased chain-wear and possibly reduced progress or burial in sandy areas (f) Mixed sand and clay conditions may make sword optimisation difficult when jetting	(3) Increase burial across small bedforms (4) Cross pipelines/cables using designed crossing. Agree with planned cable parties
341.50	348.50	CPT/VC 07-SS-02	345.43	517253	6531157	1.2	VC 07-SS-02 0-0.34 silty SAND 0.34-1.2 extremely low strength very sandy silty CLAY	CPT/VC 07-SS-02 Sand Dr 15-40% Clay 0-10 kPa	A (3)	A (3,10)	A (3,10)	A (3,10)	A (3,10)		(3) Increase burial across small bedforms (10) Potential risk of sinkage for tools without buoyancy capabilities
348.50	363.50	CPT07-SS-03	357.3	527033	6537758	1.2	No VC CPT07-SS-03 0-0.28 silty SAND 0.28-1.2 extremely low strength CLAY	CPT07-SS-03 Sand Dr 5-15% Clay 0-10 kPa	A (4,6,7)	A (4,6,7,10)	A (4,6,7,10)	A (4,6,7,10)	A (4,6,7,10)		(4) Cross pipelines using designed crossing (6) Route around pockmarks (7) Steep slopes may approach limitations of chosen tool without prior remediation. Micro-routing or pre-sweeping to mitigate slopes (10) Potential risk of sinkage for tools without buoyancy capabilities
363.50	390	CPT/VC 07-SS-04 CPT08-SS-01	363.620 387.600	532308 552194	6541337 6554771	1.2	VC 07-SS-04 0-1.2 Extremely low strength silty CLAY CPT08-SS-01 0-1.2 Extremely low strength sandy CLAY	CPT/VC 07-SS-04 Clay 0-10 kPa CPT08-SS-01 Clay 0-10 kPa	A (4,6,7)	A (4,6,7,10)	A (4,6,7,10)	A (4,6,7,10)	A (4,6,7,10)		(4) Cross pipelines using designed crossing (6) Route around pockmarks (7) Steep slopes may approach limitations of chosen tool without prior remediation. Micro-routing or pre-sweeping to mitigate slopes (10) Potential risk of sinkage for tools without buoyancy capabilities
390	409.50	CPT/VC 08-SS-02	405.880	567341	6565008	1.2	VC 08-SS-02 0-1.2 Extremely low strength CLAY	CPT/VC 08-SS-02 Clay 0-10 kPa	A (4,6,7)	A (4,6,7,10)	A (4,6,7,10)	A (4,6,7,10)	A (4,6,7,10)		(4) Cross pipelines using designed crossing (6) Route around pockmarks (7) Steep slopes may approach limitations of chosen tool without prior remediation. Micro-routing or pre-sweeping to mitigate slopes (10) Potential risk of sinkage for tools without buoyancy capabilities
409.50	413.00					1.2	*No sample in section*	*Extremely low strength clay*	A	A (10)	A (10)	A (10)	A (10)		(10) Potential risk of sinkage for tools without buoyancy capabilities
413.00	415.00					1.2	*No sample in section*	*Extremely low strength clay*	A (6,7,8)	A (6,7,8,10)	A (6,7,8,10)	A (6,7,8,10)	A (6,7,8,10)		(6) Route around pockmarks (7) Steep slopes may approach limitations of chosen tool without prior remediation. Micro-routing or pre-sweeping to mitigate slopes (8) Possible rock placement across steep iceberg scar marks (10) Potential risk of sinkage for tools without buoyancy capabilities
415.00	427.75	CPT/VC 08-SS-03	419.8	578862	6572791	1.2	VC 08-SS-03 0-1.2 extremely low strength CLAY	CPT/VC 08-SS-03 Clay 0-10 kPa	A (7,8)	A (7,8,10)	A (7,8,10)	A (7,8,10)	A (7,8,10)		(7) Micro-routing or pre-sweeping to mitigate slopes (8) Possible rock placement across steep iceberg scar marks(10) Potential risk of sinkage for tools without buoyancy capabilities (10) Potential risk of sinkage for tools without buoyancy capabilities
427.75	430.00					1.2	*No sample*	*Extremely low strength clay*	A (1,8)	A (1,8,10)	A (1,8,10)	A (1,8,10)	A (1,8,10)		(1) Subsurface boulders may impede burial tools and cause reduced burial. (8) Possible rock placement across steep iceberg scar marks (10) Potential risk of sinkage for tools without buoyancy capabilities
430.00	447.50	CPT09-SS-01 CPT09-SS-02 CPT09-SS-03	431.800 442.720 444.490	588811 597860 599317	6579503 6585619 6586602	1.2	No VC CPT09-SS-01 0-0.2 Extremely low strength silty CLAY 0.2-1.2 xtremely low strength CLAY CPT09-SS-02 0-1.2 Extremely low strength CLAY CPT09-SS-03 0-0.85 Extremely low strength CLAY 0.85-1.2 Extremely low strength CLAY	CPT09-SS-01 Clay 0-10 kPa CPT09-SS-02 Clay 0-10 kPa CPT09-SS-03 Clay 0-10 kPa	A (1,8)	A (1,8,10)	A (1,8,10)	A (1,8,10)	A (1,8,10)		(1) Subsurface boulders may impede burial tools and cause reduced burial. (8) Possible rock placement across steep iceberg scar marks (10) Potential risk of sinkage for tools without buoyancy capabilities
447.50	456.25	CPT/VC 09-SS-04 CPT/VC 09-SS-05 CPT/VC 09-SS-06	449.707 449.783 452.660	603656 603718 606052	6589531 6589579 6591259	1.2	VC 09-SS-04 0-1.2 medium strength CLAY VC 09-SS-05 0-0.25 very low strength CLAY 0.25-0.85 medium strength CLAY 0.85-1.2 medium to high strength CLAY VC 09-SS-06 0-0.15 very low strength CLAY 0.15-1.2 very low stregth CLAY Expet clay of variable strength due to localised occurence of iceberg reworking.	CPT/VC 09-SS-04 Clay 60-70 kPa. CPT/VC 09-SS-05 Clay 0-0.25 25Kpa, 0.25-0.85 50-80kPa, 0.85-1.2 100kPa CPT/VC 09-SS-06 Clay 10kPa	B (b) (1,7,8)	B (b) (1,7,8,10)	A (1,7,8,10)	A (1,7,8,10)	B (b) (1,7,8,10)	(b) Possible reduced performance/risk of ride out ploughing in high strength clays. Possible reduced performance jetting in high strength clays.	(1) Subsurface boulders may impede burial tools and cause reduced burial. (7) Steep slopes may exceed limitations of chosen tool without prior remediation. Micro-routing or pre-sweeping to mitigate slopes. (8) Possible rock placement across steep iceberg scar marks (10) Potential risk of sinkage for tools without buoyancy capabilities
456.25	460.75	CPT/VC 09-SS-07	457.363	610355	6592493	1.2	VC 09-SS-07 0-0.28 extremely low strength sandy CLAY 0.28-0.58 extremely low strength very sandy CLAY 0.58-0.76 extremely low strength CLAY 0.76-1.04 very low strength CLAY 1.04-1.14 SAND 1.14-1.2 low strength CLAY	CPT/VC 09-SS-07 Clay 10 kPa	A (4)	A (4,10)	A (4,10)	A (4,10)	A (4,10)		(4) Cross pipeline using designed crossing (10) Potential risk of sinkage for tools without buoyancy capabilities
460.75	470.00	CPT/VC 09-SS-08 CPT/VC 09-SS-09 CPT/VC 09-SS-10 CPT/VC 09-SS-11	461.949 464.259 465.232 465.805	614686 616769 617395 617913	6593862 6594370 6595014 6595256	1.2	VC 09-SS-08 0-0.28 low strength gravelly CLAY 0.28-0.43 clayey fine SAND (locally very gravelly) 0.43-0.6 very low to low strength very sandy CLAY 0.6-1.11 (VC End) silty SAND VC 09-SS-09 0-0.16 low strength gravelly CLAY 0.16-0.76 low to medium strength silty CLAY 0.76-1.2 low to medium strength silty CLAY VC 09-SS-10 0-1.2 extremely low strength silty CLAY VC 09-SS-11 0-1.2 extremely low strength silty CLAY	CPT/VC 09-SS-08 Clay 20 kPa CPT/VC 09-SS-09 Clay 35-50 kPa CPT/VC 09-SS-10 Clay 0-10 kPa CPT/VC 09-SS-11 Clay 0-10 kPa	A (1,7,9)	A (1,7,9,10)	A (1,7,9,10)	A (1,7,9,10)	A (1,7,9,10)	(e) Gravel component may not be removed when jetting and form a log in the trench bottom. (d)Possible reduced performance with some less powerful jet trenchers in medium strength clay/mixed sand/gravel	(1) Subsurface boulders may impede burial tools and cause reduced burial. (7) Steep slopes may exceed limitations of chosen tool, limiting use. (9) Shallow or exposed bedrock may preclude burial using tools and instead require rock-placement protection. (10) Potential risk of sinkage for tools without buoyancy capabilities
470.00	480.65	VC 09-SS-12A VC 09-SS-13 VC 09-SS-15 CPT/VC 09-SS-14 VC 09-SS-16 *(sample 15 occurs before 14)*	471.417 472.274 475.505 477.137 479.089	622313 623075 625365 625228	6596333 6596621 6596679 6598293	1.2	VC 09-SS-12A 0-0.71 extremely low strength silty CLAY 0.71-1.2 extremely low to very low strength silty CLAY VC 09-SS-13 0-0.28 Black fibrous organic layer *(Peat?)* 0.28-1.04 low strength silty CLAY 1.04-1.2 gravelly SAND VC 09-SS-15 0-0.42 extremely low strength sandy CLAY 0.42-0.82 extremely low strength silty CLAY 0.82-1.06 gravelly very clayey SAND 1.06-1.2 gravelly SAND VC 09-SS-14 0-0.73 extremely low strength gravelly CLAY 0.73-1.2 extremely low strength CLAY VC 09-SS-16 0-0.52 very gravelly silty SAND 0.52-0.9 silty SAND 0.9-1.2 very gravelly silty SAND	VC 09-SS-12A Clay 5-10kPa VC 09-SS-13A -no test data- VC 09-SS-15 Clay 5 kPa CPT/VC 09-SS-14 Clay 10kPa VC 09-SS-16 No Dr data	A/B* (e) (1,7,9,12)	A/B* (a) (1,7,9,10,12)	A/B* (c) (1,7,9,10,12)	A/B* (c, e) (1,7,9,10,12)	A/B* (a) (1,7,9,10,12)	(a)Sand/dense sand/ till may cause ride-out with ploughs. *Only applies to VC 09-SS-16 area, otherwise A rating (c) Expect increased chain-wear and possibly reduced progress or burial in silty/sandy areas *Only applies to VC 09-SS-16 area, otherwise A rating (e) Gravel component may not be removed when jetting and form a log in the trench bottom. Possible fibrous peat layer may resist jetting.	(1) Subsurface boulders may impede burial tools and cause reduced burial. (7) Steep slopes may exceed limitations of chosen tool, limiting use. (9) Shallow or exposed bedrock may preclude burial using tools and instead require rock-placement protection. (10) Potential risk of sinkage for tools without buoyancy capabilities (12) If bedrock encountered within assessed depth, none of these tools will achieve target burial
480.65	482.25	Unsampled				1.2	Unsampled. Diamicton Till or Bedrock	*Expect granular deposits of variable grain size possibly with very soft clay surficial veneer.*	A/B (f) (1,7,12)	A/B (a) (1,7,12)	B (c) (1,7,12)	A/B (c,f) (1,7,12)	A/B (a) (1,7,12)	(a)Sand/dense sand/ till may cause ride-out with ploughs. (c) Expect increased chain-wear and possibly reduced progress or burial in sandy areas (f) Mixed sand and clay conditions may make sword optimisation difficult when jetting *Difficulty depends upon thickness of clay veneer	(1) Subsurface boulders may impede burial tools and cause reduced burial. (7) Steep slopes may exceed limitations of chosen tool, limiting use. (12) If bedrock encountered within assessed depth, none of these tools will achieve target burial
482.25	502.30	VC-B10-SS-01 CPT/VC-B10-SS-02	489.723 499.138	627790 631809	6608737 6616669	1.2	VC 10-SS-01 0-0.71 extremely low strength silty CLAY 0.71-1.2 extremely low to very low strength silty CLAY VC-B10-SS-02 0-1.2 very low strength silty CLAY	VC-B10-SS-01 Silty Clay/ Clayey Silt,10kPa CPT/VC-B10-SS-02 Silty Clay/ Clayey Silt,10kPa	A	A (10)	A (10)	A (10)	A (10)		(10) Potential risk of sinkage for tools without buoyancy capabilities
502.30	505.75	VC 10-SS-03A	502.328	634454	6618450	1.2	VC 10-SS-03A 0-0.42 (End VC) extremely low strength silty CLAY	VC 10-SS-03A Silty Clay, 10kPa	A (1,4,7,12)	A (1,4,7,10,12)	A (1,4,7,10,12)	A (1,4,7,10,12)	A (1,4,7,10,12)	(See section below for potential problems if bedrock/till encountered within trenching depth)	(1) Subsurface boulders may impede burial tools and cause reduced burial. (4) Cross cable using designed crossing (7) Steep slopes may exceed limitations of chosen tool, limiting use. (10) Potential risk of sinkage for tools without buoyancy capabilities (12) If bedrock encountered within assessed depth, none of these tools will achieve target burial
505.75	508.75					1.0	*No sample. Interpretation suggests diamicton or Bedrock*	*Expect granular deposits of variable grain size possibly with very soft clay surficial veneer.*	A/B* (f) (1,2,7,12)	A/B* (a) (1,2,7,10,12)	B* (c) (1,2,7,10,12)	A/B* (c,f) (1,2,7,10,12)	A/B* (a) (1,2,7,10,12)	(a)Sand/dense sand may cause ride-out with ploughs. (c) Expect increased chain-wear and possibly reduced progress or burial in sandy areas (f) Mixed sand and clay conditions may make sword optimisation difficult when jetting *Difficulty depends upon thickness of clay veneer	(1) Subsurface boulders may impede burial tools and cause reduced burial. (2) Rock outcrops avoided by routing. (7) Steep slopes may exceed limitations of chosen tool, limiting use. (10) Potential risk of sinkage for tools without buoyancy capabilities (12) If bedrock encountered within assessed depth, none of these tools will achieve target burial

Project name: UK-Norway HVDC Interconnector
Project number: C831
Client name: NorthConnect
Location: Northern North Sea (Scotland / Norway)

Cable Protection Analysis

NORTHCONNECT

CATHIE ASSOCIATES

KP, Co-ordinates, Bathymetry and Seabed, Hazards

KP (RPL09 Corridor) From	To	From Easting	From Northing	To Easting	To Northing	Length [km]	Summary of Geology in upper 3m in section[7]	Additional notes on shallow geology	Bathymetry range in section [m below MSL]	Seabed features[2,3] alignment chart survey centre-line (SCL)	Surface and subsurface boulder risk [surface boulder density (per 10 000m²)][5] Green: 0-20/10 000m² Amber: 20-40/10 000m² Red: >40/10 000m²	UXO Encounter Probability[6] Green: Low (Background theat items) Amber: Medium (Background threat items) Red: High (Minefields, munitions etc)	Maximum bedform height of potential mobile sediments found in section[4] [m] Green: <1m (Ripples & Large Ripples) Amber: 1-3m (Megaripples) Red: >3m (Sandwaves)	Maximum gradient (survey centre line) Green <10° Amber ≤10° to <15° Red ≤15° (Max slope shown in brackets if >10°)	Slope Stability Risk	Rockfall and landslide risk from Fjord side *(Highlighted as potentially more critical)	Crossings on SCL (KP as-found by MMT)[4] Status (B - Buried, S - Surface laid) UK nearshore and North Sea survey: as-found location given. Fjord section: as-detected location. Burial status in Fjord unknown.	Environmental Designated Habitats (Survey centre line intersections, see GIS/Charts for 2D extents) 12NM routing avoids hard constraints incuding environmental areas	Wrecks/possible wrekcs (50m route buffer) Displayed perpendicular to KP, offset to wreck centre (offset in m, +ve = Port, -ve Starboard)
508.75	509.80	638422	6623764	638211	6623745	1.05	**BEDROCK/TILL** with veneer of **CLAY**, and **CLAY** (Extremely/Very Low Strength)		187 to 225	Numerous boulders ,<50% are >0.75m in size. KP 508.75-509.8	20-40	HIGH	0	29.8 Narrow pass, steep gradients unavoidable but may be reduced. Route around steep rocky outcrop at KP 509.3	Mass transport deposits across section				
509.8	520.6	638211	6623745	644395	6631769	10.80	**CLAY** (Extremely/Very Low Strength)		290 to 354	Rock pinnacle at KP 519.5 (avoidable) Numerous boulders KP 509.8- 510.25, Mix of numerous and occasional boulders KP 516.4 - 516.75 KP 517.4 -520.4 <50% are >0.75m in size.	Patches of boulders of density 5-40 *Not avoidable*	HIGH	0	23.8 Unavoidable gradients 509.9 - 510.2, routing around rocky area will reduce the max gradient at KP 519.5	Mass transport deposits outcrop KP 510-520.6. Possible historic slip-scarp at KP 510.6		510.916 Active cable 511.116 Active cable 511.249 Active cable 511.307 Active cable 511.548 Active cable		511.152, 247.6m 511.279, -107.7m 511.606, -152.4m 511.653, 209.8m 511.807, 29.2m 511.852, 87.2m 512.388, -17.1m 512.597, -249.3m 512.641, -46.6m 512.678, -47m
520.60	524.65	644395	6631769	647271	6634614	4.05	**TILL** with veneer of **CLAY** (Veneer thicknes unknown, TILL not sampled)	11-SS-01 samples pocket of thicker clay (not representative of surrounding geophysical interpretation of Till with veneer) 11-SS-01 samples CLAY veneer, TILL not reached after 1.6m	152 to 430	Raised area is interpreted as Till with a clay veneer. This (and later) features may have been formed as terminal moraines by periods of glacial re-advancement during the overall final retreat. High density boulders KP 521.1 - 524.4 <50% are >0.75m in size Routing may be able to avoid exposed till/bedrock KP 524.25-524.6 Reef patch at KP 521.7	≥40 *(Field unavoidable)*	HIGH	0	26.2 Unavoidable gradients, routing will reduce steepest section c. KP 524.5			523.223 Active cable		
524.65	531.50	647271	6634614	650232	6640121	6.85	**CLAY** (Extremely/Very Low Strength)	*Assuming cable is routed through low strength clay areas, avoiding bedrock	400 to 503	Large very steep "islands" of bedrock in Fjord bottom. Port/Starboard survey lines suggest these areas are easily avoidable to allow the cable to be installed in soft sediment. Occasional boulders, <50% are >0.75m in size. KP 526.3 - 526.4 KP 528.2 - 528.6	Small patches of 5-20 Avoidable through routing	HIGH	0	60.9 routing can avoid the most severe rocky slopes in section (bedrock "islands")KP 527.5 and KP 529.2-530.4)	Section consists mostly of mass transport deposits outcrop unless bedrock/till is found.		525.92 Active cable		524.864, -194.1m 525.487, 84.4m 526.107, 179.6m 526.537, 79.8m 526.556, -70.3m 526.76, -155.9m 526.914, 246m
531.50	548.25	650232	6640121	659120	6652619	16.75	**CLAY** (Extremely/Very Low Strength)		464 to 547	Occasional boulders, <50% are >0.75m in size: KP 534.25 - 534.5 Occasional boulders, >50% are >0.75m in size: KP 540.55 - 540.6 KP 544.9 - 545.1 Numerous boulders, >50% are >0.75m in size: KP 535.7 - 535.8	Small patches of 5-20 Avoidable through routing	HIGH LOW beyond KP 543	0	26.3 Steep gradients can be avoided by routing. Careful routing to the North at KP 542.5 may reduce gradient, steep area at KP 544 avoidable	Slip-scarp at KP 542.45 Possible historic slip-scarp at KP 547.7 Interpreted mass-transport deposits: KP 534.8 - 535.1 KP 539.4 - 540.6 KP 541.3 - 542.45 KP 543 - 543.8	KP 539.4 to 539.94 -Interpreted from MBES and SBP; from east, rather gentle side slopes could be from sliding during decreasing sea level KP 540.13 to 540.67 -Interpreted from MBES and SBP; across, rather gentle side slopes, could be from sliding during decreasing sea level KP 543.43 to 543.77 -Interpreted from MBES and SBP; from south, rather gentle side slopes, could be from sliding during decreasing sea level	533.666 Active cable 533.758 Active cable 533.873 Active cable 533.96 Active cable 534.077 Active cable 534.191 Active cable 534.357 Active cable 534.376 Active cable 534.742 Active cable 538.650 Out of use cable 539.229 Out of use cable 539.24 Out of use cable		534.934, 161.7m 536.961, -80m 544.544, -243.3m 546.559, 100.2m
548.25	549.00	659120	6652619	659619	6653179	0.75	**BEDROCK/TILL** with veneer of **CLAY**		547 to 605	Bedrock or Till interpreted, with a veneer of clay.	0	LOW	0	11.7 Unavoidable, but routing may reduce gradient to <10 degrees.					
549.00	557.50	659619	6653179	665014	6659116	8.50	**CLAY** (Extremely/Very Low Strength)		605 to 660	Raised area across Fjord: KP 554.9 - 555.3 interpreted as Bedrock/Till with overlying clay mass-transport deposit.	0	LOW	0	24.7 Steep gradients at KP550 and 555.0-555.3 unavoidable	Slip-scarps: KP 549.75 KP 549.9 Interpreted mass-transport deposits: KP 549.75 - 550.6 KP 555.25 - 556				552.333, 99.1m
557.50	592.60	665014	6659116	676238	6684411	35.10	**CLAY** (Extremely/Very Low Strength)		528 to 668	Raised area across Fjord: KP 586 - 588.95 interpreted as Bedrock/Till with veneer/cover of clay. Occasional boulders, <50% are >0.75m in size: KP 585.9 - 586.65	Patch of 5-20 *Not avoidable*	LOW	0	27.2 routing to the south should reduce gradient KP 585.5-586, steep gradients unavoidable KP 586-586.5	Slip-scarp: KP 585.25 Mass transport deposits outcrop: 592.1 - 592.7 Interpreted mass-transport deposits: KP 585.3 - 585.7		563.317 Active cable 566.707 Active cable 573.047 Active cable 577.246 Active cable 578.652 Active cable 582.517 Out of use cable 583.406 Active cable 584.179 Active cable 584.681 Active cable 584.707 Active cable 584.933 Active cable 585.063 Out of use cable		
592.60	594.60	676238	6684411	677261	6686119	2.00	**BEDROCK/TILL** with veneer of **CLAY** or **SAND/GRAVEL**	Sample records clay (0.7m) over SAND to 0.7-2m (end of sample)	530 to 800	Raised area across Fjord interpreted as Bedrock/Till with clay or sand/gravel veneer. Very rapid deepening, from -530m to -800m from KP 592.7- 595.5 Occasional boulders, >50% are >0.75m in size: KP 594 - 594.5, although found on port and starboard survey lines throughout section.	5-20 Avoidable through routing	LOW	0	27.3 Steep gradients unavoidable					
594.60	610.00	677261	6686119	682547	6698306	15.40	**CLAY** (Extremely/Very Low Strength)		805 to 857	Route in proximity of explosive dumping ground KP 609.5 - 611.5	0	LOW HIGH beyond 605.5	0	19.3 Gradient c.KP 599.15 unavoidable	Slip-scarp: KP 599.1 - 599.15 Mass transport deposits outcrops: KP 594.60 - 595.7 KP 599.15 - 599.8 Interpreted mass-transport deposits: KP 599.25 - 599.75 KP 603.5 - 603.9	KP 595.81 to 595.96 -Interpreted from MBES and SBP; from east, steep side slope, could be old rockfall KP 597.48 to 597.59 -Interpreted from MBES, small lobes from east and west KP 603.54 to 603.91 -Interpreted from MBES and SBP; from southeast, steep, high side slope10	596.216 Active cable 596.306 Active cable 598.021 Out of use cable 598.39 Active cable 600.323 DCC 142 Active cable 601.067 Out of use cable		603.327, -27.4m
610.00	634.75	682547	6698306	702765	6703392	24.75	**CLAY** (Extremely/Very Low Strength)		716 to 857	Numerous boulders, <50% are >0.75m in size: KP 612.8 - 613.4 Occasional boulders, >50% are >0.75m in size: KP 630.5 - 631 High-density boulders, >50% are >0.75m in size: KP 632.95 - 633.25	Small patches of 5->40 Avoidable through routing	HIGH until KP 617 LOW	0	18.6 Steep gradient KP 611.75 unavoidable, gradients KP 620-620.5 unavoidable but may be improved by routing to the south KP 620-620.25. Gradient at 630.7 unvoidable.	Slip-scarps: Multiple small scarps KP 620 - 620.5 Possible older scarp KP 621.2 Scarp KP 630.7 Mass transport deposits outcrop: KP 611.4 - 611.75 KP 619.2 - 621.2 KP 627.9 - 630.9 Interpreted mass-transport deposits: KP 611.4 - 611.65 KP 619.9 - 620.25 630.35 - 630.7		610.622 Active cable 612.582 Active cable 618.476 Active cable 619.307 Active cable 633.396 Active cable 634.611 Active cable 634.647 Active cable		620.679, 99.8m 627.616, -9.2m
634.75	658.70	702765	6703392	721786	6712367	23.95	**CLAY** (Extremely/Very Low Strength)		330 to 720	Raised section across Fjord interpreted as Bedrock/Till, covered by soft mass-transport clay deposit. KP 646.4 - 647.0 Occasional boulders, <50% are >0.75m in size: KP 636.6 - 637.1 Occasional boulders, >50% are >0.75m in size: KP 657.9 - 658.2	Small patches 5-20 Avoidable through routing	LOW	0	34 Gradient c.KP 638.15 unavoidable. Gradient 642.25 unavoidable but slopes appear slightly shallower on southern half of the corridor. Gradients across possible moraine feature KP 646.4-647 may be eased by routing over top of feature to the north or around the bottom to the extreme south of the survey corridor.	Slip-scarps: KP 638.1 - 638.25 KP 642.25 KP 650.45 KP 657.1 Mass transport deposits outcropping throughout. Interpreted mass-transport deposits occur regularly from KP 637.4 onwards, from scarps on centre and sides of Fjord.	KP 644.1 to 644.9 -Interpreted from MBES and SBP; from north west, covers 1/3 of corridor, steep, high side slope10 KP 645.88 to 646.32 -Interpreted from MBES and SBP; from north northeast , crosses the corridor, steep, high side slope (looks fresh) 11 KP 654.86 to 655.2 -Interpreted from MBES and SBP; from north, steep, covers more than half of the corridor, steep side slope (looks fresh) 11	636.228 Active cable 637.338 Active cable 637.556 Active cable 637.887 Active cable 641.7 Active cable 642.007 Out of use cable 642.044 Active cable 647.387 Active cable 654.534 Active cable		638.376, 63.4m 646.015, -84m
658.70	661.40	721786	6712367	724305	6712302	2.70	**CLAY** (Extremely/Very Low Strength). Outcrops of **BEDROCK** KP 660.5 - 661.3	*Bedrock outcrops appear to be avoidable	330 to 76	Complex section. Mix of soft sediment and Bedrock. Incidence of soft/harder material is patchy across all 3 survey lines. Considered as LOW STRENGTH CLAY for shipping assessment to remain risk-conservative and due to the very low levels of traffic. Exposed/subcropping bedrock KP 660.5 - 661.3 Numerous / occasional boulder patches across section, <50% are >0.75m in size. Exposed bedrock may be avoidable.	Patches 5-40 across section *Largely unavoidable*	LOW	0	36 Gradients unavoidable KP 660.4 - 661.4, although slopes may be reduced by routing to the north of the survey corridor (see below)	Patches of interpreted mass-transport deposits KP 659.9 - 661.3. Mass transport deposits (Where not interpreted as Till/bedrock)	^Begins in above section KP 658.64 to 658.88 -Interpreted from MBES and SBP; from north, steep, covers more than half of the corridor, steep side slope (looks fresh). Correlates with gully onshore?11 KP 659.9 to 660.18 -Interpreted from MBES and SBP; from north, steep, covers more than half of the corridor, steep side slope (looks fresh). Correlates with gully onshore?11	661.244 Out of use cable		
661.40	664.66	724305	6712302	727248	6713622	3.26	**CLAY** (Very Low Strength)		76 to 13	High density boulders, >50% are >0.75m in size, KP 663.65 - 663.8.	Small patch of ≥40 Avoidable through routing	LOW	0	35.4 Gradient of major scarp may be eased by routing to the North of the main scarp. Gradient to final landfall at 664.6 is unavoidable.	Very large slip-scarp KP 661.4 - 661.6, likely source of mass transport deposits in previous sections.	KP 663.72 to 663.82 -Lobe from south, covering 1/3 of corridor, steep mountain side with gully above.11	662.89 Active cable 664.018 Active cable 664.273 Active cable		

Cable Protection Levels, Expected Geology within Trenching Depth, Burial Tool Assessment and Comments

Burial Tool Assessment: A - Depth likely to be achieved, B - Depth may be achieved with limitations, C - Depth unlikely to be achieved. Lower case letters indicate a tool-specific comment. Numbers indicate a comment which applies to all tools (although not necessarily affecting them equally). Tools rated only on their ability to penetrate the seabed to assessed depth. Other factors such as cost, speed etc should be considered separately.

KP From	KP To	Protection Level	Target DOL	Note	Samples in section	Sample route KP location	Easting	Northing	Trenching assessed depth (m)	Summary of Geology expected within assessed depth (from VC samples)	Indicative strength/density (lab / CPT data) of soils within assessed depth	Jet Trencher	Pre-lay Plough	Chain Cutter	Combined Jet/Chain cutting tool	Jet Assisted Cable Burial Plough	Tool-specific comments	Comments relevant to multiple tools
508.75	509.80	C (D 509-509.8)	1.0 (D 1.5)	Burial increase in vicinity of yards and mobilisation area					1.2 (D 1.7)	No sample	Expect granular deposits of variable grain size possibly with very soft clay surficial veneer.	A/B* (f) (1,7,12)	A/B* (a) (1,7,10,12)	B* (c) (1,7,10,12)	A/B* (c,f) (1,7,10,12)	A/B* (a) (1,7,10,12)	(a)Sand/dense sand may cause ride-out with ploughs. (c) Expect increased chain-wear and possibly reduced progress or burial in sandy areas (f) Mixed sand and clay conditions may make sword optimisation difficult when jetting *Difficulty depends upon thickness of clay veneer	(1) Subsurface boulders may impede burial tools and cause reduced burial. (7) Steep slopes may exceed limitations of chosen tool, limiting use. (10) Potential risk of sinkage for tools without buoyancy capabilities (12) If bedrock encountered within assessed depth, none of these tools will achieve target burial.
509.8	520.6	D (B KP 520-520.8)	1.5 (B 0.5)	Burial increase in vicinity of yards and mobilisation area	CPT/VC-B10-SS-04 CPT/VC 10-SS-05	509.983 514.708	638407 641978	6623841 6626604	1.7 (B 0.7)	VC-B10-SS-04 0-1.7 very low strength silty CLAY VC 10-SS-05 0-0.95 very low strength silty CLAY 0.95-1.7 extremely low to very low strength silty CLAY	CPT/VC-B10-SS-04 Clay 10kPa CPT/VC 10-SS-05 Silty Clay <10kPa	A (1,4,7)	A (1,4,7,10)	A (1,4,7,10)	A (1,4,7,10)	A (1,4,7,10)		(1) Subsurface boulders may impede burial tools and cause reduced burial. (4) Cross cables using designed crossing (7) Steep slopes may exceed limitations of chosen tool, limiting use. (10) Potential risk of sinkage for tools without buoyancy capabilities
520.60	524.65	B	0.4		VC-B11-SS-01 VC-B11-SS-02A	521.803 523.993	645197 646790	6632666 6634169	0.6	VC-B11-SS-01 0-0.28 very low strength sandy CLAY 0.28-0.47 very low strength very sandy CLAY 0.47-0.54 silty SAND 0.54-0.7 extremely low strength silty CLAY VC-B11-SS-02A 0-0.39 very low strength very sandy CLAY 0.39-0.7 very low strength very gravelly CLAY	VC-B11-SS-01 Clay 10kPa VC-B11-SS-02A no lab test, likely 10kPa Depending on veneer thickness, may expect unsorted granular deposits of variable size with very soft clay surficial veneer	A (1,4,7)	A (1,4,7,10)	A (1,4,7,10)	A (1,4,7,10)	A (1,4,7,10)	From samples, veneer appears thick enough such that Till may not be encountered.	(1) Subsurface boulders may impede burial tools and cause reduced burial. (7) Steep slopes may exceed limitations of chosen tool, limiting use. (10) Potential risk of sinkage for tools without buoyancy capabilities
524.65	531.50	B	0.5		Unsampled				0.7	No sample	Expect extremely low strength clay	A (4)	A (4,10)	A (4,10)	A (4,10)	A (4,10)		(4) Cross cables using designed crossing (10) Potential risk of sinkage for tools without buoyancy capabilities
531.50	548.25	B (D KP 543.2 -544.8)	0.5 (D 1.5)	-Protection level D in vicinity of fish farms -Further assesment of slope stability	CPT/VC 11-SS-03 CPT/VC 11-SS-04 CPT/VC 12-SS-01 CPT/VC 12-SS-02	539.651 542.718 543.438 547.61	653856 654541 655111 658692	6646994 6649993 6650532 6652147	0.7 (D 1.7)	VC 11-SS-03 0-1.7 very low strength silty CLAY VC 11-SS-04 0-0.93 very low strength silty CLAY 0.93-1.7 extremely low strength silty CLAY VC 12-SS-01 0-1.7 extremely low to very low strength silty CLAY VC 12-SS-02 0-1.7 very low strength silty CLAY	CPT/VC 11-SS-03 Clay 15kPa CPT/VC 11-SS-04 Clay 10-15kPa CPT/VC 12-SS-01 Silty Clay 10kPa CPT/VC 12-SS-02 Silty Clay 10-15kPa	A (4,5)	A (4,5,10)	A (4,5,10)	A (4,5,10)	A (4,5,10)		(4) Cross cables using designed crossing (5) Find, cut , move and weight disused cable (10) Potential risk of sinkage for tools without buoyancy capabilities
548.25	549.00	B	0.4		Unsampled				0.6	No sample. Diamicton Till or Bedrock	Expect unsorted granular deposits of variable size , with very soft clay surficial veneer. Burial to 0.7m may be confined to soft veneer.	A/B* (f) (7,12)	A/B* (a) (7,10,12)	B* (c) (7,10,12)	A/B* (c,f) (7,10,12)	A/B* (a) (7,10,12)	(a)Sand/dense sand may cause ride-out with ploughs. (c) Expect increased chain-wear and possibly reduced progress or burial in sandy areas (f) Mixed sand and clay conditions may make sword optimisation difficult when jetting *Difficulty depends upon thickness of clay veneer	(7) Steep slopes may exceed limitations of chosen tool, limiting use. (10) Potential risk of sinkage for tools without buoyancy capabilities (12) If bedrock encountered within assessed depth, none of these tools will achieve target burial.
549.00	557.50	A	0		VC B12-SS-03	555.018	663766	6657473	0	VC B12-SS-03 0-0.5 extremely low strength silty CLAY	VC B12-SS-03 Silty Clay 10kPa	N/A*	N/A*	N/A*	N/A*	N/A*		*Protection Level A - Client stipulates no protection in this area.
557.50	592.60	B (D KP 586.7 - 588.7, KP 591 - 592.6)	0.5 (D 1.5)	-Protection level D in vicinity of fish farms. -Further assesment of slope stability	VC B12-SS-04 VC B13-SS-01A VC B14-SS-01	572.419 586.194 590.893	671601 673305 675629	6671067 6681516 6682836	0.7 (D 1.7)	VC B12-SS-04 0-1.7 extremely low strength silty CLAY VC B13-SS-01A 0-0.55 extremely low to very low strength sandy CLAY 0.55-0.68 very clayey SAND 0.68-1.7 very low strength silty CLAY VC B14-SS-01 0-0.77 extremely low strength silty CLAY 0.77-0.92 very low strength sandy CLAY 0.92-1.7 extremely low to very low strength silty CLAY	VC B12-SS-04 Silty Clay 5-10kPa VC B13-SS-01A Silty Clay, 10kPa VC B14-SS-01 Clay 5-10kPa	A (1,4,5,7)	A (1,4,5,7,10)	A (1,4,5,7,10)	A (1,4,5,7,10)	A (1,4,5,7,10)		(1) Subsurface boulders may impede burial tools and cause reduced burial. (4) Cross cables using designed crossing (5) Find, cut , move and weight disused cable (7) Steep slopes may exceed limitations of chosen tool, limiting use. (10) Potential risk of sinkage for tools without buoyancy capabilities
592.60	594.60	D	1.3	-Protection level D in vicinity of fish farms.	VC B15-SS-01A	592.698	676289	6684498	1.5	VC B15-SS-01A 0-0.7 very low strength silty CLAY 0.7-1.7 very silty SAND	VC B15-SS-01A Silty Clay 5-20 kPa Sand Dr- unknown Depending on veneer thickness, may expect unsorted granular deposits of variable size with very soft clay surficial veneer. Burial to 0.7m may be confined to soft veneer.	A/B* (f) (7,12)	A/B* (a) (7,10,12)	B* (c) (7,10,12)	A/B* (c,f) (7,10,12)	A/B* (a) (7,10,12)	(a)Sand/dense sand may cause ride-out with ploughs. (c) Expect increased chain-wear and possibly reduced progress or burial in sandy areas (f) Mixed sand and clay conditions may make sword optimisation difficult when jetting *Difficulty depends upon thickness of clay veneer	(7) Steep slopes may exceed limitations of chosen tool, limiting use. (10) Potential risk of sinkage for tools without buoyancy capabilities (12) If bedrock encountered within assessed depth, none of these tools will achieve target burial.
594.60	610.00	A (D KP 594.6 - 596, KP 598.5, 599.5)	0 (D 1.5)	-Protection level D in vicinity of fish farms -Further assesment of slope stability	CPT/VC B16-SS-01 VC B16-SS-02	598.768 609.308	676934 682546	6690101 6697615	0 (D 1.7)	VC B16-SS-01 0-1.7 very low strength silty CLAY VC B16-SS-02 0-0.5 Extremely low strength CLAY	CPT/VC B16-SS-01 Silty Clay, 5-10kPa VC B16-SS-02 Silty Clay, 10kPa	A (4,5,7)	A (4,5,7,10)	A (4,5,7,10)	A (4,5,7,10)	A (4,5,7,10)		(4) Cross cables using designed crossing (5) Find, cut , move and weight disused cable (7) Steep slopes may exceed limitations of chosen tool, limiting use. (10) Potential risk of sinkage for tools without buoyancy capabilities
610.00	634.75	A (D KP 616.5 - 619.3, KP 621 - 625)	0 (D 1.5)	-Protection level D in vicinity of fish farms -Further assesment of slope stability	CPT/VC B17-SS-01 CPT/VC B17-SS-02	620.377 630.507	690357 699382	6703185 6706051	0 (D 1.7)	VC B17-SS-01 0-0.23 very low strength silty CLAY 0.23-1.7 extremely low to very low strength silty CLAY VC B17-SS-02 0-0.5 extremely low to very low strength silty CLAY	CPT/VC B17-SS-01 Silty Clay, Clayey Silt 5-15kPa CPT/VC B17-SS-02 Silty Clay 10-15kPa	A (4,7)	A (4,7,10)	A (4,7,10)	A (4,7,10)	A (4,7,10)		(4) Cross cables using designed crossing (7) Steep slopes may exceed limitations of chosen tool, limiting use. (10) Potential risk of sinkage for tools without buoyancy capabilities
634.75	658.70	A	0	-Further assesment of slope stability	[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]	[illegible]	N/A* (4,5)	N/A* (4,5)	N/A* (4,5)	N/A* (4,5)	N/A* (4,5)		*Protection Level A - Client stipulates no protection in this area. (4) Cross cables using designed crossing (5) Find, cut , move and weight disused cable
658.70	661.40	A	0	-Further assesment of slope stability	Unsampled				0	No sample	Expect soft-sediment surficial covering when surface laying	N/A* (5)	N/A* (5)	N/A* (5)	N/A* (5)	N/A* (5)		*Protection Level A - Client stipulates no protection in this area. (5) Find, cut , move and weight disused cable
661.40	664.66	D	1.5	-Nearby quarry freight vessel anchorage, increased burial	CPT/VC B18-SS-08	661.687	724538	6712493	1.7	VC B18-SS-08 0-1.7 very low strength silty CLAY	CPT/VC B18-SS-08 Clay, 15kPa	A (4,7)	A (4,7,10)	A (4,7,10)	A (4,7,10)	A (4,7,10)		(4) Cross cables using designed crossing (7) Steep slopes may exceed limitations of chosen tool, limiting use. (10) Potential risk of sinkage for tools without buoyancy capabilities

Notes:
1. HDD exit at 170 degrees from North 170m away perpendicular from RPL09 survey centre line at KP 0.1
2. Intra-zone KP ranges of potential mobile sediments are given in the "**Seabed features**" column. The mobile sediments column gives the largest thickness of potentially mobile sediment within the zone as described by MMT. Bedform size classification range is given in the report.
3. Patches of mobile sediments are recorded to their full KP extent if they lie in part or fully within a zone.
4. See CBRA report for full details
5. At present it is not possible to accurately report the sub surface boulder risk as distinct from the surface boulder risk, therefore the two have been grouped together in this assessment.
6. For further details please refer to the 6Alpha UXO Report. UXO risk should be updated once interpretation of the 2017 Magnetometer survey is available.
7. Design thickness will vary depending on crossing type (surface laid or buried)
8. All references to KP's and coordinates are based on RPL09.
9. Section boundaries determined using previous geophysical interpretation
10. It is recognised that there is greater risk of cable damage with cable ploughs and chain cutters that make direct contact with the product during installation, however that risk is not assessed in detail in this initial study.

[illegible]

Appendix B.1.1 CPA table comments

The CPA table contains several comments for each section of the survey corridor. These are separated into comments that are applicable to all tools types (although may not affect them equally), which are numbered and comments which relate to a difficulty which may be faced by a specific tool (lettered). They are accompanied by a brief explanation.

This should be considered as a preliminary assessment and a more detailed analysis of the risks will be required as the route is finalised.

Tool specific comments (a-f)

(a) Sand/dense sand may cause ride-out with ploughs.

Ploughs function best through cohesive material, although fluidising jets on the plough share can help it pass through sands more easily.

(b) Possible reduced performance/risk of ride out ploughing in high strength clays. Possible reduced performance of jet trencher in medium-high strength clay/Till.

Clays may be of high strength such that it is not possible for a plough to shear a wedge in the seabed. Jet trenchers have an upper limit of clay shear strength in the region of 80-100Kpa although this depends on the power of the machine.

(c) Expect increased chain-wear and possibly reduced progress or burial in sandy areas

Mechanical trenchers require cohesive soil for the excavating chains to gain purchase and remove material effectively.

(d) Possible reduced performance with some less powerful jet trenchers in medium strength clay/mixed sand/gravel.

Mixed lithologies may pose a problem to jet trenchers which are able to operate in clay or sand jetting mode with different swords specific to the lithology. It is recommended that only high-powered jet trenchers e.g. >800kW are considered for the project.

(e) Gravel component may not be removed when jetting and form a lag in the trench bottom.

Gravel will not be displaced out of the trench by the jet tool, thus may accumulate and fill the base of the trench and reduce the depth of lowering achieved.

(f) Mixed sand and clay conditions may make sword optimisation difficult when jetting

Different jet swords are adapted to cohesive and non-cohesive sediments.

(g) Jetting and chain cutters may have difficulty penetrating through gravelly surficial sediment

Pertinent to UK 12NM area

Comments relevant to all tools (1-11)

(1) Subsurface boulders may impede burial tools and cause reduced burial. See section 5.7

(2) Rock outcrops avoided by routing. Applies to nearshore areas and areas within Hardangerfjorden where it is recommended that the cables are routed around outcropping bedrock where practical.

(3) Increase burial across bedforms or avoid. Specified depth of lowering may be correlated to a non-mobile reference level (NMRL) to account for mega-ripples and sandwaves. Large bedforms are anticipated to be relic features and are unlikely to be mobile. Increased burial across areas covered by smaller bedforms is accounted for in the CBRA/CPA tables.

(4) Cross cable/pipeline using designed crossing.

Crossings of in-service cables and both in-service and out of service (OOS) pipelines should be conducted according to designs, tools will be graded out and in again either side of the crossing.

(5) Find, cut, move and weight disused cable.

A procedure has already been designed for the handling of OOS cables.

(6) Route around pockmarks.

Pockmarks are easily identified on alignment charts and should be routed around to avoid steep gradient and potential free-span.

(7) Steep slopes may approach limitations of chosen tool without prior remediation. Pre-sweeping or rock dump may be required. Transverse-slopes may present stability issues to burial tools, routing should be conducted to ascend/descend significant slopes to be in-line with the slope direction. Free flying mode for some jet trenchers may also help mitigate the risk.

(8) Possible rock placement across steep iceberg scar marks.

Repeated undulations may result in cable tensions and free-spans, levelling using a plough/rock placement may ease installation.

(9) Shallow or exposed bedrock may preclude burial using tools and instead require rock-placement protection.

Bedrock (and bedrock covered by a sediment veneer) near the Norwegian Coast and between approximately KP506 and KP509 may preclude the use of burial tools and require alternative protection and stabilisation of the cable (Likely using rock placement).

(10) Potential risk of sinkage for tools without buoyancy capabilities

The NorthConnect route has many areas of soft clay with shear strength of 10kPa or less. This may pose a problem for many tools which do not possess buoyancy tanks to reduce their bearing pressure on the seabed and have skids/free flying mode. Bearing capacity failure of the seabed soils beneath the tool could cause it to get stuck or become unstable.

(11) Avoidance of surface boulder area may reduce risk of subsurface boulders

A significant surface boulder area may be avoided, reducing the chance of encountering subsurface boulders.

(12) If bedrock encountered within assessed depth, none of these tools will achieve target burial

None of the assessed tools will be able to install the cable to target depth if shallow rock is encountered. Depending on the minimum lowering requirements, this may or may not be accepted, or require rock placement remediation.

Appendix C – Alignment Charts

Alignment charts are supplied in a separate file.

Appendix D – Cable Burial Techniques and Tools

Appendix D.1.1 covers different cable burial techniques and relates primarily to the different methods and their benefits/drawbacks. Appendix D.1.2 covers cable burial tools, their strengths and limitations and suitability for the different techniques outlined in D.1.1. Appendix D.1.3 covers further protection methods other than trenching.

Appendix D.1.1 Cable Burial Techniques

The main construction methodologies available for cable burial are:

- **Horizontal Directional Drilling (HDD)** – Utilised to install cable from the onshore transition joint pit (TJP) to a point on the nearshore. Generally, distances from the TJP of hundreds of metres (although kilometres are possible) and at depths of several tens of metres below surface. Relevant for UK landfall.
- **Imbedded Ducts** – as an alternative to HDD, open trenches may be created with ducts laid and the trench backfilled, prior to cable pull in. Relevant for Norwegian landfall.
- **Post-lay trenching** – cable buried by cable plough or trencher after it has been laid on the seabed.
- **Simultaneous lay/trenching/(burial)** - cable is paid out from a cable lay vessel and entrenched in a simultaneous operation.
- **Pre-lay trenching** –a trench is pre-cut or ploughed and the cable subsequently laid into an open trench followed by an optional backfill operation by plough, natural backfill or rock placement.

The most appropriate method depends on numerous factors, not least that the cable is type-approved for the method to be utilised. These methods are discussed briefly below.

Horizontal Directional Drilling (HDD) – Cable Landing Area

The HDD landing at Boddam, Peterhead has already been assessed/designed by Riggall & Associates to transition the cable from the nearshore seabed to landfall, bypassing the rocky and environmentally sensitive cliffs. Note: The southern alignment option has been chosen for the HDD alignment. The HDD will be discussed in a separate Riggall & Associates report.

Imbedded Ducts

It is understood that the intention is to protect the cables at the Simadalen landfall using embedded ducts. This will be addressed in a separate report.

Post-lay trenching/burial

For this method, the cable would be seabed laid by a cable-laying vessel and burial is carried out using a suitable tool in post-lay mode. (See Appendix D.1.2)

Due to laying the cable first, there is a risk of damage to the unburied cable due to the time between lay and burial operations, however this risk can be mitigated using guard vessels to protect from passing trawlers etc. The friction of the cable passing through the burial tool can lead to a build-up of slack cable ahead of the tool potentially resulting in a kinked cable. At the same time, tension behind the machine can lead to free spans in areas of uneven seabed, or reduced lowering as trench back-fill before the cable under tension reaches the bottom of the trench (This may be a particular problem in the gravel in the UK nearshore waters).

Operational risks are always present surrounding launch and recovery of the burial tool from the vessel, especially in high sea states. Landing an ROV jetting tool on the seabed safely straddling the cable can also be a challenging operation in high seas.

Although both towed and self-propelled tools can use this method, control methods, and operational principles are different and carry different risks, as discussed in Appendix D.1.2.

Simultaneous lay/trenching/burial

Cables are laid, trenched and buried in a simultaneous operation with burial equipment being towed by the cable laying vessel or barge, in the case of a plough or burial sled, or operated from the cable laying vessel where a self-propelled Remotely Operated Vehicle (ROV) is utilised.

This approach offers immediate protection to the cable. Operation is efficient as only a single vessel is required. Cable tension can be managed by the cable lay system as the cable enters the burial tool. However, as with post lay burial, direct contact between the tool and cable can increase the risk of cable damage during installation. Furthermore, there is increased risk of damage due to numerous recoveries and deployments at pipeline and cable crossings.

The cable catenary can be monitored in the water column by ROV during the process. A disadvantage with this method as opposed having separate phases of trenching and cable laying is that a breakdown, weather downtime or other failure may cause greater disruption to the project critical path as both the trenching and cable laying are impacted.

Although both towed and self-propelled tools can use this method, control methods, and operational principles are different and carry different risks, as discussed in Appendix D.1.2.

Pre-lay trenching

For this method, a separate vessel would create an open trench using a plough, jet trencher or even mechanical trencher. The cable is then positioned into the trench in a separate, subsequent operation which may be assisted by ROV.

Laying the cable into a pre-cut trench is sometimes considered to offer a low risk construction method, whereby a plough/trencher is used to create a large trench, carrying out the aggressive soil cutting without the presence of the cable product(s). The product can then be laid into this trench and back filled by a second pass with a backfill plough or protected with dredged material/rock placement laid over the product. Thus, at no point should the product be expected to come into contact with a tool. This approach would mean that the risk of installation damage to the cable (requiring expensive repair) is in theory much reduced compared to the post-lay burial and the simultaneous lay and burial techniques. However, difficulties exist in the accurate positioning of the cable into the base of the trench, which may be assisted by ROV. For this reason, backfill using a plough may be seen as higher risk since the cable could be left ‘hung’ on the shoulder of the trench and risk being damaged during backfilling (less applicable for rock placement). Sediment infill and trench wall collapse could reduce trench depth over the time between the trenching and cable-laying operations.

Separating different project phases as in pre-lay and post-lay trenching methods may make the project critical-path more resilient to weather or other disruptions.

A pre-cut trench may reduce the risk of reduced burial depth compared to simultaneous lay and burial or post-lay burial, as multiple passes are possible. Ploughing a pre-cut trench may also be more effective at displacing obstructive boulders using mechanical force.

Appendix D.1.2 Cable Burial Tools

There are a diverse range of cable burial machines available on the market capable of burying and protecting offshore cables. All the cable burial tool types summarised in this section are used on a worldwide basis and on all different types of subsea cable systems. However, the suitability of all equipment discussed needs to be assessed based on seabed conditions and preferred burial methodology. Any reference to particular tools does not imply a preferred suitability for this project.

Within the UK the Department for Business, Enterprise and Regulatory Reform (BERR) produced a report (Ref. 32) detailing cabling techniques and environmental impact of cabling "Review of Cabling Techniques and Environmental Effects Applicable to the Offshore Wind Farm Industry". This report identified various types of cable burial machines which are summarised below. For this report, these fall within 5 main classes of machine:

- Cable Burial Ploughs (various types)
- Pre-trenching ploughs
- Jetting Systems (Tracked and free swimming ROV's, MFE dredging)
- Mechanical Trenchers (Chain cutters)
- Combined jetting and cutting systems

Burial sleds are not considered appropriate for NorthConnect due to the depth of water along the alignment.

Table D.1 Summary of tool types

Tool Type:	**Cable Burial Ploughs**	**Pre-cut trenching ploughs**	**Jetting Systems***	**Mechanical Trenchers (Chain cutters)***
Method of trenching:	*Clay:* Shear and displacement of clay wedge, cable laid in slot	*Clay: Shear and displacement of cohesive soil*	*Clay:* High pressure, low volume jet shearing and displacement.	*Clay:* Cutting (shear) and displacement.

Tool Type:	Cable Burial Ploughs	Pre-cut trenching ploughs	Jetting Systems*	Mechanical Trenchers (Chain cutters)*
	Sand: Displacement (can be aided by fluidising jets)	*Sand: Displacement of non-cohesive soil*	*Sand:* Low pressure, high volume water, suspension of grains and removal.	*Sand:* displacement, chains may struggle to gain purchase in sand, limiting progress and causing excessive chain-wear.
Trench profile:	*Soft sediment:* Ploughed slot partially collapses and infills after operation	*Soft sediment:* Wide V-shaped furrow in seabed with mounded displaced sediment either side.	*Soft sediment:* U-shaped trench (varies with swords), partial backfill by settled material. Rear educator (where present) may influence backfill.	*Soft sediment:* Slot which may subsequently degrade. (Some machines use two cutters in V-shape)
	Hard Clay: Narrow slot left in seabed.	*Hard Clay:* As above	*Hard Clay:* Jets may struggle to overcome shear strength of high strength clay to form trench.	*Hard Clay:* Slot in seabed. Rear cutter wheels may help collapse backfill on top of product. (Some machines use two cutters in V-shape)
	Dense Sand: As with soft sediment	*Dense Sand:* As above	*Dense Sand:* As with soft sediment	*Dense Sand:* Inappropriate tool, if slot were formed, rapid degradation likely.
Tool propulsion:	Towed	Towed	Various (self-propelled tracks, free swimming ROV thrusters, towed)	Self-propelled tracks
Installation methods for	Post-lay trenching/burial	Pre-lay trenching	*Pre-lay trenching*	Pre-lay trenching

Tool Type:	Cable Burial Ploughs	Pre-cut trenching ploughs	Jetting Systems*	Mechanical Trenchers (Chain cutters)*
which tools are appropriate:	Simultaneous lay/trenching/burial	Multiple passes possible	Post-lay trenching/burial Simultaneous lay/trenching/burial Multiple passes possible	Post-lay trenching/burial Simultaneous lay/trenching/burial
Limitations:	Dense sands may require jet-assistance on plough share to achieve adequate burial. Requires contact with product – increasing risk of damage.	Dense sand may require jet assistance on plough share if available.	Inappropriate for clays above 80-100 kPa in strength. May be more adversely affected by boulders.	Inappropriate for non-cohesive sediments as chains/cutters will struggle to gain purchase. May be more adversely affected by boulders. Requires contact with product – increasing risk of damage.
Typical Machines:	See Appendix E.1.1.1	See Appendix E.1.1.2	See Appendix E.1.1.3	See Appendix E.1.1.4

Note*: Combined chain cutting and jetting tools are available which combine the advantages, and negate some of the disadvantages, of each method.

Table D.2: Burial Performance Comparison (based on BERR, Ref. 32)

Cable Burial Devices	Burial Device Options	Sediment Type				
		Sands	Silts	Gravels	Weak Clays	Stiff Clays
Cable Burial Ploughs	Conventional plough	✓	✓	✓	✓	✓
	Advanced plough	✓	✓	✓	✓	✓
	Modular plough	✓	✓	✓	✓	✓
	Rock ripping plough	✓	✓	✓	✓	✓
	Vibrating share plough	✓	✓	✓	✓	✓
Tracked Cable Burial Devices	Jetting Systems	✓	✓	?	✓	X
	Rock Wheel cutters (mechanical trencher)	P	P	P	✓	✓
	Chain excavators (mechanical trencher)	P	P	✓	✓	✓
	Dredging systems (jetting)	✓	?	?	X	X
Free Swimming ROVs	Jetting systems	✓	✓	?	✓	X
	Dredging Systems (jetting)	✓	?	?	X	X
Burial Sleds	Jetting Systems	✓	✓	?	✓	X
	Rock Wheel Cutters (mechanical trencher)	P	P	P	✓	✓
	Chain excavators (mechanical trencher)	P	P	✓	✓	✓
	Dredging Systems (jetting)	✓	?	?	X	X

Key

✓ = Should be capable of burial

? = Performance will be related to the type of sediment and the power delivery to the burial device

P = Performance possible in the sediment type but not an ideal option

X = Unlikely to be capable of burial

D.1.2.1 Cable Burial Ploughs

See Appendix E.1.1.1 for examples

Generally, cable ploughs are towed from a host vessel with sufficient bollard pull to ensure continuous progress through the seabed with the cable being simultaneously buried as part of the lay process. The plough shears and lifts a wedge of soil and places the cable at the base of the trench, before the wedge of soil gravitationally backfills over the cable. Cable ploughs can work in a wide range of soils and may have greater resilience against smaller subsurface boulders compared to jet tools. One primary limitation of cable ploughs is the limit in product diameter and the limited allowable bend radius associated with them. However, in recent years many existing ploughs have been modified to handle larger diameter cables. Towed manoeuvrability for small-scale routing is limited compared to tracked ROV tools.

The different types of cable burial plough available are listed below:

- Conventional Narrow Share Cable Ploughs
- Advanced Cable Ploughs
- Rock Ripping Ploughs
- Vibrating Share Ploughs
- Pre-trenching Ploughs

D.1.2.2 Pre-Trench Ploughs

See Appendix E.1.1.2 for example

Some ploughs are specially adapted for creating a sizeable pre-cut trench into which a cable can be later laid and buried. These ploughs are well suited to operating across rough sea beds up to megaripple size (3m), large sandwaves may be better treated using a dredging technique. An example is the SCAR plough, see Appendix E.1.1.2., which can fulfil multiple functions including boulder clearance and backfill passes. A major advantage is that multiple passes may be performed off the critical path for installation.

D.1.2.3 Jetting Systems

See Appendix E.1.1.3 for examples

A jetting system works by fluidising the seabed using a combination of high flow low pressure and low flow high pressure water jets to cut into sands, gravels and low to medium strength clays. Progress in clays is dictated by the available power budget and the level of cohesion in the clay.

In some cases, a dredging system is employed to suck out the fluidised material to leave an open trench into which the cable then falls by its own weight.

The mechanisms for jet trenching in clays and cohesion less sands/gravel soils are fundamentally different.

- Sands are most efficiently fluidised by a large volume of water flowing over the trench cross sectional area, with a large water volume required to lift the sand particles into suspension. The trench will naturally backfill due to settlement of sand particles out of suspension. Typically, between 60% and 80% backfill may be assumed for a single pass in sand. Coarser materials such as gravels fall more rapidly through the water column and as a result it is more difficult to displace these soils and adequately bury a cable in a single pass.

- When jet trenching in clay, the jet pressure must be greater than a threshold value at which the clay can be cut into blocks and disaggregated. This pressure is related to the undrained shear strength of the clay. Backfill can vary considerably depending on the nature of the clay and on tooling (e.g. educator) set up.

Jetting machines usually bury the cable as a post-lay operation i.e. the cable would be laid on the seabed and then the jetting machine would bury the cable in a subsequent operation. Trench profiles are wider than when using cable ploughs but may be narrower than some pre-cut ploughs, although the residual profile will change dependent upon the amount of backfill achieved.

A major advantage of jet trenchers is that multiple passes may be performed although with some 1MW or even 2MW machines now available, generally a single pass is sufficient to achieve an optimised burial depth in suitable seabed sediments.

Jetting machines may be classed as either;

- Tracked
- Free swimming ROVs
- Burial sleds

<u>Tracked</u>

Tracked cable burial vehicles are usually operated and controlled from a host vessel such as a Trenching Support Vessel (TSV) or a barge, have subsea power packs, and are controlled via an umbilical cable back connected to the host vessel. They usually operate in post lay burial mode. The tracked cable burial vehicles are typically used on shorter lengths of cable burial work. Divers may be required to assist in the loading and unloading of cable into and out of the vehicle in the shallow water machines (only applicable at Norwegian shore ends for this project). However, some vehicles have fully automated cable loading/in-loading equipment. Some vehicles track over cables and straddle the cable with jetting swords. In the tracked machines, the jetting tools can be fitted with a depressor, which helps to guide the cable downwards in the fluidised trench. The effectiveness of any depressor system will be limited by the minimum bend radius, or stiffness, of the cable being buried, and the on-bottom weight of the tracked cable vehicle itself to provide a downwards force onto the cable. This type of burial operation gives rise to sediments being suspended in the water adjacent to the burial operation, and it takes several hours for sediments to settle before full visibility recovers in the water column. Some examples of the tracked cable burial machines with jetting systems on the market are Q1000, T1200, Capjet Trencher, CT2, Trencher T1 or Trencher T2.

<u>Free Swimming ROVs</u>

Free swimming ROVs are operated and controlled from a host vessel such as a TSV or a barge. They will always operate in post-lay burial mode with their range of application limited to sands and clays (performance in clay will be directly related to available jetting power). Some of the current Free-Swimming Burial ROVs can interface to a tracked work package. This provides the free-swimming burial ROV with a stable work platform for burial operations and the capacity to revert to free swimming mode when inspection and intervention tasks are required, as well as more manoeuvrability. Some free-swimming burial ROVs have power budgets of over 300kW and are equipped with manipulators for handling tasks. Cable cutters, cable grippers and burial tools are fitted to both the forward and rear sections of the ROV. Also, jetting lances fitted to the end of a manipulator arm, allow for localised burial. Some examples of the free-swimming burial ROVs with jetting systems on the market are Excalibur, CMROV3 and CT1.

Such tools could be utilised in areas of very steep slope in the Hardangerfjorden.

Burial Sleds

Burial sleds are usually operated in shallow waters for work in ports, estuaries, river crossings and shore-ends for cable systems. Water depths encountered on the NorthConnect route discount burial sleds such as the Prysmian Hydroplow (50m depth max) from use.

D.1.2.4 Mechanical Trenchers

See Appendix E.1.1.4 for examples

Mechanical trenchers fall into two categories mechanical rock wheel cutters or mechanical chain excavators. These two types are discussed below.

- Mechanical rock wheel cutters: Mechanical rock wheel cutters are used to cut narrow trenches into hard or rocky seabed and consist of a rotating wheel disc, which is fitted with rock cutting teeth.
- Mechanical chain excavators: The chain excavator tool consists of many cutting teeth and a further number of mechanical scoops which are used to transport the cut material away from the trench. An auger is sometimes in place, which helps move material away from the trench or clogging the chain cutters.

When trenching in extremely high strength clays and rock for both rock wheel cutter and mechanical chain trenchers a narrow slot is formed into which the cable is lowered. The material is removed as the action of the cutting causes it to be broken down into its constituent parts.

When using chain excavators in sands and gravels the movement of the chain fluidises the granular soil near the cutter, forming a low resistance "slot" for the cable to be pushed through. In this case, because the soil is being fluidised without an open slot being formed, the disturbed material can and does largely remain contained within the ground. Unlike in cohesive conditions where the soil is physically sheared, in non-cohesive conditions the chains will gain limited purchase on sands which may limit forward progress and cause excessive chain-wear.

Mechanical trenchers are usually post lay burial machines. Some examples of the mechanical rock wheel cutters on the market are LBT1, TM02, TM03. Some examples of the mechanical chain excavators in the market are I-Trencher, Trencher T1, Trencher T2, TM03, RT1.

In addition, some machines now have added jetting capabilities. An example of this would be SMD's CBT800, and CBT110 which is a tracked vehicle and is equipped with chain cutters, dredge pump and jet legs with depressor.

Appendix D.1.3 Additional Cable Protection Methods

Cable routing is noted to be the principal method of avoiding hazards. Once the final routes have been identified, any remaining risks to the cables, and the impact to other seabed users from the cables can be accurately identified. This then allows for further protection if required.

Circumstances in which external protection may be required include; burial not achieved due to ground conditions, slopes too steep for burial tools or limited sediment thickness over rock head in which to bury the cable. Protection can be achieved by the following methods:

- Rock placement – This technique, one of the most established methods of cable protection, is anticipated to be used in areas of cable crossings, where pre-lay (separation layer) and post-lay (protective cover) rock placement is applied. It shall also be employed in areas of reduced/limited burial to provide a height of external protection equivalent to the targeted depth of burial. Initial berm designs have been established, with some preliminary design checks completed to satisfy hydrodynamic stability and trawl/anchor impact resistance. Further analysis will be performed at detailed design stage. The total volume of rock placement will be restricted according to the marine licence.
- Mattressing - Concrete mattresses are also used for crossings over existing subsea cables and pipelines. Typically, they are prefabricated concrete block sections connected by polypropylene rope and form a semi rigid structure. One of the main benefits of the use of concrete mattresses is their acceptance by fishermen who consider concrete mattresses to be potentially less damaging to their fishing gear and the local environment than other methods such as rock placement, however installation time is significantly longer than for rock placement and so is unsuitable for long distances.
- Frond mattresses – are a variation on concrete mattresses. Their primary objective is to stimulate the deposition of sediment from the water column at a location in the direct vicinity of the cable or pipeline. When the suspended sediment comes into contact with the frond mattress, it is forced to settle, thus creating a new sandbank which serves to protect the cable.
- External cable protection system (e.g. iron half shells, Tekmar, Uraduct etc.) – iron or a high performance polyurethane elastomer encases the cable, typically through the use of cylindrical half shells which overlap and interlock to form close fitting protection. The half shells are usually less than 2 m in length for ease of handling and may possess a degree of flexibility (plastic versions only) to suit the required minimum bend radius of the cable. These types of product also come in varying degrees of stiffness to resist different levels of predicted impact. As a result, these products are particularly useful at cable crossing points or in areas close to structures such as wind

turbines or oil and gas installations, where the risk from dropped objects is high. In addition, they can be used as bend restrictors for cables. These systems are not typically used to protect long lengths of cable but are being considered for the Norwegian shore ends.

- Grout or sand bags – effectively a small-scale concrete mattress system, lying over the cable. In most cases, they are lowered, pre-filled to the seabed and then positioned across the cable/pipe by a diver. In some instances, grout bags are lowered empty, before being filled on the seabed by a diver, utilising a grout mix pumped from the host vessel. Whilst they offer protection from impacts from smaller scale fishing gear and anchors, they are primarily used to stabilise or fix a cable over short distances or for short durations.
- Kyowa's Filter Unit - this is essentially a bag made of synthetic raschel knitted net which is typically used for protection of river banks, sea revetments or bridge footings. Usually filled with stones or cobbles, the bag can be placed over cables in much the same manner as a grout or sand bag. The major benefit of using this method is the fact that the bag acts as a sediment trap, resulting in the creation of sandbanks. As with previously mentioned methods, which result in sandbank creation, environmental impacts need to be accounted for.
- Primary Cable Armour - Cable armour provides a level of protection to the cable and can be increased depending upon the severity of the hazard identified. For example, armour can provide protection against small vessel anchors and fishing gear. Generally however, impact from such hazards should be avoided all together.

Appendix E – Contractors and Equipment

Table E.1 – Summary of various contractors with interconnector capability

Contractor	Example Equipment	Interconnector / OWF Export Cable Experience	Comments
Prysmian (Turn-key)	HydroPlow HD3 plough Sea Mole SeaRex Jet Trenching Tractor	North Sea Link Trans Bay Cable Western Link Hudson Transmission Project Walney 2 OWF SAPEI Thanet OWF Greater Gabbard OWF Presently Awarded – COBRA	Single tool internal solution and sub-contract for greater redundancy e.g. Canyon. Good interconnector experience.
NKT Cables (incl. former ABB cables) (Turn-key)	Equipment of Opportunity, e.g. Ecosse Sub Sea Scar plough	East-West Interconnector Project Caithness Moray System BritNed Baltic-1 OWF Riffgat OWF	Presently subcontract installation works. Good interconnector experience.
Nexans (Turn-key)	Capjet Jet Trenchers	Moyle Interconnector Maritime Link (just starting) Kintyre-Hunterston Romulo Sheringham Shoal OWF NorNed Cometa	Single tool internal solution, limited experience with other tooling (chain cutter, controlled flow excavation, dredging etc.) but willing to subcontract (DeepOcean). Good interconnector experience.
VBMS	HD3 Plough Sea Stallion Plough Trenchformer (mechanical cutter / exchangeable jetting sword) ROV107-1100	Guernsey–France Interconnector Galloper OWF Luchterduinen OWF Solent Crossing Java–Bali Interconnector Westermost Rough OWF West of Duddon Sands OWF Baltic 2 OWF Humber Gateway OWF	Highly experienced and flexible approach, good staff retention. Capable vessels and tools. Limited interconnector experience but plenty of export cable experience and very capable tools.

Contractor	Example Equipment	Interconnector / OWF Export Cable Experience	Comments
Jan de Nul	UTV1200 (tracked trencher) Trailing dredger options	Burbo Bank Extension OWF Ras Laffan – Halul Island Interconnector	Highly experienced and flexible approach, good staff retention. Limited interconnector experience but some export cable experience. Numerous capable vessels
Tideway (DEME Group)	CBT1100 (Tractor-based jetter)	Thornton Bank OWF Northwind OWF Statnett / NorNed Interconnector	Highly experienced and flexible approach, good staff retention. Limited interconnector experience.
Van Oord	Trailing dredger options Q1600	Gemini OWF Eneco Luchterduinen OWF	Highly experienced and flexible approach, good staff retention. Limited / zero interconnector experience.
DeepOcean	ACP, MD3, MPS, PCP-1, PCP-2, AMP-500 (Ploughs), UT-1, T1000, PT-1, T2 (Jetters), T3200 (Rock Trencher)	NEMO Link (UK – Belgium) Walney Extension OWF Race Bank OWF East Anglia OWF	Highly experienced and flexible approach, good staff retention. Multiple assets.
Siem Offshore	Equipment of Opportunity, e.g. Ecosse Sub Sea Scar plough, LD Travocean	Caithness Moray System Beatrice OWF Hornsea One OWF Nordess One OWF Veja Mate OWF Galloper OWF	Route preparation works only to date on interconnectors. Extensive array cable experience and capable vessels.
LD Travocean	ROVJETS 810, 806, 605; Trenchers TM03, TM04; Ploughs TJV06, TJV 07, EBJ	Thornton Bank OWF	Limited / zero interconnector experience. Extensive OWF infield cable experience, some export cable experience.
Canyon (Helix)	T Series jet trenchers I-Trencher (mechanical trencher)	East West Interconnector Project Sheringham Shoal OWF	Highly experienced and flexible approach, good staff retention. Good interconnector experience.
Ecosse Subsea Systems	SCAR seabed system (multiple configurations), SCAR Jet	Hornsea Project One Interconnector Project Phase 1& 2 Kriegers Flak Beatrice Offshore Wind Farm Wikinger Offshore Wind Farm	Pre-cut trenching, boulder clearance, backfill ploughing operations. System aimed at providing economic trenching that minimises risk to product.

Contractor	Example Equipment	Interconnector / OWF Export Cable Experience	Comments
Global Marine Group	Q1000 Atlas Hi-plough Rocksaw Injector ST200 XT600	Estlink Gunfleet Sands export cable Gwynt Y Mor export cables Kentish Flats export cables	Extensive track record in offshore renewables and telecommunications. Limited interconnector experience. Multiple tools available.
JD Contractors	In house jetting ROVs, mechanical trenchers, and jet sleds	Horns Rev 3 export cable	Track record in offshore renewables and telecommunications. Limited interconnector experience.

Appendix E.1.1 – Summary of Example Tools on the Market

The following section provides a selection of the specifications of various tools used by different contractors which may be suitable for this project. Performance is dependent on multiple factors; the required burial depth, soil conditions and product size. The water depth encountered on the NorthConnect corridor rule out tools such as the Prysmian Hydroplow as it is limited to 50m operating depth, similarly the HD3 plough is not suitable for the deepest sections of the corridor (more than 800m). In terms of product diameter, the anticipated ~120mm HVDC NorthConnect cables should be suitable for the majority of tools on the market.

This section will cover the five main types of tool that may be considered for the NorthConnect project, as well as a brief summary of rock placement vessels at the end of this section.

This list is by no means exhaustive or constituting a recommendation. It is intended only to provide examples of the types of machines available and a brief summary of their specifications and capabilities in different soil conditions

E.1.1.1 Cable Burial Ploughs

SMD HD3 Plough (Prysmian, VBMS)

This tool offers simultaneous lay/burial capabilities with jet assistance in sand. Limited depth of operation makes it unsuitable for parts of Hardangerfjorden*. Progress is provided by towing force and jet fluidization on the plough share is utilised to reduce ride-out in sandy areas.

- Max burial depth: 3.3m
- Max soil undrained strength: 300 kPa
- Max water depth: 500m*
- Jet assist power: 350 HP
- Max product diameter: 300mm

HD3 Plough (Source: Prysmian)

PCP-2 (DeepOcean)

A jet-assisted plough offering either simultaneous lay/burial or post-lay burial modes.

- Max burial depth: 3m
- Suitable soils: Sands, very soft to hard clays
- Jet assist power: 400 HP
- Max product diameter: 230mm

PCP-2 Plough (Source: DeepOcean)

E.1.1.2 Pre-trenching ploughs

SCAR Plough (Ecosse Subsea Systems)

Plough available in two main sizes, 17-40 Ton (ballast variable, SCAR 1,2,3) and 105 Ton (SCAR MAX The plough is towed by a vessel and can be configured for the following roles:

- Boulder clearance
- Pre-cut trenching
- Simultaneous or post-lay trenching and Burial
- Trench backfilling

Main specifications:

- Max operating depth: 0 to 3000m+
- Trench depth: SCAR 1,2,3 1.4m single pass, 3.4m multiple. SCAR MAX 3m single 7.4m multiple.
- Minimum turning radius <50m (Scar 1,2,3), <75m SCAR MAX, duplicates vessel route.
- Can be launched I high seas from stern roller.

SCAR Plough (Source: Ecosse Subsea Systems)

E.1.1.3 Jet Trenchers

T1200 (Canyon/Helix)

The T1200 ROV can operate as a tracked vehicle over c_u > 3.5 kPa shear strength soils, or as a skidded configuration utilizing its buoyancy tanks and thrusters. Different swords allow burial to 1,2 or 3m and configuration to suit sand or clay soils. The ROV can be equipped with a real-time burial depth indicator. Optional rear educator provides backfill. A tool is fitted to enable the ROV to collapse the trench and bury the cable during as a separate pass.

- Power: 1200 HP (1500 HP version also available)
- Max trenching depth**:** 3m
- Max soil undrained strength: 125 kPa (100 max recommended)
- Speed: 25 – 780 m/hr. As an example, for 2m burial in a single pass in 10 kPa Clay, the expected progress rate is 450m/hr.
- Max product diameter: 915mm

T1200 (Source: Helix)

T1000 (DeepOcean)

The T1000 utilizes the same concept as the T1200 (above). It can operate on tracks or skids. A rear educator dredge can be fitted to provide backfill. It can operate in multiple passes as with the T1200.

- Power: 1000HP (1400 HP system also available)
- Max trenching depth: 3m
- Max soil undrained strength: 80 kPa
- Max speed: 400 m/hr.
- Max product diameter: 500mm

DeepOcean T1000 (Source: DeepOcean)

ROV Trencher 107-1100 (VBMS)

Tracked/ROV system

- Power: 1100 HP
- Max trenching depth: 2.3m
- Max soil undrained strength: 110 kPa
- Speed: 100-600 m/hr.
- Max product diameter: 630mm
- Single sword

VBMS 107-1100 (Source: VBMS)

CAPJET 1MW systems (Nexans)

Wheeled ROV trenching system with dual swords, fore and aft, three near identical machines available.

- Power 1340 HP
- Max trenching depth: 2.8m
- Max soil undrained strength: 40 kPa for efficient trenching, >100 kPa cannot expect acceptable performance.
- Speed: see Nexans Standard Trenching Qualifications.
- Max product diameter: 500mm

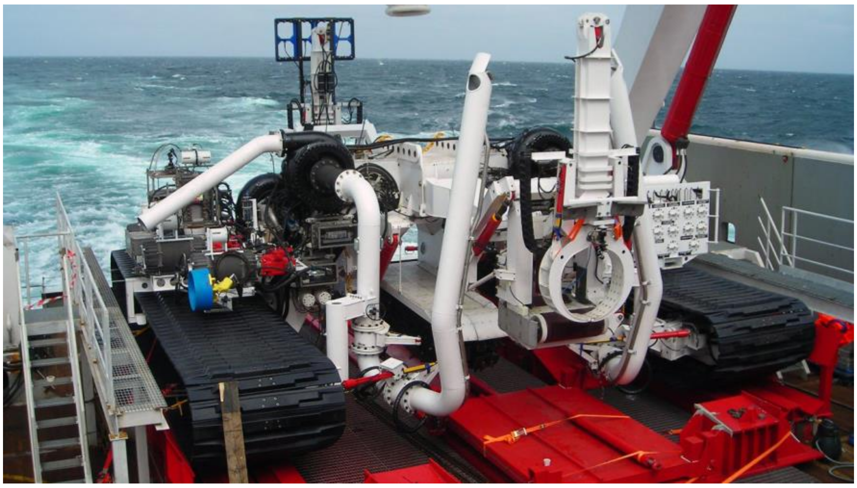
CAPJET 1MW (Nexans)

E.1.1.4 Mechanical Trenchers (Chain Cutters)

I-Trencher (Canyon/Helix)

Tracked mechanical trencher with different cutter options depending on trenching requirements.

- Cutting power: 540 HP (400kW)
- Max burial depth: 2m
- Minimum soil strength for bearing of tracks: 10 kPa
- Max Speed: 500 m/hr. (as with other products, depends on burial depth target)
- Max strength of material: >600 kPa



I-Trencher (Image Source: Royal IHC)

E.1.1.5 Combined Jet Trenchers and Chain Cutters

T3200 (DeepOcean)

Combined jetting and cutting, tools can be deployed independently depending on the conditions encountered.

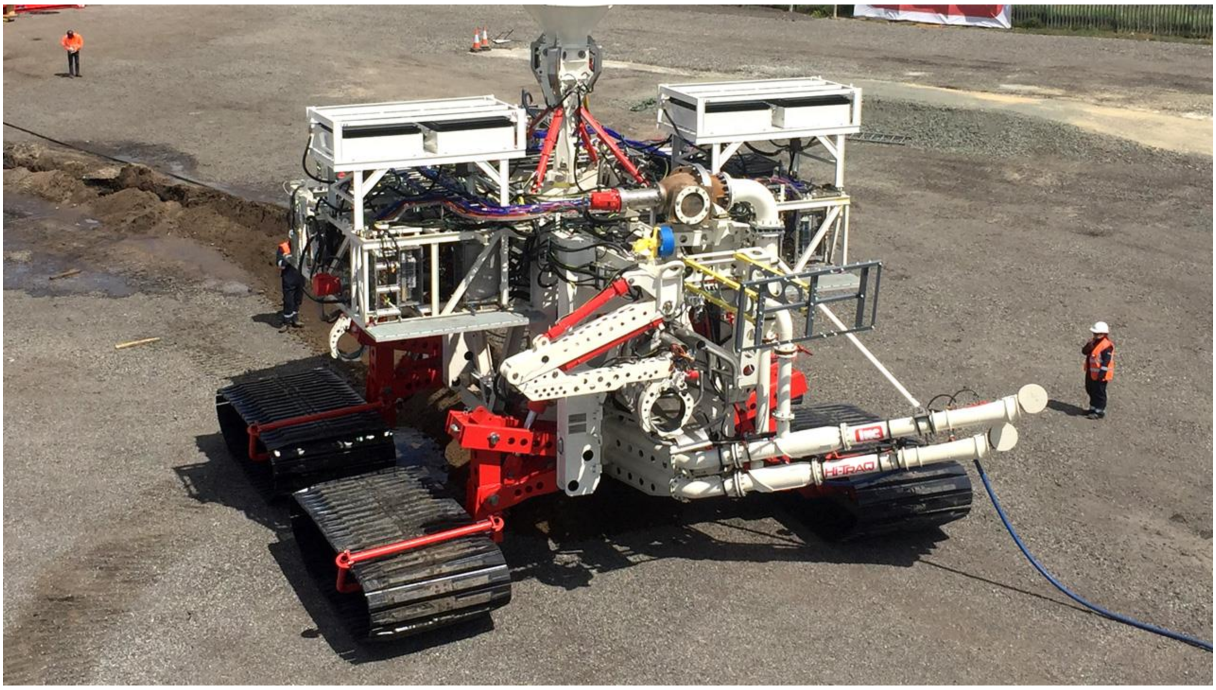
- Maximum operating depth 500m
- Total power: 3200hp (2400kW)
- Jetting power: 1200kW (1600hp), maximum trench depth 3.5m
- Chain cutter: 800kW (1100hp), maximum trench depth 3.5m
- Soil bearing pressure 35-42kPa depending on tooling (unknown how this translates to minimum soil strength, enquire. Very heavy machine so likely to be high)

DeepOcean T3200. Image source: deepoceangroup.com

Hi-Traq (Canyon/Royal IHC)

The Hi-Traq is a new tool that is targeted at installations in challenging conditions, namely variable soil types, steep and transverse slopes. To this effect it has 4 independently controlled sets of tracks allowing self-levelling along transverse slopes of up to 20°, as well as a minimum turning radius of 15m. Both jetting and chain cutting tools are carried, to be deployed as required in soft or hard soils. Jetting pressure can be varied along length of the sword allowing power to be targeted at specific horizons.

- *Main specifications:* Total power: 1200kW (1600hp)
- Jetting power: 900kW (1200hp), maximum trench depth 3.3m
- Chain cutter power: 600kW (800hp), maximum trench depth 2.3m
- Minimum soil strength: 15 kPa
- Maximum operational slopes: 20° (pitch and yaw)



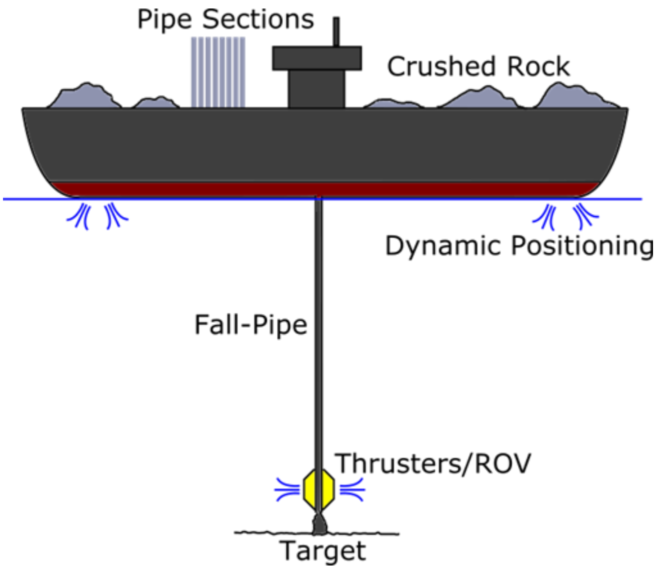
Hi-Traq: Image source: Royal IHC

Appendix E.1.2 –Rock Placement Contractors and Vessels

Rock placement is achieved in deep water using fall pipe vessels (FPV's). The following table provides examples of rock placement contractors and their vessels. See schematic below table E.2.

Table E.2: Rock Placement contractors and vessels (Fall-Pipe)

Contractor	Vessels
Boskalis	Rockpiper
Jan de Nul	Multiple vessels e.g. Joseph Plateau, Simon Stevin
Van-Oord	Stornes, Nordnes
DEME/Tideway	Seahorse, Rollingstone, Flintstone



Schematic of Fall-Pipe vessel

Appendix F – Rock Placement Volume Estimate

Project Name:	**NorthConnect**
Project Number:	**C831**
Client Name:	**NorthConnect KS**
Location	**Northern North Sea**

Estimated Rock Placement Volumes (Per Cable)

FOR INFORMATION ONLY

CATHIE ASSOCIATES

NORTHCONNECT CONNECTING RENEWABLES

NOTE: No losses of material are accounted for when jet trenching, whereas complete backfill with placed rock is accounted for when pre-lay ploughing.

Reduced burial length, assuming a conceptual grid model of boulders (0.5m x 0.5m x 0.5m in size) based upon observed density (MMT), and expected corridor width and depth of influence of installation tool.

	Length of reduced burial (km)					
Jetting (up to 1.0m width and 1.5m depth of influence)	Layer 1 (0-0.5m) distruptive strike (no burial)	% length	Layer 2 (0.5-1.0m) disruptive strike (burial limited to 0.5m)	% length	Layer 3 (1.0-1.5m) disruptive strike (burial limited to 1m)	% length
Occasional boulders	0.01125	1.125	0.01125	1.125	0.01125	1.125
Numerous boulders	0.0225	2.25	0.0225	2.25	0.0225	2.25
High density boulders	0.045	4.5	0.045	4.5	0.045	4.5
Pre-lay ploughing 3m wide 1m deep V-shaped share	Layer 1 (0-0.5m) distruptive strike (no burial)	% length	Layer 2 (0.5-1.0m) disruptive strike (burial limited to 0.5m)	% length	Layer 3 (1.0-1.5m) disruptive strike (burial limited to 1m)	% length
Occasional boulders	0.0225	2.25	0.01125	1.125		
Numerous boulders	0.045	4.5	0.0225	2.25		
High density boulders	0.09	9	0.045	4.5		

TOTALS PER CABLE

Assessed Length	m^3 remedial rock placement estimate	m^3 backfill estimate	SUBTOTAL	m^3 crossings estimate (see crossing rock placement sheet for pre- and post lay)	THEORETICAL TOTAL (per cable)	PRACTICAL TOTAL (Incl. Contingency/ Overdumping Factor)	Contingency / Overdumping Factor %*
Full Route: Option 1 - Jetting	33835	0	33835	27112	**60947**	**85326**	40
Full Route: Option 2 - Jetting with Pre-lay ploughing KP0.823 - KP 17.891	10905	24282	35187	27112	**62299**	**87219**	
KP0 to 12NM limit: Option 1 - Jetting	25169	0	25169	864	**26033**	**36446**	
KP0 to 12NM limit: Option 2 - Jetting + pre-lay ploughing KP 0.823 - KP 17.891	2239	24282	26521	864	**27385**	**38339**	
KP0 to UK EEZ limit: Option 1 - Jetting	26214	0	26214	6864	**33078**	**46309**	
KP0 to UK EEZ limit: Option 2 - Jetting + pre-lay ploughing KP0.823 - KP17.891	3284	24282	27566	6864	**34430**	**48202**	
KP0 to KP 330: Option 1 - Jetting	26214	0	26214	12709	**38923**	**54492**	
KP0 to KP 330: Option 2 - Jetting + pre-lay ploughing KP 0.823 - KP 17.891	3284	24282	27566	12709	**40275**	**56385**	
KP 330 to KP 664.66: - Jetting	7621	0	7621	14403	**22024**	**30833**	

*This Global Factor of Safety has been applied to account for the uncertainty in the method of rock placement calculation. It is also consistent with the overdumping factor that might be applied by a typical rock placement contractor.

Boulders in section (length, km) / Estmate of Remedial Rock Placement - Jet Trenching

RPL	KP From	KP To	Protection Level (FEED)	FEED DoL to top of product in sediment	Target trench depth allowing 0.2m for product	DoB of placed rock or DoB+DoL of rock/trench combination.	Occasional	Numerous	High Density	Note	Conceptual (0.5m) boulder layers interacted with by tool	Length where no burial is anticipated (km)	Height of remedial berm to satisfy DoB requirement using rock placement (m)	Rock volume (assuming 3:1 gradient, triangular profile) (m3)	Length of Burial limited to 0.5m (0.3m DoL) (km)	Height of remedial berm required to satisfy DoB+DoL requirement for combined rock/trench (m)	Rock volume (assuming 3:1 gradient, triangular profile) (m3)	Length of Burial limited to 1m (0.8m DoL) (km)	Height of remedial berm required to satisfy DoB+DoL requirement for combined rock/trench (m) Minimum rock height 0.2m where FEED DoL >0.8m	Rock volume (assuming 3:1 gradient, triangular profile) (m3)	Total Remedial Rock Volume in section (m3)
	HDD EXIT -0.382	0.823	D	1.3	1.5	1.3															0
RPL12NM (Pre-lay plough suggested for potential use KP 0.823 - KP 17.891)	0.823	4.333	C	0.8	1	0.8	0.491	0.027	2.725		2	Boulder methodology not used across coarse surficial sediment areas for jetting: Assume conservative 0.1m trench depth achieved across full length of 3									5160
	4.333	17.891	C	0.8	1	0.8	2.813	6.684	0.205		2	coarse route sections, 0.1m DoL to top of product, requiring a 0.7m high 3:1 berm to achieve 0.8m cover.									19930
	17.891	25.089	C	0.8	1	0.8	1.391				2	0.016	1	47	0.016	0.5	12	BEYOND TOOL DEPTH			59
	25.089	27.700	C	1	1.2	0.8		0.230			3	0.005	1	16	0.005	0.5	4	0.005	0.2	0.6	20
RPL09	27.700 (12NM Limit)	32.500	C	1	1.2	0.8		1.000			3	0.023	1	68	0.023	0.5	17	0.023	0.2	3	87
	32.500	40.000	C	1	1.2	0.8		5.600			3	0.126	1	378	0.126	0.5	95	0.126	0.2	15	488
	40.000	44.500	C	1	1.2	0.8		1.600			3	0.036	1	108	0.036	0.5	27	0.036	0.2	4	139
	44.500	49.750	C	1	1.2	0.8		3.800		*(mix of occ, num, and high boulder areas, model as average numerous).	3	0.086	1	257	0.086	0.5	64	0.086	0.2	10	331
	49.750	60.000	C	1	1.2	0.8															0
	60.000	72.750	C	1	1.2	0.8															0
	72.750	79.500	C	1	1.2	0.8															0
	79.500	102.000	C	1	1.2	0.8															0
	102.000	107.500	C	1	1.2	0.8															0
	107.500	119.600	C	1	1.2	0.8															0
	119.600	126.000	C	1	1.2	0.8															0
	126.000	200.000	C	1	1.2	0.8															0
	200.000	224.000	C	1	1.2	0.8															0
	224.000 EEZ Limit	240.500	C	1	1.2	0.8															0
	240.500	276.000	C	1	1.2	0.8															0
	276.000	290.500	C	1	1.2	0.8															0
	290.500	330.000	C	1	1.2	0.8															0
	330.000	341.500	C	1	1.2	0.8															0
	341.500	348.500	C	1	1.2	0.8															0
	348.500	363.500	C	1	1.2	0.8															0
	363.500	390.000	C	1	1.2	0.8															0
	390.000	409.500	C	1	1.2	0.8															0
	409.500	413.000	C	1	1.2	0.8															0
	413.000	415.000	C	1	1.2	0.8															0
	415.000	427.750	C	1	1.2	0.8															0
	427.750	430.000	C	1	1.2	0.8	0.200				3	0.002	1	7	0.002	0.5	2	0.002	0.2	0.3	9
	430.000	447.500	C	1	1.2	0.8	16.500				3	0.186	1	557	0.186	0.5	139	0.186	0.2	22	718
	447.500	456.250	C	1	1.2	0.8		8.750			3	0.197	1	591	0.197	0.5	148	0.197	0.2	24	762
	456.250	460.750	C	1	1.2	0.8							1								0
	460.750	470.000	C	1	1.2	0.8	1.400	3.100			3	0.086	1	257	0.086	0.5	64	0.086	0.2	10	331
	470.000	480.650	C	1	1.2	0.8	1.200	2.200	0.400	*Note, total estimate in this section includes 4800m^3 of rock estimated for areas where bedrock outcrops prevent cable burial	3	0.081	1	243	0.081	0.5	61	0.081	0.2	10	5113
	480.650	482.250	C	0.8	1	0.8			1.600		2	0.072	1	216	0.072	0.5	54	BEYOND TOOL DEPTH			270
	482.250	502.300	B	0.5	0.7	0.4							0.6								0
	502.300	505.750	B	0.5	0.7	0.4							0.6								0
	505.750	508.750	B	0.4	0.6	0.4			2.000		2	0.090	0.6	97	0.090	0.1	3				100
	508.750	509.8*	B (D 509-509.8)	0.5	0.7	0.4		0.800			2	0.018	0.6	19	0.018	0.1	1	BEYOND TOOL DEPTH			20
	508.75*	509.800	D B (508.75 - 509)	1.5	1.7	1.3		0.250		Part of above section, separated for deeper burial (D)	3	0.006	1.5	38	0.006	1	17	0.006	0.5	4	59
	509.800	520.600	D (B KP 520-520.8)	0.5	0.7	1.3					2		1.5								0
	520.600	524.650	B	0.4	0.7	0.4			3.300		2	0.149	0.6	160	0.149	0.1	4	BEYOND TOOL DEPTH			165
	524.650	531.500	B	0.5	0.7	0.4							0.6								0
	531.500	548.250	B (D KP 543.2 - 544.8)	0.5	0.7 (1.7 in near fish farms)	0.4	0.250	0.100		No boulders in D protection seciton	2	0.005	0.6	5	0.005	0.1	0	BEYOND TOOL DEPTH			6
	548.250	549.000	B	0.4	0.6	0.4							0.6								0
	549.000	557.500	A	0	0	0							0.2								0
	557.500	592.600	B (D KP 586.7 - 588.7, KP 591 - 592.6)	0.5	0.7 (1.7 in near fish farms)	0.4	0.750			No boulders in D protection section	2	0.008	0.6	9	0.008	0.1	0	BEYOND TOOL DEPTH			9
	592.600	594.600	D	1.3	1.5	1.3	0.500				3	0.006	1.5	38	0.006	1	17	0.006	0.5	4	59
	594.600	610.000	A (D KP 594.6 - 596, KP 598.5, 599.5)	0 (D 1.5)	0 (1.7 in near fish farms)	0															0
	610.000	634.750	A (D KP 616.5 - 619.3, KP 621 - 625)	0 (D 1.5)	0 (1.7 in near fish farms)	0	0.500	0.600	0.300	Boulders are in protection level A areas and thus have not been included)	-	NO PROTECTION STIPULATED									0
	634.750	658.700	A	0	0	0	0.800			Boulders are in protection level A areas and thus have not been included)	-										0
	658.700	661.400	A	0	0	0	1.350	1.350		Boulders are in protection level A areas and thus have not been included)	-										0
	661.400	664.660	D	1.5	1.7	1.3															0

(Left value- see note*)

Estmate of Remedial Rock Placement - Pre-lay ploughing (KP0.823 - KP17.891, 12NMRPL) MATERIAL ABOVE SEABED LEVEL / Pre-lay Ploughing - Trench Backfill Estimate MATERIAL BELOW SEABED LEVEL

KP From	KP To	Length where no burial is anticipated (km)	Height of remedial berm to satisfy DoB requirement using rock placement (m)	Rock volume (assuming 3:1 gradient, triangular profile) (m3)	Length of Burial limited to 0.5m (0.3m DoL) (km)	Height of remedial berm required to satisfy DoB+DoL requirement for combined rock/trench (m)	Rock volume (assuming 3:1 gradient, triangular profile) (m3)	Total Remedial Rock Volume in section (m3)	Volume rock required for backfill of fully formed 3m x 1m V-shape trench to DoL+DoB requirement (m3), asuming no natural backfill, 0.2m product sitting in base of trench.	Volume of Reduction in backfill where burial limited to 0m and cover will be achieved by berm (m3)	Volume of Reduction in backfill where burial limited to 0.5m and cover will be achieved by partial berm (m3)	Total estimated backfill for pre-lay ploughing
0.823	4.333	0.258	1	773	0.129	0.5	97	869	5265	386	145	4734
4.333	17.891	0.383	1	1148	0.191	0.5	143	1291	20337	574	215	19548

Project Name:	**NorthConnect**
Project Number:	**C831**
Client Name:	**NorthConnect KS**
Location	**Northern North Sea**

Crossing pre-lay and post-lay rock volume calculations.

	Crossing design[1]	A	B	C/D [2]	C/D [2]	C/D [2]
	Protection Level	C	C	B	C	D
	DoB over cable using Rock	0.8	0.8	0.4	0.8	1.3
Length Rock placement	Total length of rock placement. (No trenching within 50m + 10:1 gradient berms over grade-out lenths.	120	120	112	120	130
	Rock placement length CHECK	120	120	112	120	130
PRE-LAY (see Note **2**)	Height of full-height pre-lay berm over infrastructure (Separation from pipelines >0.5m + asset diameter allowance, 0.5m for pipes, 0.2m for cables) (m). Assumes top of buried pipes is at seabed.	1	0.5	0	0	0
	Assumed total length of full-height berm over infrastructure (m)	4	4	0	0	0
	Width of flat top (m)	4	4	0	0	0
	Gradient sides (1 to: x)	2.5	2.5	0	0	0
	Volume full-height berm (m³)	26	10.5	0	0	0
	Total length of wedge-shaped berms each side of infrastructure (assuming 1:10 gradient of centre wedge to reduce height to 0m. (m)	20	10	0	0	0
	Volume of wedge shaped transition berms (m³)	57	14	0	0	0
	Total Volume (m³)	**83**	**25**	**0**	**0**	**0**
POST-LAY (Pre-lay volume subtracted at end of calculation)	Cover requirement (m)	0.8	0.8	0.4	0.8	1.3
	Height of complete full-height berm over infrastructure.(Allowing for separtation, cover and 0.2m allowance for HVDC product) (m)	2	1.5	0.6	1	1.5
	Assumed total length of full-height berm over infrastructure (m)	4	4	4	4	4
	Width of flat top (m)	1	1	1	1	1
	Gradient sides (1 to: x)	2.5	2.5	2.5	2.5	2.5
	Volume full-height berm (pre-lay to be subtracted from total at end of calculation) (m³)	48	28.5	6	14	28.5
	Total length of wedge-shaped berms to reduce height from full-height to seabed level (some in two stages of equal length, with flat berm in between), assuming 1:10 gradient in both cases. (m)	40	30	12	20	30
	Volume of wedge-shaped transition berms (both stages) (pre-lay to be subtracted from total at end of calculation) (m³)	173	79	7	27	79
	Length of section of level mid-height berm over seabed-laid cable. (m)	76	86	96	96	96
	Height of berm protecting untrenched cable (m)	1	1	0.6	1	1.5
	Volume of level mid-height berm (m³)	266	301	144	336	684
	POST-LAY volume (m³)	**405**	**384**	**157**	**377**	**791**
TOTAL	TOTAL (m³) (Pre-lay + Post-Lay), no overdumping/contingency factor applied.	487	408	157	377	791

Notes:
1. Height of rock cover over the cable has been applied according to the local protection level using table 4.2.2 of Appendix E03.01- Design Basis - Cable and Pipeline Crossings.
2. It has been assumed that for crossing surface-laid cables (Design D), the thickness of the exising infrastructure will be negligible and pre-lay rock will not be used, thus the volume will be as for design C.

Crossing list with Volumes

KP (B - Buried, S - Surface laid)	Design (A,B,C,D)	Protection Level	DoB of rock (m)	Pre-lay Volume (m³) (Theoretical)	Post-lay Volume (m³) (Theoretical)	Total Volume (m³) (Theoretical)	Note
10.964 B Active cable (B complete)*	D	C	0.8	0	377	377	*If pre-trench ploughing utilised in this area, length of no-trenching buffer will depend on agreement with crossing owner.
18.558 S Active pipeline	A	C	0.8	83	405	487	
53.403 S Active pipeline	A	C	0.8	83	405	487	
60.326 B Active pipeline	B	C	0.8	25	384	408	
137.347 B Group 4 x Active pipelines	B	C	0.8	25	384	408	Expect reduced volume across grouped pipelines.
137.391 B - (2nd pipe piggy-backed)	B	C	0.8	25	384	408	
137.449 B -	B	C	0.8	25	384	408	
140.250 B Group 2 x Active pipelines	B	C	0.8	25	384	408	Expect reduced volume across grouped pipelines.
140.288 B -	B	C	0.8	25	384	408	
142.830 B Group 5 x Disused pipelines	D	C	0.8	0	377	377	Expect reduced volume across grouped pipelines.
142.861 B -	B	C	0.8	25	384	408	
142.895 B -	B	C	0.8	25	384	408	
142.926 B - (2 pipes in same location)	B	C	0.8	25	384	408	
156.395 S Active pipeline	A	C	0.8	83	405	487	
205.053 S Active pipeline	A	C	0.8	83	405	487	
219.410 S Active pipeline	A	C	0.8	83	405	487	
235.929 B Active cable	D	C	0.8	0	377	377	
244.610 S Active pipeline	A	C	0.8	83	405	487	
246.750 S Active pipeline	A	C	0.8	83	405	487	
248.384 B Active cable	B	C	0.8	25	384	408	
248.414 S 2 x Active pipelines	A	C	0.8	83	405	487	
248.445 S -	A	C	0.8	83	405	487	
259.413 B Active cable	B	C	0.8	25	384	408	
264.888 S Active pipeline	A	C	0.8	83	405	487	
268.635 S Active pipeline	A	C	0.8	83	405	487	
280.857 S Active pipeline	A	C	0.8	83	405	487	
287.657 B Active cable	D	C	0.8	0	377	377	
304.477 B Active cable	D	C	0.8	0	377	377	
326.208 S Active pipeline	A	C	0.8	83	405	487	
Volume Subtotal KP 0 to KP 330 (m³)				**1346**	**11363**	**12709**	
338.965 Planned cable	B	C	0.8	25	384	408	
351.365 Planned cable	B	C	0.8	25	384	408	
374.606 Planned pipeline	A	C	0.8	83	405	487	
390.661 B Active cable	A	C	0.8	83	405	487	
397.186 B Active cable	C	C	0.8	0	377	377	
446.595 S Active pipeline	C	C	0.8	0	377	377	
456.816 S Active pipeline	A	C	0.8	83	405	487	
505.435 Active cable	C	B	0.4	0	157	157	
510.916 Active cable	D	D	1.3	0	791	791	
511.116 Active cable	D	D	1.3	0	791	791	
511.249 Active cable	D	D	1.3	0	791	791	
511.307 Active cable	D	D	1.3	0	791	791	
511.548 Active cable	C	D	1.3	0	791	791	
523.223 Active cable	C	B	0.4	0	157	157	
525.92 Active cable	C	B	0.4	0	157	157	
533.666 Active cable	C	B	0.4	0	157	157	
533.758 Active cable	C	B	0.4	0	157	157	
533.873 Active cable	C	B	0.4	0	157	157	
533.96 Active cable	C	B	0.4	0	157	157	
534.077 Active cable	C	B	0.4	0	157	157	
534.191 Active cable	C	B	0.4	0	157	157	
534.357 Active cable	C	B	0.4	0	157	157	
534.376 Active cable	C	B	0.4	0	157	157	
534.742 Active cable	C	B	0.4	0	157	157	
563.317 Active cable	C	B	0.4	0	157	157	
566.707 Active cable	D	B	0.4	0	157	157	
569.500 - *Crossing TBC as cable not crossed by survey centre (DCC 30m)*	-	-	-	0		0	
573.047 Active cable	D	B	0.4	0	157	157	
577.246 Active cable	D	B	0.4	0	157	157	
578.652 Active cable	D	B	0.4	0	157	157	
583.406 Active cable	C	B	0.4	0	157	157	
584.179 Active cable	C	B	0.4	0	157	157	
584.681 Active cable	D	B	0.4	0	157	157	
584.707 Active cable	D	B	0.4	0	157	157	
584.933 Active cable	C	B	0.4	0	157	157	
596.216 Active cable	C	A	0	0		0	
596.306 Active cable	C	A	0	0		0	
598.39 Active cable	C	A	0	0		0	
600.323 Active cable	C	A	0	0		0	
610.622 Active cable	C	A	0	0		0	
612.582 Active cable	C	A	0	0		0	
618.476 Active cable	C	D	1.3	0	791	791	
619.307 Active cable	C	D	1.3	0	791	791	
633.396 Active cable	C	A	0	0		0	
634.611 Active cable	C	A	0	0		0	
634.647 Active cable	C	A	0	0		0	
636.228 Active cable	C	A	0	0		0	
637.338 Active cable	C	A	0	0		0	
637.556 Active cable	C	A	0	0		0	
637.887 Active cable	C	A	0	0		0	
641.7 Active cable	C	A	0	0		0	
642.007 -OOS?				0		0	
642.044 Active cable	C	A	0	0		0	
647.387 Active cable	C	A	0	0		0	
654.534 Active cable	C	A	0	0		0	
662.89 Active cable	C	D	1.3	0	791	791	
664.018 Active cable	C	D	1.3	0	791	791	
664.273 Active cable -C?	C	D	1.3	0	791	791	
Volume Subtotal KP 330 to KP 664.66 (m³)				**297**	**14105**	**14403**	
TOTALS				1643	25469	27112	Not factored for overdumping/conting-ency.