Cenos Offshore Windfarm Limited

Cenos EIA

Appendix 2 – Preliminary CBRA and BAS Report for the Export Cable Route

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XODUS

Aberdeen

5th Floor Capitol Building
429-431 Union Street . Aberdeen
AB11 6DA . UK

www.xodusgroup.com

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Cenos Offshore Windfarm – Preliminary CBRA and BAS Report for the Export Cable Route

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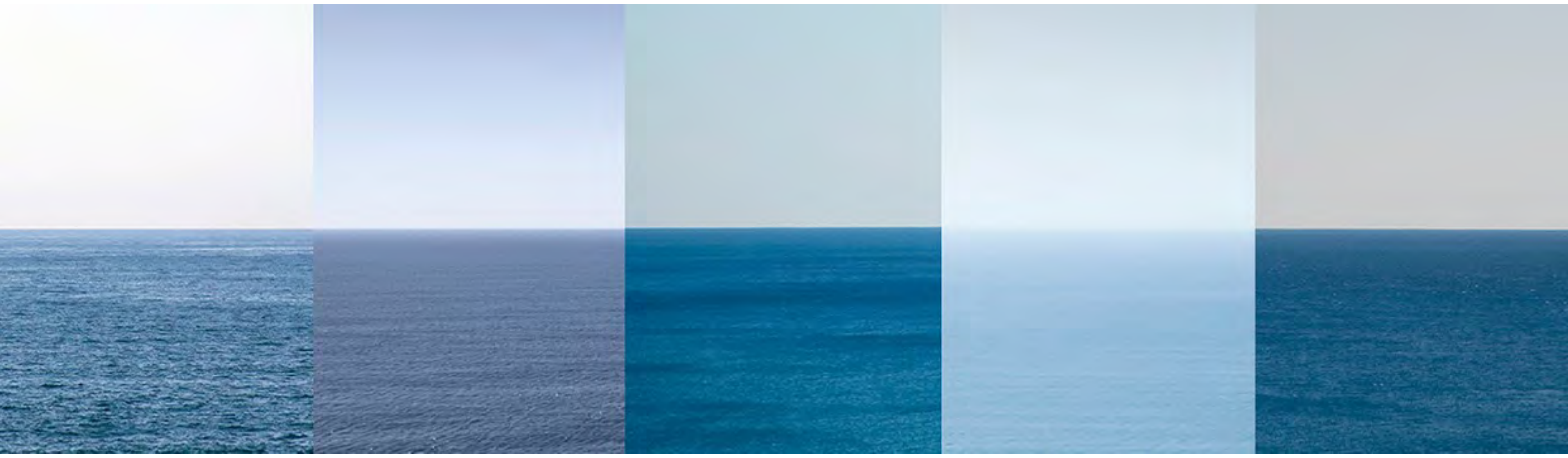

Cenos Offshore Windfarm – Preliminary CBRA and BAS Report for the Export Cable Route

For Flotation Energy

GM-PRJ111506-GEO-RP-0006 CEN001-GLM-01-OEC-ENG-RPT-0001

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Global Maritime Consultancy Ltd.
8 Nelson Street

NE1 5AW Newcastle upon Tyne
United Kingdom
T F
www.globalmaritime.com

1. SUMMARY

On behalf of Floatation Energy and Vårgrønn, Global Maritime (GM) have conducted a full CBRA and BAS study for the Export Cable Route (ECR) for the Cenos floating offshore wind farm. This document details the assessment of the geophysical survey data and work conducted thus far by GM for the Cenos project, including its suitability for application to the CBRA process; and both the CBRA and BAS results. Finally, based on the results of these works, a recommended method for cable installation and protection is provided.

A site conditions assessment has been performed to determine the geological layers of the seabed within the export cable route. Within the depth of interest, this assessment found that the majority of the cable route is situated across surficial clayey sands and sandy clays, with higher-strength clays present either underneath these surficial layers or outcropping at the seabed. Geological units were assigned in previous work done by GM, with the geotechnical properties of these inferred based on publicly available data and GM's own experience in the region. These units, with their spatial extents defined by the geophysical survey data for the export cable corridor, could then be used in the CBRA calculation.

A Stable Seabed Level has been calculated, based on a single bathymetric survey from 2023. The resultant SSBL provides an indicative level, below which seabed geology is unlikely to be impacted by short- or medium-term seabed mobility. The SSBL output from this workflow represents a snapshot only, based on available bathymetric data, and does not account for forward modelling at this stage. Rates and directions of mobility should be confirmed through repeat bathymetric survey combined with a comprehensive morphodynamics study.

Global Maritime's optimised CBRA method was applied with modelled post-windfarm installation vessel traffic to analyse the anchor strike risks to the cable and propose target burial depths along each RPL to minimise the risk to acceptable levels whilst also maintaining practical burial depth along the cable route. This burial depth is constant along the cable route, due to the relatively low density of modelled vessel traffic. The proposed burial depth and risk profile for the cable is detailed in the alignment charts within this report. The route engineered by GM for the export cable was used as the basis for the calculation and presentation of the CBRA and BAS results.

2. INTRODUCTION

2.1 Project Description

Flotation Energy, in conjunction with Vårgrønn, through Cenos Offshore Windfarm Limited (‘The Company’) are developing the Cenos Project, an offshore wind project of up to 1.4 GW capacity on the UK Continental Shelf. The aim of the project is to decarbonise existing oil and gas assets in the Central North Sea, saving up to 1,700,000 tonnes of CO_2 per year. The location of the Export cable Corridor (ECC) is shown in Figure 1.

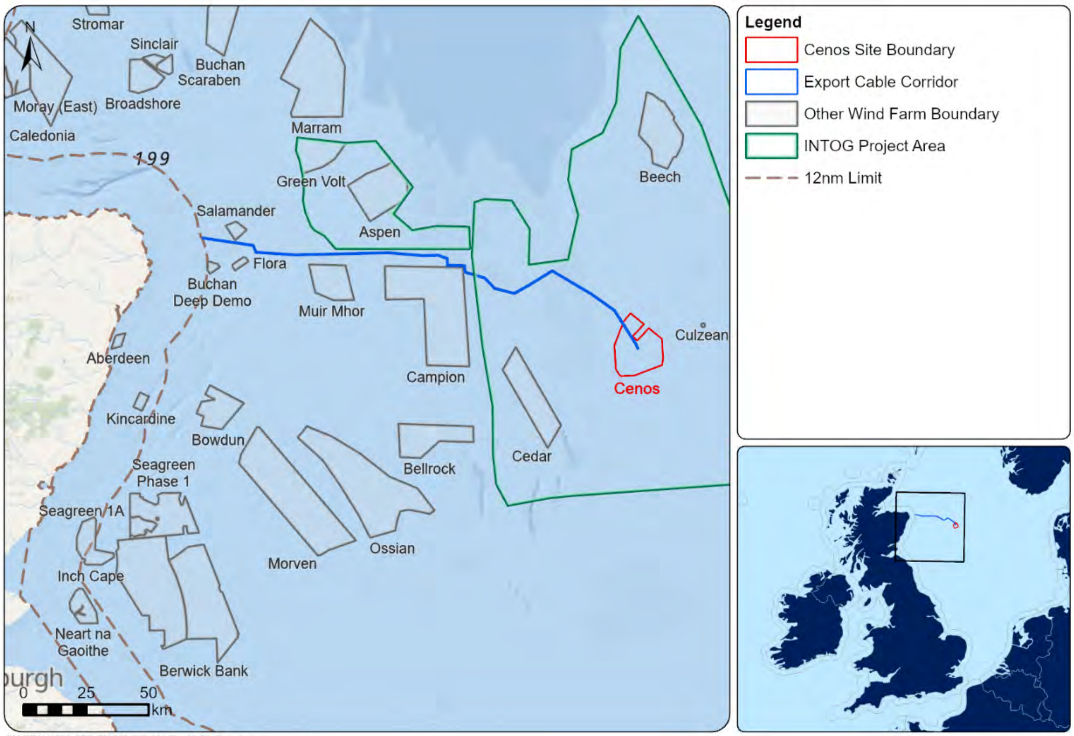


Figure 1: Location of Cenos Offshore Windfarm Project

2.2 Purpose of Report

The purpose of this report is to present the results of the CBRA and BAS completed by Global Maritime for the Cenos export cable route. These studies have been conducted based on the cable route developed as part of the wider work package GM are producing for the Cenos project.

The following works have been completed and results detailed within this report for the entire export cable corridor (starting at 12nm from shore, and ending within the lease area at the OSP):

- Data review and gap analysis of all provided site data
- Review of the site conditions within the offshore export cable corridor
- Cable Burial Risk Assessment (CBRA)

- Burial Assessment Study (BAS)

2.3 Abbreviations

Abbreviation	Description
AIS	Automatic Identification System
BSB	Below Sea Bed
BAS	Burial Assessment Study
CBRA	Cable Burial Risk Assessment
CFE	Controlled Flow Excavation
DOB	Depth of Burial
DOC	Depth of Cover
DOL	Depth of Lowering
DNV	Det Norske Veritas
DWT	Dead Weight Tonnage
ECR	Export Cable Route
ECC	Export Cable Corridor
GIS	Geographic Information System
GM	Global Maritime
GW	Gigawatts
ICPC	International Cable Protection Committee
KP	Kilometre Post
LA	Lease Area
LARS	Launch and Recovery System
LAT	Lowest Astronomical Tide
MBES	Multibeam Echosounder
mBSB	Metres Below SeaBed
MFE	Mass Flow Excavation
OSP	Offshore Platform
ROV	Remotely Operated Vehicle

Abbreviation	Description
RPL	Route Position List
SBP	Sub-Bottom Profiler
SRI	Subsea Rock Installation
SSBL	Stable SeaBed Level
SSS	Side Scan Sonar
TSV	Trenching Support Vessel
UHC	Ultimate Holding Capacity

Table 1: Table of Abbreviations

2.4 Geodetic Parameters

The following geodetic parameters, unless specified otherwise, have been used throughout this report.

Reference	Description
Datum	WGS 1984
Projection	UTM Zone 31N
Vertical Reference	Lowest Astronomical Tide (LAT)

Table 2: Geodetic Parameters

2.5 Units

All distance and depth units within this report are measured in metres, unless stated otherwise.

Dates are given in dd/mm/yyyy format.

2.6 KP system

The kilometre post reference system assigns landfall as KP 0. The scope of this report begins at the 12nm boundary, at KP 27.971.

3. DATA REVIEW AND GAP ANALYSIS

3.1 Data Sources

The below project specific data have been used:

1) Cable_Route_B_250mBuffer_WGS84_Z31N.shp (Export Cable Corridor)
2) Cenos_B1_ECR_CentreLine_WGS84_Z31N.shp (Export Cable Corridor Centreline)
3) SSDM_PR111506_Floatation_Cenus.gdb (2023 ROVCO Geophysical Survey Data)
4) FLOCEN_INEX_Route_v01_240524_emo_32631 (GM Preliminary Export Cable Route)
5) NSTA_Pipelines_Linear_WGS84_Z31N.shp (NSTA Offshore Infrastructure Pipelines Linear)
6) UKHO_Wrecks_WGS84_Z31N.shp (UKHO Wrecks and Obstructions Shapefiles)
7) 23014-EN-SU-RP-004 C2 ECC Geophysical Results Report
8) CEN001-GLM-01-CON-GPH-RPT-0001 Cenos Geological Desktop Study
9) GM-PRJ111506-GEO-TN-0005 Preliminary Cenos Export Cable Corridor Ground Model
10) GM-PRJ111506-GEO-TN-0007 Geotechnical Phase 1 Ground Investigation Locations in the Cenos ECC Area
11) CEN001-GLM-01-OEC-ELE-TEC-0001 Preliminary Cenos ECC Routing
12) 240703_FLO_CEN_ECC_CrossingsInv_FE_V1 Cenos cable crossings list
13) Davie, S. (2024), ‘RE: ECC CBRA Additional Crossings’ Email to F. Dick, M. Owen and M. Laing, 23 October.

The below external references have been used:

14) DNVGL, Recommended Practice, Subsea Power Cables in Shallow Water, Doc. No. DNVGL-RP-0360, March 2016
15) Cigre, Technical Brochure, Installation of Submarine Power Cables, Doc. No. TB883, October 2022.
16) DNV, Recommended Practice, Risk Assessment of Pipeline Protection, Doc. No. DNV-RP-F107, October 2010
17) Carbon Trust, Application Guide for the Specification of the Depth of Lowering using the Cable Burial Risk Assessment (CBRA) methodology, Dec 2015
18) Carbon Trust, Cable Burial Risk Assessment Methodology, Guidance for the Preparation of Cable Burial Depth of Lowering Specification, CTC835, February 2015
19) European Subsea Cables Association (2016), ESCA Guideline No. 6, The Proximity of Offshore Renewable Energy Installations & Submarine Cable Infrastructure in UK Waters, Issue 5, 10 March 2016

20) International Cable Protection Committee (2015), ICPC Recommendation No. 2, Recommended Routing and Reporting Criteria for Cables in Proximity to Others, Issue 11B, 3 November 2015
21) The Crown Estate (2012), Guideline for Leasing of Export Cable Routes/Corridors
22) BERR - Review of Cabling Techniques and Environmental Effects Applicable to the Offshore Wind Farm Industry.
23) Navigation Safety Branch, Maritime & Coastguard Agency, Marine Guidance Note MCN543 (M+F) Section 3d, File Ref: MNA/053/010/0626, January 2016.
24) Ashley et al. (1990). Classification of large-scale subaqueous bedforms: a new look at an old problem. Journal of Sedimentary Petrology. 60. 160-172.
25) Cathie Associates (2018), NorthConnect Cable Burial Risk Assessment, Revision 4, C831R01, May 2018
26) Digital Terrain Modelling: Principles and Theory. Li, Z., Zhu, Q. & Gold, C., 2005
27) Digital Elevation Model. Wiki.gis.com. Available at http://wiki.gis.com/wiki/index.php/Digital_Elevation_Model. Accessed 10th October 2022.
28) Everything you need to know about Digital Elevation Models (DEMs), Digital Surface Models (DSMs), and Digital Terrain Models (DTMs). Marwaha, N. & Duffy, E. Available at https://up42.com/blog/tech/everything-you-need-to-know-about-digital-elevation-models-dem-digital. Accessed 10th October 2022.
29) Discrete Differential Geometry: An Applied Introduction. Notices of the AMS, Communication. Crane K., 2018
30) Map Use: Reading, Analysis, Interpretation. Kimerling, A. et al, 2016. 7th Edition.
31) Cartigny, M.J., Postma, G., Van den Berg, J.H. and Mastbergen, D.R., 2011. A comparative study of sediment waves and cyclic steps based on geometries, internal structures and numerical modeling. Marine Geology, 280 (1-4), pp.40-56.
32) Cathie Associates (2018), NorthConnect Cable Protection Analysis Report, Revision 5, C831R02, 01 June.

3.2 Data Review and Gap Analysis

To inform the routing, CBRA, and BAS, Global Maritime utilised the geophysical data pack from the ROVCO 2023 survey (Ref.7). An adequacy review of the provided data for the purposes of this study is provided in Table 3. Commentary and a traffic light assessment are also provided, representing **Adequate**, **Partially Adequate**, and **Inadequate**.

Data Type	Source	Comment	Adequacy
Project Boundary / RPL	(1), (2), (11)	Defined cable corridor and corresponding centreline. RPL is GM's preliminary export cable route.	Adequate
Bathymetry	(3), (7)	Full corridor coverage (<200%) MBES at 0.5m and 1.0m resolution.	Adequate
Shallow Geology	(3), (7)	SBP data at 8kHz and 0.1m vertical resolution, with 100m line spacing. Consultation on seismic velocities and required penetration. No cross lines acquired.	Inadequate
Side Scan Sonar	(3), (7)	Full corridor coverage (<200%) dual frequency SSS data at 230kHz and 540kHz, with 0.3m and 0.2m resolution respectively. Target height from seabed estimated at ±20% accuracy.	Adequate
Magnetometer	(3), (7)	Cycled at 10Hz and a survey speed of 4 knots, resulting in approx. 0.1m along track sampling resolution. Magnetometer was piggybacked on SSS and flown at a target height of 12.5m above seabed, meaning some targets may not have been detected. Positional accuracy is estimated to be ±3m, and discrepancies were corrected using SSS and MBES data.	Partially adequate
Soil Provinces	(9), (10)	Based on the geophysical survey data and ROVCO's interpretation, and re-interpreted by GM using publicly available data and GM's knowledge of the region	Adequate
Seabed features & targets	(3), (7)	Surficial targets are adequate in MBES and SSS data, though smaller targets may not be resolved due to resolution. Ferrous and buried targets may not be detected due to mag and SBP coverage.	Partially adequate
Geotechnical	N/A	No geotechnical data available. Soil geotechnical properties are inferred	Inadequate
Asset Crossings	(12), (13)	Asset crossing lists provided by the client in both spreadsheet incl. coordinates, asset type, name and owner. Also provided charts and additional crossings via email. No dedicated survey data. No burial information.	Inadequate

Table 3: Data Adequacy

4. SITE CONDITIONS

4.1 Bathymetry

The seabed within the ECC reaches a maximum depth of -107.4m LAT and a minimum depth of -78.9m LAT. The topography is varied, with areas of flat relatively benign seabed, areas of outcropping hard-ground and areas of sand waves. Gradients on average are less than 1°, but some steeper gradients of up to 37° are present in areas of bedforms. Generally, the depth trends deeper from west to east (7).

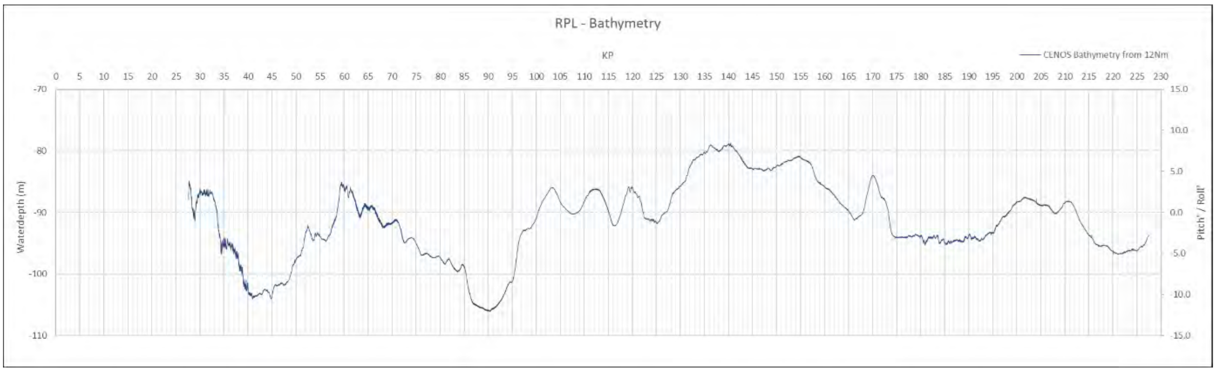


Figure 2: Bathymetry Profile along ECC Route

4.2 Local Geology

The Cenos project is located in the central North Sea, situated in The Graben, with the ECC crossing several other areas of the North Sea basin. The basin originated during episodic extensional rifting from the Palaeozoic to the early Cretaceous, followed by continuous subsidence throughout the late Cretaceous and Cenozoic, and basin inversions during the Paleogene.

The region is characterised by the formation of hydrocarbon deposits in the Jurassic and Tertiary, and glacial and interglacial cycles during the Quaternary. During the latter, an extensive shallow marine environment was created, and fluvial-deltaic and glacial sediments were deposited. During the Pleistocene, marine conditions (including further sediment deposition) were succeeded by glacial sedimentation and regional erosion, and further sediments were deposited during glacial retreat during the Holocene.

A detailed description of the regional geological history can be found in GM's Geological Desk Top Study (8).

4.3 Boulders

Boulders present a risk to cable installation for several reasons impacting cable lay where free-spanning can occur, resulting in faults due to movement and subsequent fatigue over time, and preventing the ability of trenching tools to adequately bury the cable. Boulders should therefore be avoided, however even if the cable avoids boulders at the seabed, they must also be avoided to prevent collision with burial tools, including sub-surface boulders.

In areas of sparse boulders, this can be achieved by cable routing alone, however in areas with dense boulders, some must be cleared to make way for cable installation.

Boulders can be cleared using various methods, which are described in greater detail in section 6.6. The export cable corridor contains a large number of boulders, which are found along the entire length of the cable route but are particularly dense in defined areas such as the section outlined in the geophysical survey report (7) equating to KP27.971 to KP40.971 on the export cable route. To understand the magnitude of a potential boulder clearance campaign, a size distribution of the boulders identified in the survey data was conducted.

Boulder Count	2,258
Mean Size (m)	1.51
Standard Deviation of Boulder Size (m)	0.76
Minimum Size (m)	0.31
P - 25% Size (m)	0.99
P - 50% Size (m)	1.34
P - 75% Size (m)	1.79
Maximum Size (m)	7.23

Table 4: Statistics of the boulders in the ECC based on their maximum dimension in metres

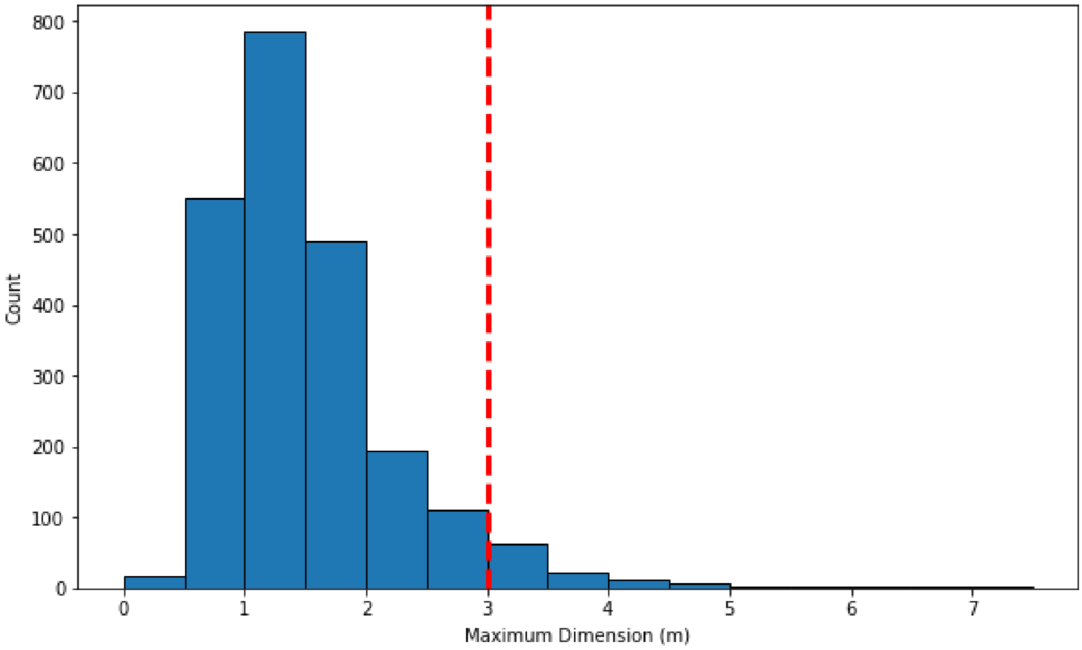


Figure 3: Size distribution of the boulders within the ECC

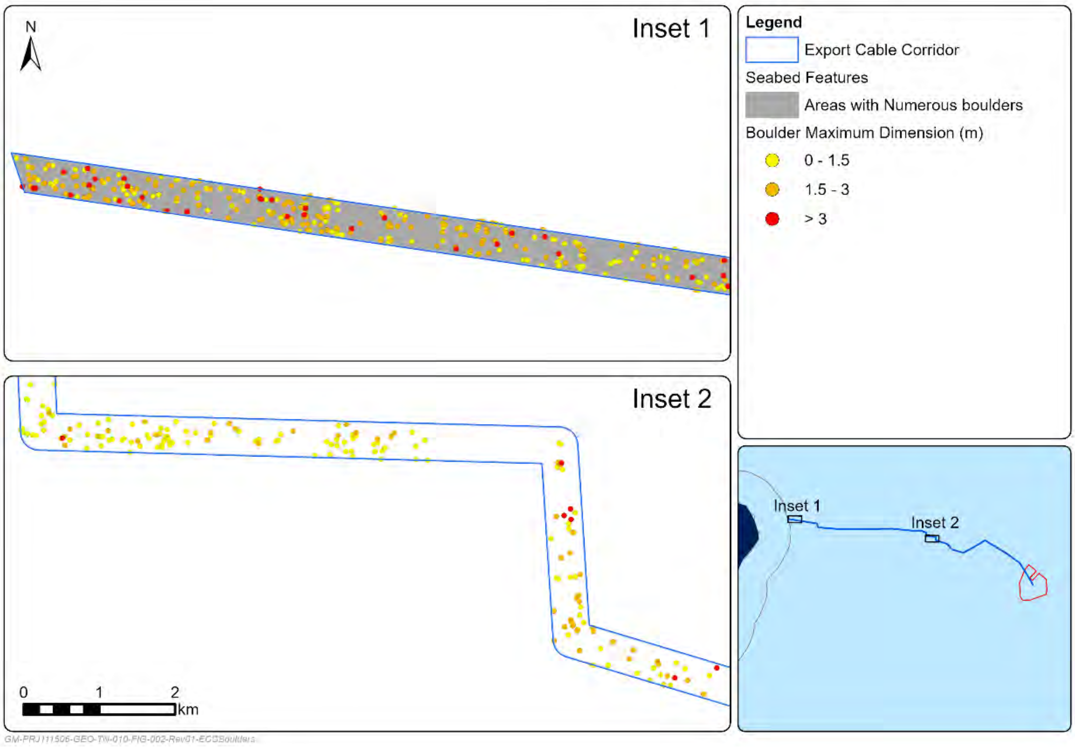


Figure 4: Spatial and size distribution of the boulders in the ECC

The size distribution indicates that the majority of the boulders would be movable with a plough or grab. The limit of 3m in maximum dimension is highlighted to show the number of boulders that would need to be routed around. In the routing report, it is described that boulders of over 3m are avoided by the cable route entirely, and boulders smaller than this are avoided unless it becomes too difficult to do so with micro-routing. In these areas, where routing cannot avoid the remaining boulders, utilisation of a plough and grab may be necessary. Once final cable routing is completed, a full listing of boulders to be cleared can be generated.

4.4 Ground Model

From GM's knowledge of the regional geology and review of publicly available data and literature, a preliminary ground model of the ECC was developed using seismic survey data collected by ROVCO in 2023 (ref. 7). The production of the ground model is detailed in the Preliminary Ground Model Report (ref.9) and is summarised below.

The acoustic horizons defined by ROVCO correspond to geological units and formations that are documented in the region. Based on published literature, GM has inferred the physical properties of these units, as described in the Geotechncial Ground Investigation Locations Report Table 5 (ref. 10).

Epoch	Geological Formation/ Unit	Expected Lithology	Geotechnical properties			
			Undrained Shear Strength (kPa)	Moisture Content (%)	Plasticity Index (%)	Bulk Density (Mgm-3)
Holocene	Witch Ground Formation	Soft silty clay with pockmarks	1-47	15-49	6-35	1.5-1.9
	Forth Formation – Whitehorn Member	Sand with thin clay layers	1-65	8-58	5-45	1.7-1.9
	Forth Formation – Fitzroy Member	Clay with thin sand layers				
Pleistocene	Wee Bankie Formation	Till (well graded sand, clay and gravel) interbedded with thin clays of sand and silty clay; coarse sand and gravel	39-278	9-41	8-52	-
	Coal Pit Formation	Silty clay with occasional pebbles; some sand laminae	20-150	20-35	20-50	1.9-2.1

Table 5: Inferred properties of interpreted geological units

4.5 CBRA Ground Model Development

GM's 3D CBRA modelling method uses a two-layer ground model, with defined units assigned to each layer based on the kPa and relative density values of the actual soils. This approach is used to simplify the model production, without compromising the results of the CBRA. The model units are assigned based on the units identified from geophysical and geotechnical survey (or in this case inferred from the geophysical data), and the geophysical horizons used to define the boundary between the upper and lower layer of the model.

Unit Code	Soil Description	Su From	Su To	Dr From	Dr To
S1	Loose SAND	n/a	n/a	0%	35%
S2	Medium dense SAND	n/a	n/a	36%	65%
S3	Dense SAND	n/a	n/a	66%	100%
C1a	Extremely low strength CLAY	1	5	n/a	n/a
C1b	Extremely low strength CLAY	5	10	n/a	n/a
C2	Very low strength CLAY	10	20	n/a	n/a
C3	Low strength CLAY	20	40	n/a	n/a
C4	Medium strength CLAY	40	75	n/a	n/a
C5	High strength CLAY	75	150	n/a	n/a
C6	Very high strength CLAY	150	300	n/a	n/a
C7	Extremely high strength CLAY	300	1000	n/a	n/a

Table 6: GM CBRA ground model unit codes

Using the ground model described in section 4.4, the two-layer CBRA model was developed for the ECC. The units inferred from the ground model (Ref. 9)Table 5 were assigned the CBRA units codes as follows:

GM Ground Model				CBRA Two-Layer Ground Model		
Epoch	**Geological Formation/ Unit**	**Expected Lithology**	**Base Seismic Horizon**	**Unit Code**	**Su From**	**Su To**
Holocene	Surfical Sediments	Silty Clayey Sand, Sand and Silty Clay with occasional gravel and isolated to scattered cobbles and boulders*	H03	S	N/A	N/A
	Witch Ground Formation	Soft silty clay with pockmarks	H05	C1b	5	10
	Forth Formation – Whitehorn Member	Sand with thin clay layers	H07	C1b	5	10
	Forth Formation – Fitzroy Member	Clay with thin sand layers	H10	C1b	5	10
Pleistocene	Wee Bankie Formation	Till (well graded sand, clay and gravel) interbedded with thin clays of sand and silty clay; coarse sand and gravel	H17	C5	75	150

GM Ground Model				CBRA Two-Layer Ground Model		
Epoch	**Geological Formation/ Unit**	**Expected Lithology**	**Base Seismic Horizon**	**Unit Code**	**Su From**	**Su To**
🟧	Coal Pit Formation	Silty clay with occasional pebbles; some sand laminae	H20, H40	C7	300	1000
	Fisher Formation	Silty Clay overconsolidated; sand intercalations	N/A	C6	150	300

**Derived from ROVCO survey report*

Table 7: GM Ground Model and conversion to CBRA model units

Using the seismic horizons, the spatial distribution and vertical extent of each unit across the two layers in the CBRA model has been determined, as shown in Figure 5Figure 5, Figure 6Figure 6 and Figure 7Figure 7.

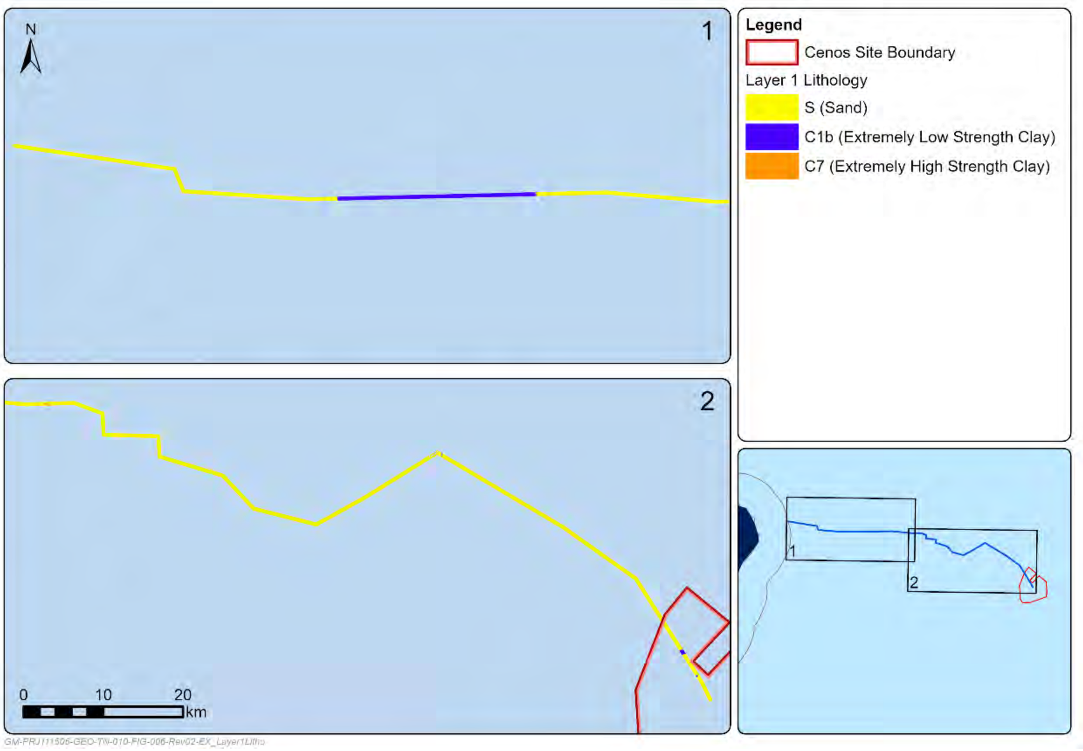


Figure 5: GM CBRA model layer 1 lithology in the ECC

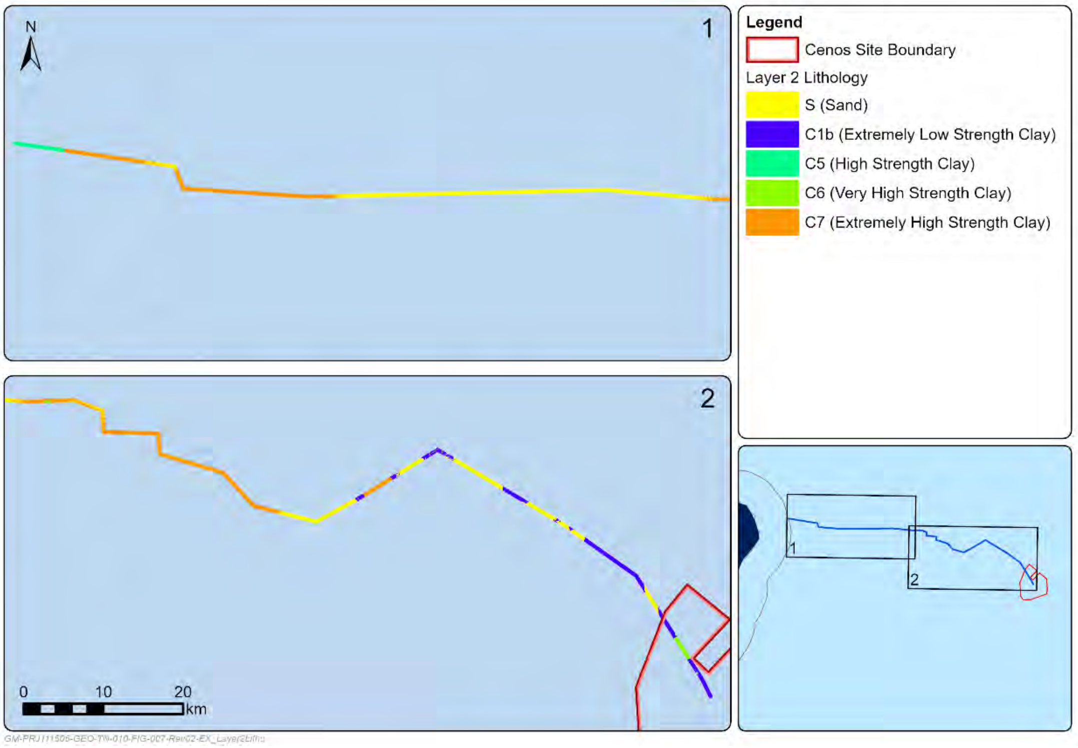


Figure 6: GM CBRA model layer 2 lithology in the ECC

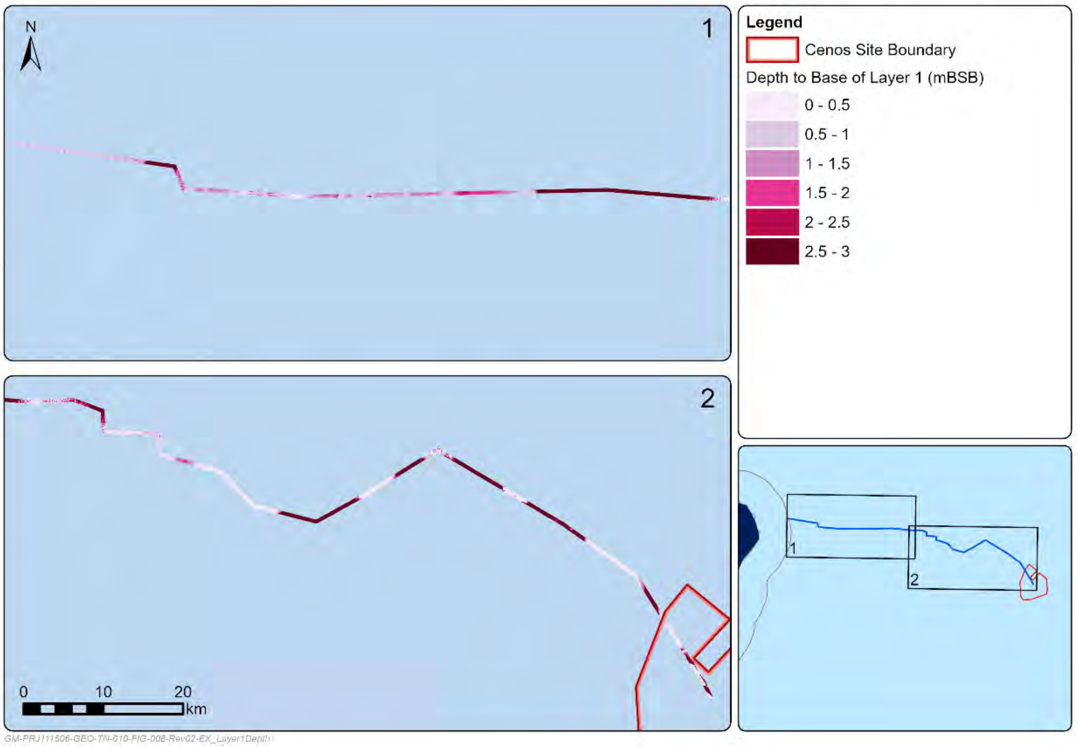


Figure 7: Depth to the base of layer 1 in the ECC

As illustrated in the above figures, the majority of the upper layer along the cable route is designated code S, with a section as C1b and some small sections of C7. This is consistent with the presence of extensive surficial Holocene sands, with some outcropping sections of the Witch Ground and Wee Bankie formations.

Layer 2 also features long sections of unit S, corresponding to deeper Holocene sands, and C5, C6 and C7, corresponding to subcropping Forth, Witch Ground and Wee Bankie formations.

4.6 Stable Seabed Level

4.6.1 Terminology and Definitions

Digital Elevation Models, Digital Terrain Models and Digital Surface Models

A Stable Seabed Level (SSBL) is a form of Digital Elevation Model (DEM), which are in turn defined as “a digital representation of ground surface topography or terrain”. While the term DEM can be used for any representation of terrain as geospatial data, it is generally restricted to the use of a regular grid of elevation values (26).

DEMs can be further split into two distinct categories, both of which are applicable to development of a SSBL. Firstly, Digital Surface Models (DSM) are used to represent the earth’s surface including all objects on it. In a marine environment these surface features may include the anthropogenic (wrecks, pipelines) or those related to the natural, physical environment (bedforms, boulders). A DSM captures both natural and human-made features of the environment. Digital Terrain Models (DTM) represent the underlying “bare-earth” terrain, such as channels and ridges, after surface features have been removed.

In the case of SSBL the input bathymetric grid (inclusive of bedforms) can be considered a DSM. The final output SSBL, with bedforms removed, is a DTM.

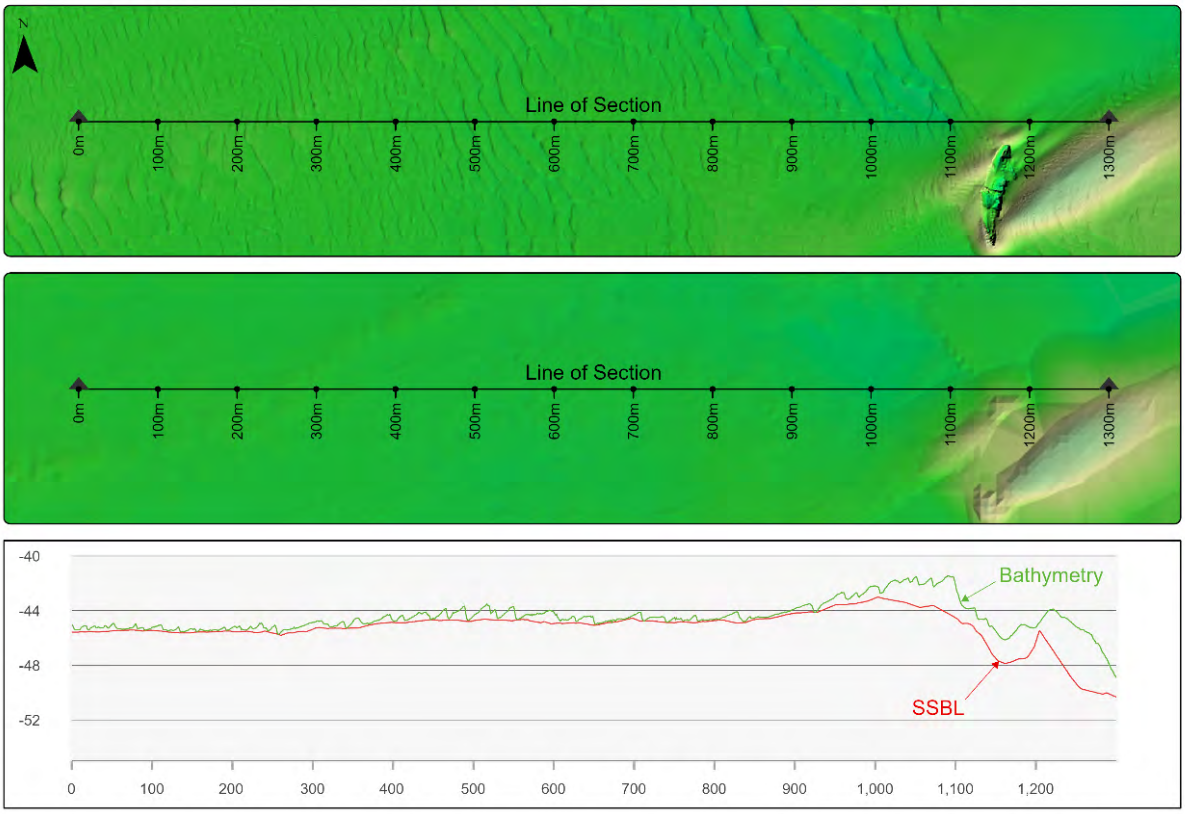


Figure 8: Comparison of Seabed (DSM) and SSBL (DTM) Surfaces – Example for Illustration of Method Only

Stable Seabed Level

A SSBL is a form of DTM, which aims to determine a base of mobile seabed sediments. In its most comprehensive form, an SSBL will factor in temporally disparate, repeat bathymetric surveys, along with long-term morphodynamical modelling, to produce a surface below which seabed will not fall below for the lifetime of the project.

This SSBL is based on a single bathymetric dataset collected in 2023 (7). The SSBL output from this workflow therefore represents a snapshot only, based on available bathymetric data, and does not account for forward modelling at this stage. The resultant SSBL should therefore be considered an indicative level, below which seabed geology is unlikely to be impacted by short- or medium-term seabed mobility.

From this model it is possible to identify features which fit a general profile expected in mobile features; however, it is not possible to confirm the rates or directions of migration for any of the features identified. It is also possible that the current SSBL is exceeded by future events. Accuracy and confidence can be improved by incorporating in additional bathymetric surveys; and by integrating full project lifecycle morphodynamical modelling.

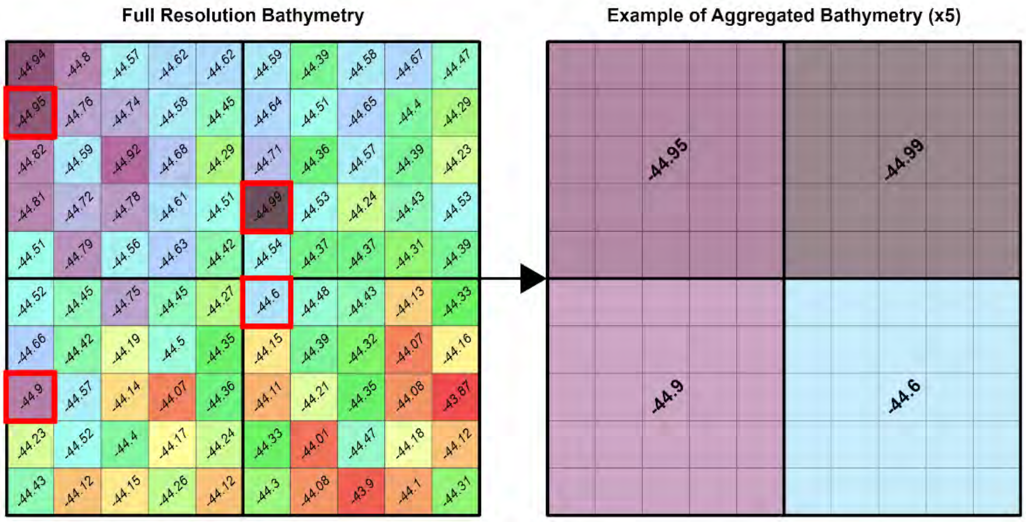
4.6.2 Methodology

Area of Study

The primary aim of this study is to identify the stable seabed level along export cable routes, and it is along these routes that the charting and reporting focuses. The result is a SSBL surface with full coverage within the extent of the input bathymetric grid.

Aggregation of Bathymetry

In the case of Cenos, the SSBL is derived from a single, 0.5m resolution mosaicked bathymetric surface. The resolution of input bathymetry is aggregated to 10m resolution, retaining only the lowest value in each 10x10m cell. Reducing resolution through aggregation allows for identification of only small or medium features. Retaining only the lowest value ensures the resultant SSBL surface will never intersect above the original input bathymetry.



Full Resolution Bathymetry

-44.94	-44.8	-44.57	-44.62	-44.62	-44.59	-44.39	-44.58	-44.67	-44.47
-44.95	-44.76	-44.74	-44.58	-44.45	-44.64	-44.51	-44.65	-44.4	-44.29
-44.82	-44.59	-44.92	-44.68	-44.29	-44.71	-44.36	-44.57	-44.39	-44.23
-44.81	-44.72	-44.78	-44.61	-44.51	-44.99	-44.53	-44.24	-44.43	-44.53
-44.51	-44.79	-44.56	-44.63	-44.42	-44.54	-44.37	-44.37	-44.31	-44.39
-44.52	-44.45	-44.75	-44.45	-44.27	-44.6	-44.48	-44.43	-44.13	-44.33
-44.66	-44.42	-44.19	-44.5	-44.35	-44.15	-44.39	-44.32	-44.07	-44.16
-44.9	-44.57	-44.14	-44.07	-44.36	-44.11	-44.21	-44.35	-44.08	-43.87
-44.23	-44.52	-44.4	-44.17	-44.24	-44.33	-44.01	-44.47	-44.18	-44.12
-44.43	-44.12	-44.15	-44.26	-44.12	-44.3	-44.08	-43.9	-44.1	-44.31

Example of Aggregated Bathymetry (x5)

-44.95	-44.99
-44.9	-44.6

Figure 9: Aggregation based on the Lowest Value

Identification and Removal of Convex Seabed

The aggregated surface is reclassified into areas of convex and concave seabed based on its curvature. Geometric curvature finds the best fitting (osculating) circle to approximate the shape of a curve at any point. The curvature is the reciprocal of the radius of that circle (1/r). A straighter line will be best fit with a larger circle resulting in a smaller curvature, and tighter curved line will be best fit with a smaller circle resulting in a larger curvature (28).

Profile curvature affects the acceleration or deceleration of flow across the surface (29) and can be visualised as the shape of a profile cross section through the surface (Figure 9). A negative value indicates that the surface is upwardly convex at that cell. A positive profile indicates that the surface is upwardly concave at that cell. A value of zero indicates that the surface is linear.

Profile (normal slope line) curvature is calculated parallel to the direction of the maximum slope within a given neighbourhood, measuring the geometric normal curvature along the slope line. This curvature is typically applied to characterise the acceleration and deceleration of flow down the surface by force of gravity. At higher velocity, water can carry and move larger amounts of material; areas of acceleration become areas of erosion and areas of deceleration become areas of deposition. Profile curvature is therefore considered the most appropriate method to identify bedforms (18), (28).

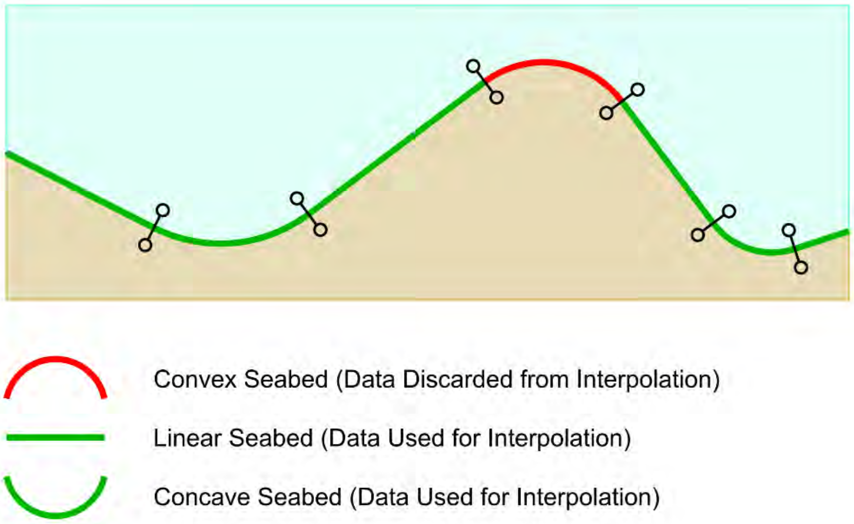


Figure 10: Curvature Radius

Interpolation

Convex areas are removed from the model, retaining only the 10m aggregated lowest points of the seabed between bedforms. The gaps between bedforms are interpolated using Delaunay triangulation, resulting in a continuous surface lowered below bedforms.

4.6.3 Results

The methodology described in Section 4.6.2 results in two gridded surfaces: one representing the SSBL; and another representing bedform heights, which is calculated by subtracting the original input bathymetry from the SSBL. The SSBL uses the original bathymetry in areas of non-crystalline bedrock, till, and clay, which are considered stable surficial sediments.

Figure 11 below illustrates that for the majority of the route, there is a minimal difference between the SSBL and the bathymetry along the export cable route, due to the lack of significant mobile features. Some areas, such as between KP28.300 to KP41.400, and KP57.400 to KP69.3, have a larger difference due to the presence of larger potentially mobile features, such as the sandwaves and linguoid sandwaves described in section 4.1. Rates of mobility for all sizes of features on the cable route cannot be confirmed ahead of a comprehensive morphodynamical study, complimented with repeat bathymetric survey; however, the size of the bedforms suggests that the impact on cable installation and operation should be minimal.

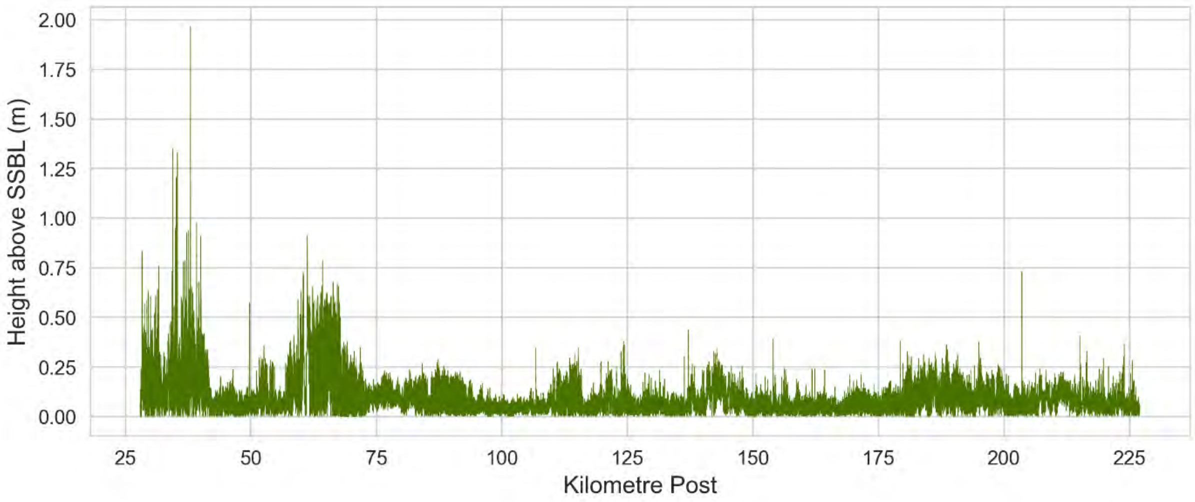


Figure 11: Bedform Heights along the Preliminary ECR

5. CABLE BURIAL RISK ASSESSMENT (CBRA)

5.1 CBRA Methodology

5.1.1 Risk Assessment Methodology

There are a wide range of obstacles and seabed users that present potential hazards to subsea cables; or which have direct interactions with cables that risk damage. Such hazards include ship anchors, which could impact or snag the cable if dragged along the seabed; and fishing, where bottom trawling gear can snag and damage cables. The aim of this study is to evaluate potential risks to the cable and provide recommendations as to the most efficient risk mitigation, including recommendations of burial depth where appropriate.

The basis of a risk assessment for a submarine cable relies on identifying the potential hazards, associated risks, and evaluating the level of protection that may be afforded to the cable by its armouring (internal and/or external), cable burial beneath the seabed or any other means, such as rock dumping or concrete mattressing.

The most reliable and cost-effective form of cable protection is generally recognised to be ensuring no interaction between the cable and the identified hazards. This is most easily achieved by routing the cable away from such hazards or, where this is not practical, by burial below the seabed.

The simplified methodology followed in this report is adopted in accordance with the industry guidance documents:

- Carbon Trust, Cable Burial Risk Assessment (CBRA) Methodology (Ref. 18)
- Carbon Trust, CBRA Application Guide (Ref. 17)
- DNV-GL Subsea Power Cables in Shallow Water (Ref. 14)

The methodology for the CBRA includes an assessment of the seabed conditions followed by the identification and quantitative assessment of the threats/hazards for the area. A probabilistic assessment has then been performed using Global Maritime’s in house GIS based software to assess the risk posed to the cable by external threats and a recommended burial depth has been established. This includes a full 3-dimensional approach to the probabilistic calculation of the threat of an anchor strike.

The CBRA method reviews an identified hazard based on its anticipated frequency and consequence. The combined outcome of frequency and consequence indicates whether risk is unacceptable, ‘As Low As Reasonably Practical’ (ALARP) or Acceptable. This adheres to the criteria outlined in DNVGL-RP-F107 (Ref. 14). The risk matrix used, and definitions of probability and severity are shown in the below tables.

		Probability				
		A	B	C	D	E
Consequence	1	🟩	🟩	🟩	🟨	🟨
	2	🟩	🟩	🟨	🟨	🟨
	3	🟩	🟨	🟨	🟨	🟥
	4	🟨	🟨	🟨	🟥	🟥
	5	🟨	🟨	🟥	🟥	🟥

Table 8: Risk Matrix

Probability	**Definition**
A (Very Unlikely)	Never Heard of in Industry
B (Unlikely)	Heard of in Industry
C (Possible)	Incident has been known to occur, but rarely
D (Likely)	Happens several times a year in Industry
E (Very Likely)	Happens several times a year at project location

Table 9: Probability Definitions

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/ Significant unplanned loss of capacity

Table 10: Consequence Definitions

5.1.2 Hazard Classification

Hazards are classified as primary or secondary. Primary hazards are those that have a direct impact upon the cable and can cause damage and secondary hazards are those that do not damage the cable directly but can result in increased risk or susceptibility to damage from primary hazards.

An example of a primary hazard would be impact or snagging of the cable due to a ships anchor being deployed. An example of a secondary hazard would be seabed mobility resulting in reduced cable burial cover or exposure, leaving the cable vulnerable to primary hazards.

5.1.3 Cable Burial - Carbon Trust Terminology

As presented in the methodology above, threat lines have been suggested for the identified site hazards for cable burial (sections 5.2 and 5.3). These follow the information and terminology described in the Carbon Trust Guidance Documents (Ref. 18). Figure 12 provides an illustration and summary of the main abbreviations and terminology used for burial in this report. The Target DOL generally includes an installation tolerance (or safety allowance).

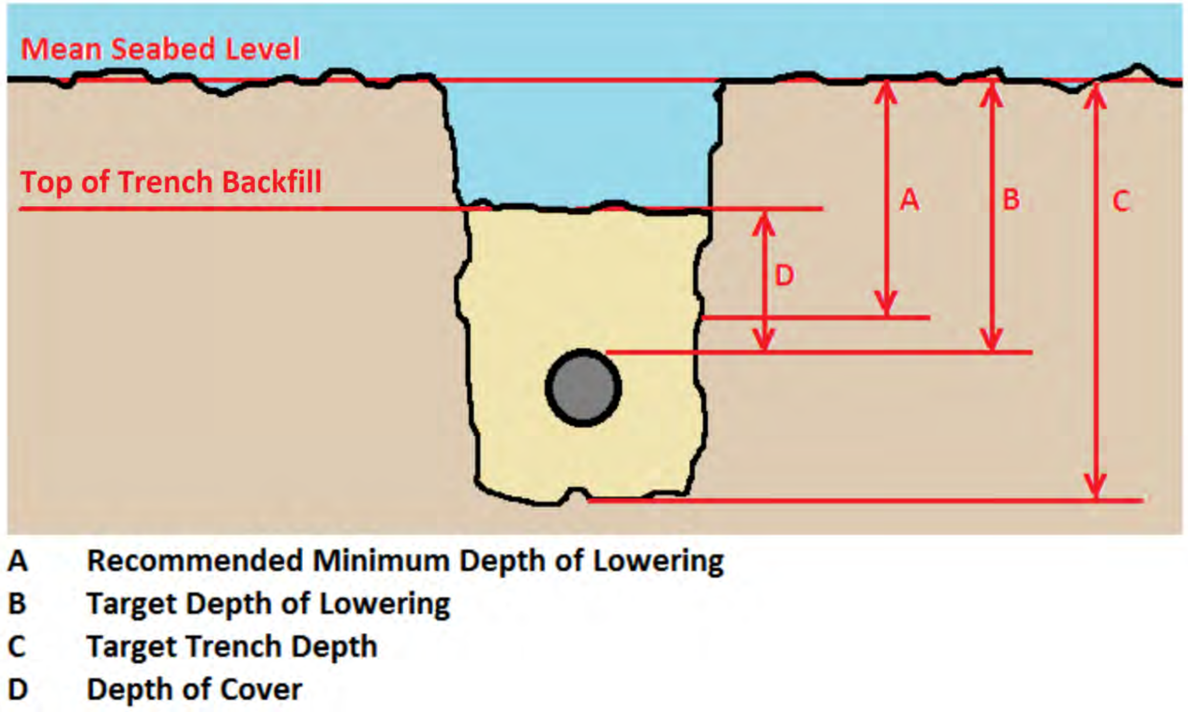


Figure 12: Definition of Trench Parameters and Abbreviations

5.2 Hazard Identification and Assessment

5.2.1 Introduction and Risk Register

Data supplied and acquired from third parties has been assessed to develop a risk register (Appendix A), which has been compiled using probability and severity classification to evaluate the potential risks to cables across the site for both installation phases and the operational lifetime of the wind farm. The purpose of this exercise is to ensure that all hazards are identified and assessed and the risk to cables appropriately acknowledged, with initial indications on mitigations presented where possible. The main hazards identified in the risk register are discussed in more detail below.

The Risk Register is considered a live document which is to be updated throughout the life of the project and should be reviewed frequently.

5.2.2 Primary Hazards

5.2.2.1 Shipping Activity

Shipping is generally the most onerous anthropogenic risk to cables in terms of threat line depth (even if not the most likely to occur). The main hazard associated with shipping is the deployment of an anchor in proximity to a cable leading to anchor strike. Anchor strike does not necessarily lead to cable damage though it is likely to occur if a cable is inadequately protected through burial to an appropriate depth. The risk of this hazard is associated with the type of vessel traffic, its density, and the frequency of transit in proximity to the cable or cables. The vessel traffic density for August 2022 to August 2024 is shown for all vessel categories and sizes in Figure 13.

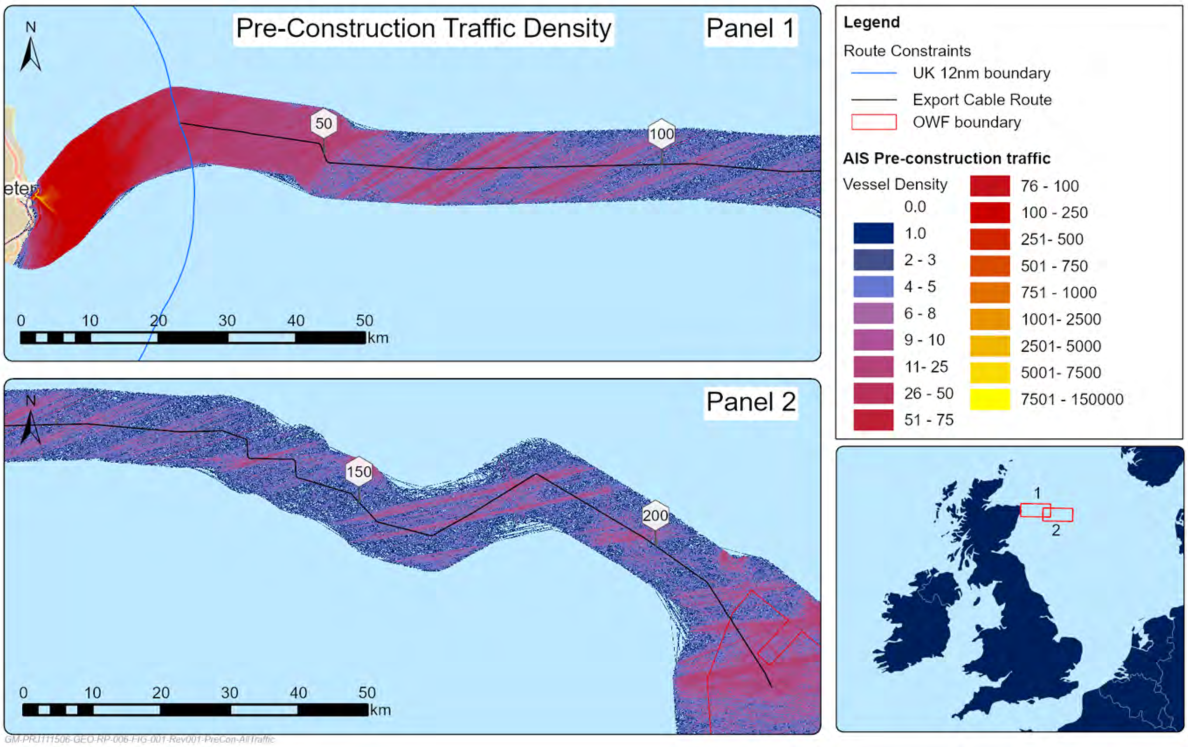


Figure 13: AIS derived vessel traffic density

The hazard to subsea cables from shipping is associated with the deployment of anchors either in designated anchorage zones (which should be avoided through routing) or in emergency situations that result in anchor deployment through mechanical failure or deployment without due care. The potential impact on the seabed and/or the resultant snagging of a deployed anchor can result in damage to a buried cable.

Vessel traffic is concentrated immediately offshore of Peterhead, within the 12nm limit. Beyond 12nm and towards the wind farm site, traffic dissipates substantially. It is expected that post-construction, traffic will avoid the wind farm area and give the turbines a wider berth where possible.

The marine traffic data can be further analysed and categorised into various vessel categories as follows:

- Cargo / Tanker Vessels
- Fishing Vessels
- Government Vessels
- Offshore Industry Vessels
- Passenger / Pleasure Vessels
- Port / Dredging Vessels

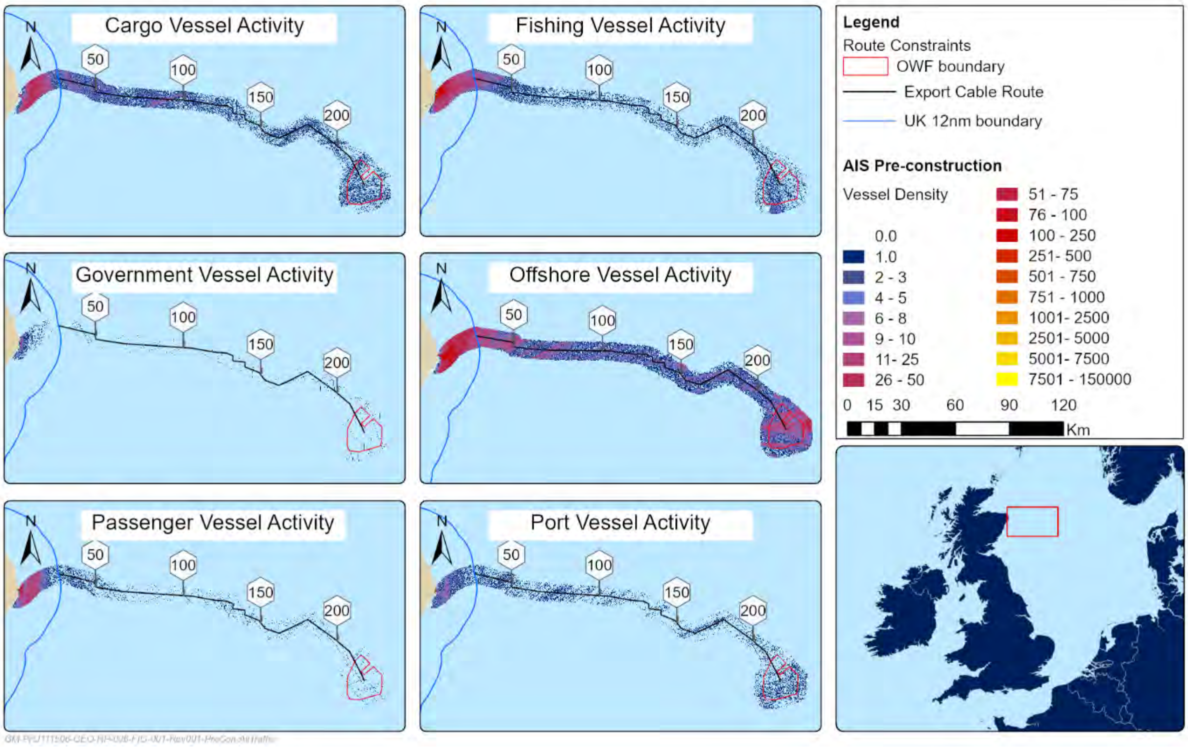


Figure 14: AIS derived vessel traffic density by vessel category

The majority of the vessels present in the region are fishing and offshore industry vessels. Fishing vessels exhibit a higher density nearshore, within the 12nm boundary, whilst offshore industry vessels are fairly well distributed across the corridor (with a concentration close to Peterhead as vessels converge to the port. Other vessels, such as those falling into the cargo category, are present but generally reduce in density with distance offshore.

AIS transmitters also provide a status of the vessels, as determined by the vessels themselves. Few vessels in proximity of the ECR in the AIS data had their status as ‘at anchor’, with the vast majority within or immediately offshore of Peterhead. Vessels with the status ‘engaged in fishing’ appear sporadically along the route, but with far higher density closer to shore. This suggests a reduced risk of impact associated with these activities; however, it should be noted that this information relies on the vessel crews accurately updating their status, which is not necessarily always the case.

Global Maritime have completed an exercise of re-distributing shipping traffic around the wind farm lease area to model the vessel traffic that would be expected post-wind farm installation, where it would be expected that the vessels previously transiting the lease area would adjust course to avoid the turbines once installed. This was conducted with assistance from Senior Mariners within Global Maritime who provided input into the modelling and a review of the post installation shipping activity. The post-installation shipping activity was used to conduct the CBRA as this is more representative, with some of the vessels that are seen in the historic data crossing the lease area, now crossing the export cables, with an overall greater number of vessels crossing the export cable. A summary of the modelled traffic can be seen in Figure 15, with a breakdown of vessel activity by category shown in Figure 16.

This shows the vessels previously crossing the windfarm and redistributes them to their most likely new transit route spatially given a criteria of exit point and entry point of the lease area, as well as the wider to and from destinations taken generally from wider open-source density mapping of the area. This also adds in any service vessels for the windfarm expected to be additionally used for operations and maintenance throughout the lifetime of the Wind farm. This process typically redistributes a greater level of traffic crossing the export cable corridor. On the Cenos site, this effect is noticeable in the redistributed AIS data, however as the vessel density was relatively low to start with, the risk of the redistributed traffic is not significantly higher.

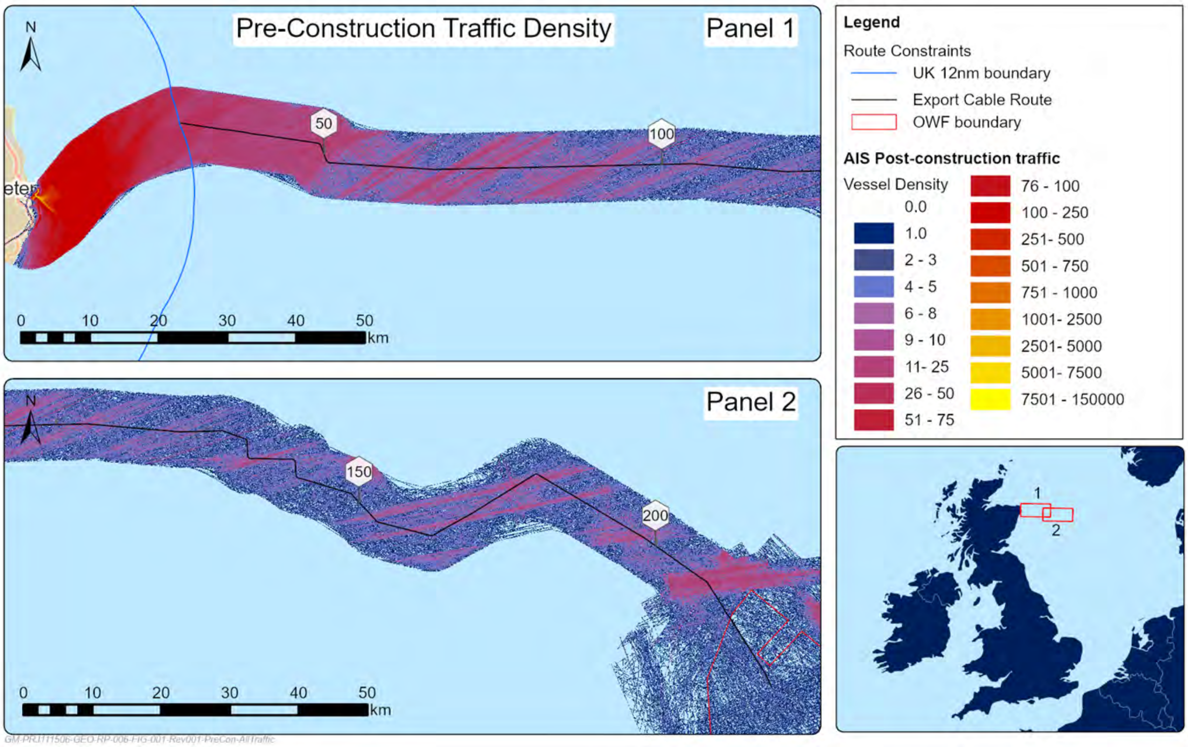


Figure 15: AIS-derived post-construction vessel traffic density

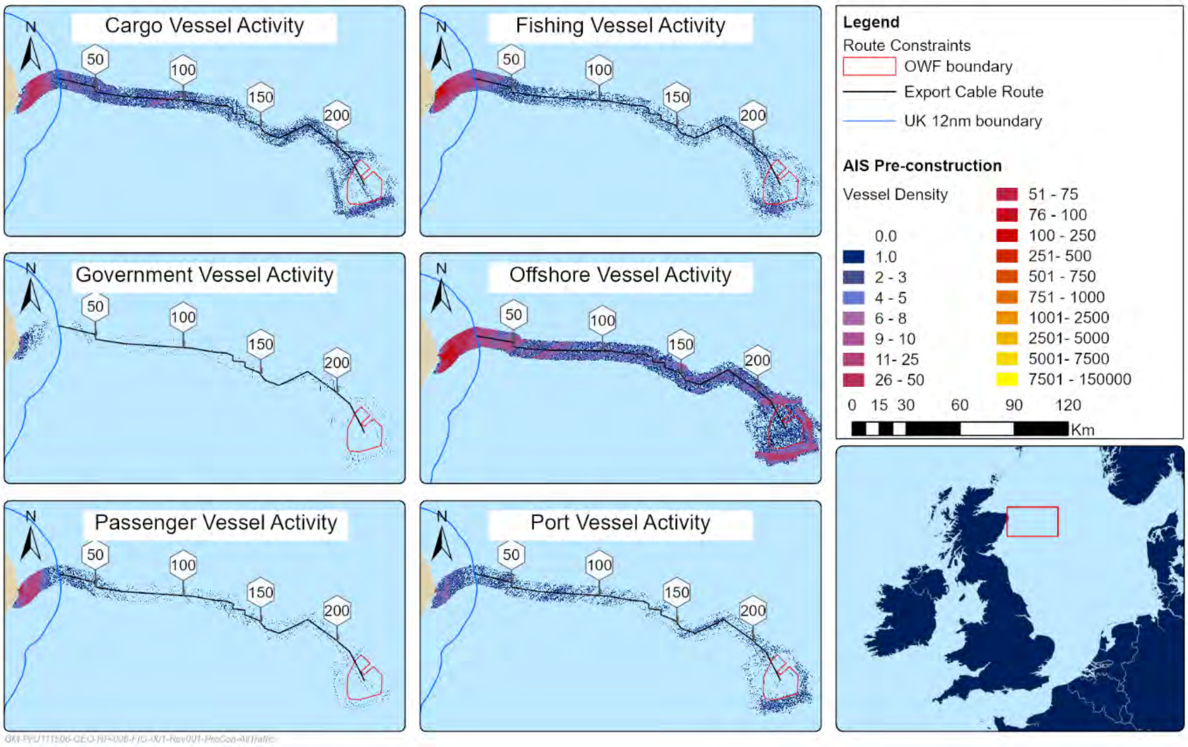


Figure 16: AIS-derived post-construction vessel traffic density categories

The main mitigation for shipping hazards (anchor strike) is typically burial beneath the identified threat line for a given return period/acceptable level of risk. The optimum burial depth is dependent on the results of the probabilistic risk assessment and cost of achieving the target burial depth. The method and results of the probabilistic assessment are discussed in Section 5.3 and 5.4.

This threat line should also only be considered as below a reference seabed level. This reference seabed level should be taken as the base seabed level taken below any mobile bedforms therefore ensuring that the minimum depth of lowering specified is always maintained despite any seabed movement observed throughout the life of the cable.

5.2.2.2 Fishing Activity

Commercial fishing is a hazard to subsea cables (even armoured cables) where fishing gear interacts with the seafloor, potentially resulting in damage due to impact or snagging. It should also be noted that a cable can pose a risk to the fishing vessels themselves if left on or close to the seabed, as small vessels can founder if snagged on a significant obstruction, of particular concern in areas of strong currents. For example, fishing vessels have been known to founder when trawl gear has become snagged on subsea infrastructure and attempts to free the gear have been unsuccessful.

As can be seen from the AIS data shown above, fishing vessel density is highest within the 12nm boundary, with some higher-density traffic (relative to the rest of the corridor) continuing to approximately KP47. Whilst the overall density of vessels is lower further offshore, vessels crossing the cable route is still a regular occurrence, and this in combination with other evidence suggests fishing activity is occurring frequently across the

ECC. The SSS data from the geophysical survey (7) detected 140 trawl scars, and 83 pieces of fishing gear and 2 fishing traps.

Given this fishing activity, it is clear that protection will need to be implemented against the risk of damage through impact / snagging of bottom trawl gear with the export cables. In the case of the identified fishing methods currently employed in the region the following threatline depth is considered reasonable below a non-mobile seabed:

- Fishing gear threatline depth in sand/mud ~0.2 m
- Fishing gear threatline depth in Soft Clay ~0.3 m
- Fishing gear threatline in bedrock/glacial till ~0.1 m

These values are in line with the Carbon Trust CBRA guidance (Ref. 18), which provides an estimate of maximum penetration of fishing bottom trawl equipment. It should be considered that fisherman will typically try to avoid allowing gear to dig into the seabed, as it greatly increases fuel consumption and increasing the risk of losing their gear as a result of snagging on the seabed, or even causing foundering of the vessel in extreme cases. Repeated scouring of the seabed by fishing gear would be naturally mitigated by natural backfill via sediment transport. It is noted that the risk of emergency anchor deployment described previously provides a greater threatline and is the governing case along the cable routes.

5.2.2.3 Stability/Fatigue

Surface laid cables are subject to loading from waves and currents and this could result in cable movement and migration across the seabed. Excessive movement on the seabed could cause abrasion and/or fatigue issues. Wave induced movements will be likely in shallow areas towards the shore approaches and during storm activities over the remainder of the site. If the cable is unstable then abrasion can occur where unburied cable is migrating across the seabed and 'rubbing against' outcropping rock, often causing significant damage.

Cable migration is also likely to increase the risk profile, as the cable movement is likely to cause a cable fault. It is also possible that the cable position will no longer be accurately identified on marine charts and this is likely to result in an increased risk from other primary hazards such as vessel anchors, fishing and construction activities. However, power cables such as the proposed are heavy and likely to have high friction with the seabed, therefore damage to the cable is more likely to occur than large displacements with suitable continued cable performance.

Whilst cable migration and fatigue may be issues for unburied cables, where a fatigue life of 20 years may be assumed in less energetic environments, experience indicates that minimal burial/embedment is usually required to ensure on-bottom stability. Therefore, where practical it is recommended that cable burial is planned unless not practical or proven to not be necessary with further in-depth analysis. If the cable is not to be buried due to outcropping rock or other factors, a more detailed cable protection strategy including the following is recommended:

- Micro-routing is undertaken to take advantage of any local features (gullies, ridges, depressions) to avoid freespans and shelter the cable where possible.

- On-bottom stability and fatigue assessments should be carried out to investigate the cable response and ascertain the likelihood for damage of the cable and the likely fatigue life under the loading regime.
- Plan appropriate mitigation methods i.e., pinning by anchoring or rock dumping, external around, additional internal stiffeners/armour, etc.

Cable burial is planned for the full length of the export cable regardless of route option, however, nearshore (as discussed in Section 4) there is bedrock near the surface and burial may be more difficult to accomplish. This is discussed further within the burial assessment in Section 6, and understood greater following further geotechnical survey campaigns, however, if burial is not possible then the stability and fatigue implications and mitigations should be further investigated with external protection likely required.

5.2.3 Secondary Hazards

5.2.3.1 Mobile Sediments

ROVCO's survey report (Ref. 7) highlights numerous areas where mobile bedforms occur. Within the ECC, sand waves are present between KP27.974 to KP37.507, and intermittently between KP40.032 to KP68.249, KP0.000 to KP 4.456, KP5.157 to KP6.000 and KP109.877 to KP144.066 (KPs in reference to the survey corridor centreline). The sandwaves in these sections typically have wavelengths of between 6-43 m.

The report also defines areas of linguoid sandwaves associated with higher-flow regimes and interfering current flows. These are interpreted to be intermittent between KP35.507 to KP40.032, KP59.118 to KP68.258, KP4.456 to KP5.157. The features are large with wavelengths of between 80-278 m (overlain with smaller sandwaves of 9-29 m wavelength).

The report does not detail the amplitudes of either the sinusoidal or linguoid sandwaves. As described in section 4.6, an SSBL has been calculated based on the 2023 bathymetry, which indicates that the majority of mobile features on the route are either stable within the lifespan of the wind farm or are too small to present an issue for burial. There are however some areas where the difference in SSBL and the bathymetry indicates that large mobile bedforms are present, and these should be either routed around where possible, or an increased burial depth (from seabed) considered to ensure the recommended DOL is reached, and the cable does not become exposed in the future.

Where there is the presence of sediment mobility at the site, this could result in (deeper) burial of cables sections and/or the exposure/freespanning of previously buried sections, as the bedforms migrate. Therefore, the following should be considered:

- The performance of the cable when buried, confirming that there is not a risk of overheating at the possible burial depth due to the mobile sediments in this area.
- The increased risk of primary hazards such as fishing, anchoring and stability/fatigue due to mobility and exposure of the cable.

It is recommended that an allowance be made for sediment mobility where appropriate, with increased burial depth in areas of confirmed mobile features following further studies. The threatlines discussed in this report are based on the non-mobile layer as calculated using the SSBL. It is recommended that a full sediment mobility study is conducted and the results of this should be considered alongside this CBRA study and further repeat bathymetry surveys to calculate the total installation depth of lowering required to adequately protect the cable for its full design life.

5.3 Probabilistic Risk of Anchor Strike

A probabilistic assessment of the export cable anchor strike risk due to the identified shipping activity has been performed following the carbon trust guidelines (Ref. 18) using Global Maritime's GIS based approach. This has been performed using the site AIS data which was adjusted to model the post-windfarm construction traffic.

This method evaluates the external threat to the cable by considering the amount of time vessels spend within a critical distance of the cable and the probability that a vessel might have an incident that requires the deployment of an anchor. The effect of water depth and bathymetric profile is considered very important and is included as a qualitative factor.

The calculation for the probability of a cable strike is given by the following formula:

$$P_{strike} = P_{traffic}\, P_{wd} \sum_{1}^{No.\ ships\ in\ Section} \frac{D_{ship}}{V_{ship} * 8760hrs\ per\ year} P_{incident}$$

Where:

$P_{traffic}$: Probability modifier based on the tolerable level of risk

P_{wd} : Probability modifier for nature and depth of seabed

V_{ship} : Ship speed (metre/hr)

D_{ship} : Distance travelled by ship's deployed anchor in area under consideration (metre)

$P_{incident}$: Probability of incident occurring for that vessel size and type

$8760hrs$: Facture to annualise the results

Values for the above parameters are shown in the table below:

Parameter	Description / Comments	Value Used
$P_{traffic}$	Probability modifier to determine acceptable level of risk. Indicates the percentage of vessels for which burial is required for protection. Conservative value used for initial assessment.	1

P_{wd}	Indication of risk due to seabed profile and water depth. Values chosen as per the Carbon Trust guidelines.	See Table 12
V_{ship}	Individual vessel speeds taken from AIS data when crossing cable, with a maximum speed of 2 knots	Various
$\boldsymbol{D_{ship}}$	Distance travelled by the anchor when deployed to exert its holding capacity and immobilise the vessel. Vessel outside of a distance equal to D_{ship} from the cable is not a hazard. Calculated on vessel mass (m) taken as displacement, and estimated Ultimate Holding Capacity (UHC) which is estimated for each individual vessel.	$D_{ship} = \frac{m * V_{ship}^2}{4 * UHC}$
$P_{incident}$	This is the probability of an incident occurring on the vessel which requires the deployment of an anchor. This is taken as the probability of engine failure in single engine tankers in the North Sea, as per DNV guideline DNV-RP-F107	$1.75x10^{-1}$ incidents per year per vessel

Table 11: Parameter Values of Probabilistic Risk Assessment

Vessel DWT (t)	**Minimum Water Depth (m)**			
	0-10	**10-30**	**30-50**	**>50**
0	1	0.1	0	0
2000	1	0.3	0	0
5000	1	0.5	0.1	0
20000	1	0.9	0.3	0.1

Table 12: P_{wd} Values According to Water Depth and Vessel DWT

Possible anchor penetration can be estimated, based on the soil properties and the typical anchor sizes (fluke length) used by vessels categorised by their deadweight tonnage. As described within Section 4, the seabed along the cable route consists primarily of sand units of varying thickness overlying high-strength clays and glacial till. The penetrative ability of anchors of different sizes in these variable soil conditions must be considered in the CBRA. This is summarised in the below table for the vessels identified. This is representative results for a single soil layer only, the full modelling performed for the results presented later in this report and shown in the alignment charting utilises a multiple layer solution from the available geophysical data.

Vessel Deadweight (DWT, Te)	**Maximum Anchor Fluke Length (m)**	**Anchor Penetration in Unit S1 (Sands) (m)**	**Anchor Penetration in Unit C5 (Clays and Till) (m)**	**Anchor Penetration in Unit C7 (Chalk, Sandstone and Mudstone) (m)**
1000	0.8	0.6	0.6	0.4
2000	0.9	0.7	0.7	0.5
5000	1.2	0.8	0.8	0.6
10000	1.3	1.0	0.9	0.7
20000	1.6	1.1	1.1	0.8
50000	1.9	1.4	1.3	1.0
100000	2.2	1.6	1.6	1.1
200000	2.6	1.8	1.8	1.3

Table 13: Anchor Penetrations for different sizes of vessel in the expected soil conditions

The main mitigation for the hazard of anchor strike is generally burial beneath the identified threat line for a given return period / acceptable level of risk. This has been calculated in terms of a recommended depth of lowering along the length of each cable to sufficiently protect it to reduce the risk below acceptable levels. As such the recommended depth of lowering will vary along the ECR depending on the modelled traffic density and the seabed composition.

5.4 CBRA Results

The threat lines based on modelled post-windfarm installation shipping density and seabed composition were produced for each of the five cable route options. The threat lines were interpreted to define recommended burial depths for sections of the cables to satisfy the risk requirement and minimise burial depth where possible to reduce installation costs through maximising tooling choice and reducing installation schedules. The results for the export cable are summarised below and shown clearly in the provided alignment charts (Appendix C). The tables detail the recommended depth of lowering of the cable within zones established along the cable length. The strike return period and corresponding DNV risk category (Ref. 16) is also stated for each zone along with the values for the entire cable. The strike return period is equal to $1/P_{strike}$. As P_{strike} is annualised, this gives the theoretical period in years between anchor strikes on the cable based on the probabilistic CBRA calculation i.e. the number of years statistically within which one anchor strike will occur.

DNV Risk Category	P_{Strike}	Return Period (years)
1	<0.00001	100,000+
2	0.00001 - 0.0001	10,000 to 100,000
3	0.0001 - 0.001	1,000 to 10,000
4	0.001 - 1	1 to 1,000

Table 14: DNV Risk categories (Ref. 8)

Cable Start/End Point		Zone Length (km)	Recommended Burial Depth (m)	Strike Return Period (Years)	DNV Risk Category
KP Start	KP End				
0.000	27.971 (12 nm)	27.971	See Table 16		
27.971 (12 nm)	227.000	199.029	0.5	22,921	2

Table 15: Export cable CBRA results summary

5.4.1 Results Discussion and Summary

The results of the CBRA have allowed the determination of suitable target depth of burial along the cable route. The outcome of the analysis has shown that no individual sections of the cable, when categorised by the recommended DOL, have a DNV risk category above 2 (equivalent to the probability of the cable being struck by an anchor being between 10,000 and 100,000 years). There is no standard of what risk level is acceptable, and this is down to the developer's appetite to risk, and the lowering of costs during the installation phase, but typically across the industry having a risk of DNV Category 2 is considered appropriate for export cable sections. As the same depth of burial is assigned for the entire cable route, the cumulative risk is also DNV category 2.

It is common for an export cable route, especially one as long as the Cenos route, to have multiple different recommended DOL sections, to meet the best compromise between the CBRA output and what is practically feasible with burial tools. However, as the vessel traffic is relatively light across the Cenos ECC, the risk profile and therefore the burial requirement is relatively low. As the vessel traffic density is higher closer to shore, it is likely that a deeper DOL may be required here, however this section (within 12nm of shore) has not been considered in this report. It should also be noted that deeper overall burial may be required due to the presence of mobile features, as in this case the overall burial depth will be the DOL plus the height difference between the SSBL and the mobile surface of the seabed. Deeper burial may impact burial progress rates when compared to the DOL of 0.5m, though this is highly dependent on the ground conditions and burial tool being used (section 6).

The addition of the risk within the 12nm boundary, and the addition of cable length, would affect the cumulative strike return period for the entire export cable from shore to the array area. The CBRA for the NorthConnect route (Ref. 25), which is publicly available on

Marine Scotland's website, lists the strike return periods for the cable route within the 12nm boundary, for the level of study performed in that instance. The cumulative risk for the full Cenos ECR can be approximated by combining the reported risk within the 12nM zone with the risk calculated in this study:

Cable Start/End Point		**Zone Length (km)**	**Recommended Burial Depth (m)**	**Strike Return Period (Years)**	**Pstrike**	**DNV Risk Category**
KP From	**KP To**					
0.000	4.600	4.600	0.2	49,000	0.00002	2
4.600	5.100	0.500	0.2	>100,000	0.00001	1
5.100	20.000	14.900	0.3	19,000	0.00005	2
20.000	24.000	4.000	0.3	>100,000	0.00001	1
24.000	27.700	3.700	1	>100,000	0.00001	1
			Cumulative:	9,705	0.0001	3

Table 16: Results from the NorthConnect CBRA (Ref. 25) for within 12nm

Route Section	**Cumulative Strike Return Period (Years)**	**Cumulative Pstrike**	**DNV Risk Category**
Landfall to 12nm	9,705	0.0001	3
12nm to OSP	22,921	0.00004	2
Cumulative for entire route	**6,825**	**0.00014**	**3**

Table 17: Cumulative Strike return Period and Pstrike Summary

The results from combining the NorthConnect CBRA results with the CBRA detailed in this report indicate a substantially lower anchor strike return period, and corresponding higher DNV risk category. This is due to the higher vessel trafffic nearshore and greater effective cable length when including the route within the 12nm boundary. The cumulative strike return period decreases with this addition, as it is equal to 1 divided by the sum of the Pstrike values for each section. The actual cumulative risk for the full route should be computed and the acceptability of risk considered to fully define the recommended DoL.

6. BURIAL ASSESSMENT STUDY

6.1 Overview

As described previously, GM have assessed seabed conditions for the export cable routes to define recommendations for cable installation methodology. Burial techniques considered, at this stage, to be most appropriate for the site, can be taken forwards for further consideration when additional information becomes available.

At a high level, the site can be described as consisting primarily of clayey and silty sands overlying stiff clays and glacial till, with some occasional areas of outcropping stiff clays and glacial till. Boulders and cobbles are common at the surface throughout the length of the route.

6.2 Cable Lay Options

The main construction options available for the offshore sections of the cable burial are:

- Post-lay burial of the cable utilising separate cable lay and burial campaigns with cable buried by cable plough or trencher after it has been laid on the seabed.
- Simultaneous lay and burial with a cable plough or trencher deployed and operated from the cable lay vessel.
- Pre-lay trenching utilising separate trenching and cable lay campaigns where the trench is pre-cut by a large plough or trencher followed by cable lay directly into an open trench followed by backfill by plough, natural backfill or rock placement.

The most appropriate method will depend on a number of factors, for example the cable type being approved for the method to be utilised or the required vessel/trenching tool combination being available for the desired installation dates and the burial conditions on the cable route. These three methods are discussed briefly below.

6.2.1 Post-Lay Burial

In a post-lay burial operation, the cable is laid onto the seabed by a cable installation vessel. The same vessel can then return to carry out cable burial with the cable in place. Alternatively, a different vessel could carry out burial at a later date.

With the post-lay burial method, there is a risk of damage to the unburied cable during the intermediate stage between cable lay and burial operations from primary threats or cable instability at seabed due to metocean conditions. Post-lay burial with tools such as jet trenchers and mechanical cutters can induce tensions into the pre-laid cable due to cable friction as the cable travels through the machine. This can lead to free spans in sand wave areas. In addition, a kink can develop in the cable ahead of the machine.

Operational risks are always present surrounding launch and recovery of the burial machine from the vessel, especially in high sea states. Landing the machine on the seabed safely over the cable can also be a challenging operation in energetic seas and will be performed according to weather limitations identified through installation analysis. Cable routing through the machine can also be problematic, most modern tools are equipped with manipulators to manually pick up and load the cable into the trencher for burial, however, there are some machines in service that require diver assistance.

6.2.2 Simultaneous Lay and Burial

During simultaneous lay and burial, cables are laid and buried simultaneously with burial equipment (plough or burial sled) being towed by the cable laying vessel or barge or operated from the cable laying vessel where a self-propelled Remotely Operated Vehicle (ROV) is utilised generally for jetting or mechanical cutting burial methods. These may be free flying ROVs, or self-propelled tracked machines (TROVs).

This approach offers immediate protection to the cable and cable tension can be managed by the cable lay system as the cable enters the plough or trencher. The cable catenary can be monitored by ROV during the process.

6.2.3 Pre-Lay Trenching

For this method, a separate vessel would tow a plough or operate a trencher to cut a trench in the seabed for which the cable can be laid into by the cable lay vessel in a separate operation.

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. The cable can then be laid into this trench and back filled by a second pass with a backfill plough. This approach would mean that the risk of damage to the cable is much reduced compared to the post lay burial and the simultaneous lay and burial techniques. However, difficulties exist in co-ordination of the two vessels working together in this way, for accurate positioning of the cable and for maintaining an open trench, due to sediment infill. Broad disturbance of the seabed in this manner may also be less desirable from an environmental consenting perspective.

6.3 Cable Burial Options

The results of the CBRA detailed in section 5.4 ultimately determine what type of burial tool to use to achieve the recommended DOL. In general, burial methods can be categorised as ploughing, jetting or mechanical cutting. Different burial tools are optimised to perform in certain sediments – the types of tools available on the market are discussed in sections 6.3.1, 6.3.2 and 6.3.3 below, and section 6.3.4 evaluates their suitability for the site based on conditions discussed in section 4 and the results of the CBRA, detailed in section 5.4.

6.3.1 Cable Ploughs

Cable ploughing is the process of towing a subsea plough with a vessel with sufficient bollard pull capability to create a trench for the cable. This method has the largest effective range of soil conditions and will be suitable up to the dense / very dense sand and stiff clays. Ploughs are generally utilised for simultaneous lay and burial whereby the installation vessel tows the plough, and the cable is routed through the plough and laid into the open cut trench with assistance from a depressor on the plough. The trench can then either be left to backfill naturally or a backfill plough can be used to relocate the spoil from the initial trenching into the open trench on top of the laid cable.

Alternatively, ploughs can be used prior to cable lay to cut a trench along the lay route for which the cable can then be laid into. This may be required where boulder presence is a concern and the pre-lay trenching is used to clear smaller boulders, with some tooling setups quoting the capability to clear boulders up to 1m diameter. Where this is deemed necessary, specialist boulder clearance ploughs can be utilised. When pre-cutting a trench, this should only be undertaken if it can be performed close enough to cable lay operations or in a non-mobile seabed such that the trench will not naturally backfill prior to cable lay.

Some additional considerations should be made when considering ploughing operations. Firstly, manoeuvrability is restricted for ploughing compared with alternative burial methods. This limits the achievable cable turn radius and means that less complex lay routes can be achieved. Many ploughs also require longer burial transition lengths compared with alternate methods. Geological hazards should also be considered such as excessive seabed slope resulting in risk of tooling overturning or less control of cable burial depth, along with soft soils resulting in risk of plough sinkage. Tool selection should also be made considering features of available tooling on the market, for example some will require diver assistance for routing of the cable through the tooling and some will have diverless options which may be favourable in terms of project risk and commercial costs of diving operations.

As discussed, cable ploughs can work in a wide range of soils and are suitable for low to high strength clays which can be sheared but less suitable for dense sands which can increase tow force and likelihood of plough ride out. The high tow forces exhibited in sand are caused as the plough shears the granular material, this causes dilatancy in front of the shear. As the sand accumulates strain, the soil particles dilate, increasing void space. Pore pressures become negative causing apparent strength gain, until pore pressures eventually equalise due to water ingress. To reduce the high tow force generally exhibited in sands during ploughing, the cable plough shear can be fitted with a jet system. This addition of water reduces the negative pore pressure and therefore reduces the tow forces experienced.

The different types of cable burial ploughs are listed below:

- Conventional Narrow Share Cable Ploughs
- Advanced Cable Ploughs – a new generation of cable ploughs, which have been designed to achieve increased depth of lowering for subsea cables of depths up to 3.0 m.
- Rock Ripping Ploughs – suitable for outcropping rock, or where the seabed strata are exceptionally hard and beyond the capabilities of a conventional narrow share plough.
- Vibrating Share Ploughs - consists of a narrow share, which is vibrated to ensure cutting progress through difficult seabed conditions, such as gravel beds.

6.3.2 Jet Trenchers

A jetting system works by fluidising and/or cutting the seabed using a combination of high flow low pressure and low flow high pressure water jets to cut into sands, gravels and soft to firm clays. Jetting tooling is generally effective from very loose up to medium dense or dense sands. In some cases, a dredging/eduction 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 cohesionless sands/gravel soils are fundamentally different. Sands are most efficiently fluidised by a large volume of water (high flow / low pressure water jets) flowing over the trench cross sectional area, with a large water volume required to lift the sand particles into suspension. Coarser materials such as gravels fall rapidly through the water column and as a result it is very difficult to displace these soils and adequately bury a cable through coarse soils. Reduced DOL could be seen in areas of higher gravel content.

Conversely, in clays, the jet pressure (low flow / high pressure water jets) must be greater than a threshold value at which the clay can be cut, related to the undrained shear strength. As this pressure is partly generated through the available hydrostatic pressure at seabed, it may not be suitable in low water depths unless modified. A second pass may also be required utilising the high flow / low pressure setup, to remove the pre-cut clay blocks if the flow rate on the first pass is not sufficient.

The trench will naturally backfill due to settlement of sand particles out of suspension. Based on experience with jetting machines, between 60% and 80% backfill in the trench will be achieved to natural seabed level if one pass is required.

Jetting systems are most commonly used for post lay burial operations; however they can be used for simultaneous lay and burial. Tooling for this method are generally Tracked Remotely Operated Vehicles (TROVs) but may also be free flying tools or towed tools mounted on skids. Jetting nozzles are generally installed on two long jetting swords that are lowered into the seabed either side of the cable to fluidise / remove seabed material to allow the cable to be lowered. Sword lengths can be adjusted according to the required burial depth of the cable.

Jet trenchers generally reduce the risk of cable damage as there is no planned direct contact with the cable, and therefore can also be used near cable crossings. Multiple passes are possible in order to achieve target depth of lowering/depth of cover requirements. However, where deep burial is required, cable detection may be difficult.

Jetting tools are generally best suited to softer and looser ground conditions. Where bearing capacity of soil is a concern to support the TROV weight, buoyancy can be installed as required to reduce the submerged tooling weight, however lighter tools or free-flying tools are more susceptible to metocean conditions and may have high weather limitations. Tooling operations may be limited by water depth for submerged pumps to work, in which case surface water supply may be required when working in shallow water for example near landfall areas.

6.3.3 Mechanical Cutters

Mechanical trenchers are usually post lay burial machines suitable for consolidated high strength cohesive sediments and weak/fractured rock. They typically 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 hard 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.

Significant thicknesses of sand and gravel are likely to hinder performance as the tool relies on the action of ripping cohesive soils. To aid with lowering, mechanical cutters can be fitted with a rear jet leg/eduction system which clears the trench of granular soils and back fill material. A mechanical cutter is generally fitted with a depressor which guides the cable through fluidised materials increasing DOL. On rocky outcrops, the seabed might be too uneven for the trencher to operate normally. Typically, sudden changes in elevation should be smaller than 0.3 m and slopes below 15°, although this is dependent on the size and limitations of the specific trencher. Aratellus' Leviathian Trencher, for example, has fully articulated separate tracks and so is likely to be much more capable of operating on an irregular, rocky seabed.

The magnitude of the seabed relief, in the context of the footprint of a mechanical trenching tool, must be understood in detail in order to assess the stability of the trencher and its ability to progress across the seafloor.

It is common that mechanical cutters are utilised for short sections of cable routes where required to trench within hard ground. These are generally avoided where possible due to slow progress rates, for this reason they are generally used for pre-lay or post-lay trenching rather than simultaneous lay and burial which would significantly slow the progress of the cable installation vessel.

Mechanical cutting tools are deployed and controlled from a vessel with sufficient capacity crane or A-frame LARS. They are generally TROV type vehicles and can include additional features such as cable loading manipulators. Cutting tool wear is a particular consideration for these tools, and rock wheel / cutting chain teeth should be selected carefully based on the seabed material.

Mechanical cutting can cause substantial suspension of sediments in the vicinity of the tool, which can be a risk for environmental consenting. The relevant authorities should be consulted on what mitigation is required, but this could include for example turbidity monitoring buoys.

6.3.4 Cable Burial Tool Suitability

As described above, multiple different types of burial tools are available for subsea cable installation, however the performance of the tools will vary depending upon the sediment type and other factors. The general suitability of different burial equipment is given within Table 18, taken from the BERR report 2008 (Ref. 22).

Cable Burial Devices	Burial Device Options	Sediment Type					
		Sands	Silts	Gravel	Weak Clays	Stiff Clays	Rock
Cable Burial Ploughs	Conventional narrow share cable ploughs	✓	✓	✓	✓	✓	✗
	Advanced cable ploughs	✓	✓	✓	✓	✓	✗
	Modular cable ploughs	✓	✓	✓	✓	✓	✗
	Rock ripping ploughs	✓	✓	✓	✓	✓	✓
	Vibrating share ploughs	✓	✓	✓	✓	✓	✓
Tracked Cable Burial Devices	Jetting systems	✓	✓	?	✓	✗	✗
	Rock wheel cutters	P	P	P	✓	✓	✓
	Chain excavators	P	P	✓	✓	✓	✗
	Dredging systems	✓	?	?	✗	✗	✗
Free Swimming ROVs with Cable Burial Capability	Jetting systems	✓	✓	?	✓	✗	✗
	Dredging systems	✓	?	?	✗	✗	✗
Burial Sleds	Jetting systems	✓	✓	?	✓	✗	✗
	Rock wheel cutters	P	P	P	✓	✓	✓
	Chain excavators	P	P	✓	✓	✓	✗
	Dredging systems	✓	?	?	✗	✗	✗

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 application.

✗ = Unlikely to be capable of burial.

Table 18: Burial Performance Comparison

Figure 17 below from DNV (Ref. 14) also summarises burial method suitability in various ground conditions and thus the optimum ground conditions for each burial tool can be derived. As can be seen for cutting, by adding a dredging (or jetting) system, the graph could be extended into looser materials. The figure also highlights that ploughing is more suitable for a wider range of soils. Therefore, in sites with variable material, ploughing could be the optimum tool. However, this is based purely on soil conditions, other factors such as water depth, seabed features and commercial factors all influence the choice of burial asset used.

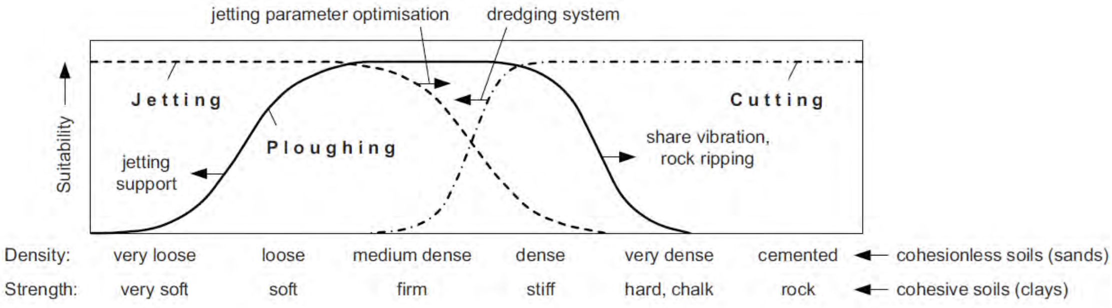


Figure 17: Indicative Burial Tool Suitability in Different Ground Conditions (Ref. 14)

In general, it can be summarised that the ploughing method is suitable for a wide range of ground conditions, jetting techniques are suitable for soft or loose soil conditions, and mechanical cutting is required in the hard or dense soils and rock.

The above is a guide that should be considered when selecting burial methodology, however, additional considerations need to be made with regards to the site conditions when selecting the burial tooling and methodology. For example, boulder presence within the lay route, geological features, potential mobility and expected metocean conditions will all factor into the decision-making process when selecting burial tooling, along with the overall methodology including if post-lay burial or simultaneous lay and burial will be most suitable. This is further described for each method in the sections below.

The three methods described above have differing anticipated progress rates within different seabed materials. These anticipated progress rates are shown in the table below:

Burial Tool	**High Level Anticipated Progress Rate**	
	Loose Sand / Soft Clay	**Dense Sand / Stiff to Hard Clay and Rock**
Jet Trencher	200-350 m/hr	100-200 m/hr
Cable Plough	200-400 m/hr	200-400 m/hr
Mechanical Cutting	200-350 m/hr	70-150 m/hr

Table 19: Anticipated Burial Tool Progress Rates

6.4 Burial Assessment Methodology

A preliminary burial assessment and tool suitability assessment has been undertaken for the cable route options for most commonly used tools, as described above. This assessment was based on the anticipated ground conditions along each cable as well as tool specifications and limitations that might affect suitability. Each tool to be used alone is graded into the following system:

- Suitable – Likely to achieve burial
- Possible – Unlikely to achieve consistent burial throughout
- Not Suitable – Unlikely to achieve burial

The tool suitability has been assessed for the seabed conditions and required burial depths for each of the export cable options. Broadly speaking, sections of the export cable routes can be categorised by burial class which is determined by the seabed composition within the target depth of lowering established within the CBRA (Section 5). These burial classes are shown below:

Burial Class	Description		Achievable Burial Depth
	General	Geology	
A	Full burial expected to target depth in a single trencher pass. Constant burial conditions with low variability. Optimal plough or jetting progress rate.	Thick very loose to medium dense sands / silts and soft to firm clays. Generally flat seabed and absence of features hindering burial operations.	Target or beyond
B	Reduced and variable burial conditions. Reduced progress rate possible. Potential for reduced success with jetting tools and / or multiple passes expected with potentially different tooling such as mechanical cutters.	Medium dense to dense sand and stiff to very stiff clay or loose / soft sediment sitting over a dense to very dense unit. Minor bedforms, slopes <10 degrees expected to impact tool progress.	Within Target
C	Poor burial expected, with possible areas of cable exposure. Slow progress rate with high risk of not achieving full burial.	Stiff to very stiff clay and up to very dense sand/silt and consolidated sediment / bedrock, or a thin unit of loose/soft sediment sitting over a dense to very dense unit or rock. Bedform slopes > 10 degrees.	Potentially Less than Target

Table 20: Cable Burial Classification

6.5 Burial Assessment Results

The results of this analysis, in the form of Burial Assessment tables, are shown in full in Appendix D. The most suitable tools and burial classes for defined sections of the two cable routes are summarised in Figure 18 and

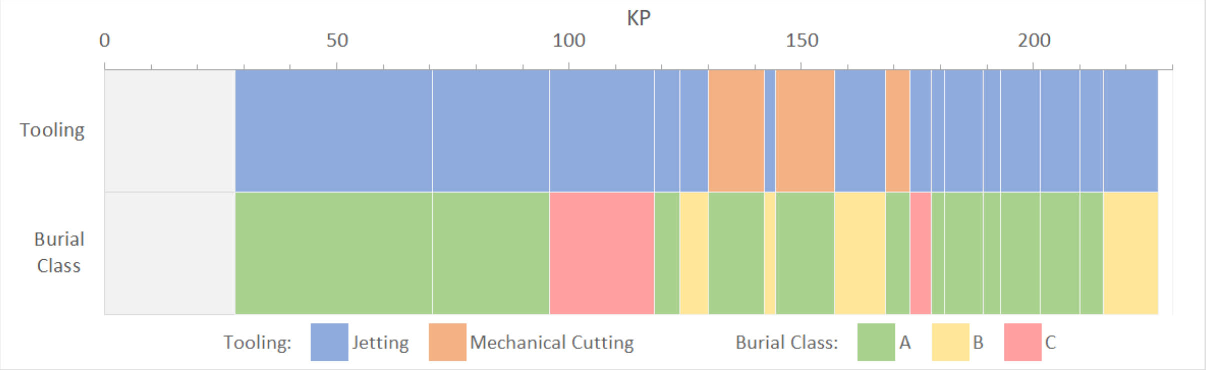


Figure 18: Suggested Burial Tooling and Class along the export cable route

KP Start	KP End	Length	% of Total Length	Burial Method	Burial Class
0	27.971	27.97	16.12	Out of Report Scope	
27.971	70.671	42.70	28.47	Jetting	A
70.671	95.771	25.10	22.76	Jetting	A
95.771	118.471	22.70	24.30	Jetting	C
118.471	123.971	5.50	7.38	Jetting	A
123.971	129.971	6.00	7.74	Jetting	B
129.971	141.971	12.00	15.00	Mechanical Cutting	A
141.971	144.471	2.50	3.42	Mechanical Cutting	B
144.471	157.171	12.70	15.39	Mechanical Cutting	A
157.171	168.171	11.00	15.75	Jetting	B
168.171	173.471	5.30	9.01	Mechanical Cutting	A
173.471	177.971	4.50	8.41	Jetting	C
177.971	180.971	3.00	6.12	Jetting	A
180.971	189.171	8.20	17.81	Jetting	A
189.171	192.971	3.80	10.05	Jetting	A
192.971	201.471	8.50	24.98	Jetting	A
201.471	209.971	8.50	33.30	Jetting	A
209.971	214.971	5.00	29.36	Jetting	A
214.971	227.000	12.03	100.00	Jetting	B

Table 21: Suggested Burial Tooling and Class along the export cable route

Using the results from the CBRA and SSBL and planning a burial strategy with regards to tool type and burial depths in the BAS allows the recommendation of an installation methodology of the options outlined in section 6.2, and suggested vessels and tools to conduct the operation. Burial depth is recommended to be 0.5m for the entire route, with a combination of jetting (covering the majority of the route) and mechanical trenching the recommended tooling.

6.6 Recommended Cable Installation Methodology

The suggested cable lay methodology is a post-lay burial solution, using a powerful jetting tool in combination with Mechanical Trenching and remedial protection. The vast majority of the cable corridor has soils that are suitable for jet trenching within the recommended burial depth, with some small areas where jetting may become more difficult due to the presence of subcropping high-strength clays. These areas occur between KP120.571 to KP121.171, KP177.971 to KP180.971, and KP214.971 and KP227.000. In these limited areas, a tool that can be reconfigured with a mechanical chain cutter will be advantageous - mobilising a dedicated chain cutting tool and TSV in addition to a jetting spread may not be cost-effective. Subsea Rock Installation (SRI) may be required in these sections if the target DoL is not met after the trenching campaign, either due to challenging conditions preventing full burial being reached or for scenarios such as bights for tool deployment and grade-in/out. SRI is further described in section 6.7.

Post-lay burial is recommended to avoid the risk of trench infill by the surficial sands found over much of the corridors for each cable route option that could happen if a pre-lay trenching approach is used. Despite the risks outlined in section 6.2.1, most modern post-lay burial solutions are now equipped to mitigate issues locating and acquiring the cable on the seabed. As much of the route is jettable, using a dedicated jetting tool (or configuration of a hybrid tool) and a small amount of mechanical trenching maximises efficiency of the burial campaign, whilst separating the two burial phases allows more flexibility in scheduling. This method also decreases the amount of time a dedicated cable ship is required, as all the burial can be conducted using a TSV, after the cable is laid on the seabed.

Mechanical chain cutters should be sufficient for the mechanical trenching scope, as the sediments requiring excavation are stiff clay or glacial till. Tools capable of digging in extremely high-strength seabed such as rock-wheel excavators could be used but would not be suitable for most of the route length and are more limited in burial depth capability compared to chain cutters due to the diameter of their cutting wheels.

A boulder clearance campaign is likely to be required, as detailed in section 4.3. Depending on final cable routing and the number of boulders to be cleared, a combination of a clearance plough and Tine grab is recommended.

As less preferential options and depending on burial asset and vessel availability, simultaneous lay and burial using a jet-assisted cable plough, or pre-lay trenching if the sediments are stable enough could also be used. Simultaneous lay and burial is less preferential as there is a greater risk of damage to the cable during installation, and using this method may limit the cable ship that could be used, as it would need sufficient bollard pull for a plough and would take more time when compared to surface-laying the cable. Additionally, ploughs typically encounter grade-out issues and reduced or changeable burial in dense sands, which are likely to be present across much of the site. The drawbacks of using a plough may be mitigated by using a simultaneous pre-trenching and boulder clearance plough, described in section 6.6.5.1. If the trenches backfill between the trenching and cable laying campaigns, post-lay jetting could be used to ensure the reccommended DOL is reached.

Based on the water depths nearshore, most cable ships should be capable of getting close enough to shore during neap tides to safely carry out a cable float-in operation. Due to the length of the Cenos export cable route, a priority when selecting a cable installation vessel would be turntable capacity to accommodate the large amount of cable and minimise potential joints. To mitigate the risk of damage to the cable in between laying on the seabed and the burial campaign, guard vessel(s) can be utilised along with working with the relevant authorities to impose navigational restrictions on the cable route if feasible.

6.6.1 Suggested Jetting Tools

Delta Subsea T1000 – Post-lay Burial

The T1000 is a 750kW jetting ROV capable of up to 3m burial depth. It is capable of jetting in sands to firm clays up to 80kPa resistance, allowing it to cover the majority of the cable route. Whilst not amphibious, it can operate in as little as 0.5m, which in conjunction with a sufficient umbilical and cable ship or barge, would allow burial almost all the way onto shore. The T1000 is also self-propelled meaning a high bollard pull vessel is not required, and it can also be deployed under relatively high sea-state conditions.

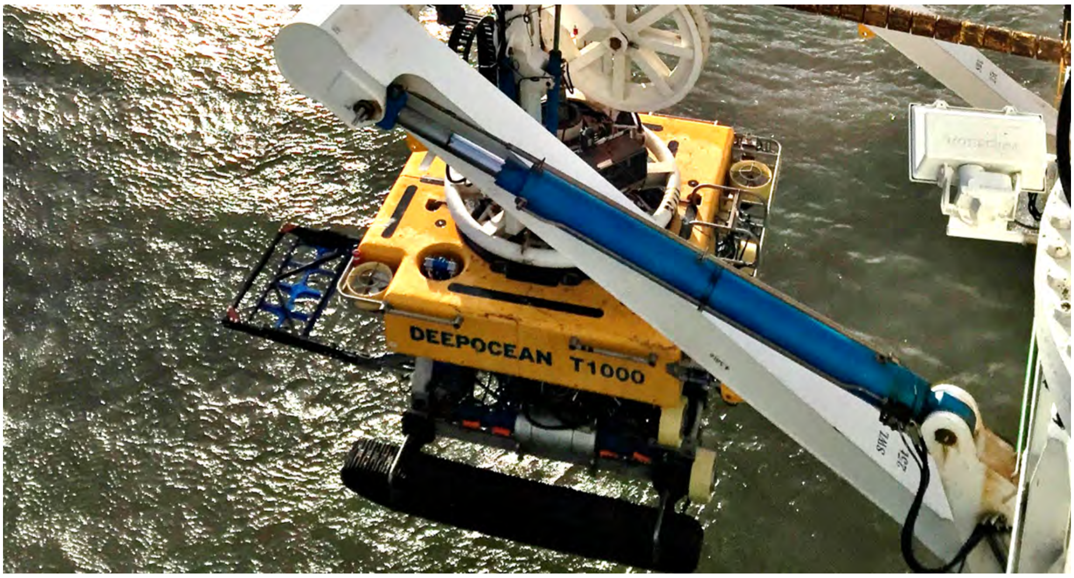


Figure 19: Delta Subsea’s T1000 Jetting ROV

Asso Subsea AssoJet III MK2 – Post Lay Burial

As a more powerful jetting option, the newly developed AssoJet III MK2 has up to 1.56MW of power with a 3.2m burial depth capability, allowing it to work in soils up to 150kPa. This capability means it should achieve burial in approximately 80% of soil conditions across the site. The tool can be configured with sleds or tracks for towing or self-propelling and has multiple jetting sword options to cater for the expected soil conditions. It can be deployed in high-sea states and also has backfill/trench collapsing capability.

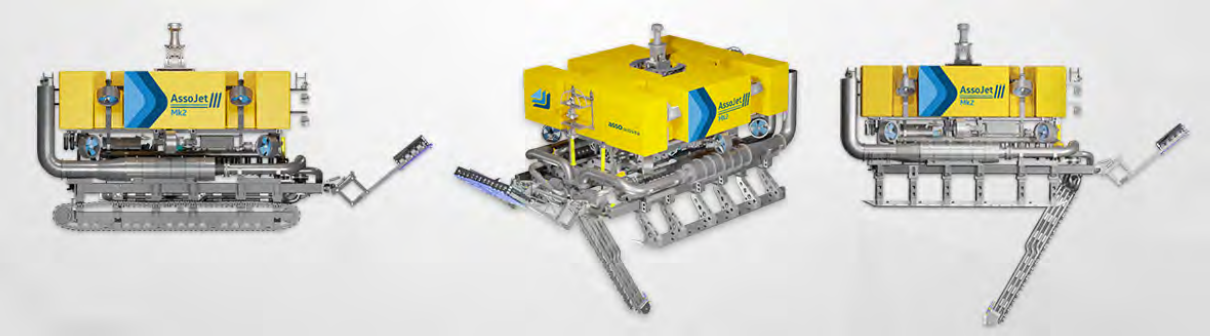


Figure 20: AssoJet III MK2 Jet Trencher

6.6.2 Suggested Mechanical Trenching Tools

Jan de Nul UTV1200 – Post or Pre-Lay Burial

This trencher, whilst not self-powered, has the ability to work over 1km from its support vessel due to the long umbilical available. It can use either a chain cutting tool or jetting sword to facilitate burial, both of which can be swapped at sea, saving on mobilisation and reconfiguration time. With the site conditions expected, the cutting tool would likely be the tool of choice for section of the cable with burial class C. The jetting sword could be used for sections classed A or B, the latter of which may need multiple jetting passes or cutting if jetting fails. The overall design is low and wide, meaning it will be stable in turbulent metocean conditions.

Figure 21: Jan de Nul’s UTV1200 Mechanical cutter

Boskalis Trenchformer – Post or Pre-lay Burial

The Trenchformer is a 1200kW vehicle designed to work in sands, silts, clays and rock, using a variety of interchangeable tools. This means it could be used both for cutting and jetting scopes of the protection campaign, if reconfigured. It is suitable for post-lay trenching but can also work in simultaneous lay and burial mode. It has amphibious capability, meaning it could start burial on the beach and progress offshore, if deployed with a suitable cableship or barge. As with the UTV1200, the Trenchformer's cutting tool would be most suitable for areas designated burial class C, and the jetting spread could be used for areas classed A and B.

Figure 22: The Boskalis Trenchformer

6.6.3 Suggested Ploughing Tools

Delta Subsea ACP2 Plough (or equivalent) – Simultaneous Installation and Burial

As an alternative to post-lay jetting, simultaneous lay and burial of the cable could be conducted using a jet-assisted plough like the ACP2. Many companies now own and operate jet-assisted cable ploughs as they are cost-effective ways of installing cables based on the smaller well-established telecom cable ploughs. The main disadvantage of using ploughs is having to run the cable through them to achieve burial, which can increase the risk of cable damage. A jet-assisted plough should however perform well in all but the hardest soil conditions encountered on the route. Ploughs can also be started from the beach and towed offshore, allowing potentially uninterrupted burial from landing to deep water, though they can only be operated by a cable lay vessel with a sufficient bollard pull and A-frame.

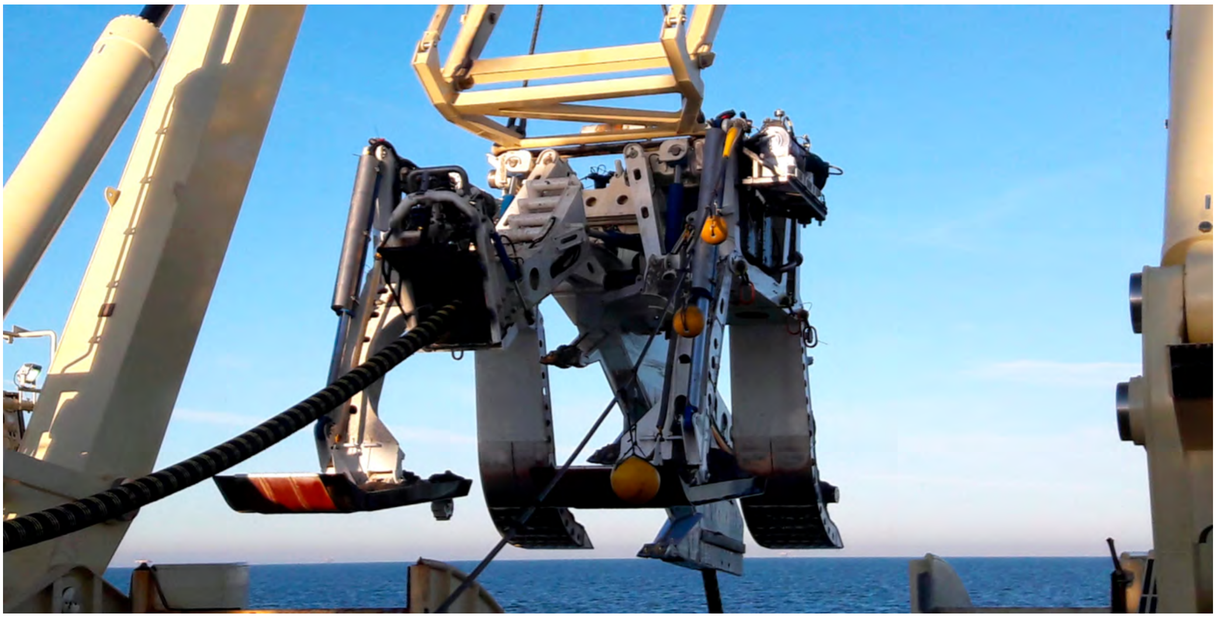


Figure 23: Delta Subsea's ACP2 cable plough

6.6.4 Suggested Installation Vessels

Nexans Aurora

Aurora is Nexans' flagship, designed for deep water cable installation with a large 10,000Te capacity turntable, and a 150Te A-frame able to accommodate large installation equipment and burial tools including Nexans' in-house jet trencher CAPJET.

Figure 24: Nexans' Aurora

Prysmian Leonardo Da Vinci

The Leonardo Da Vinci is Prysmian's newest vessel, designed for deep water cable installation of very long cable systems. It has two turntables with 7,000Te and 10,000Te capacity respectively, DP3 positioning and the ability to conduct simultaneous lay and burial.

Figure 25: Prysmian's Leonardo Da Vinci

Jan de Nul Issac Newton

The Issac Newton is a DP2 cable laying vessel with a total turntable capacity of 10,700Te, split across two turntables of 7,400Te and 5,000Te. It has two tensioners of 20Te, a bollard pull of 100Te and is fully equipped with other installation equipment.

Figure 26: Jan de Nul's Issac Newton

Future High-Capacity Vessels

Due to the length of the cable, and to minimise joints in the system, a cable vessel with an even higher capacity than the aforementioned vessels would be an optimal solution. Multiple operators are developing these next-generation vessels to accommodate longer interconnector and export cables in deeper waters.

An example of an upcoming vessels include Jan de Nul’s Fleeming Jenkin, commissioned in 2024 and due to be completed in 2026. The ship is designed with a total carrying capacity of 28,000Te of cable. Another example is NKT’s Eleonora, expected to be operational from 2027, and designed with a 23,000Te capacity.

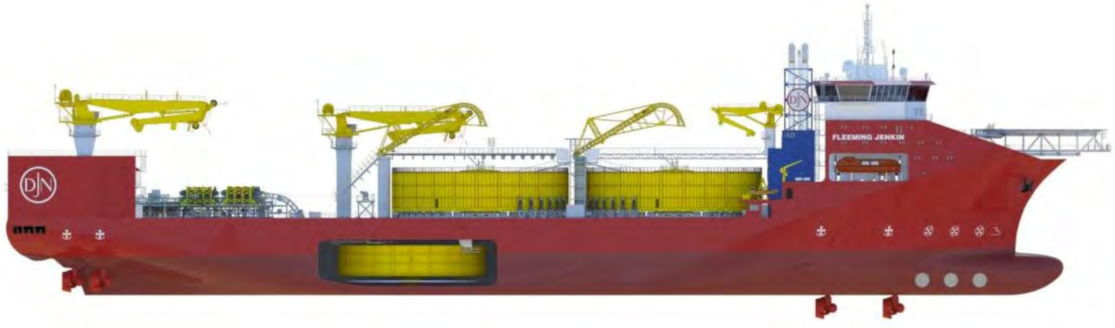


Figure 27: Jan de Nul's Fleeming Jenkin (under construction)

Figure 28: NKT's Eleonora (under development)

6.6.5 Suggested Boulder Clearance Tools

6.6.5.1 Ploughs

Various ploughs are available on the market for boulder clearance, and work by being dragged along the cable route by a high bollard pull vessel and pushing the boulders to either side of their share. Some ploughs can also be reconfigured for pre-lay trenching and backfill operations. Some tools, such as Helix's iPlough, can simultaneously clear boulders and excavate a trench.

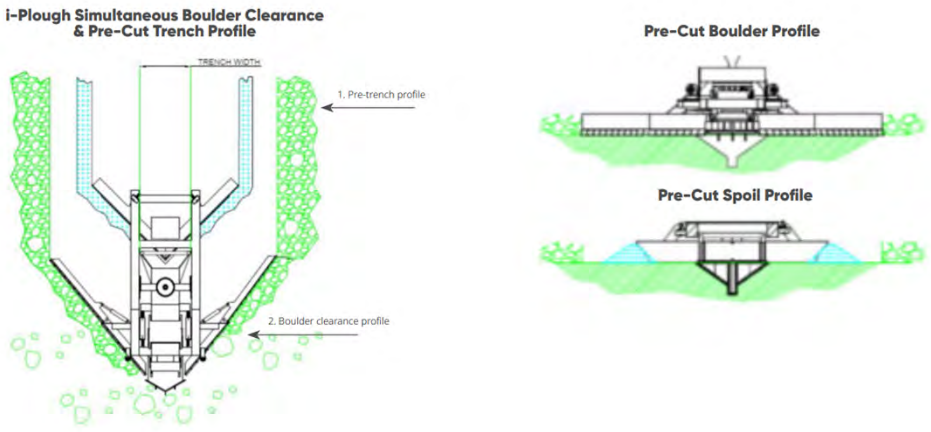


Figure 29: Helix's iPlough simultaneous boulder clearance and trenching tool

6.6.5.2 Tine Grabs

Tine grabs (also often called orange peel grabs) are a relatively simple method for boulder relocation outside of the cable corridor, and typically consist of a hydraulically actuated grab, deployed by a vessel crane and accurately positioned using a module with acoustic sensors and thrusters.

Figure 30: UTROV's TA01 tine grab

6.7 Remedial Protection

Remedial protection is used after cable installation to effectively increase the DOB over any sections of the cable where the recommended DOL was not achieved by burial alone, by placing additional material to provide further coverage and protection to the cable. Various methods of remedial protection are available, but primarily these fall into three categories:

- Rock Dumping or Subsea Rock Installation (SRI)
- Concrete Mattresses
- Cable Protection System (CPS)

Often, combinations of these methods are used to protect cables.

Rock Dumping or Subsea Rock Installation

Subsea Rock Installation (SRI) is the process of accurately piling rock on a location or along a route, using a specialised vessel and subsea tool. The vessels have large bulk stores for carrying the rock material, which is deposited via a fallpipe with a controllable opening at the seabed-end. The opening is controlled by the subsea tool, which usually features cameras and sonar to monitor the rock placement and thrusters for accurate positioning. SRI is typically used to provide scour protection to subsea structures and additional protection to buried or surface-laid products by means of ‘artificially’ increasing the burial depth.

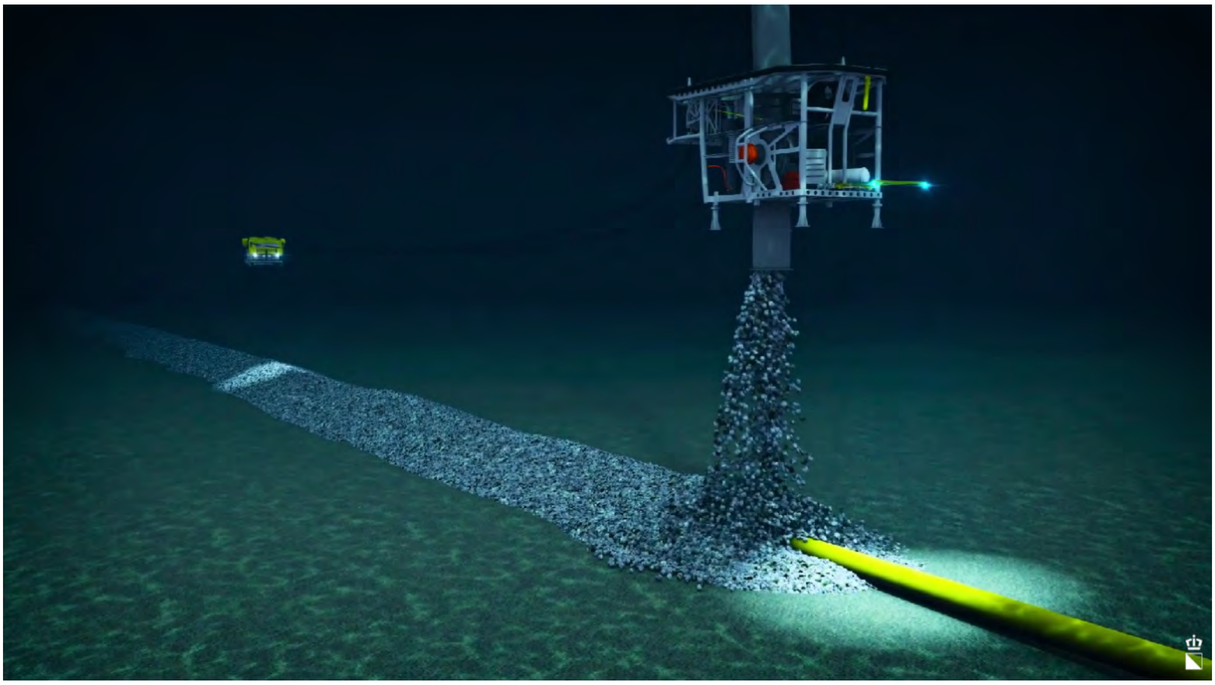


Figure 31: Boskalis’ Fall Pipe ROV with integrated inspection ROV conducting rock placement

Concrete Mattresses

Concrete mattresses are standardised units constructed of interlinked high strength concrete blocks connected by a series of U.V. stabilised polypropylene rope. They are supplied in standard 6x3x0.3m units of standard density, however modifications to size, density, and shape (tapered edges for high current environments, or denser concrete) can be engineered bespoke to the locality. They are used industry wide for a variety of subsea projects for applications such as cable and pipe crossings as well as providing dropped object protection and stability.

Crossing construction generally involves installation of pre-lay mattresses that would be placed on top of the existing cable, normally 2-3 mattresses are installed next to each other along the length of the existing cable. This provides a crossing corridor for the cable to be laid over. The central mattress is normally marked with highly visible paint to aid cable lay. Following cable lay, post-lay mattresses can then be placed on top of the new cable. Additional mattresses are generally required to provide cover for the entire cable transition length either side of the crossing, such that risk of exposure is removed. Mattresses are installed using a vessel's crane to lift and deploy a mattress suspended on a Mattress Lay Frame (MLF) or Mattress Installation Frame (MIF).

Figure 32: Mattress Installation Frame

Cable Protection Systems (CPS)

Cable Protection Systems can be used to describe various types of ducting or 'shell' that can be applied to a cable during its installation, acting as an additional layer of armour around the cable. Different systems have different applications that they are most suited for, but could all be feasible for use as additional protection in areas where the recommended DOL is not reached.

Cast iron split pipe is common in the industry providing impact protection and on bottom stability in areas of high currents or shore landings. This is installed on the cable during lay, and in this solution could be laid direct to the seabed and not buried, buried with a jet trencher (subject to soils) or laid into an open cut trench, followed by infill to level of the seabed provided by rock or Mass Flow Excavation.

Figure 33: Cast Iron Split Pipe on a Cable

As an alternative, ‘Uraduct’ - a name trademarked by Trelleborg, but commonly used to describe a polyurethane split pipe solution can be used. It has the same attributes in terms of object and abrasion protection as the cast iron split pipe but without the on bottom stability control (unless weighted, which is feasible).

Figure 34: Cable Protection System - 'Uraduct' Polyurethane

The use of Subsea Rock Installation to create rock berms is assumed the base case for remedial protection along the export cable route.

6.7.1 Remedial Protection Locations

Locations for remedial protection are selected based on the results of the BAS, where the recommended DOL is not likely or will not be achieved. This is generally in areas with more onerous burial conditions, or areas where the cable cannot be buried such as when crossing existing assets such as other cables and pipelines. The final areas to employ remedial protection will be determined by the results of the as-protected survey, where cable tracking is used in conjunction with bathymetry to determine if the cable has reached the recommended DOL.

The following sections of the cable have been designated remedial protection due to an increased likelihood of the DOL not being reached (Appendix D):

- KP120.571 to KP121.171

As part of the export cable routing (Ref. 11), and subsequent updates of anticipated crossings, the following assets to be crossed have been identified:

Route Section	Asset Name	Type	KP
Landfall to 12nm	Fulmar A to St Fergus	Pipeline	N/A
12nm to MPA Boundary	Forties C to Cruden Bay PL721	Pipeline	49.700
	Forties C to Cruden Bay PL8	Pipeline	49.700
	Durward Manifold to Dauntless Oil	Pipeline	122.700
	Durward Manifold to Dauntless Water	Pipeline	122.700
	Durward Manifold to Dauntless Gas	Pipeline	122.800
	Fulmar A to St Fergus (second crossing)	Pipeline	128.500
	Fulmer A to St Fergus (third crossing)	Pipeline	164.300
MPA Boundary to OSP	Langeled	Pipeline	203.600
	CATS	Pipeline	215.200

Table 22:Expected pipeline crossings on the Cenos Export Cable Route

Though all crossings derived from the routing report are pipelines, it is expected that power cables will also be crossed closer to shore (within 12nm) where the cable route is not yet confirmed. The predicted power cables to be crossed are listed in Table 23.

Route Section	Asset Name	Type
Landfall to 12nm	EasternLink2 HVDC (planned)	Power (Interconnector)

	EasternLink3 HVDC (planned)	Power (Interconnector)
	Hywind	Power (OWF)
	Muir Mhor (planned)	Power (OWF)
	Salamander (planned) (first crossing)	Power (OWF)
12nm to MPA Boundary	CNSE (planned)	Power (O&G)
	Greenvolt (planned)	Power (OWF)
	Tampnet CNSFTC	Fibre-Optic
	Salamander (planned) (second crossing)	Power (OWF)

Table 23: Expected cable crossings on the Cenos export cable route

6.7.2 Rock Berm Design

6.7.2.1 Shallow-Buried Cable

In the case of the sections of cable allocated for remedial protection due to onerous burial conditions in section 6.7.1, it is assumed that the cable will be shallow buried into the surficial sediment, and the assumed product diameter is 275mm. Based on the results of the CBRA, 0.5m of coverage is required to reduce the risk of anchor strike to DNV category of 2 or lower. The overall cross-sectional design of the rock berm for these sections of the cable route is shown in Figure 35.

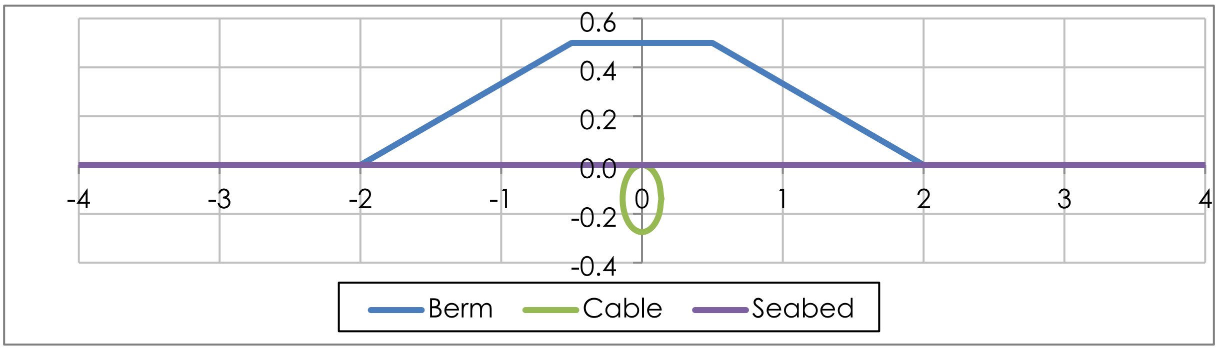


Figure 35:Shallow-buried cable rock berm cross-sectional design

The berm crest height is set at 0.5m as per the CBRA results, with a 1m crest width and to provide stability, a 1 in 3 gradient is used for the sides. This results in a cross-sectional area of 1.25m2. The length of these berms corresponds to the length of the cable sections identified in section 6.7.1. Burial grade in/out would be an additional 10m, where the cross-sectional area decreases as the cable descends into the seabed as burial conditions improve, and a decreasing height of rock berm is needed to provide the recommended DOC. This would result in an additional 10m of rock berm at either end of the section at 63% of the volume of an equivalent length full height rock berm. The total volume of rock needed for the rock berms for mitigation of shallow burial is therefore 765.75m3.

Along with the above calculated volume, an additional 10,905m^3 of SRI was calculated for KP0.000 to KP27.000 (12nm boundary) of the route as part of the aforementioned CBRA (ref. 25) and Cable Protection Analysis Report (ref. 32) conducted by Cathie Associates for the NorthConnect interconnector (the CBRA results are summarised in section 5.4.1). The much larger value is due to the substantial amount of outcropping rock in this section. Two scenarios for rock dumping values were presented, and the chosen value is for the pre-lay trenching and jetting scenario, which aligns with the recommendations for installation methodology in section 6.6.

6.7.2.2 Cable Crossings

The cables expected to be crossed are all on the Cenos export cable route and are all either interconnector or wind farm export power cables, with one fibre optic cable also crossed. For both protection and stability, it is expected that all crossed cables are buried at the crossing points, therefore it is not expected that a pre-lay rock berm will need to be installed. It is assumed that a pre-lay rock berm will be installed at the crossing point to provide a minimum of 0.3m separation in case the existing cable is near to or at the surface due to, as an example, sediment mobility. The export cable would then be laid onto the mattress and a rock berm built over the top to provide the recommended DOC. Cables should be crossed with as close to a 90° angle as possible.

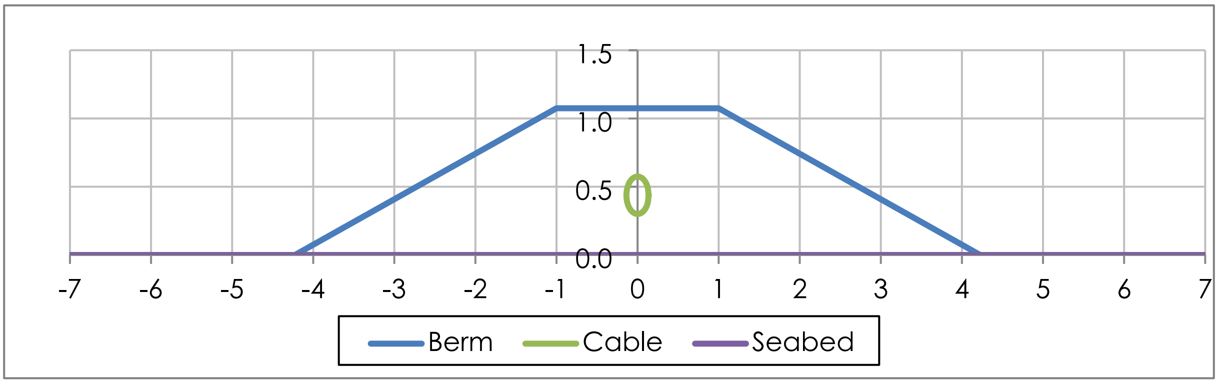


Figure 36: Cable crossing rock berm cross-sectional design

The rock berm crest height is set at 1.075m above seabed, equal to the height of the pre-lay rock berm (0.3m), plus the product diameter of 275mm, plus the recommended DOL of 0.5m. The berm crest width is 2m, with the side slopes set at a 1 in 3 gradient. This results in a cross-sectional area of 5.62m2. The burial of the cable is assumed to stop and resume 250m prior to and after the crossing point, resulting in a 500m long rock berm. This distance could be reduced through consultation with the asset owner, but may vary between different assets. As with the rock berm design in section 6.7.2.1, a 10m burial grade in/out section is added at each end of the berm at 63% of the volume of an equivalent length full height rock berm. With this berm design, each cable crossing requires a rock volume of 2879.33m3.

6.7.2.3 Pipeline Crossings

With the exception of the Durward Manifold to Dauntless Water pipeline, all pipelines crossed by the export cable are visible at the surface in the SSS data (Ref. 7). Though exact dimensions of all assets are not known, from initial research they vary in diameter from 20” to 44”.

Due to the large diameter of these assets, pre-lay SRI would be required to create a smooth transition over the pipeline for the cable to be laid onto. Further post-lay SRI would then be undertaken to provide the required DOC. The pre-lay rock berm is designed to extend 50m either side of the pipeline, to provide a shallow gradient and smooth transition over the pipeline for the cable to be laid onto. The shape of the berm is designed to be the base of the overall rock berm (including the post-lay SRI). The height of the cable above seabed at the crossing point is much higher due to the large diameter of the pipelines.

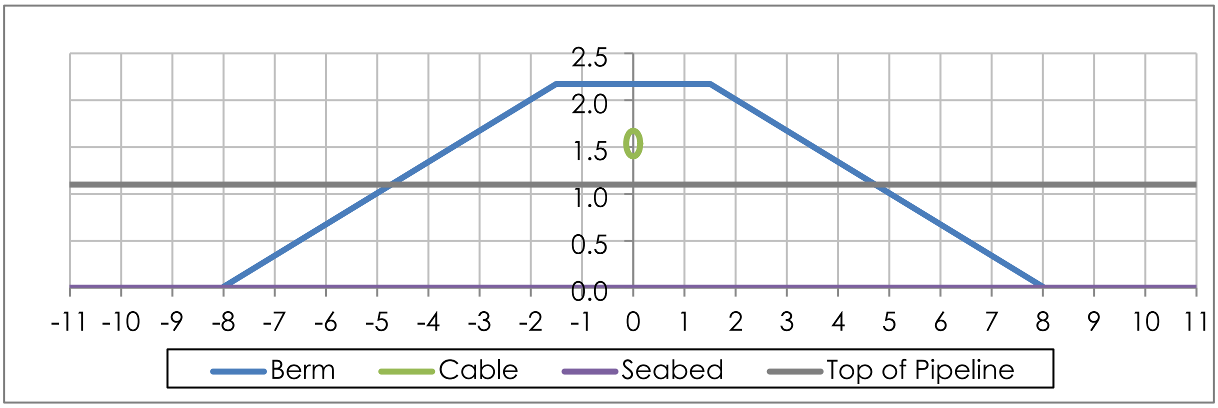


Figure 37: Pipeline crossing rock berm cross-sectional design

The berm crest height is 2.18m, as the sum of the pipeline diameter, 0.3m minimum separation between the pipeline and cable, the cable diameter of 275mm and DOL of 0.5m. As with the cable crossings, the berm extends 250m either side of the crossing point, resulting in a 520m long berm including the 10m burial grade/in out sections at each end. This distance also could be reduced through consultation with the asset owner, but may vary between cables and pipelines. A key difference with the pipeline crossing design vs the cable crossing is the difference in berm height 50m either side of the pipeline crossing. Up to 50m before the crossing point and 50m after the crossing point, the cable is surface laid on the seabed as the pre-lay berm starts/ends. In these sections, the berm size can be reduced to the design in section 6.7.2.2 whilst maintaining 0.5m coverage. The more complex design of the pipeline crossing berm is illustrated in Figure 38 and Figure 39. With this design, the volume of rock required for each pipeline crossing is 2934.09m3.

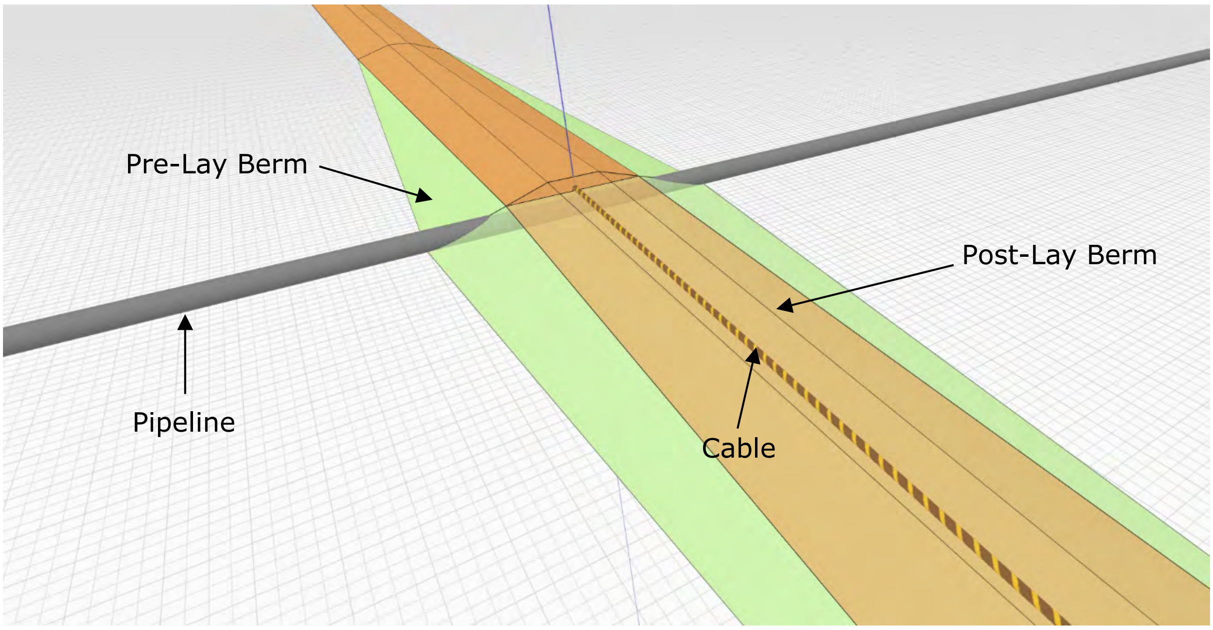


Figure 38: Pipeline crossing berm design with pre-lay berm (green) and post-lay berm (orange)

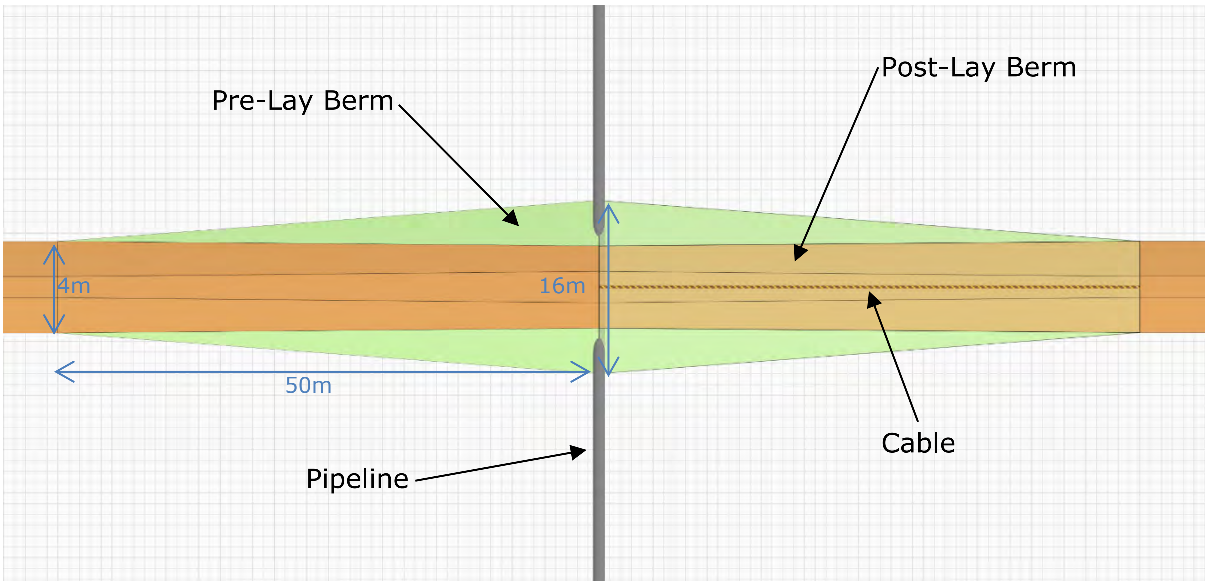


Figure 39: Plan view of pipeline crossing berm design with pre-lay berm (green) and post-lay berm (orange)

6.7.3 Remedial Protection Summary

Locations that may or will require remedial protection have been identified, and Subsea Rock Installation chosen as the base case method for providing this protection. One section of the cable routes, where subcropping high-strength clays present an issue in a section designated for dredging, has been allocated for SRI, along with the cable and pipeline crossing locations. Rock berms have been designed to estimate a volume of rock required for remedial protection on the export cable route. Table 24 and Table 25 summarise this estimation.

Rock Installation Location	**Volume of Rock Required (m³)**
Shallow burial	765.75
Cable crossings	2,879.33
Pipeline crossings	2,934.09

Table 24: Estimated Rock Volume for Each Berm Design

Route Section	**Rock Installation Location**	**Number of Occurrences**	**Volume of Rock Required (m³)**	**Total volume of Rock Required (m³)**
Landfall to 12nm	Shallow burial	1	10,905*	28,236
	Cable crossings	5	14,396.65	
	Pipeline crossings	1	2,934.09	
12nm to MPA Boundary	Shallow burial	1	765.75	32,822
	Cable crossings	4	11,517.32	
	Pipeline crossings	7	20,538.63	
MPA Boundary to OSP	Shallow burial	0	0	5,868
	Cable crossings	0	0	
	Pipeline crossings	2	5,868.18	
Total Rock Volume Required for Export Cable:				**66,926**

Table 25: Estimated Rock volumes required by cable route section. *Value based on Ref. (32)

7. CONCLUSIONS AND RECOMMENDATIONS

Global Maritime have conducted a CBRA for the Cenos Floating Offshore Windfarm export cable, including a review of the bathymetry and sub-seabed geology, and a resulting BAS, concluding on a recommended Depth of Lowering across the export cable route, from the 12 nM boundary, and suggested installation methodology.

The site conditions were assessed to determine the geological layers of the seabed within the export cable route option corridors. Using the provided Ground Model Report, 2DUHRS, SBP and Geotechnical data from Fugro, geological units could be spatially defined along the routes, and simplified into a two-layer ground model for input into the CBRA calculations.

The site condition assessment and two-layer ground model were then utilised using Global Maritime's CBRA method with modelled post-windfarm installation vessel traffic to analyse the anchor strike risks to the cable and propose target burial depths along each RPL to minimise the risk to acceptable levels whilst also maintaining a practical burial depth along the cable route. The burial depth and risk profile for the cable is detailed within the alignment charts appended.

An SSBL was also calculated to identify areas in which mobile bedforms could create burial depths beyond the capability of typical burial tools on the market. As the recommended depth of burial form the CBRA is relatively shallow, even in areas of larger mobile bedforms, the overall burial depth is still manageable without a dedicated dredging campaign.

The predominant geological conditions are surficial mobile and non-mobile sands, clayey sands and sandy clays, all with gravel content. Boulders and cobbles are frequent at the seabed, but with varying density along the route. Subcropping and outcropping high-strength clays and glacial till occur in several areas along the cable route.

An assessment of the potential requirement for remedial protection has been conducted, with subsea rock installation used as a base case method. Rock berms have been designed for shallow-buried sections of cable, cable crossings, and pipeline crossings, using the DOL requirement derived from the CBRA. An estimated total rock volume has been calculated based on these design criteria.

Key risks on the site can be defined as:

- Dense sands and gravels present a potential risk to ploughing and jetting operations respectively, and are present across the vast majority of the route;
- Subcropping and outcropping high-strength clays of the Coal-Pit formation are frequent along the route, and will prevent the DOL being reached with jetting alone;
- Mobile features are present along the route, a small number of which will require deeper burial of the cable across their width to ensure the recommended DOL is achieved.
- Boulders are frequent and a clearance campaign will likely be required to allow for cable lay and burial tool operation.

It should be noted that whilst there is no specific acceptable risk value that must be attained through protection from anchor strike through burial, it is common for cables to be protected to specifications to DNV Cat 2, which is specified as a return period > 10,000 years. As this is not specified by cable length, target burial depths were determined based on maintaining > 10,000 years return period cumulative across each section of the cable routes as defined by changes in burial depth, hence where the cumulative return period across the entire cable routes in this case have a return period of less than 10,000 years.

As mentioned, a key driving factor when determining the required burial depth for anchor strike protection is the soil properties, as these dictate anchor penetration. The results of the CBRA should be computed if the cable routes are changed, as this study focusses on specific routes engineered in conjunction with the CBRA.

At this stage, all geotechnical information relating to the geological units used to perform the CBRA calculation have been inferred by GM based on publicly available data and in-house experience. It is recommended that a full geotechnical survey is conducted along the cable route to ground-truth the geophysical data used to inform this report.

With this additional information, it is also recommended that a detailed BAS with the specific burial tool(s) to be used for cable installation and consideration of the strengths of the geological units in relation to the specific tool’s ability is conducted to further optimise the cable protection methodology, further reducing burial and vessel time.

APPENDICES

APPENDIX A DESIGN RISK REGISTER

Geohazard & Geotechnical Risk Register (GRR) - Cables

Client :	Floatation Energy, Vårgrønn
Project :	Cenos Floating Offshore Wind Farm
Project No :	PRJ111506
Revision History:	2

Revision	**Date**	**Reason for Revision**	**Author**	**Reviewer**	**Approver**
1	29/08/2024	First issue	FDI	MLA	MLA
2	25/10/2024	Second Issue	FDI	MLA	MOW
3	05/11/2024	Third Issue	FDI	MLA	MOW

RISK MATRIX

Severity	Consequences/ Impact			Probability				
Category	**Injury/ Illness**	**Environmental Impact**	**Financial Loss/ Asset Damage/ Reputation**	**A (Very Unlikely)**	**B (Unlikely)**	**C (Possible)**	**D (Likely)**	**E (Very Likely)**
1 (Negligible)	Negligible injury or health implications, not affecting work performance or causing absence (First Aid Case)	- Pollution/ spills of <1 litre - Minimal/ insignificant environmental impact	<USD $10,000, or <1% cost impact	L	L	L	M	M
2 (Minor)	Minor injury/ illness leading to Medical Treatment Case (MTC)	- Pollution/ spills between 1 - 10 litres - Minor/ short term pollution impact	USD $10,000 - <USD $100,000, or 1-5% cost impact	L	L	M	M	M
3 (Significant)	Significant injury/ illness leading to Restricted Work Case (RWDC)	- Pollution/Spills between 10 - 100 litres - Pollution with some worksite impact	USD $100,000 - <USD $500,000, or 5-10% cost impact	L	M	M	M	H
4 (Serious)	Serious injury/ill-health leading to days away from work (Lost Work Day Case - LWDC)	- Pollution/Spills between 100 litres - 100 m3 - Significant pollution with worksite and off-site impact	USD $500,000 - <USD $1,000,000, or 10-20% cost impact	M	M	M	H	H
5 (Critical)	Fatality(s), permanent disability, terminal occupational illness	- Pollution/Spills in excess of >100 m3 - Extensive pollution with long term implications or massive site impact	≥USD $1,000,000, or >20% cost impact	M	M	H	H	H

GUIDELINES

Severity	Further consequence/ impact definition	Probability	Probability Definition	Risk Level		
1 (Negligible)	- Minimal injury or health implications requiring no treatment; no absence from work; requires first aid treatment only (First Aid Case FAC) - Minimal or limited pollution effect/impact; negligible recovery work (spills of up to 1 litre of hydrocarbons, or an amount of other spill type resulting in equivalent environmental imapct) - Insignificant or slight financial loss or equipment/ asset damage (<USD $10,000), or >1% of project/ asset cost - Negligible damage to reputation, including some minor negative feedback	**A (Very Unlikely)**	- Not known by GM to have happened within the industry - A freak combination of factors would be required for an incident to occur	**LOW**	As a guide, when a LOW risk level is calculated, then no additional controls are required. However monitoring should take place to ensure that the controls are implemented and where possible, improved.	**Acceptable** Task/ Activity may be carried out by those authorised to do so
2 (Minor)	- Minor injury or illness requiring medical treatment (Medical Treatment Case - MTC) - An Environmental incident contained within the site boundary; short-term impact; recovery work by worksite personnel (spills of 1-10 litres of hydrocarbons, or an amount of other spill type resulting in equivalent environmental imapct) - Minor financial loss, or repairs required for damaged asset/ equipment (USD $10,000 - <USD $100,000), or 1-5% of project/ asset cost - Formal complaint by a Client or 3rd party (reputation damage)	**B (Unlikely)**	- Unlikely to occur - May have happened once at GM, or in the industry - A rare combination of factors would be required for an incident to occur	**MEDIUM**	Where a risk level has been calculated to be MEDIUM, further controls should be identifed where possible, in order to reduce the risk to As Low As Reasonably Practical (ALARP).	**Tolerable** Task/ Activity may only proceed with Management authorisation
3 (Significant)	- Restricted Work Case (RWC) injury; without long term disablement - An Environmental incident went beyond the site boundary, moderate short-term impact, recovery may requires external assistance (10-100 litres of hydrocarbons, or an amount of other spill type resulting in equivalent environmental imapct) - Damage to property/equipment requiring significant repair with costs up to USD $500,000, or 5-10% of project/ asset cost - Local media coverage, and local community complaint	**C (Possible)**	- Could possibly occur - Additional external factors to be combined/ present for an incident to occur	**HIGH**	A HIGH risk level is considered intolerable, and work must commence or continue until the risk has been reduced significantly. If it is not possible to reduce the risk, work is not permitted	**Unacceptable** Work must not proceed change task or further control measures required to reduce risk
4 (Serious)	- Serious injury/illness leading to days away from work or involving a single lost work day case (LWDC) - Serious medium-term environmental effects; recovery requires external assistance; pollution incurring significant restitution costs (spills between 100 litres to 100 m3 of hydrocarbons, or an amount of other spill type resulting in equivalent environmental imapct) - Damage to property/equipment resulting in major loss of operational capability; costs up to USD $1,000,000, or 10-20% of project/ asset cost - Regional-level negative publicity/ media coverage	**D (Likely)**	- Has happened more often than once, at GM, or known to have happened multiple times within the industry - An additional factor may be required to result in an incident			
5 (Critical)	- A fatality(s) or multiple serious injuries leading to permanent disability or terminal disease - Extensive pollution with long-term implications or massive site impact and recovery work; very high restitution costs resulting in serious economic liability on the business; spill in excess of 100m3 of hydrocarbons, or an amount of other spill type resulting in equivalent environmental imapct) - Damage with major long-term implications on operational capability; extensive costs in excess of USD $1,000,000 or >20% of project/ asset cost - International negative publicity/ media coverage	**E (Very Likely)**	- A regular occurrence in the industry - Almost inevitable that an incident will happen			

GLOBAL MARITIME

Global Maritime Risk Matrix | G-HSE-FM-002 | Rev. 2

GEOHAZARD & GEOTECHNICAL RISK Register (GRR) - Cables

Project Number:	**PRJ111506**	**Project Name:**	**Cenos Floating Offshore Wind Farm Export Cables**
GRR Review Date:	**23/08/2024**	**Project Manager:**	**Matthew Laing**

			Risk Evaluation				**Risk Evaluation**		
Ref.		**Hazard Details**	**Inherent Risk Severity**	**Inherent Risk Probability**	**Inherent Risk Level**	**Control Measures**	**Residual Risk Severity**	**Residual Risk Probability**	**Residual Risk Level**
Cable Installation	**PRJ111361**								
2	Hard Soils Within Burial Profile	Presence of hard soils can cause issues to cable installation. Trenchability along those areas is highly dependable on the geotechnical parameters of the soils and cables might be not sufficiently protected if targeted burial depths are not achieved. Exposed cables have increased risks to internal and external threats.	3	D	M	Geotechnical survey of the full cable route, and detailed assessment of the geotechnical parameters of the tertiary soil units is recommended, in order to understand the burial feasibility. The recommended burial strategy already limits exposure, in so far as possible, with use of a mechanical trencher capable of excavating the stiffer clays and Glacial Till. Alternative protection methods such as rock dumping or mattressing might be required, and have been suggested in areas where more onerous burial conditions are anticipated.	2	D	M
3	Boulders at and within Seabed	Boulders of indurated and cemented material derived from the underlying geological units. Boulders create obstructions for trenching and installation activities. Buried boulders can cause reduced burial.	4	E	H	Detailed, high resolution bathymetric and side scan sonar survey. Sympathetic routing design, resilient trenching methods, boulder clearance campaigns ahead of or simultaneous with trenching.	2	D	M
4	Soft Soils at and within Seabed	Presence of soft, unconsolidated soils can cause issues to cable installation. Soft soils can cause trencher sinkage and less efficient trenching if not planned for.	3	D	M	Detailed installation engineering examining trencher types, bearing pressures and means of reducing bearing pressure if necessary.	1	B	L
5	Irregular Seabed	Presence of irregular seabed can cause issues with trencher traction and progress, also reduced burial where trencher tools pull out of seabed.	3	E	H	Detailed installation engineering examining trencher types, utilise suitable trencher. Computation of an SSBL and identification of areas that may have a possible requirement for avoidance via micro-routing or deeper burial depth to achieve recommended DoL.	2	D	M
6	Gravel Reduces Depth of Lowering	Gravels present within seabed soils may not be fully removed from trench, limiting the depth to which lowering can occur.	3	C	M	Evaluate detailed geotechnical and geophysical survey. Account for risk with increased trench depth and trenching methods to maximise suspension and eduction.	3	B	M

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			Risk Evaluation				**Risk Evaluation**		
Ref.		**Hazard Details**	**Inherent Risk Severity**	**Inherent Risk Probability**	**Inherent Risk Level**	**Control Measures**	**Residual Risk Severity**	**Residual Risk Probability**	**Residual Risk Level**
8	Existing Asset Crossings	Numerous asset crossings create many areas where the cable will be initially exposed after lay, while remedial protection is put in place. Cable is more suceptible to damage due to movement or external aggression during this time.	4	C	M	Negotiate crossing agreements with existing asset owners well in advance of cable installation. Design asset crossings based on CBRA recommended DOL to provide suitable protection to the both the existing asset and new cable. Minimise time between cable installation and remedial protection, utilise guard vessels if necessary.	3	B	M
Cable Operation									
1	Shipping	Ships can cause direct damage to exposed or insufficiently buried cables by deploying anchors either deliberately (in case of anchorages) or accidentally over / next to a cable. Direct cable strike or more likely snagging of cable can cause damage to cable (and potentially the vessel).	2	E	H	Probabilistic assessment of shipping and estimation of likely anchor penetration depth relative to seabed geology and shipping activity. Conservative approach to be taken with regard to unknown factors (e.g. number of smaller vessels without AIS). Determination of appropriate cable burial depths to provide adequate protection.	1	E	L
2	Fishing	Fishing activities can result in direct damage to exposed or insufficiently buried cables by fishing gear snagging on the cable. Also (greater) risk to the fishing vessel in the event of a snagging incident. Fishing vessels account for a proportion of the traffic in the area.	2	C	M	Assessment of likely fishing gear penetration based on identified fishing types relative to seabed geology and recommendation of burial to sufficient depth to afford adequate protection. Ongoing monitoring of fishing activity and methods as part of IMR regime. Identification of new cables on nautical charts / fishermen awareness initiatives.	2	B	L

GEOHAZARD & GEOTECHNICAL RISK Register (GRR) - Cables

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			Risk Evaluation				**Risk Evaluation**		
Ref.		**Hazard Details**	**Inherent Risk Severity**	**Inherent Risk Probability**	**Inherent Risk Level**	**Control Measures**	**Residual Risk Severity**	**Residual Risk Probability**	**Residual Risk Level**
3	Fishing - future variations in equipment	Fishing methods and equipment could vary with time resulting in increased risk to the cables.	2	E	H	Ongoing monitoring of fishing activity and methods as part of IMR regime. The risk to the cables should be reassessed if there is a significant change in fishing activities which results in greater penetration of fishing equipment into the seabed. If necessary, mitigation actions to be taken (deeper burial, rock dump, fishing exclusion zones, etc.). Given the increased vessel running costs of deeper penetrating fishing gear (higher towing force), increase in this factor is considered unlikely, however it is possible that the locations of fishing grounds will change in future.	2	B	L
4	On-bottom Stability	Water depth and metocean conditions influence cable on bottom stability (abrasion / fatigue effects on surface laid cables, which could be exacerbated by the uneven seabed surface in areas of outcropping rock or sand waves).	2	C	M	Cables are planned to be buried for the entirety of the route. Where burial may not be possible, and alternative method of cable protection is to be considered. Water depth along vast majority of route is beyond typical metocean influence at surface.	2	A	L
5	Dredging / Dumping	Dredging activity can result in direct damage to cables as well as exposure of buried cables or reduction in burial, increasing risk to primary hazards such as shipping or fishing. Over-burial by dumping, can result in exceeding cable thermal / physical design parameters.	2	B	L	Consultation with dredging licence holders, as required. Identification of new cables on nautical charts / implementation of exclusion zones for dredging / dumping activity.	2	A	L
6	Mobile Sediment / Seabed Mobility	Areas of mobile seabed may overtime expose the cable and potentially cause freespans if cable not buried to a sufficient depth. Cable exposure increases risk of impact damage. Freespans can cause fatigue damage over time.	4	C	M	Bathymetry has been utilised to generate SSBL, and used when defining CBRA results. Survey prior to the cable lay to confirm assessment of site / RPL(s). Regular survey of cables as part of IMR regime - with emphasis on areas anticipated to be mobile. Reassessment of cable risks and mitigation works as required if cable becomes over-buried or exposed.	2	B	L

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GRR Review Date:	**23/08/2024**	**Project Manager:**	**Matthew Laing**

			Risk Evaluation				**Risk Evaluation**		
Ref.		**Hazard Details**	**Inherent Risk Severity**	**Inherent Risk Probability**	**Inherent Risk Level**	**Control Measures**	**Residual Risk Severity**	**Residual Risk Probability**	**Residual Risk Level**
7	Soils with Insulative properties	Clays/till can have insulating properties and increase the risk of overheating, which is exacerbated by deeper burial	4	C	M	Thermal resistivity tests of the Clay-rich till should be consulted. Burial depth is however relatively shallow for the whole route. Should burial depths need reducing, CBRA calculation should be run for route section to determine if the resultant pstrike and return period are acceptable	2	B	L

APPENDIX B DRAWINGS

REDACTED

APPENDIX C CBRA ALIGNMENT CHARTS

REDACTED

APPENDIX D BAS TABLES

KP Start	KP End	Section Length (km)	Water Depth (mLAT)		Seabed Composition At Target Depth of Lowering	GM Ground Model				SSBL		CBRA Results				Crossings		Burial Recommendations							Comments
			Min	Max		Layer 1	Min Base of Layer 1 (mBSB)	Max Base of Layer 1 (mBSB)	Layer 2	Max Mobile Thickness (m)	Min Mobile Thickness (m)	Recommended Depth of Lowering (m)	Pstrike at Recommended DOL	Strike Return Period (Years)	DNV Risk Category	Crossed Assets	Assumed rock volume for crossings (m^3)	Jetting	Ploughing	Mechanical Cutting	Burial Class	Remedial Protection	Assumed Rock volume for remedial protection (m^3)	Key Risks in Zone	
0.000	27.971	27.971	Inside 12nM Boundary - Outside of Report Scope													- Easternlink2 (Interconnector) - Hywind (OWF Export) - Muir Mhor (OWF Export) - Salamander (OWF Export) - Fulmar A to St Fergus (Pipeline)	14,451.41	Inside 12nM Boundary - Outside of Report Scope							
27.971	70.671	42.700	-84.01	-105.02	Silty Clayey SAND, Sand and Silty CLAY with occasional gravel and isolated to scattered cobbles and boulders; TILL (well graded sand, clay and gravel) interbedded with thin clays of sand and silty clay; coarse sand and gravel; Silty CLAY with occasional pebbles; some sand laminae	S1	0.050	3.010	C7	2.309	0	0.5	0.000023	44,305	2	- Salamander (OWF Export) - Forties C to Cruden Bay PL271 (Pipeline) KP49.7 - Forties C to Cruden Bay PL8 (Pipeline) KP49.7 - Tampnet CNSFTC (Fibre Optic) KP49.9	11,626.84	Suitable	Possible	Not Suitable	A			Dense sands may slow plough progress, jet assistance may be required. Gravels may reduce DOL when jetting.	Subcropping stiff clays are likley at the bottom of the burial profile throughout, and within the burial profile between KP36.000 and KP39.000. Wee Bankie till is present at the bottom of the burial profile bewteen KP0 and KP6.4.
70.671	95.771	25.100	-90.77	-107.02	Soft silty CLAY with pockmarks	C1b	0.360	3.000	S1	0.41	0	0.5	0.000008	120,334	1			Suitable	Possible	Not Suitable	A			Soil should be assessed for bearing capacity for chosen burial tool. Pockmarks can create localised steep gradients	
95.771	118.471	22.700	-83.34	-98.03	Silty Clayey SAND, Sand and Silty CLAY with occasional gravel and isolated to scattered cobbles and boulders	S1	0.200	3.010	S1	1.014	0	0.5	0.000003	307,760	1			Suitable	Possible	Not Suitable	A			Dense sands may slow plough progress, jet assistance may be required. Gravels may reduce DOL when jetting.	
118.471	123.971	5.500	-85.63	-91.59	Silty Clayey SAND, Sand and Silty CLAY with occasional gravel and isolated to scattered cobbles and boulders; Silty clay with occasional pebbles; some sand laminae; Silty Clay overconsolidated; sand intercalations	S1	0.140	3.100	C7	0.549	0	0.5	0.000000	>1,000,000	1			Possible	Possible	Not Suitable	C	KP120.571 to KP121.171 (600m)	765.75	Dense sands may slow plough progress, jet assistance may be required. Gravels may reduce DOL when jetting. High-strength clays present in burial profile are unlikely to be cut by jetting.	Short section of outcropping Fisher Formation (high-stength clays) between KP92.600 and KP93.200. Jetting is still recommended as section is majority surficial sediments. If jetting is used, remedial protection may be needed in outcropping section if recommended DOL is not achieved.
123.971	129.971	6.000	-85.04	-91.96	Silty Clayey SAND, Sand and Silty CLAY with occasional gravel and isolated to scattered cobbles and boulders	S1	0.360	3.000	C7	0.635	0	0.5	0.000000	>1,000,000	1	- Durward Manifold to Dauntless Oil (Pipeline) KP122.7 - Durward Manifold to Dauntless Water (Pipeline) KP122.7 - Durward Manifold to Dauntless Gas (Pipeline) KP122.8 - Fulmar A to St Fergus (Pipeline) KP128.5	11,736.36	Suitable	Possible	Not Suitable	A			Dense sands may slow plough progress, jet assistance may be required. Gravels may reduce DOL when jetting.	Subcropping Coal-Pit clays are not within the burial profile.
129.971	141.971	12.000	-77.93	-86.08	Silty Clayey SAND, Sand and Silty CLAY with occasional gravel and isolated to scattered cobbles and boulders; Silty clay with occasional pebbles; some sand laminae	S1	0.120	3.000	C7	1.887	0	0.5	0.000001	781,383	1			Not Suitable	Possible	Suitable	B			Subcropping high-strength clays prevent achieving DOL by jetting. Surficial sands may cause partial trench collapse if pre-lay trenching.	Pre-lay mechanical cutting may be supplemented with post-lay jetting to achieve recommended DOL.
141.971	144.471	2.500	-79.73	-83.55	Silty Clayey SAND, Sand and Silty CLAY with occasional gravel and isolated to scattered cobbles and boulders	S1	0.460	3.000	C7	0.456	0	0.5	0.000000	>1,000,000	1			Possible	Possible	Suitable	A			Dense sands may slow plough progress, jet assistance may be required. Gravels may reduce DOL when jetting.	Subcropping Coal-Pit clays are not within the burial profile.
144.471	157.171	12.700	-77.69	-83.62	Silty Clayey SAND, Sand and Silty CLAY with occasional gravel and isolated to scattered cobbles and boulders; Silty clay with occasional pebbles; some sand laminae	S1	0.060	3.000	C7	1.714	0	0.5	0.000000	>1,000,000	1			Not Suitable	Possible	Suitable	B			Subcropping high-strength clays prevent achieving DOL by jetting. Surficial sands may cause partial trench collapse if pre-lay trenching.	Pre-lay mechanical cutting may be supplemented with post-lay jetting to achieve recommended DOL.
157.171	168.171	11.000	-81.69	-91.49	Silty Clayey SAND, Sand and Silty CLAY with occasional gravel and isolated to scattered cobbles and boulders	S1	0.480	3.010	S1	1.026	0	0.5	0.000001	892,905	1	- Fulmar A to St Fergus (Pipeline) KP164.3	2,934.09	Suitable	Possible	Not Suitable	A			Dense sands may slow plough progress, jet assistance may be required. Gravels may reduce DOL when jetting.	
168.171	173.471	5.300	-81.56	-93.41	CLAY with thin sand layers; Silty CLAY with occasional pebbles; some sand laminae	S1	0.100	2.220	C7	0.765	0	0.5	0.000000	>1,000,000	1			Not Suitable	Possible	Suitable	B			Subcropping high-strength clays prevent achieving DOL by jetting. Surficial sands may cause partial trench collapse if pre-lay trenching.	Fitzroy member (soft clays) present at start and end of section. Pre-lay mechanical cutting may be supplemented with post-lay jetting to achieve recommended DOL.
173.471	177.971	4.500	-89.75	-94.45	Silty Clayey SAND, Sand and Silty CLAY with occasional gravel and isolated to scattered cobbles and boulders	S1	0.180	3.000	C1b	0.57	0	0.5	0.000000	>1,000,000	1			Suitable	Possible	Not Suitable	A			Dense sands may slow plough progress, jet assistance may be required. Gravels may reduce DOL when jetting.	Fitzroy member (soft clays) are not within the burial profile
177.971	180.971	3.000	-90.08	-95.28	CLAY with thin sand layers; Silty CLAY with occasional pebbles; some sand laminae	S1	0.120	3.000	C7	0.597	0	0.5	0.000000	>1,000,000	1			Possible	Possible	Not Suitable	C			Subcropping and outcropping Fitzroy clays are present throughout section, which may slow jetting progress (compared to sands). Subcropping Coal-Pit high-strength clays may prevent recommended DOL being achieved.	Jetting nozzels may need to be optimsed for cutting clays in this section to improve burial progress rates.
180.971	189.171	8.200	-91.01	-95.52	Silty Clayey SAND, Sand and Silty CLAY with occasional gravel and isolated to scattered cobbles and boulders	S1	0.130	3.010	C1b	0.536	0	0.5	0.000001	856,442	1			Suitable	Possible	Not Suitable	A			Dense sands may slow plough progress, jet assistance may be required. Gravels may reduce DOL when jetting.	Fitzroy member (soft clays) are not within the burial profile
189.171	192.971	3.800	-91.97	-94.84	CLAY with thin sand layers	S1	0.100	3.000	C1b	0.912	0	0.5	0.000000	>1,000,000	1			Suitable	Possible	Not Suitable	A			Subcropping Fitzroy clays are present throughout section, which may slow jetting progress (compared to sands).	
192.971	193.704	8.500	-87.30	-94.08	Silty Clayey SAND, Sand and Silty CLAY with occasional gravel and isolated to scattered cobbles and boulders	S1	0.370	3.010	C1b	0.277	0	0.5	0.000000	>1,000,000	1			Suitable	Possible	Not Suitable	A			Dense sands may slow plough progress, jet assistance may be required. Gravels may reduce DOL when jetting.	Fitzroy member (soft clays) are not within the burial profile
Start of East of Gannet and Montrose Fields Marine Protected Area																									
193.704	201.471	21.267	-87.30	-94.08	Silty Clayey SAND, Sand and Silty CLAY with occasional gravel and isolated to scattered cobbles and boulders	S1	0.370	3.010	C1b	0.652	0	0.5	0.000000	>1,000,000	1			Suitable	Possible	Not Suitable	A			Dense sands may slow plough progress, jet assistance may be required. Gravels may reduce DOL when jetting.	
201.471	209.971	8.500	-85.83	-90.59	CLAY with thin sand layers	S1	0.060	2.910	C1b	1.027	0	0.5	0.000000	>1,000,000	1	- Langeled (Pipeline) KP203.600	2,934.09	Suitable	Possible	Not Suitable	A			Subcropping Fitzroy clays are present throughout section, which may slow jetting progress (compared to sands).	
209.971	214.971	5.000	-88.03	-95.03	Silty Clayey SAND, Sand and Silty CLAY with occasional gravel and isolated to scattered cobbles and boulders	S1	0.070	3.010	C1b	0.497	0	0.5	0.000000	>1,000,000	1			Suitable	Possible	Not Suitable	A			Dense sands may slow plough progress, jet assistance may be required. Gravels may reduce DOL when jetting.	Fitzroy member (soft clays) are not within the burial profile
214.971	227.000	12.029	-92.07	-98.06	Silty Clayey SAND, Sand and Silty CLAY with occasional gravel and isolated to scattered cobbles and boulders; CLAY with thin sand layers; Silty CLAY overconsolidated; sand intercalations	S1	0.000	3.150	C1b	0.978	0	0.5	0.000000	>1,000,000	1	- CATS (Pipeline) KP215.2	2,934.09	Suitable	Possible	Not Suitable	B			Subcropping Fitzroy member and Fisher formation clays are present intermittently throughout section, which may slow jetting progress (compared to sands).	C6 present between 190.5 to 192.5. C1b outcropping 191.8 to 192.5

KP Start	KP End	Length	% of Total	Tooling	Target Depth of Lowering (m)	Burial Class
0	27.971	27.97	16.12	Outside of Report Scope		
27.971	70.671	42.70	28.47	Jetting	0.5	A
70.671	95.771	25.10	22.76	Jetting	0.5	A
95.771	118.471	22.70	24.30	Jetting	0.5	C
118.471	123.971	5.50	7.38	Jetting	0.5	A
123.971	129.971	6.00	7.74	Jetting	0.5	B
129.971	141.971	12.00	15.00	Mechanical Cutting	0.5	A
141.971	144.471	2.50	3.42	Mechanical Cutting	0.5	B
144.471	157.171	12.70	15.39	Mechanical Cutting	0.5	A
157.171	168.171	11.00	15.75	Jetting	0.5	B
168.171	173.471	5.30	9.01	Mechanical Cutting	0.5	A
173.471	177.971	4.50	8.41	Jetting	0.5	C
177.971	180.971	3.00	6.12	Jetting	0.5	A
180.971	189.171	8.20	17.81	Jetting	0.5	A
189.171	192.971	3.80	10.05	Jetting	0.5	A
192.971	201.471	8.50	24.98	Jetting	0.5	A
201.471	209.971	8.50	33.30	Jetting	0.5	A
209.971	214.971	5.00	29.36	Jetting	0.5	A
214.971	227.000	12.03	100.00	Jetting	0.5	B

Totals:

Tooling	Length (km)	Length (%)
Jetting	166.53	83.67
Mechanical Trenching	32.50	16.33

Burial Depth	Length (km)	Length (%)
0.5m	227.00	100.00

Burial Class	Length (km)	Length (%)
A	168.27	74.13
B	31.53	13.89
C	27.20	11.98