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Cable Burial and Protection Plan

LT000009 - Shetland HVDC Link

Rev.	Purpose	Date	Description	Prepared	Reviewed	Approved
01	IFR	2020-12-14		Sondenaa, Elisabeth	Kerkhoff, Duncan	Walker, Nigel
02	IFR	2021-02-01	Issued for Review	Sondenaa, Elisabeth	Kerkhoff, Duncan	Walker, Nigel
03	IFR	2021-02-25	Issued for Review	Kerkhoff, Duncan		Walker, Nigel
04	IFR	2021-03-19	Issued for Review	Sondenaa, Elisabeth	Kerkhoff, Duncan	Abrahamsson, Arne
05	IFR	2021-04-19	Issued for Review	Sondenaa, Elisabeth	Kerkhoff, Duncan	Walker, Nigel

Cable Burial and Protection Plan

Shetland HVDC Link

Doc. ID.:	1AA0395404	Classification:	Project report	Prepared by:	Sondenaa, Elisabeth
Revision:	E	Language:	eng	Prepared date:	2021-04-19
Status:	Approved	Function:	Installation	Approved by:	Walker, Nigel
Security level:	Public	Project ID:	G19009	Approval date:	2021-04-19

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List of Terms and Abbreviations

Term	Definition
SHE Transmission	Scottish Hydro Electric Transmissions plc
NKT	NKT HV Cables AB
DOC	Depth of Cover is defined as the depth measured from the top of the backfill material or rock berm to the top level of the cable (reference Figure 0.1).
DOL	Depth of Lowering is the calculated vertical distance between Top of Product to Mean Seabed Level.
DOT	Depth of Trench is defined as the depth measured from mean undisturbed original seabed level to the bottom of the trench (reference Figure 0.1). To achieve the required DOL a certain DOT is defined: DOT = DOL (TOC) + Cable diameter + Margin Where margin is the additional depth setting to the burial tool necessary in order to achieve the required DOL by allowing for some infilling of the trench between the bottom of trench and bottom of cable.
Holocene	The Holocene is the current and most recent Epoch (period) in the geological record. It began at the time of the retreat of the ice sheets at the end of the last glaciation. Various dates are given for this retreat, but many sources place it at around 11,500 years before present (BP).
Subcontractor	NKT's appointed installation contractor for specific work scopes.
TOC	Top of Cable is defined as the top level of the cable (reference Figure 0.1), or in case of bundled cables, the top of the highest cable when those cables are not fully adjacent to each other.
BAS	Burial Assessment Study
CBPP	Cable Burial and Protection Plan
CP	(Offshore) Campaign

Term	Definition
CPT	Cone Penetration Test
D50	The particle size at the 50th percentile, by weight, of the rock material particle distribution curve
FO	Fibre-Optic (Cable)
HDD	Horizontal Directional Drilling
HMB	Horse Mussel Bed
HVDC	High Voltage Direct Current (Cable)
KP	Kilometre Point
LAT	Lowest Astronomical Tide
MHWS	Mean High Water Springs
MNCR	Marine Nature Conservation Review
MPA	Marine Protected Area
MW	Mega Watt
NM	Nautical Mile
OOS	Out-of-Service (Cables)
PLGR	Pre-Lay Grapnel Run
ROV	Remotely Operated Vehicle
RPL	Route Position List
SROV	Survey Remotely Operated Vehicle
UXO	Un-eXploded Ordnance

Term	Definition
VC	Vibro-Core

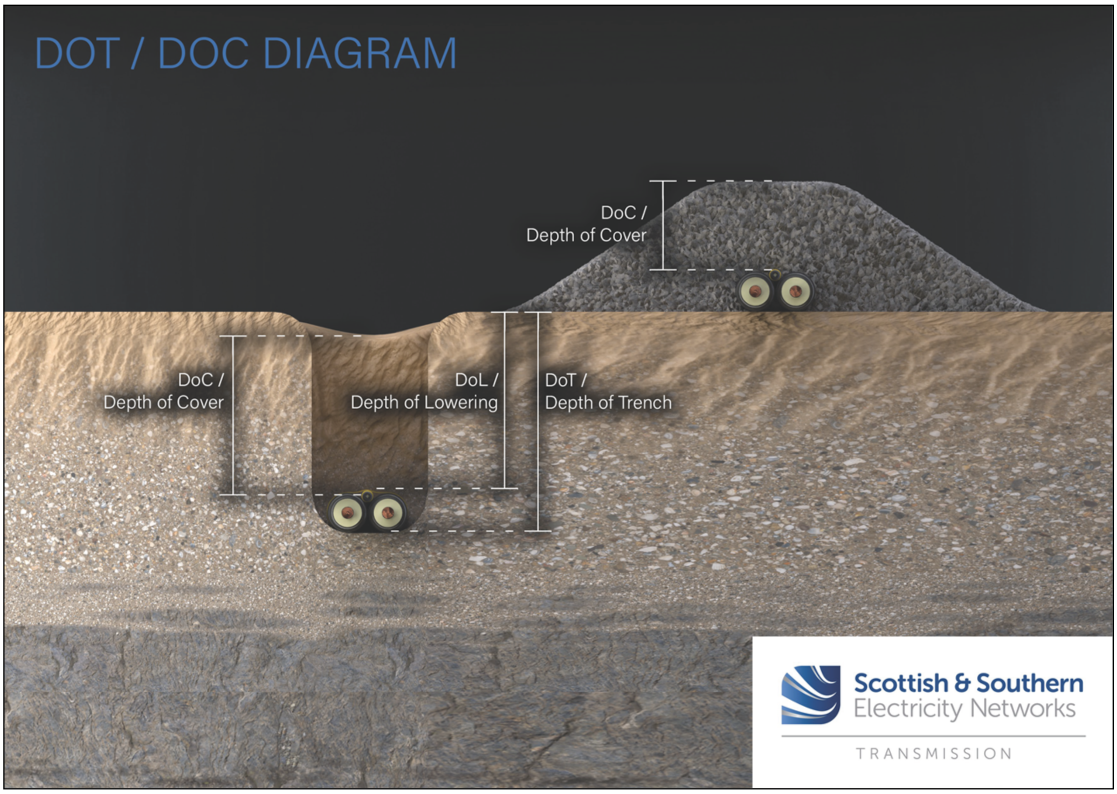

Figure 0.1: Definitions for Cable Burial and Rock Berm Protection (*source:* [02])

Table of Reference

Reference	Document Number	Document Title, (Created by)
[01]	A-200396-S00-TECH-001	Burial and Protection Summary Revision A01, (Xodus, 2019)
[02]	A-200409-S00-REPT-003	Shetland HVDC Link Marine Environmental Appraisal, (Xodus, 2019)
[03]	A-200409-S04-TECH-003	LT09 Shetland HVDC Link Communications Plan (Xodus, 2021)

Reference	Document Number	Document Title, (Created by)
[04]	A-200409-S04-TECH-004	LT09 Shetland HVDC Link Inspection, Repair and Maintenance Plan (Xodus,2021)
[05]	A-200409-S04-TECH	005LT09 Shetland HVDC Link Fisheries Liaison Mitigation Action Plan (Xodus, 20201)
[06]	A-200409-S04-TECH-006	LT09 Shetland HVDC Link Marine Archaeological Written Scheme of Investigation (ORCA, 2020)
[07]	1AA039544	Construction Environmental Management Plan (CEMP), (NKT, 2021)
[08]	1AA0392078	Construction Method Statement (CMS) - (Offshore Permits), (NKT, 2021)

Reference	Drawing Number	Drawing Title
[09]	1AA0428474	CBPP Overview Charts, (NKT, 2021)

For survey references, see Table 2.2 in Section 2.

1 Introduction

In line with Part 4 of the Marine (Scotland) Act 2010 and Part 4 of the Marine and Coastal Access Act 2009 and Scottish Hydro Electric Transmission plc's (SHE Transmission) application for a Marine License for the Shetland HVDC Link, this document describes the planning for the burial of the Shetland HVDC Link. Where burial is not feasible due to either obstructions on or in the seabed, geological limitations or environmental restrictions, this plan also describes the alternative protection of the marine cable.

The applicable Marine Licences issued by Marine Scotland and Works Licences from Shetland Island Council are mentioned below:

- Shetland Island Council (SIC) Decision for Works Licence Application Ref. 2020/011/WL: Cable installation from Weisdale Voe out to 12 nautical miles (NM) from the Shetland Islands (referred to hereafter as SIC Marine Works Licence 2020/011/WL);
- Marine Scotland Licence Number 07203/20/0: Licence to Construct, Alter or Improve and works within the Scottish Marine Area (referred to hereafter as ML 07203/20/0);
- Marine Scotland Licence Number 07357/20/0: Licence to Construct, Alter or Improve and works within the Scottish Offshore Region (referred to hereafter as ML 07357/20/0);

This plan is submitted to the Shetland Islands Council and Marine Scotland to discharge:

- Condition 3 of the Shetland Islands Council Marine Works Licence 2020/011/WL;
- Condition 20 of Marine Licence 07203/20/0; and
- Condition 20 of Marine Licence 07357/20/0.

The document is designed to cover all works below MHWS.

1.1 Structure of this document

Table 1.1 below sets out the details of these conditions and how they are addressed, with more detail on the structure of the document provided in Table 1.2:

Table 1.1: Relevant Licence Conditions

Relevant Licence Condition	Relevance to this CBPP
Shetland Islands Council Marine Works Licence 2020/011/WL, Site Specific Condition 3. "Prior to the works commencing a Cable Burial Plan (CBP) will be submitted to the Planning Authority and agreed in writing. Within 28 days of the completion of the development hereby permitted, as-laid coordinates of the cable between the levels of Mean High Water Springs (MHWS) out to 12 nautical miles from the Shetland Islands shall be submitted to the Planning Authority.	Addressed through provision of this document and associated plans

Reason: To ensure other marine users and the cable are protected and the completed development can be accurately recorded in the interests of maintaining navigational safety”.	
Marine Licence 07203/20/0 “The licensee must submit a Cable Burial and Protection Plan (CBPP) to the licensing authority for their written approval no later than two months prior to the commencement of operations relating to the licence. It is not permissible for operations relation to the licence to commence prior to the granting of such approval. In granting such approval, the licensing authority may consult any such other advisors, organisations or stakeholder as may be required at their discretion. The CBPP must be consistent with the marline licence application and supporting information. All works must proceed in accordance with the approved CBPP. The CBPP must include the following: a) Details of the location of all works relating to the license and cable laying techniques; b) Summaries of the survey work used to inform cable routing. The summaries must include geophysical, geotechnical and benthic surveys, desk top studies and cable route studies where available. A non-technical summary of this information must be provided; c) A burial plan based on survey data to show proposed burial depths throughout the whole cable route. In locations where burial is not proposed it must be demonstrated, to the satisfaction of the licensing authority, that burial is not feasible. In locations where burial is not feasible, cables must be suitably protected through recognised and approved measures where practicable, and as risk assessments direct; d) Micrositing of the cable to avoid any areas where horse mussels are recorded as ‘frequent or above’ on the SCAFOR abundance scale where feasible; e) Proposals for survey activity and programming to ensure safety of navigation to other legitimate users of the sea, and with particular relevance to fishing activity, in line with industry	Addressed through provision of this document and associated plans

best practices and guidelines. Such proposals must apply to the entire cable route; f) Proposals for further surveys to be undertaken, determined by the analysis of the data from previous survey activity and subsequent modelling and trending of seabed conditions; g) The cable must be surface laid and protected using articulated Tekduct, Uraduct or Duragaurd half shells between KP 248.9 and KP 250.2; h) The licensee must ensure that no trenching or rock is placed between KP 248.9 and KP 250.2; i) Best method of practice to minimise re-suspension of sediment during the works; and j) Steps to ensure existing and futures safe navigation is not compromised. A maximum of 5% reduction in surrounding depth referenced to Chart Datum must not be exceeded without the approval of the licensing authority"	
Marine Licence 07357/20/0 "The licensee must submit a Cable Burial and Protection Plan (CBPP) to the licensing authority for their written approval no later than two months prior to the commencement of operations relating to the licence. It is not permissible for operations relation to the licence to commence prior to the granting of such approval. In granting such approval, the licensing authority may consult any such other advisors, organisations or stakeholder as may be required at their discretion. The CBPP must be consistent with the marline licence application and supporting information. All works must proceed in accordance with the approved CBPP. The CBPP must include the following: a) Details of the location of all works relating to the licence and cable laying techniques; b) Summaries of the survey work used to inform cable routing. The summaries must include geophysical, geotechnical and benthic surveys, desk top studies and	Addressed through provision of this document and associated plans

cable route studies where available. A non-technical summary of this information must be provided; c) A burial plan based on survey data to show proposed burial depths throughout the whole cable route. In locations where burial is not proposed it must be demonstrated, to the satisfaction of the licensing authority, that burial is not feasible. In locations where burial is not feasible, cables must be suitably protected through recognised and approved measures where practicable, and as risk assessments direct; d) Proposals for survey activity and programming to ensure safety of navigation to other legitimate users of the sea, and with particular relevance to fishing activity, in line with industry best practices and guidelines. Such proposals must apply to the entire cable route; e) Proposals for further surveys to be undertaken, determined by the analysis of the data from previous survey activity and subsequent modelling and trending of seabed conditions; h) Best method of practice to minimise re-suspension of sediment during the works; and i) Steps to ensure existing and futures safe navigation is not compromised. A maximum of 5% reduction in surrounding depth referenced to Chart Datum must not be exceeded without the approval of the licensing authority.”	

Table 1.2: Structure of the Document, highlighting where Specific Requirements of the Conditions are Met

Section of this Document		Contains information on:	Addresses Requirement
Section 1 Page 9	Introduction	• Purpose of this Plan • Background information on the Project • Location of the Work and reference to the cable route (RPL)	Condition 20 of ML07203, (a) Condition 19 of ML07357, (a)
Section 2 Page 19	Survey Data	• Reference to survey data used • Summaries of the survey work	Condition 20 of ML07203, (b) Condition 19 of ML07357, (b)

Section of this Document		Contains information on:	Addresses Requirement
		○ Geotechnical ○ Geophysical ○ Benthic	
Section 4 Page 34	Methods of Burial and Protection Proposed	• Description of trenching equipment and alternative methods for burial • Re-suspension of sediment during the works	Condition 20 of ML07203, (c), (d)(g), (i) Condition 19 of ML07357, (c), (i)
Section 6 Page 41	Cable Burial and Protection Assessment	• Burial by trenching • Cable protection by means or rock placement • Cable protection by means of cable protection system (CPS) • Cable protection by means of HDD and open trench duct	Condition 20 of ML07203, (c), (d), (g), (h) Condition 19 of ML07357, (c) Site Specific Condition 3 of the SIC Decision
Section 7 Page 54	Reduction in Water Depth	• Locations with description of reduction in water depth	Condition 20 of ML07203, (i) Condition 19 of ML07357, (i) Site Specific Condition 3 of the SIC Decision
Section 8 Page 57	Further Investigations	• Planned survey activities, pre-commencement of the works.	Condition 20 of ML07203, (f) Condition 19 of ML07357, (e) Site Specific Condition 3 of the SIC Decision
Section 9 Page 57	As-Built Data and Documentation	• As-built reporting	Condition 20 of ML07203, (j) Condition 19 of ML07357, (i)

1.2 The Project

Shetland is not presently connected to the UK mainland electricity Transmission grid and as such is solely reliant on island-based generation, this generation is in the majority derived from fossil fuels with the support of onshore wind.

There is currently approximately 600MW of consented renewable energy generation on the Shetland Isles, which will require connection to the UK mainland transmission network once these projects are constructed. Scottish Hydro Electric Transmission Plc (SHE Transmission) is the licenced Transmission Owner in the north of Scotland, and as such, has a requirement to provide connection to the UK's network when requested by a generator.

In order to meet the dual requirement of the provision of reliable transmission level supply and export surplus renewable generation, SHE Transmission are planning to install a single circuit 253km long, 600MW High Voltage Direct Current (HVDC) link between Weisdale Voe in Shetland and Noss Head in Caithness ('Shetland HVDC Link' or 'the Project'). The marine cable infrastructure will consist of a single bundle comprising two conductor cables and one fibre optic communications cable, to allow control of the substation and HVDC converter station. Marine cable solution provider, NKT, will be responsible for the manufacture and installation of the subsea cable.

An overview of the marine installation corridor is provided in Figure 1.1.

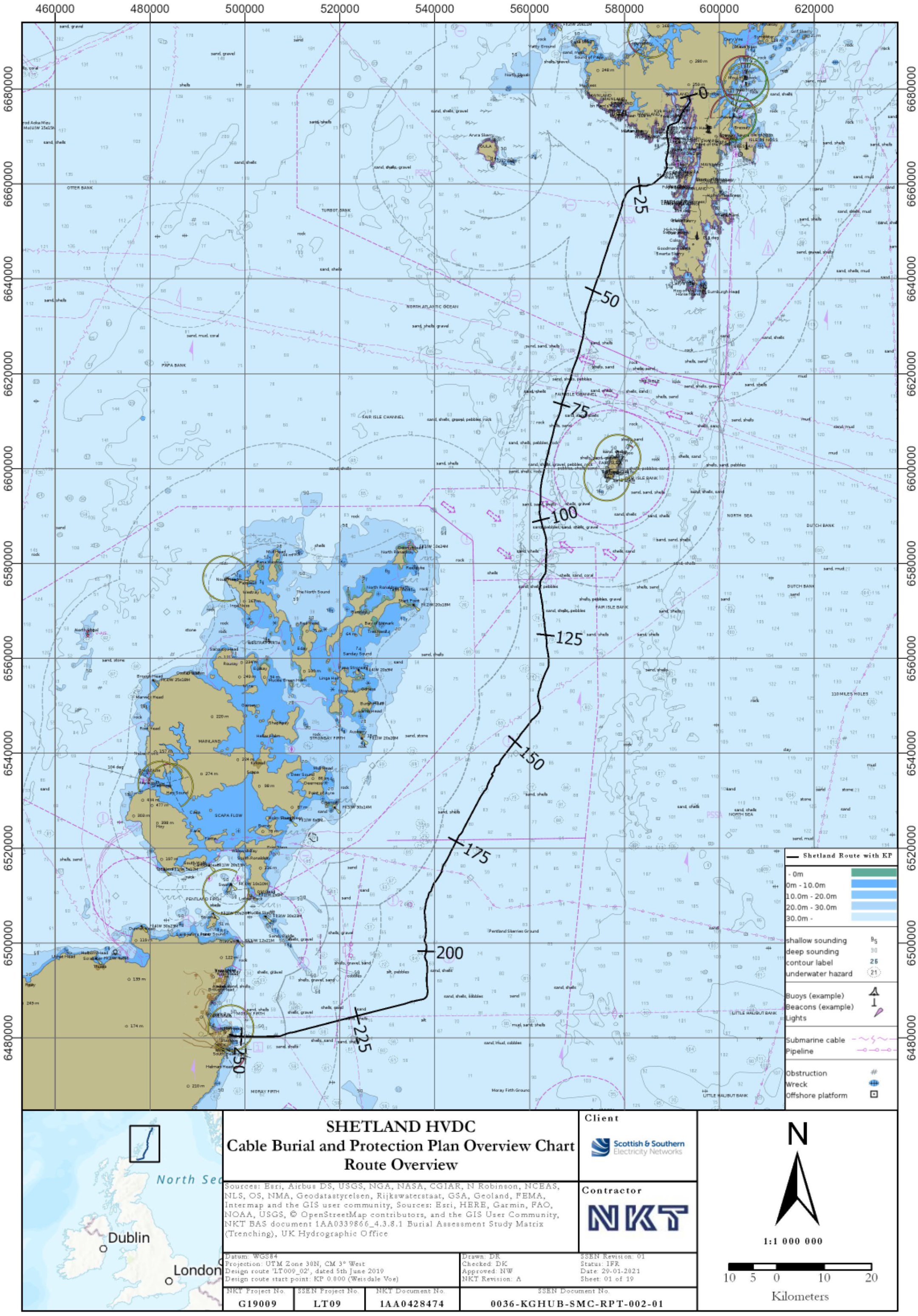

Figure 1.1: Shetland HVDC Link Route Overview

From landfall at Weisdale Voe, Shetland, the cable will briefly exit the Shetland 12NM Zone before again entering the Zone which surrounds Fair Isle (Shetland).

From KP 59.062 to KP 64.277 and between KP 110.447 and KP 229.485 the cable route is outside any 12NM zone, here in this document named “Offshore”.

The cable will enter the 12NM zone for mainland Scotland East of Noss Head.

Refer to Table 1.6 for 12NM zone limits.

Reference is made to Table 6.5 regarding locations along the route where alternative protection methods are being performed due to partial or no protection provided by trenching.

RPL Reference

The route described within this report and KP references are based on coordinates contained within RPL_LT009_02_20190605 unless stated otherwise.

Ref.	Route	Name	Version / Date of issue	KP
[10]	Shetland Link marine HVDC cable	RPL_LT009_02_20190605	02 / 05 June 2019	Start KP at Weisdale Voe (KP0) End KP at Noss Head (KP252.523)

Table 1.3: RPL Source Data

Datum Parameters	
Datum	WGS84
Spheroid	GRS 1980
Prime meridian	Greenwich
Prime meridian	0;00;00.000 E
Conversion factor to metres	1.000000000000000
Semi Major Axis	6378137.000 m
Semi Minor Axis	6356752.314 m
Inverse Flattening	1/298.257222101
Flattening	0.003352810681182
First eccentricity	0.081819191042816
First eccentricity squared	0.006694380022901
Second eccentricity	0.82094438151917
Second eccentricity squared	0.00673949677479

Table 1.4: Datum Parameters

Datum Parameters	
Projection	UTM
Zone	UTM30N
Central Meridian	3°W
Latitude origin	0°
False Northing	0 m
False Easting	500000 m
Central Scale Factor	0.9996
Units	Metres

Table 1.5: Projection Parameters

Latitude (N)	Longitude (W)	Easting	Northing	KP (km)	Note
12NM Zone Shetland					
60.232807°	1.310132°	593587.00	6678537.00	0.000	Start
59.790144°	1.728267°	571380.20	6628725.03	59.062	End 12NM
12NM Zone Shetland					
59.744943°	1.751599°	570165.45	6623667.00	64.277	Start 12NM
59.344340°	1.884515°	563444.26	6578926.78	110.447	End 12NM
12NM Zone Scotland					
58.492076°	2.668501°	519325.08	6483544.33	229.485	Start 12NM
58.467172°	3.055081°	496786.70	6480725.09	252.523	End

Table 1.6: Cable Route KPs at 12NM Zone Limits from RPL [10]

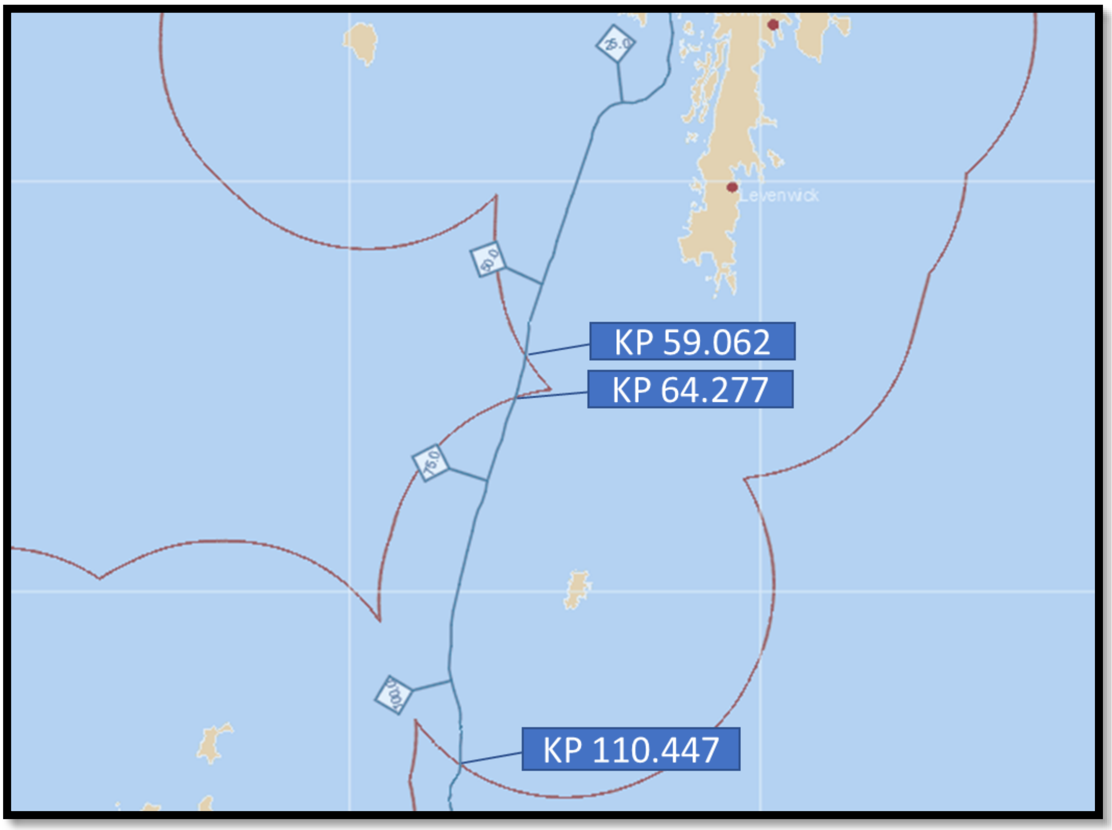

Figure 1.2: Cable (Blue) KPs at Shetland 12NM Lines (Red)

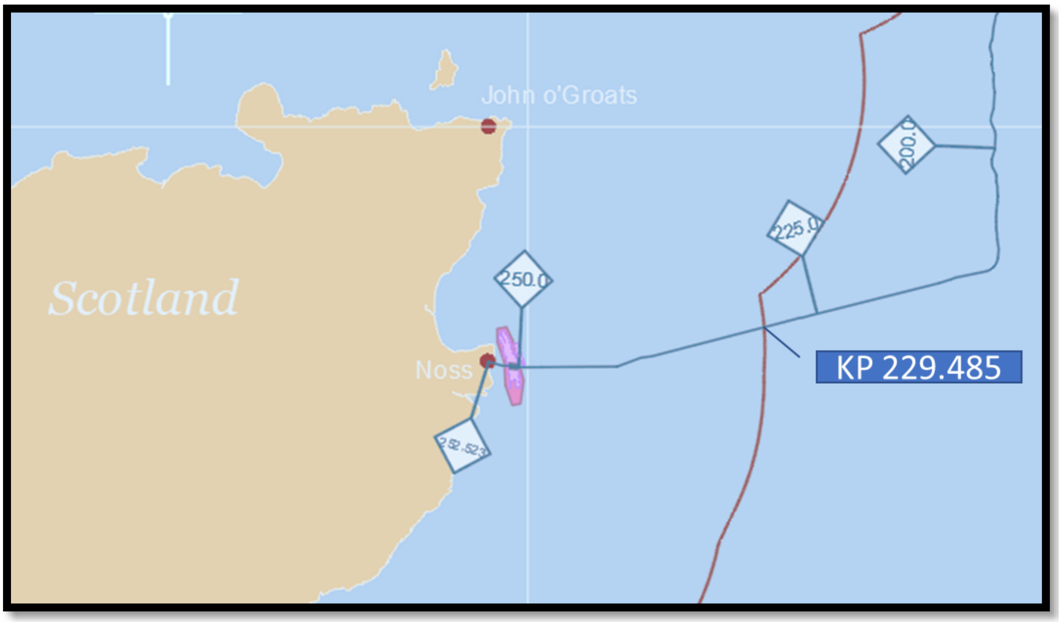

Figure 1.3: Cable (Blue) KP at Scotland 12NM Line (Red)

2 Survey Data

This section describes the features and conditions found along the route which need to be evaluated in regard to the burial and protection of the marine cables. Any further elaboration of the assessment process regarding the cable burial or protection design and activities are detailed in the subsequent sections.

2.1 Summary

The 2013 report [18], [19] summarises the survey data as follows:

The seafloor, from the Weisdale Voe in Shetland to the Scottish coast, comprises several provinces with different seabed morphologies. The depth ranges between 0 to 124 meters, and the seabed gradients, although generally very low, varies between different areas. The seabed is mainly composed of mixed sandy sediments, with different proportions of shells, gravels and silt.

Weisdale Voe is dominated by a highly irregular bedrock surface, with troughs infilled by clay and coarse sediments. These are often overlain by thin layer of gravel to gravelly sand/sandy gravel which at some areas forms ripples on the seabed.

The midsection of the route, mainly located offshore, is generally a flat, sandy area, with occasionally outcropping or sub-cropping flat bedrock surface around the Orkney platform. This is commonly blanketed by a thin layer of marine sediments, with an upper discontinuous recent mobile sediment layer, in places observed as current induced bedforms e.g. sandwaves and mega ripples.

The area towards the Scottish coast is dominated by a slightly irregular seabed, gently sloping towards the northeast. The surface is usually covered with gravelly or sandy sediments with large proportions of shells and gravels of shells as thin mobile layers, on top of coarse sediment and bedrock.

The above is confirmed by data provided in the 2018 survey report [12],[13].

The description of survey methods performed are split under Chapter 2.3 and 2.4, however geotechnical and geophysical surveys are done in conjunction and data should align. Assessment of the available survey data will therefore be an integrated approach when using the information for engineering purposes.

2.2 Survey Data Reference

The seabed conditions for the cable route are based on the following list of reference survey reports:

Ref.	Doc. Title	Survey Contractor	Date of Issue	External Doc. No.	Doc. Rev.
[11]	1AA0399088_LT000009-TN-182 Aspects Noss Head Data Survey Files	Aspect Surveys	2020-11-03	N/A	A
[12]	Marine Survey Report	MMT	2019-11-14	102967-SSE-MMT-SUR-REP-SURVEYRE	D
[13]	Geotechnical Report	MMT	2019-11-15	1027967-SSE-MMT-SUR-REP-GEOTECH	02

[14]	Geodatabase MMT 2018 surveys: SSE-102967-Shetland-Geotech.gdb	MMT	2019-11-15		
[15]	Noss Head	Bibby Offshore	2019-08-28	REP-F-015	04
[16]	Horse Mussel Bed	MMT	2016-06-02	101594-ABB-MMT-SUR-REP-ENVIRON	02
[17]	The structural geology of a coastal zone south of Noss Head, near Wick, Caithness Geology and Landscape Scotland Programme	BGS	2014-01-31	Commercial Report CR/13/129	1.0
[18]	Marine Survey Report – Geophysical, Geotechnical and Environmental Survey Volume 1 Western Route	MMT	2013-06-12	101290-SSE-MMT-SUR-REP-SURCMSWE-A	A
[19]	Marine Survey Report – Geophysical, Geotechnical and Environmental Survey Volume 2 Eastern Route	MMT	2013-05-20	101290-SSE-MMT-SUR-REP-SURCMSEA-A	A
[20]	Survey Shetland Isles to Scottish Mainland Volume 3: Environmental Report February - April 2013	MMT	2013-06-12	101290-SSE-MMT-SUR-REP-ENVIRCMS	A
[21]	Geodatabase MMT 2008 – 2013 surveys: SSE-101290-MMT-Survey2013.gdb	MMT	2013	SSE-101290-MMT-Survey2013.gdb	
[22]	HVDC Subsea cable link route between Shetland and mainland Scotland Western Route (including alternative landing point) Marine Survey 2008 Volume 1	MMT	2009-01-02	100364	4
[23]	HVDC Subsea Cable Link Route between Shetland and Mainland Scotland Eastern Route (Including Alternative Landing Point) Marine Survey 2008 Volume 2	MMT	2009-01-02	100364	4
[24]	VDC Subsea cable link route between	MMT	2009-01-02	100364	4

Shetland and mainland Scotland Biological report Marine Survey 2008				

Table 2.1: Reference List of Survey Reports and Data Provided

Where reference to the above documentation is made within this report, such references are in the form [12] etc.

For survey work performed in 2018, a previous RPL, RPL_LT009_01_20190125, were used as KP reference [12][13].

2.3 Geotechnical Survey

Geotechnical survey is the physical penetration of the seabed to test the soil strength and taking samples of the soil.

The geotechnical surveys consist of vibro-core sampling (VC) and cone penetration tests (CPT) [13].

Vibrocore

Information	Reason	Obtained from	Accuracy
Geological description	General description Possibility to identify geological risk.	Geology description	High
Layer thickness	Required for burial assessment	Core	Low to high
Soil type	Possibility to take samples for lab tests	Lab samples	High
Soil strength	Required for burial assessment Strength determines burial speed and risks	Lab samples	Low to medium. However, often not possible

Table 2.2: VC Information

Cone penetration test

Information	Reason	Obtained from	Accuracy
Geological description	General description	Geology description from CPT data	Medium
Layer thickness	Required for burial assessment	CPT data	High
Soil type	Can be obtained from CPT data Soil samples cannot be taken	CPT data	Medium
Soil strength	Required for burial assessment Strength determines burial speed and risks	CPT data	High

Table 2.3: CPT Information

Quantities of Geotechnical Data Input

The reports received provide collocated CPT and VC data along the Shetland HVDC Link, [13][18][19][22][23]. The GIS data [21] includes a few more VC sample points, however these are not reported in the survey reports, which indicates the samples were not successful.

An overview is presented in Table 2.4.

Weisdale Voe to Noss Head (KP 0 – KP 251.961)			
Type	**Location**	**2018 Survey**	**Pre-2018 Survey**
VC	12NM Zone Shetland	80	37
	Offshore	106	42
	12NM Zone Scotland mainland	15	9
	Total	201	88
CPT	12NM Zone Shetland	79	37
	Offshore	142	42
	12NM Zone Scotland mainland	13	4
	Total	234	83
TOTAL		*435*	*171*

Table 2.4: Geotechnical Stations Along the Shetland Link Route

It is to be noted that the geotechnical data are generally available with an interval of approximately 1 – 3 km between the geotechnical stations (sample location) for the 2018 data, while the for the older data the interval is approximately 2.5 – 3.5 km between the samples.

Geotechnical Assessment

The geological and geotechnical assessments have been carried out in order to perform a burial assessment using the described trenching equipment (Section 4.2) and evaluate necessary remedial work where only trenching is not sufficient. The geotechnical data is also used for evaluating soil behaviour where rock berms are being placed as cable protection.

Summary of Geotechnical Survey

- Approximately 42% of the route comprises greater than 1.8m thickness of seabed sediments (generally coarse Holocene non-cohesive material such as sand, gravelly sand and sandy gravel) over bedrock.
- Approximately 35% of the route comprises bedrock, within the 1.8m of seabed. Generally, with an overlying layer of Holocene sediments (sand, gravelly sand and sandy gravel).

- Approximately 23% of the route comprises of a layer of fine grained sediments, which mostly comprises very soft to soft clays and silts in conjunction with granular material. The layer thickness is between 1m and 5m.

Survey reports show a summary and conclusion which is based on both geotechnical and geophysical survey aspects regarding the soil layers, however there seem to be a general agreement regarding the indications of certain soil characteristics between the sub-bottom profiler survey (as part of geophysical survey) and the test samples taken.

2.4 Geophysical Survey

Geophysical survey utilises non-intrusive survey techniques (i.e. techniques that do not require physical penetration of the seabed) to provide a complete and continuous picture of the soils along the route, the seabed movements and any potential obstacles on the seabed (e.g. boulders / wrecks / in service and out of service cables or pipelines). It is good survey practice for a thorough geophysical survey to be performed to support and supplement the geotechnical survey and clarify the variability in soil conditions between geotechnical sample points. These surveys are performed with a swathe at least equivalent to the route corridor and have the following functions:

1. Bathymetric survey – to provide details of the water depth and the seabed movements, such as sandwave migration.
2. Sidescan sonar survey – to provide images of the seabed and assist in identifying potential obstacles such as boulder outcrops, wrecks or other dropped objects like anchors along the route.
3. Magnetometer survey – to identify metallic objects buried/on the surface along the route, such as military ordnance, in-service and out of service cables and pipelines.
4. Sub-bottom profiler survey – to get an interpretation of the soil layers present between the geotechnical stations using profile techniques.

This survey is important for the route engineering, to identify features for which the cable route can be adapted to avoid obstacles and any potential exclusion zones around them.

Geophysical Assessment

The geophysical evaluation is crucial for the cable routing and also forms a part of the input data for trenching and remedial activities together with the geotechnical information.

Boulders and UXOs Identification

The assessment of the MMT survey data and associated reports on obstacles based on the 2018 survey relative to the Weisdale Voe – Noss Head route [10] indicates:

- Some total of 1991 probable, individual boulders (>0.5m) not detected in a boulder field, were detected in the surveyed corridor where 19 were identified within +/-10m of the route.
- A total of 112 probable man-made objects (excluding wrecks) were detected in the surveyed corridors where 4 were identified within +/-10m of the route.
- A total of 2 wrecks have been identified, however outside +/-100m of the route, at KP 162.519 (Offshore) and KP248.670 (12NM Zone Scotland) [12].

Since no dedicated gradiometer survey has been executed during the 2018 survey, the targets are based on data from previous surveys [22][23].

- A total of 821magnetic targets were detected in the surveyed corridors. Excluding crossings (linear trends), a total of 410 targets (magnetic anomalies) are found from which 2 of these targets are obstacles within +/-25m of the route, however 1 of these are from a cable crossing. Target F-M-005 detected in 2008 lies within +/-10m of RPL at KP 186.430.

It is assumed that the distance of all these targets listed can be increased to at least 25m by micro-rerouting, although less is also tolerated for non-magnetic targets.

At KP 124.134-124.179 (Offshore), an unidentified linear trend was detected outside the cable corridor by the magnetometer. This might indicate the presence of a possible cable crossing. However, no data of this possible crossing is available. An additional survey could provide a confirmation on this linear object.[18].

In addition, multiple boulder fields have been identified along the route. In these boulder fields, compared to the 1991 individual boulders previously mentioned, no exact position of single boulders is provided.

The type of area has been evaluated by the survey contractor under 2 different density definitions [12];

- Occasional Boulders Field; Concentration of 5-20 boulders within a maximum area of 50 x 50 m
- Numerous Boulders Field; Concentration of ≥20 boulders within a maximum area of 50 x 50 m

An assessment of these boulder fields estimates 2060 boulders (>0.3m dimension) along the RPL centre in a +/- 5m wide corridor in 87 separate areas (occasional boulders field and numerous boulders field).

A boulder clearance operation will be performed prior to the installation. However, the preferred mitigation is that of micro-rerouting within the existing survey corridor, especially regarding boulder fields.

Sandwaves

The term sandwaves is being used throughout this document section, which is an informal description terms of different type of bedforms. However, for this document, this definition is deemed sufficient for the assessments made.

Along the route several sandwaves were reported confirmed during the 2018 Survey.

Whilst the presence of mobile seabed features is reported they have not been discussed in detail regarding mobility. Since sandwaves could have a negative impact on the burial depth over time it is advised to compare the data of the proposed survey prior to installation with the 2013 and 2018 survey data to determine mobility, height and wavelength of possible features along the route. See Figure 2.4 in Section 2.4.

Shetland 12NM Zone

Around KP 48 and KP 89 sandwaves were noted.

At KP 110 sandwaves are located at a depth of around 100 meters having in general a height of 10 meters above the surrounding seabed.

Offshore

Between KP 110 and KP 117.5 sandwaves are located at a depth of around 100 meters having in general a height of 10 meters above the surrounding seabed.

Scotland 12NM Zone

Between KP 243.5 and KP 246.45 various sandwaves up to 4 m high run parallel to the route with associated gradients of up to 10°. By comparing the data from 2013 to 2018, it has been estimated that the features have been moving North with approximately 2 meters a year based on NKT assessment.

Sub-Bottom Profiling

The seabed and shallow sub-surface soil conditions can also be assessed by means of a geophysical survey. Such information can be used to interpolate between the geotechnical locations (CPT and/or VC).

Along the Shetland HVDC Link cable route corridor geophysical surveys including sub-bottom profile surveys have been carried out. These surveys were carried out with a sub-bottom profiler that is suitable for investigating the upper 2-10 meters of soil.

It is to be noted that gravel and clay & silt layers (occasionally associated with gas charged sediments) can acoustically blank the underlying layers which is typically bedrock in the Fair Isle Channel area.

Bathymetry

At Weisdale Voe the assumed open trench runs until circa 10m LAT where the seabed decreases to a maximum depth of 124.8 m LAT close to KP 25, where after the seabed gradually rises to 100 m LAT around KP 81.

From KP 81 to approximately KP 94.2, the depth increases to 114.9. From that point the seabed rises.

This increment gradually decreases, and from KP 115 to KP 247 the seabed depth range lies between 61 and 83 m LAT.

From KP 248.3 the depth decreases gradually towards 22m LAT close KP 251.961 where the assumed Noss Head HDD pop up hole is located.

A depth profile of the Weisdale Voe – Noss Head route is presented in Figure 2.1.

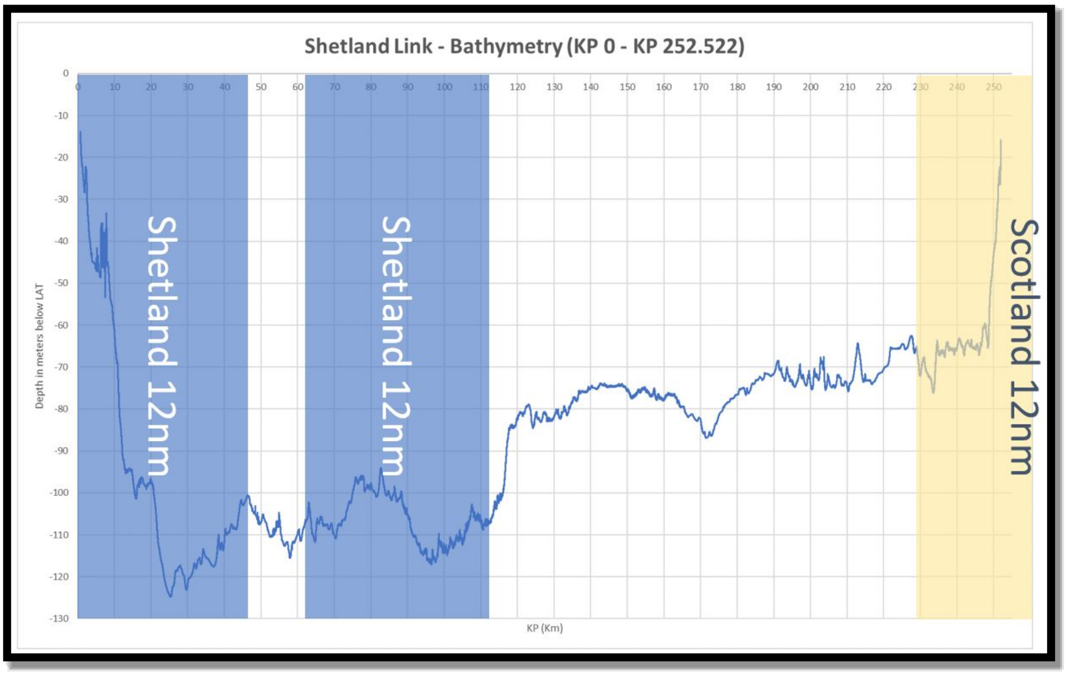

Figure 2.1: Depth Profile Weisdale Voe – Noss Head *(source: [12])*

Summary of Geophysical Survey

Summarizing the geophysical survey information from the abovementioned surveys, the following conclusions are drawn:

12NM Zone Shetland

- The northern area until approximately KP 21 comprises a relatively rough and uneven seabed, with mounds and ridges. One of the most prominent features in this section is an area of rocky outcrop. Also, shallow channels across the route can be found.

- From KP 21 the seabed consists of a relatively smooth surface. However, smaller geological features and sandwaves of different size are present.

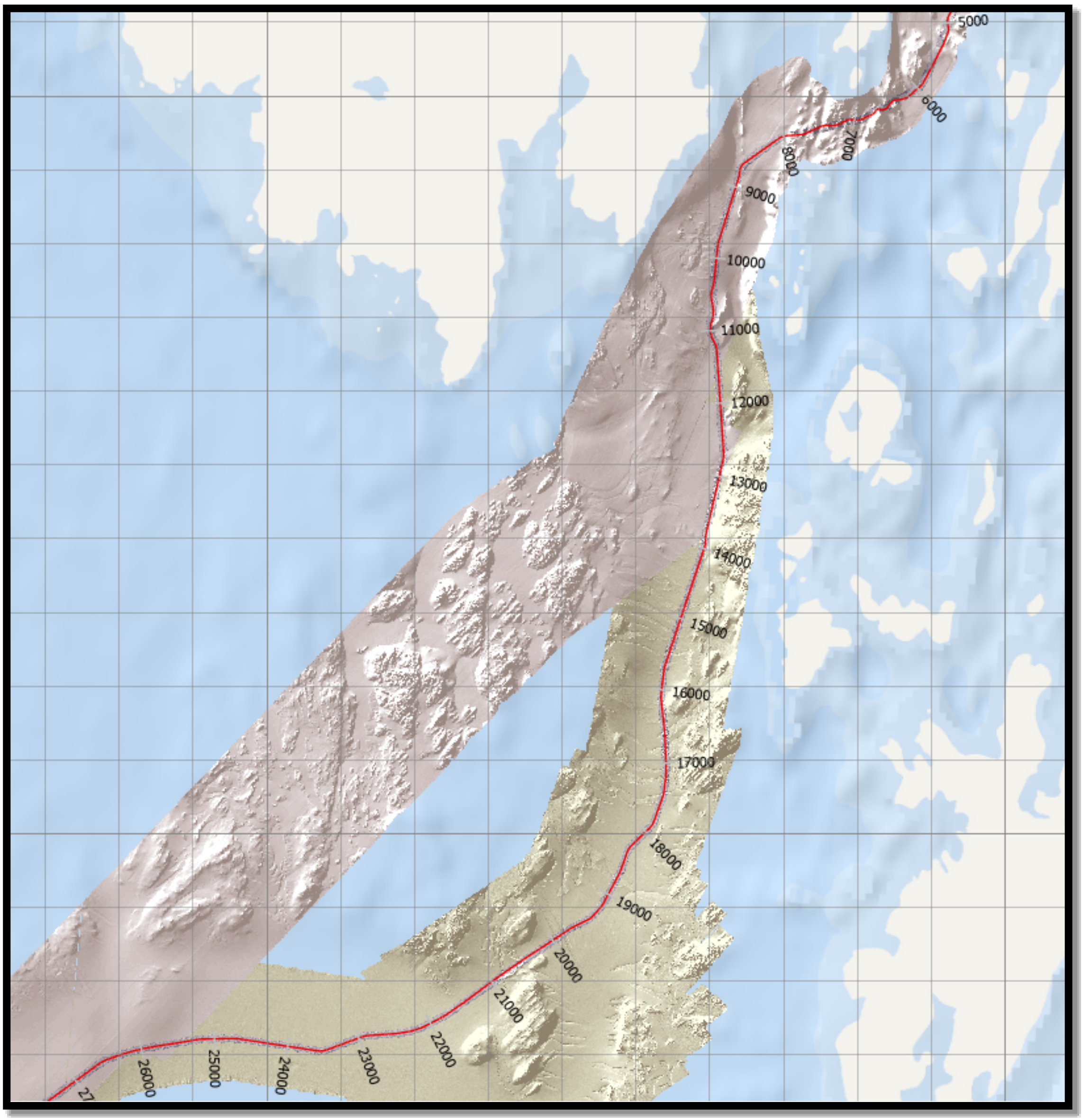

Figure 2.2: Seabed Overview Nearshore Shetland showing RPL [10].

Offshore

- One of the most prominent features in the middle section of the route are the sandwaves located between KP 110 (At the 12NM zone border) and KP 117.5. They are located at a depth of around 100 meters and have in general a height of 10 meters above the surrounding seabed. Since the corridor width at this location from the 2018 survey is not sufficiently wide, the assumptions for these sandwaves are based on survey data pre-2018.

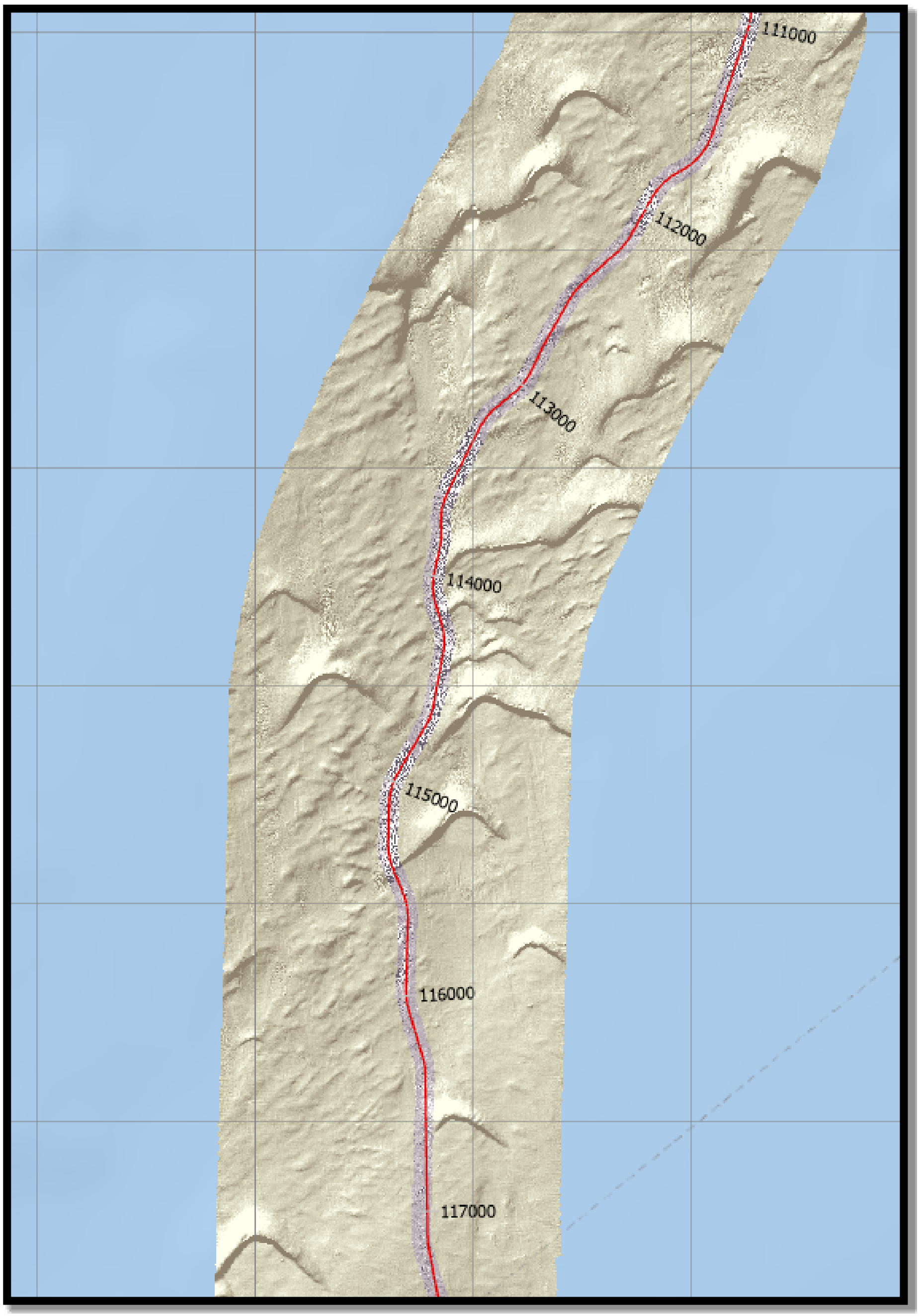

Figure 2.3: Subaqueous Barchan Sandwaves Shown in Survey Data Pre 2018

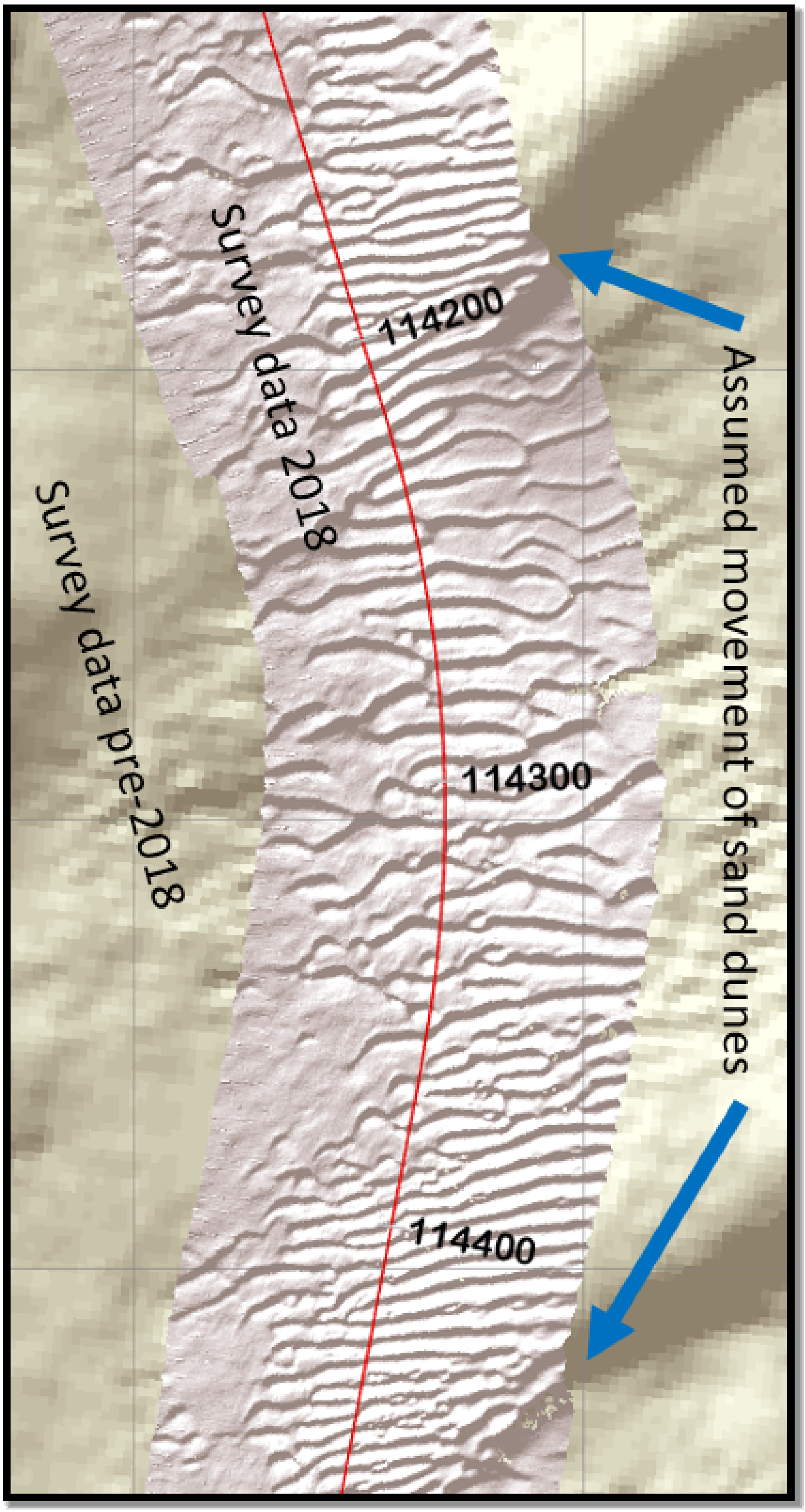

Figure 2.4: Comparing Survey Data from 2018 with Pre 2018 Survey Data

- Beginning at KP 176 numerous mounds intersect the surveyed corridor, which continue frequently to the southern extent of the survey area. The slope values range from moderate to gentle then back to moderate and steep as it moves south. The maximum slope angle of around 9° is found at KP 193.58.

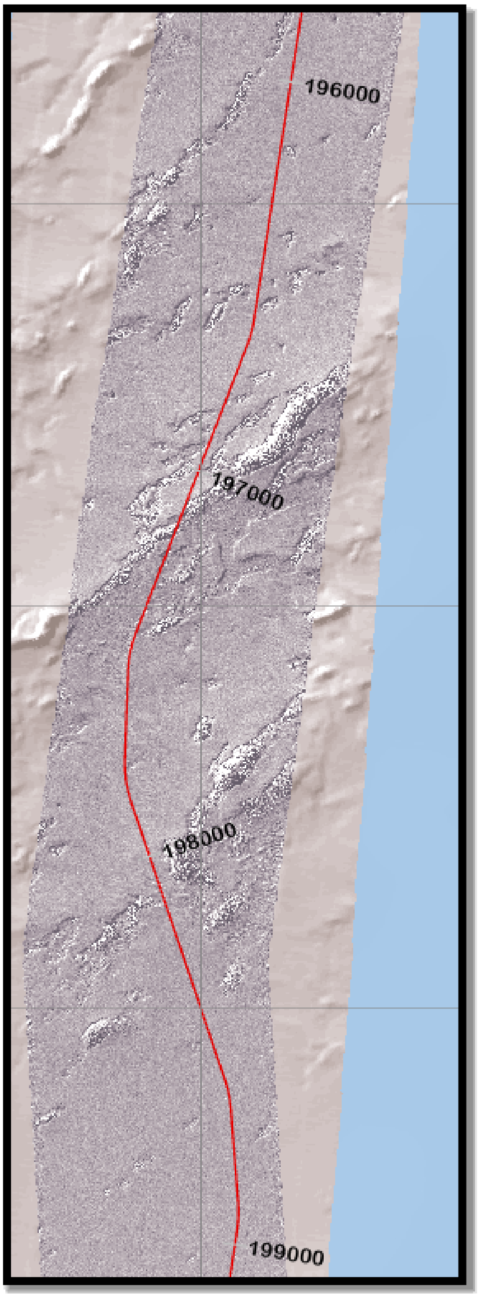

Figure 2.5: Irregular Seabed with Ridges Around KP 197

- From KP 206 towards approximately KP 228, a smooth seafloor with few geological features is present.

12NM Zone Scotland

- After KP 228 the seafloor is characterized with sections of large sandwaves. One of the most prominent features are the sandwaves and scour areas which can be found between KP 242 and KP 247. These sandwaves have a height of around 3 meters above the surrounding seabed and indicate a complex current regime.

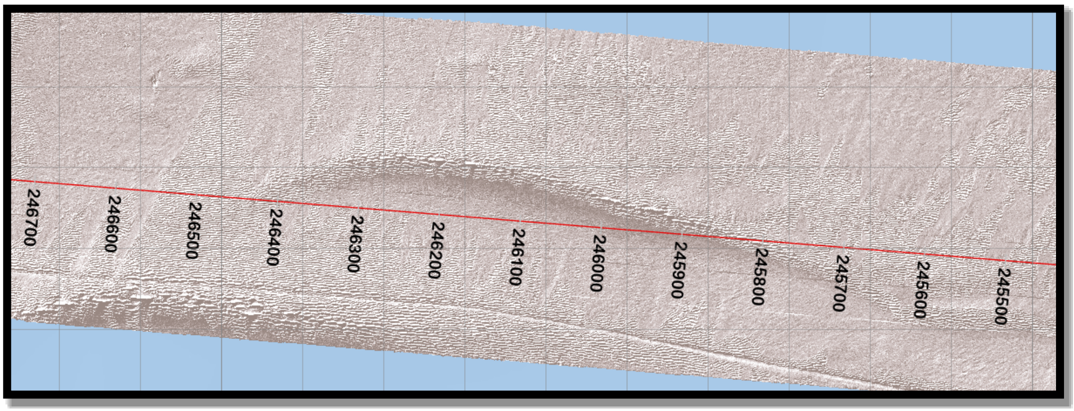

Figure 2.6: Sandwave Around KP 246

2.5 Benthic Survey

Grab sampling and camera equipped with both video and still camera were used in addition to geophysical surveys for the benthic surveys performed in 2013[20]and 2008[24].

When assessing the habitats encountered, the Marine Nature Conservation Review (MNCR) SACFOR abundance scale were used during both of the environmental surveys for recording the abundance of marine benthic flora and fauna.

Quoted from the 2008 Environmental Survey:

"In order to evaluate the environmental impact, the biological sampling programme "Scope of Work for Biological Survey" was set up by SSE in collaboration with Scottish Natural Heritage, SNH. The primary aim of the biological survey was to identify species and biotopes along the route for further environmental evaluation. The methods used are mainly based on the procedural guidelines of Joint Nature Conservation Committee, JNCC, Marine Monitoring Handbook (Davies J. et al. 2001) and the biotope classification follows the Marine Habitat Classification for Britain and Ireland, originally developed by the Marine Nature Conservation Review (MNCR)."

Quoted from the 2013 Environmental Survey:

"One of the main objectives of this survey was to identify areas where sensitive or protected habitats and species occurred. Special emphasis was placed on the PMF (Priority Marine Features) species; the ocean quahog Arctica islandica and the heart cockle Glossus humanus.

The ocean quahog is also listed on the OSPAR list of protected species and habitats (OSPAR Commission, 2008). Marine habitats and invertebrate species listed in the EC habitat directive (The Council of the European Communities, 1992) and the JNCC's lists of UK BAP (Biodiversity Action

Plan) were also targeted in this survey (BRIG (ed. Ant Maddock), 2008 (Updated Dec 2011)).

Priority Marine Features, PMFs, are listed by the SNH (Scottish Natural Heritage) as a guidance to which species and habitats found in existing conservation mechanisms require conservation action in Scottish territorial waters (At the time of writing this list was not yet adopted by the Scottish Ministers). The OSPAR list of protected species and habitats lists sensitive habitats and species in need of protection in the North-East Atlantic. For the contracting parties it works as a complement to the EC habitats directives."

The 2013 survey classifies 15 different habitats along the route.

Ocean quahog (Arctica islandica) was observed in low abundance along the whole cable route [02][20][24]. The assessed impact significance of temporary and permanent habitat loss due to the marine works is considered "not significant" for this bivalvia species [02].

No specimens of the heart cockle Glussus humanus were found during the 2013 survey and is also not mentioned in the 2008 survey report.

12NM Zone Shetland

Seapens were observed along the cable installation corridor in Weisdale Voe, however these were not identified as sensitive biotopes for the Weisdale Voe nearshore works [02][20].

12NM Zone Scotland

During the biological surveys [16][20] an area inhabited by Modiolus modiolus (Horse Mussels) was detected to be present on the seabed along the route between KP 250.032 and KP 250.780 [16] within the Scottish 12NM Zone. This feature is classified as a biogenic reef.

Modiolus modiolus is a protected species and no burial or rock placement activities are allowed in this area. The area lies within the Noss Head Nature Conservation Marine Protected Area (MPA).

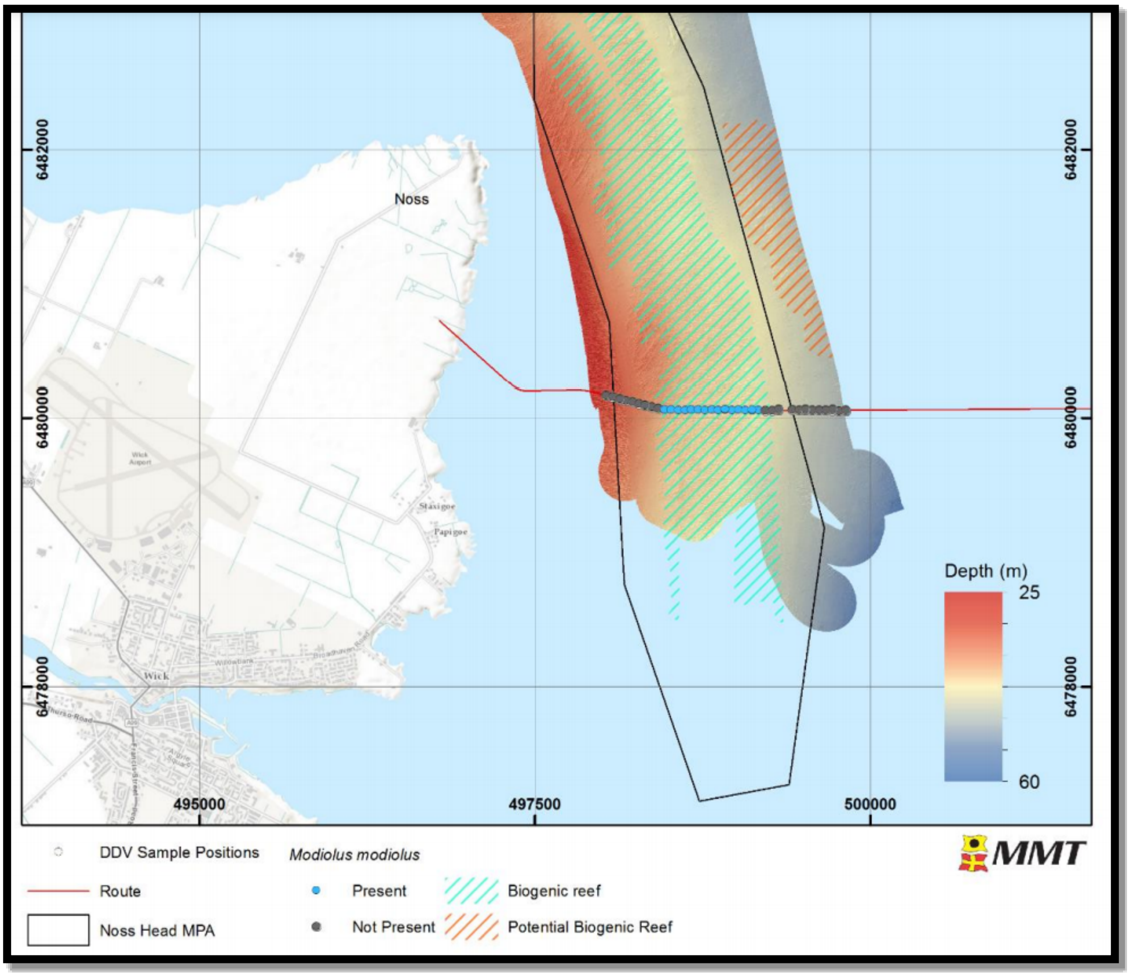

Figure 2.7: Horse Mussel Bed (Marine Growth) Extents (*source:* [16])

For protection method at the Horse Mussel Bed (HMB) see Section 4.4.

Seapens were also observed at the southern part of the cable route corridor but is not considered a sensitive biotope.

Offshore Zone

No sensitive biotopes were recorded for the cable corridor offshore. Reference is made to Environmental Appraisal [02].

3 Route Engineering

The process of route engineering assesses the best option to minimise installation and post-installation risk for the marine cable based on the survey data received. The shortest route is not always feasible and route engineering is the basis for any further burial and protection assessments considering the conditions which is encountered along the cable route. Examples such as obstacles at the seabed, steep slopes, pock marks, soil descriptions, bedrock formations and the marine cable crossing existing assets (in-service cables and pipelines) may enforce the cable routing to change heading at these specific locations.

Route engineering is an essential design activity to the planning of cable burial and protection which has consequential environmental benefits. It is the foundation for the further seabed assessments which is done with regards to preparation work such as pre-lay grapnel run (PLGR), boulder removal, trenching works and seabed rock placement. The minimum cable bending radius, minimum alter course radius trenching, maximum grading of trencher and the minimum alter course radius cable lay vessel gives restrictions in how to plan the route and must be adhered to when evaluating the route in regard to avoiding non- or less feasible areas along the planned cable corridor.

Re-routing of current route position list (RPL) within the consent corridor is performed during the engineering stage of the project, to avoid areas where excessive seabed preparation work or challenges to the burial and protection can be assumed from the available survey data. Micro-siting is currently being investigated/developed and may also be performed after retrieving data from survey planned in 2021, reference to Section 8.1.

4 Methods of Burial and Protection Proposed

For a more detailed description of the methods proposed, reference is made to the Construction Method Statement (CMS). [08].

Seabed features are anticipated to be within cable installation and protection tolerances given that micro-routeing will be conducted to avoid excess slopes.

For sections of the cable route where mega ripples and sandwaves are found, reference is made to CMS.

4.1 Overview

The points listed below will show which sections in the CMS where more information regarding the specific activities can be found.

NKT will use the cable installation and protection strategy that comprises as a base case the following:

- PLGR and Route Clearance operations. Route clearance operations consists of boulder removal operations and Cut-and-Peel operations for the Out-of-Service (OOS) crossed assets. Mattress installation and pre-lay rock placement at crossing locations is also part of the preparation works for the cable lay. *CMS Section 8 and Section 11*

- Duct installation by HDD at Noss Head. *CMS Section 6*

- Open trench with PE duct and backfill (and / or Cast-Iron Shells or similar as an alternative) at Weisdale Voe. *CMS Section 5*

- Post cable lay jetting insofar as possible using a tracked jetting trencher. This would be undertaken as a full first-pass followed by a remedial jetting pass where considered necessary / beneficial based on the initial post-trench survey results. *CMS Section10*

- Remedial rock placement where jetting is unsuccessful in achieving required minimum DOL and/or DOC based on the initial post trench survey results. *CMS Section 11*

- Buried cable (by jetting) with cable protection system at Subsea 7's bundle tow route. *CMS Section 4.4*

- Rock placement where trenching is not possible due to shallow soil and/or bedrock. Mechanical cutting tool is considered as an option, however currently not planned for. *CMS Section 11*

- Post lay rock placement at in-service crossings. *CMS Section 11*

- Surface laying the cable with cable protection for crossing the Horse Mussel Bed at Noss Head. *CMS Section 4.4*

- Rock placement at HDD exit area at Noss Head and until reaching Horse Mussel Bed and / or (partly) cable protection system. *CMS Section 11*

For sections of the cable route where mega ripples and sandwaves are found, NKT considerations are included in the Construction Method Statement (CMS). [08].

4.2 Trenching

Jet trenching is the preferred method for cable burial. The current burial assessment conducted identifies only jet trenching to be used. For further details on trenching equipment, see CMS Section 10.

4.3 Subsea Rock Installation

To provide sufficient cover to protect the cable in areas where jet trenching is restricted, or in areas where the backfilling has provided insufficient cover, rock placement will be applied as a methodology for cable protection. At the following locations rock placement shall be applied:

- Bedrock sections near Shetland
- Cable crossings along the route
- Joint locations (2)
- Inner edge of Horse Mussel Bed until HDD pop up hole at Noss Head
- Sections where after trenching works the DOL or DOC is insufficient, depending on the area’s soil conditions and risk assessments regarding trawler or anchor impact, remedial rock placement may also be deemed necessary.

For further proposals regarding rock berm design and locations see Section 6.2.

4.4 Cable Protection System (CPS)

Two locations, both within the Scottish 12NM zone, CPS will be used for both surface laid and buried cable.

Surface Laid Cable with Protection System, 12NM Zone Scotland

A cable protection system shall be applied to the cables within the Noss Head MPA where sensitive biological seabed features are encountered. The key protected biological seabed feature is the Horse Mussel Bed located within the Noss Head MPA.

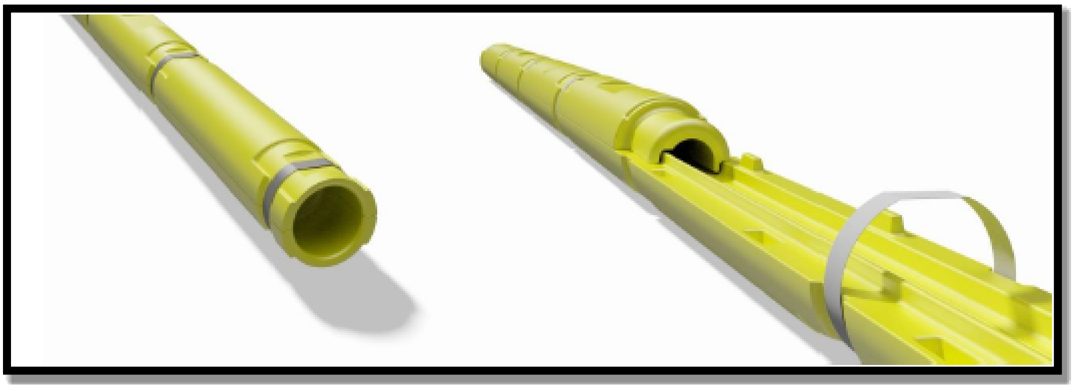

Figure 4.1: Example of External Protection Sleeve Example

The Horse Mussel Bed is considered to have a high sensitivity and is vulnerable to change and damage. Therefore, no trenching or rock placement will be utilised in this area. Instead the cables shall be surface laid and fitted with a ballasted cable protection sleeve or cast-iron shells. Ballasted cable protection system is required to ensuring on-bottom stability to minimise/prevent movement of the cable which might result in chaffing/damage to the Horse Mussel Bed.

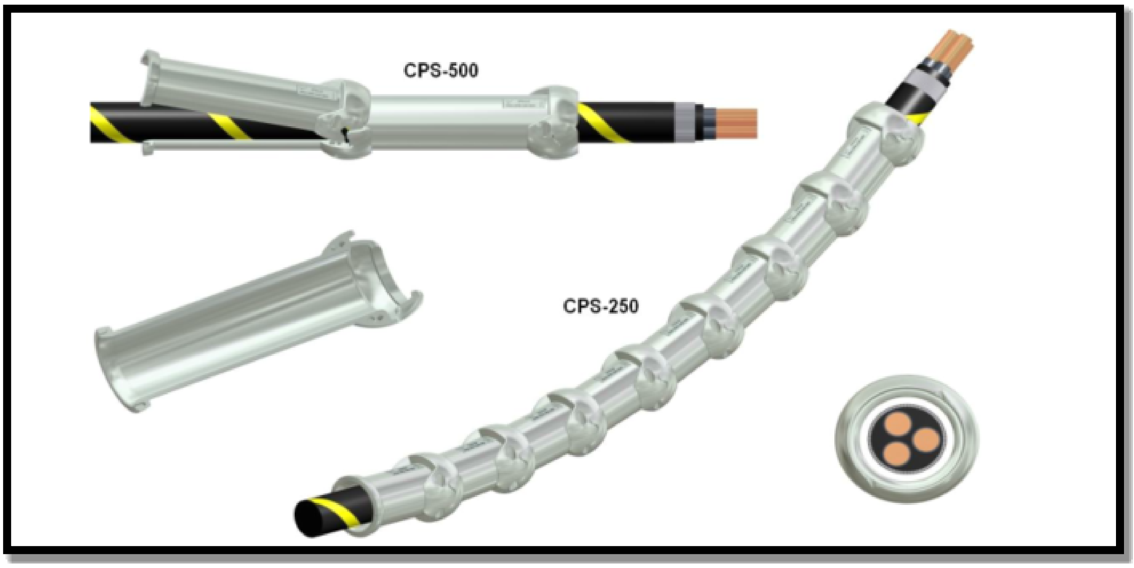

Figure 4.2: Cast-Iron Shell Cable Protection System Example

Application of external protection will be applied 100m before and after the Horse Mussel Bed area.

Buried Cable with Protection System, 12NM Zone Scotland

For the area where the cable is crossing the bundle tow route corridor from Subsea 7's facility at Bridge of Wester, the cable will also be installed with a cable protection system before burial. This is to prevent any potential damage to the cable in case of drag-chains being used for towing the pipe bundles from the production facility to offshore installation sites.

A cable protection system (Uraduct or similar), will also be used at the tow route.

CPS in Combination with Rock Berm at Noss Head

From exit point and approximate 50m outwards the cable may have a CPS as a means of protection, in combination with rock berm.

4.5 PE Pipes in Trench, 12NM Zone Shetland

2 options for the ducts (PE Pipes) in open trench layouts are considered for the landfall at Weisdale Voe.

Option No.	Number of ducts	Cable bundled	
1	2	No	one HDVC cable in each duct, FO cable in one duct
2	2	Yes	bundle in one duct, one spare duct

Table 4.1: Options for Cable in Ducts at Weisdale Voe

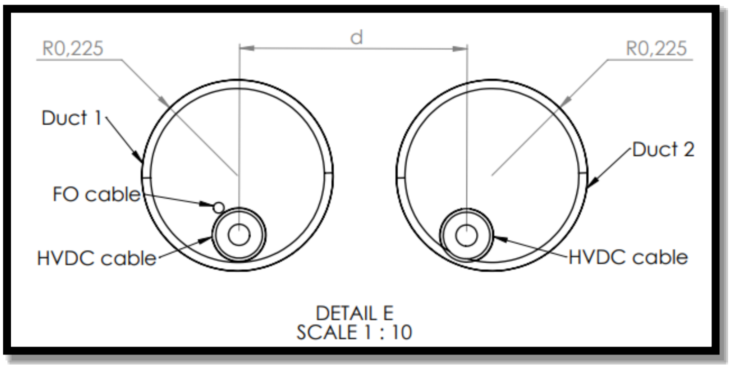

Figure 4.3: Option 1 for Weisdale Voe Landfall Burial

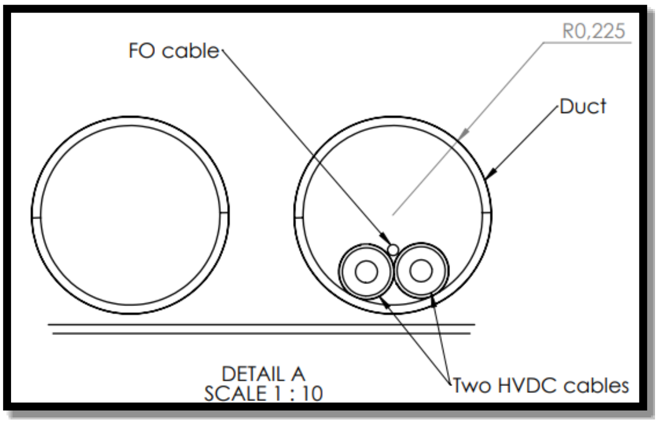

Figure 4.4: Option 2 for Weisdale Voe Landfall Burial

Cast Iron Half Shells or Concrete Half Shells at Weisdale Voe

Alternative options for the Weisdale Voe landfall include the use of cast iron half shells or similar laid over bedrock, with rock pinning and/or rock cover. For further details see CMS Section 5.1.

4.6 Horizontal Directional Drilling (HDD), 12NM Zone Scotland

NKT will appoint dedicated subcontractor for the HDD work at Noss Head.

The drill site shall be located in the same field location at Noss Head used in the Caithness-Moray project via a single work site access track.

NKT shall install three (3) HDD steel ducts of 324mm in diameter of approximately 560m in length from the transition joint bay location (HDD Compound) to extend to outside the wave break zone. The HDD is planned at a rock outcrop

Some dive work at the exit point is expected after finalization regarding cutting of excess duct, fitting of steel bell mouths which are secured by welding and pigging of the duct. Further details of methods for the HDD is to be found in the CMS Section 6.

5 Best Method of Practice to Minimise Re-suspension of Sediment During the Works

Reference is made to CEMP Section 4.6.4.

5.1 Cable Lay Operations

Cable laying operations will be performed from a dedicated cable lay vessel, NKT Victoria. The cable will be laid on the seabed where burial by trenching or protection by means of rock placement will be performed by other vessels. Where CPS is installed on the cable, this will be done onboard NKT Victoria prior to lowering the cable to the seabed. Some re-suspension of sediments may be seen during cable-lay operations, however based on the soil data received from surveys, this is expected to be minimal. Silt and soft clay is not heavily represented (23% of the cable route) along the cable route, which will give rise to more sediment re-suspension than sand, gravelly sand and sandy gravel (73% of the cable route).

5.2 Trenching Operations

Trenching operations will be carried out using industry standard burial equipment, operated at minimum power levels required to achieve expected burial in order to maximise sediment retained in trench and, thereby minimising re-suspension of sediments. The power levels used are common within the industry, to be able to minimise the sediment suspension during the works. The impact of re-suspension of sediments is expected only in the near vicinity of the trench, less than 10m on either side [02].

OSPAR Commission "Guidelines on Best Environmental Practice (BEP) in Cable Laying and Operation" (Agreement 2012-2) states that

> *"Installation via jetting by means of sledge or ROV or use of a plough involves the lowest environmental impacts. […] Another option is to dredge a trench in which the cable is laid and which is subsequently refilled. However, the latter burial method leads to significantly greater sediment displacement."*

5.3 Rock Placement

Turbidity in the water during the rock placement activities are expected due to the mass flow effect which occurs when the rocks are exiting the fall-pipe. Most of the cable route encompasses sandy gravel (Section 2.3), and where rock is being used as a means of remedial work higher bulk densities are seen for the soil material which in effect gives less sediment re-suspension.

Aggregates used for offshore rock placement should follow their respective grading requirements regarding fines content to reduce the turbidity during installation. Rock material produced for offshore installation generally follow the EN-13383-1 "Armourstone – Part1: Specification" with regards to quality requirements for the material. This standard specifies that the material *"shall not contain any foreign matter in a quantity that will cause damage to the structure or the environment in which it is used."*

To minimize any re-suspension of sediments due to rock placement, the aim is to critically evaluate the amount of rocks which will be needed, especially regarding remedial work.

This is done by route engineering and micro-siting to make sure sections which may be challenging to trench are minimized as far as reasonably possible.

Using a fall pipe vessel for rock placement operations increases control of rock placement and reduce speed of the rock placed on the seabed, hence reducing potential sediment disturbance.

For more detailed rock placement activities, reference is made to the Construction Method Statement *Section 11*.

5.4 Horizontal Directional Drilling, HDD

The HDD drill profile will most of the part drill through bedrock. Some discharge of cuttings and drilling fluids will be expected at the exit point for the bore hole. The drill fluid used on this project will be formed from a suspension of bentonite (montmorillonite clay) in fresh water. The drill fluid is fully biodegradable and certified for use in water-well drilling due to its biodegradability and lack of any form of toxicity.

The exit point is below water and, as such, there is little possibility to contain and control breakout as the drill approaches the exit point. Prior to breakout (c. 50m) a dedicated cleaning run of the bore using standard drilling fluid will be performed so as to flush any residual cuttings or detritus from the borehole. The drilling assembly is then run back into the hole and the drilling continues until the drill bit breaks through onto the seabed.

At the HDD exit point, minor to none seabed sediment disturbances are expected due to drilling.

For more detailed horizontal directional drilling activities, reference is made to the Construction Method Statement *Section 6*.

6 Cable Burial and Protection Assessment

Survey data described in Section 2 has been used for the assessment regarding burial and protection of the marine cable.

Where cable burial by trenching cannot be performed the alternative methods mentioned in Sections 4.3, 4.4 and 4.5 will be used. Reasons for no or limited burial by trenching are listed below:

- DOL or DOC achieved by trenching is deemed insufficient to meet the protection criteria,
- No trenching performed due to bedrock formations at the seabed,
- No trenching performed due to crossed assets,
- Environmental assessment in regard to marine flora and fauna restricts burial of the cable,
- No trenching due to water depth restrictions (at landfalls).

6.1 Soil Assessment in Relation to Trenching

The burial assessment performed is based on the latest RPL [10].

For a significant part of the route the soil is classified as coarse material (Holocene sediments). These are soils generally suitable for jet trenching. However, for these sections, remedial jetting passes may be required due to the quick sedimentation of the soil particles when being fluidised.

The main factors that affect jet trenching performance in clay are related to the undrained shear strength and plasticity of the clay. Along the Shetland HVDC Link route there are some sections with cohesive material which can consist of stiff to very stiff clay. A remedial jetting pass and/or remedial rock placement has been proposed as a mitigation measure in case the possibility of encountering stiff to very stiff clay is deemed feasible within trenching depth.

Also, very soft to soft clay and extremely/very soft silt is encountered along the route. With very soft clay a very low bearing capacity should be considered. The possibility of the jet trencher sinkage can occur where bearing capacity is less than 5kPa. This will be minimised with the buoyancy and bearing pressure of the jetting tool configuration.

Bedrock is reported to be within the trenching profile along the Weisdale Voe – Noss Head route. A jet trencher is not able to penetrate bedrock and thus it will impact the required trench depth. When bedrock is encountered the tools will be gradually graded out until the bedrock is passed where after it will be graded in back to required target depth of trench.

The following further burial risks have been identified along the route corridor which may have a possible negative effect on burial operations and feasible burial depth:

- Boulders,
- Other (buried or surface) obstructions along the route.
- Sandwaves

Further assessments will be performed regarding micro-rerouting of the cable due to mentioned burial risks.

Required DOL and DOC are Shown in Table 6.1.

KP Start	KP End	DOL (m)	DOC (m)	Notes
0.00	0.15	Min.0 Max. 1.68	Min.0 Max 1.68	12NM Zone Shetland Open trench with PE ducts and backfilled or cast-iron half-shells and/or concrete half-shells.
0.15	0.75	1.75	0.35	12NM Zone Shetland
0.75	2.00	1.75	0.35	12NM Zone Shetland
2.00	3.70	1.00	0.15	12NM Zone Shetland
3.70	5.48	1.25	0.35	12NM Zone Shetland
5.48	10.90	1.00	0.15	12NM Zone Shetland
10.90	12.60	1.75	0.35	12NM Zone Shetland
12.60	17.43	1.00	0.15	12NM Zone Shetland
17.43	18.50	1.25	0.35	12NM Zone Shetland
18.50	32.43	1.00	0.15	12NM Zone Shetland
32.43	34.70	1.50	0.35	12NM Zone Shetland
34.70	59.062	1.00	0.15	12NM Zone Shetland
59.062	64.277	1.00	0.15	Offshore
64.277	67.00	1.00	0.15	12NM Zone Shetland
67.00	81.40	1.25	0.15	12NM Zone Shetland
81.40	82.40	1.50	0.35	12NM Zone Shetland
82.40	86.90	1.00	0.15	12NM Zone Shetland
86.90	89.90	1.50	0.35	12NM Zone Shetland
89.90	92.30	1.00	0.15	12NM Zone Shetland
92.30	93.70	1.50	0.35	12NM Zone Shetland
93.70	107.00	1.00	0.15	12NM Zone Shetland
107.00	110.447	1.25	0.15	12NM Zone Shetland
110.447	114.50	1.25	0.15	Offshore
114.50	190.50	1.00	0.15	Offshore
190.50	196.00	1.25	0.15	Offshore
196.00	229.485	1.00	0.15	Offshore
229.485	239.80	1.00	0.15	12NM Zone Scotland
240.28	241.85	1.50	0.60	12NM Zone Scotland; *Bundle Tow Area*
241.90	248.90	1.00	0.15	12NM Zone Scotland
248.90	250.20	-	-	12NM Zone Scotland *Horse Mussel Bed*

KP Start	KP End	DOL (m)	DOC (m)	Notes
250.20	250.70	1.00	0.15	12NM Zone Scotland
250.70	252.30 (Pop-Out)	12NM Zone Scotland *Expected to be rock placement e.g. ≥ 0.6m rock cover*		
252.30 (Pop-Out)	TJB	Subject to further engineering 12NM Zone Scotland		

Table 6.1: Cable Route Required DOL and DOC Zones

Where DOL or DOC achieved by trenching is deemed insufficient to meet the protection criteria, alternative protection methods will be introduced, see Section 6.2.

Reference is made to CBPP Overview Charts [09] for a visualization of the different protection methods of the cable.

Start KP	Stop KP	Length [m]	Remedial Rock work anticipated	Area
0.000	0.750	600	Alternative protection method anticipated	12NM Zone Shetland
0.750	*2.00*	*1 250*	*No*	*12NM Zone Shetland*
2.000	3.700	1 700	Yes	12NM Zone Shetland
3.900	*5.150*	*1 250*	*No*	*12NM Zone Shetland*
5.300	7.000	1 700	Yes	12NM Zone Shetland
7.800	9.000	1 200	Yes	12NM Zone Shetland
9.000	*10.900*	*1 900*	*No*	*12NM Zone Shetland*
11.200	*30.456*	*19 256*	*No*	*12NM Zone Shetland*
30.456	*38.300*	*7 844*	*No*	*12NM Zone Shetland*
38.300	53.000	14 700	Yes	12NM Zone Shetland
53.000	59.005	6 005	Yes	12NM Zone Shetland
59.005	63.759	4 754	Yes	Offshore
63.829	64.342	513	Yes	Offshore
64.342	68.479	4 137	Yes	12NM Zone Shetland
68.549	71.759	3 210	Yes	12NM Zone Shetland
71.829	82.400	10 571	Yes	12NM Zone Shetland
82.400	*86.900*	*4 500*	*No*	*12NM Zone Shetland*
86.900	92.300	5 400	Yes	12NM Zone Shetland
92.300	*94.000*	*1 700*	*No*	*12NM Zone Shetland*
94.000	96.166	2 166	Yes	12NM Zone Shetland
96.236	110.238	14 002	Yes	12NM Zone Shetland

Start KP	Stop KP	Length [m]	Remedial Rock work anticipated	Area
110.238	139.557	29 319	Yes	Offshore
139.627	158.000	18 373	Yes	Offshore
158.000	*165.800*	*7 800*	*No*	*Offshore*
165.800	170.200	4 400	Yes	Offshore
170.200	*172.700*	*2 500*	*No*	*Offshore*
172.700	179.700	7 000	Yes	Offshore
179.700	*181.936*	*2 236*	*No*	*Offshore*
182.006	*190.500*	*8 494*	*No*	*Offshore*
190.500	199.500	9 000	Yes	Offshore
199.500	*201.800*	*2 300*	*No*	*Offshore*
201.800	214.000	12 200	Yes	Offshore
214.000	*215.000*	*1 000*	*No*	*Offshore*
215.000	216.000	1 000	Yes	Offshore
216.000	*221.500*	*5 500*	*No*	*Offshore*
221.500	226.322	4 822	Yes	Offshore
226.392	229.485	3 093	Yes	Offshore
229.485	231.000	1 515	Yes	12NM Zone Scotland
231.000	*241.900*	*10 900*	*No*	*12NM Zone Scotland*
241.900	246.500	4 599	*No*	12NM Zone Scotland

Table 6.2 : Sections where Trenching Activities will be Performed

The total planned trenching length is approximately 241.9km where 102km will be within 12NM of Shetland, 122.9km Offshore and 17km within 12NM of Scotland.

Where burial by trenching is deemed insufficient, rock placement will be used to provide sufficient cover for the cable, see further details in Section 6.2

6.2 Alternative Subsea Cable Protection Measures

Where the cable is crossing third party assets such as in-service cables and pipelines, the cable will be laid on the seabed, and rock berms will be placed on top to protect the cable from impacts. Some areas are also not possible to trench due to bedrock formations at the seabed. These areas will also have rock berms protecting the cable on the seabed.

KP Start	KP End	Berm Length [m]	Concept	Campaign Schedule	Area
3.700	3.900	200	Bedrock	CP3	12NM Zone Shetland
5.150	5.300	150	Bedrock	CP3	12NM Zone Shetland
7.000	7.800	800	Bedrock	CP3	12NM Zone Shetland
10.90	11.20	300	Bedrock	CP3	12NM Zone Shetland
30.456	30.561	105	Crossing	CP3	12NM Zone Shetland

53.000	56.000	3.000	Bedrock	CP3	
56.995	57.015	20	Inline joint	CP2/CP3	12NM Zone Shetland
63.759	63.829	70	Crossing	CP2	Offshore
68.479	68.549	70	Crossing	CP2	12NM Zone Shetland
71.760	71.830	70	Crossing	CP2	12NM Zone Shetland
96.166	96.236	70	Crossing	CP2	12NM Zone Shetland
TBC	TBC	70	Crossing	CP2	12NM Zone Shetland
139.557	139.627	70	Crossing	CP2	Offshore
154.900	155.01	110	Omega Joint KP 155	CP1/CP2	Offshore
181.932	182.002	70	Crossing	CP1	Offshore
226.323	226.393	70	Crossing	CP1	Offshore
246.500	249.932	3.432	Bedrock	CP1	12NM Zone Scotland
250.880	251.962	1.082	Nearshore rock berm Noss Head	CP1	12NM Zone Scotland

Table 6.3: Surface Laid Cable Locations with Rock Berm Protection

The trenching strategy is based on a confidence level for the tool reaching a certain DOL and achieving required DOC. This outlines the requirements for remedial rock placement along the specified section.

The confidence levels are rated as following:

- High confidence. Achieving the required DOL or DOC for more than 90% of the specified section length (KP start – KP stop) (10% remedial work)
- Moderate confidence. Achieving required DOL or DOC for 70% - 90% of the section (10-30% remedial work)
- Low confidence. Achieving required DOL or DOC for less than 70% of the section (more than 30% remedial work)

Section		Section Length [km]	Confidence Level	Estimated Remedial Rock Work of Section Length		Campaign Schedule
KP start	KP End			[%]	[km]	
0.00	0.75	0.75	Low	Alternative protection method anticipated		CP3
2.00	2.45	0.45	Low	100	0.45	CP3
5.48	6.25	0.77	Medium	20	0.15	CP3
6.25	7.00	0.75	Low	100	0.45	CP3
7.80	9.00	1.20	Medium	20	0.24	CP3

56.00	62.80	6.80	Low	50	3.40	CP2/CP3
62.80	63.40	0.60	Low	80	0.48	CP2
63.40	67.00	3.60	Medium	30	1.08	CP2
78.40	81.40	3.00	Medium	10	0.30	CP2
81.40	82.40	1.00	Low	40	0.40	CP2
86.90	92.30	2.00	Medium	20	0.40	CP2
99.50	107.00	7.50	Low	50	3.75	CP2
107.00	114.50	7.50	Low	80	6.00	CP2
114.50	116.80	2.30	Medium	30	2.30	CP2
116.80	128.10	11.30	Low	100	11.30	CP2
128.10	134.00	5.90	Low	50	2.95	CP2
134.00	137.00	3.00	Low	75	2.25	CP2
137.00	151.00	14.00	Low	50	7.00	CP2
151.00	158.00	7.00	Medium	30	2.10	CP1/ CP2
165.80	170.20	4.40	Low	50	2.20	CP1
172.70	179.70	7.00	Low	50	3.50	CP1
190.50	196.00	5.50	Low	60	3.30	CP1
196.00	199.50	3.50	Low	60	2.10	CP1
201.80	205.00	3.20	Low	60	1.92	CP1
212.00	214.00	2.00	Medium	10	0.20	CP1
215.00	216.00	1.00	Low	75	0.75	CP1
221.50	231.00	9.50	Medium	20	1.90	CP1

Table 6.4: Areas with Medium and Low Trenching Confidence Level

Out-of-Service cables (OOS) will be cut and removed from the cable corridor and at these locations, burial of the cable by trenching is expected. Exemption is OOS "UK-Faroes_Rev1" which is in the close vicinity of an existing crossing location.

Rock Berm Design

For areas where no trenching will be performed, the minimum DOC by rock placement will be 0.6m excluding the nearshore berm at Noss Head. Top width is 1m for all berms.

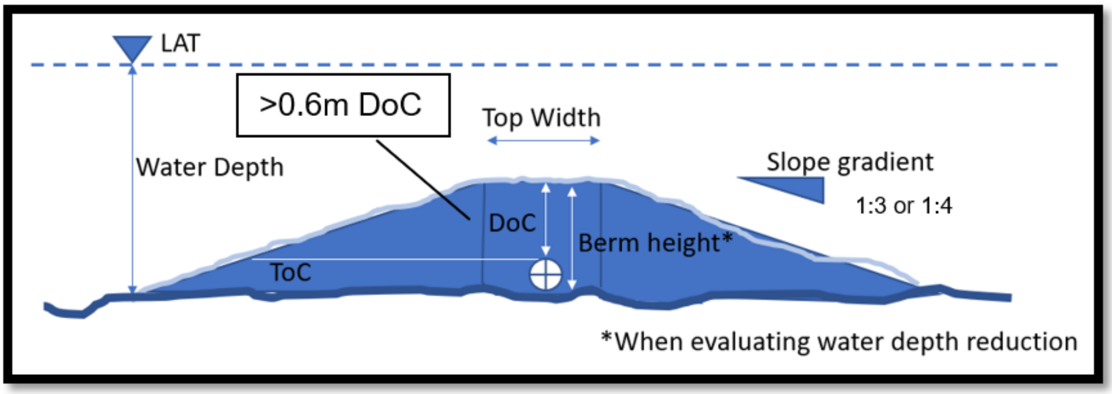

Figure 6.1: Rock Berm Design for Cable on Seabed (Not to Scale)

For trenched areas where the burial of the cable by trenching is deemed not sufficient, remedial rock placement is required. The total cover of the cable shall be minimum 0.6m, however this cover will be a combination of the trenched seabed material and additional rock cover which makes sure the DOC is a minimum of 0.6m.

In Section 7 it has been assumed a 0.3m rock berm on top of seabed for remedial rock placement areas. 0.3m is normally quoted as a minimum berm height from an operational perspective as any lower height is unfeasible to produce by a standard DPFPV using and offshore aggregate material grading 22-125mm (1-5").

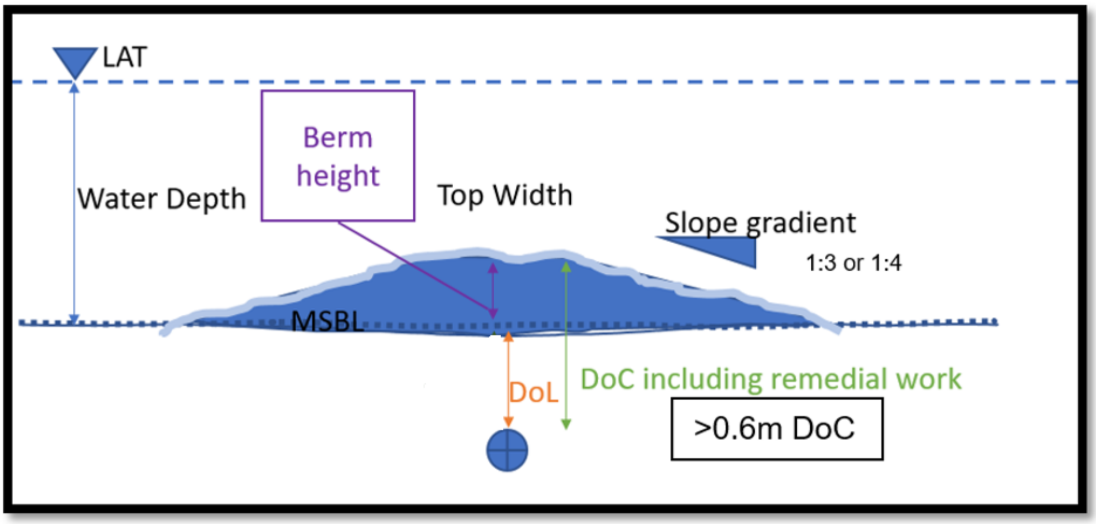

Figure 6.2: Remedial Rock Berm Design (Not to Scale)

DOL from trenching + Berm Height (on top of as-found seabed, not MSBL) = DOC including remedial work.

After trenching, DOC and DOL will be assessed. Then a final decision can be made on the extent of remedial rock berms.

Material sizes (grading) intended for the rock berms are further discussed in CMS, Section 11.5.

Nearshore Rock Berm Noss Head

Between the HDD exit point at Noss Head and the start of the Horse Mussel Bed the cable will be surface laid with a double layer rock berm protection. This is subject to detailed engineering.

Material sizes (grading) intended for the rock berms are further discussed in CMS, Section 11.5.

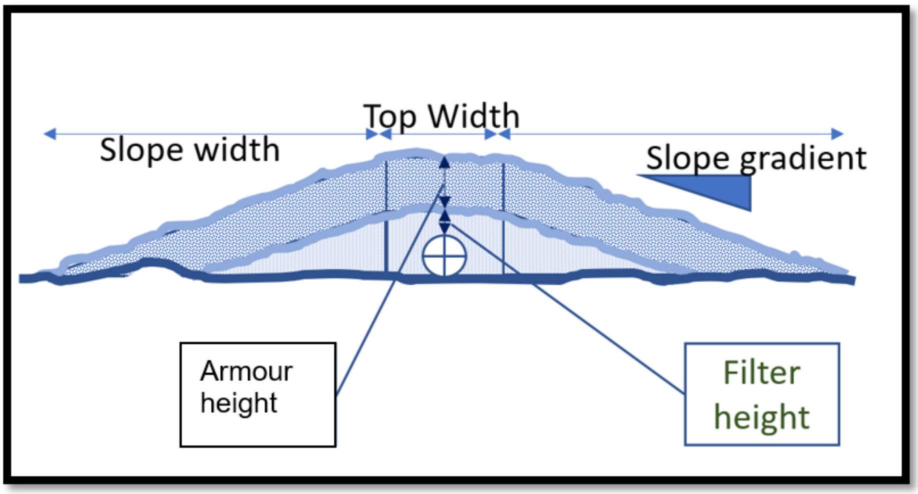

Figure 6.3: Noss Head Nearshore Berm Design Profile (Not to Scale)

Rock Berm and Volume

Estimated rock tonnages, rock berm locations and lengths are included in the table below.

NKT Summary of Estimated Rock Tonnages		
402,177	Estimated Total Rock tonnage (MT) all Protection Works, inclusive of estimated losses 20% and overburden tolerance 0.3m	
185,080	Inside 12NM - Estimated Total Rock tonnage (MT) all Protection Works, inclusive of estimated losses 20% and overburden tolerance 0.3m (Noss Head has 20% loss and average tolerance which is material dependent, as design is not yet finalized)	
217,097	Outside 12NM - Estimated Total Rock tonnage (MT) all Protection Works, inclusive of estimated losses 20% and overburden tolerance 0.3m	
Licence Tonnages		
287,975	MT within 12nm zones	
245,090	MT offshore	

Summary of Estimated Rock Lengths		
90,915m	Estimated Total Length of Rock Berms	
45,075m	Inside 12NM - Estimated Total Length of Rock Berms	
45,840m	Outside 12NM - Estimated Total Length of Rock Berms	

Table 6.5: Estimated Rock Tonnages

Total rock berm length for the whole cable route is estimated to be approximately 91km.

The total overall rock placement footprint is estimated to be approximately 840,353 m^2

Both, the rock berm length and the rock placement footprint, to be confirmed during detailed engineering phase.

6.3 Weisdale Voe Landfall, Shetland

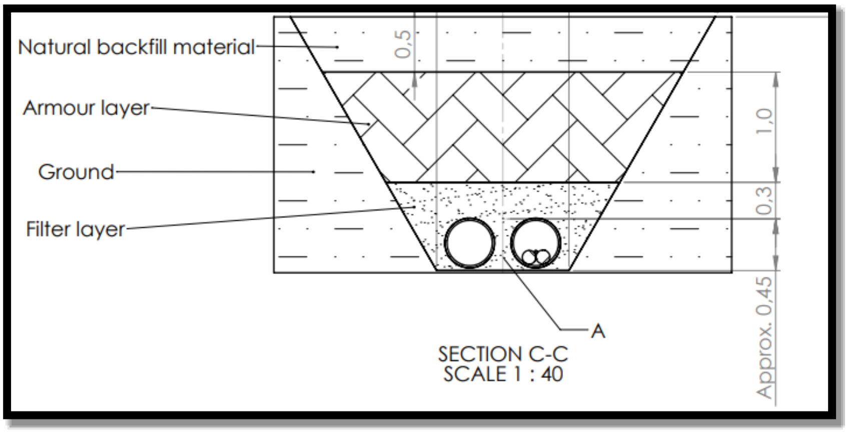

Figure 6.4: Burial of Ducts in Open Trench

The burial and protection philosophy will be similar for both options mentioned in Section 4.5, with a filter layer covering the ducts below an armour layer and 0.5m natural backfill material at the seabed level, Figure 6.4. The ducts will be approximately 150m in length and exit point will be at 10m LAT. For further details see CMS Section 5.

6.4 Noss Head Landfall, Scotland

The shoreline is highly irregular, and consists of rock, in the shape of cliffs, a rock platforms and further submerged rock structures. Many geological faults and joints are present in the area. The geological structure in the area is shown in Figure 6.6.

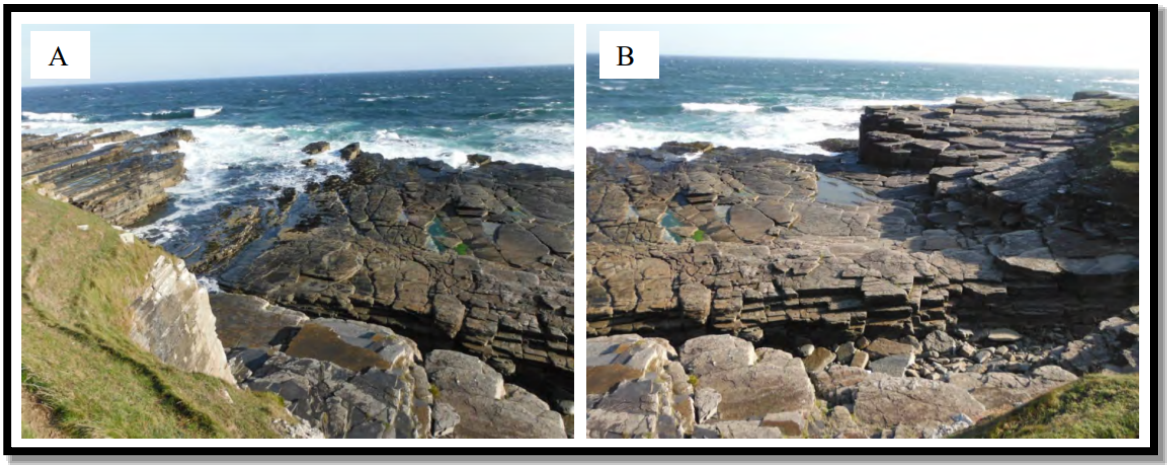

Figure 6.5: Coast at Noss Head Within Onshore Target Zone 1, Picture A Looking Towards Offshore Target Zone 2 , north-east (source: [15])

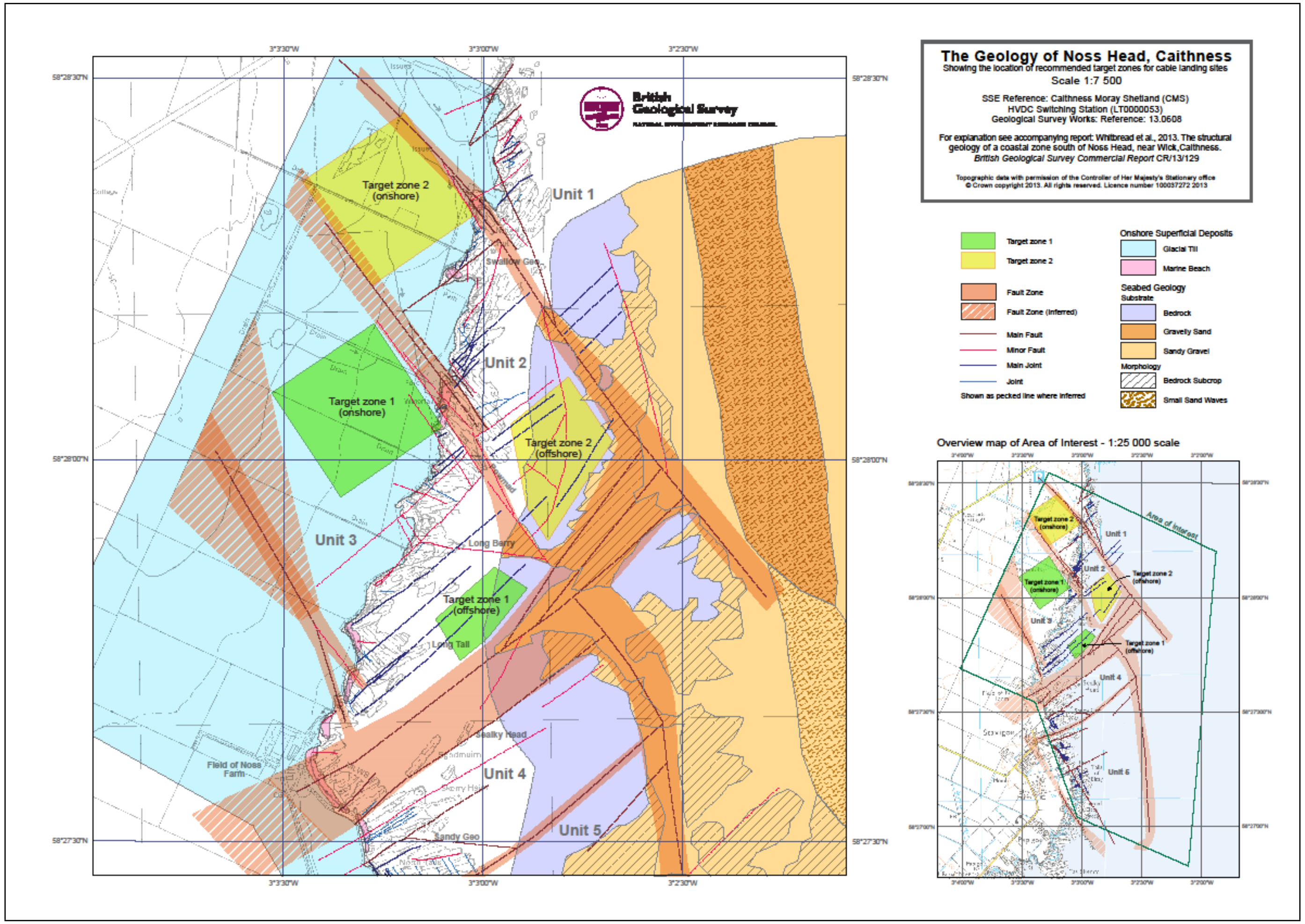

Figure 6.6: Seabed Geology at Noss Head (source: [16])

At the Noss Head landfall, the pop-out will be on the edge or slightly outside Target Zone (TZ) 2, see Figure 6.7. The exit point in will be around 20m LAT. Route TZ2 Offshore to TZ1 in Figure 6.7 is the planned duct route. Due to drilling through the PowMad fault zone a pilot drill will be performed to assess the material encountered. Route TZ2-TZ2 (red-black) line is a contingency drill route.

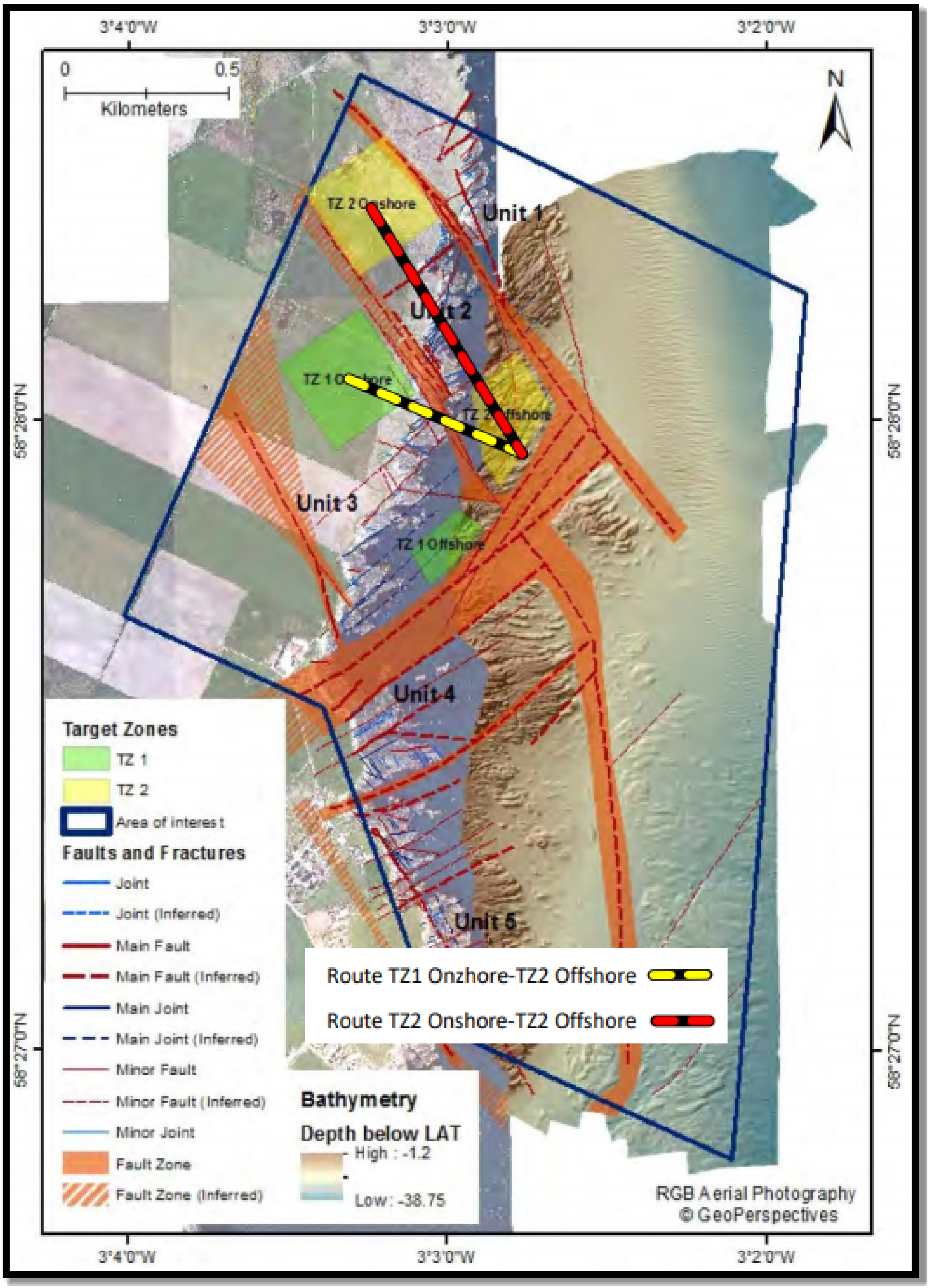

Figure 6.7: Landfall Noss Head with HDD Routes Showing Geological Fault Lines

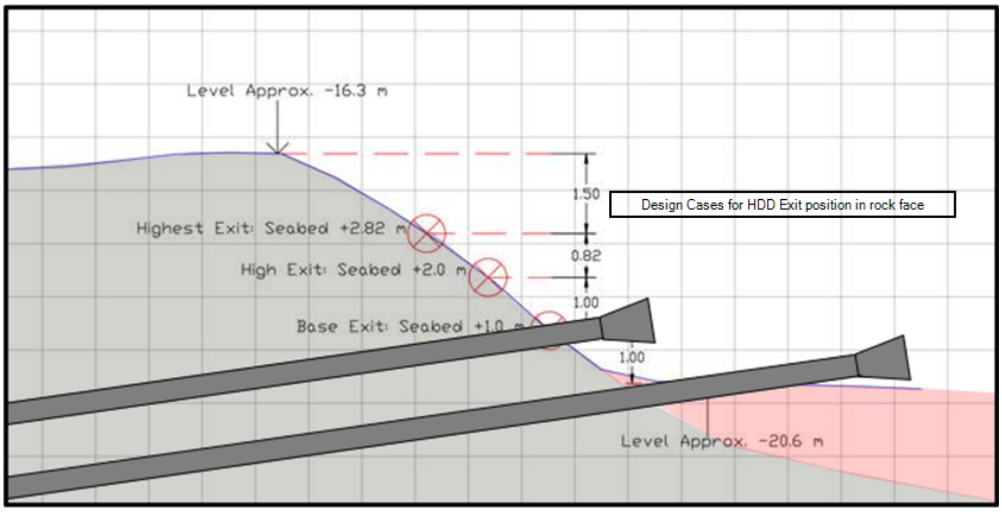

Figure 6.8: Design cases for HDD Exit Position - Noss Head

Exit points (red lines) occur in a rock outcrop on the edge of TZ2 Offshore. Base exit is set to 19.6m. This will be the point for the central drill; the other two drills exit from this same rock outcrop, the (orange line is a distance guide). See image below.

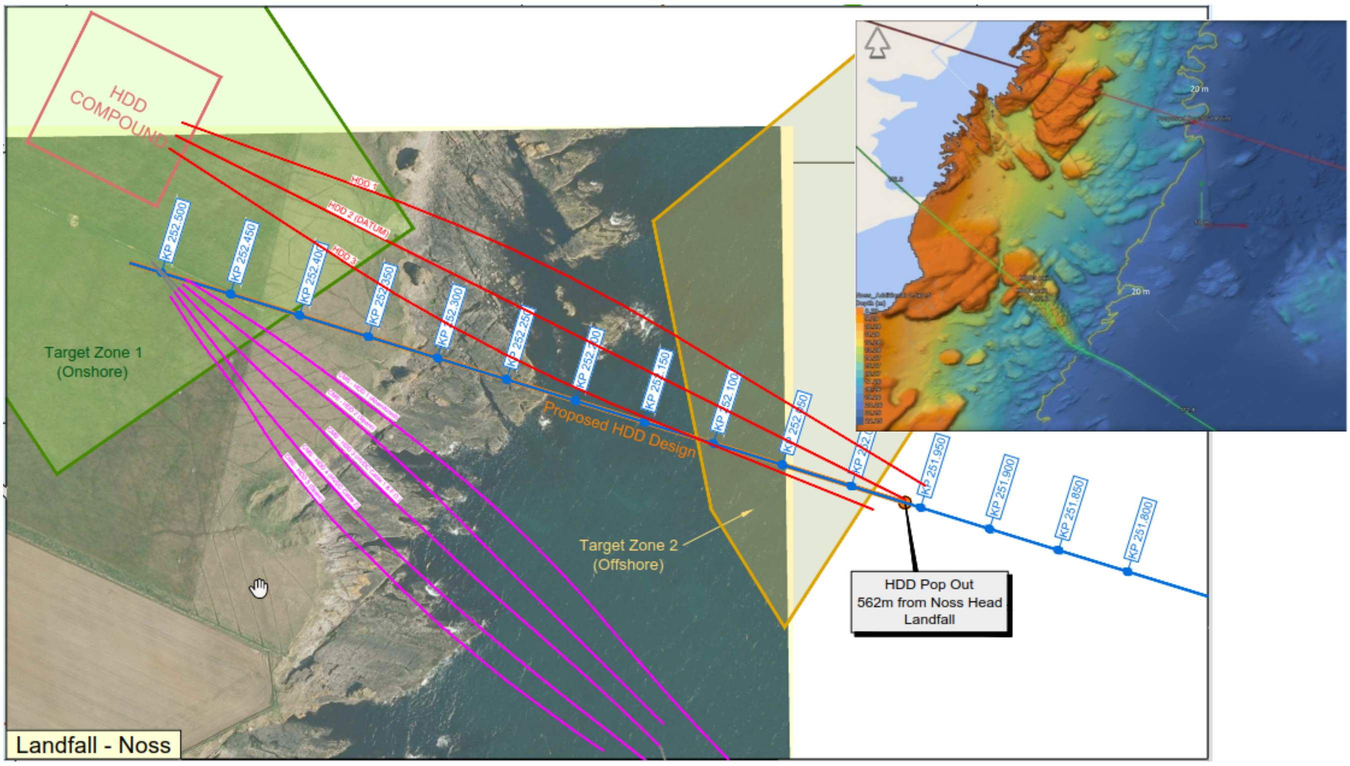

Figure 6.9: Noss Head Landfall and HDD duct routes

7 Reduction in Water Depth

For the cable burial and protection, an assessment regarding water depth reduction has been performed. This assessment allows for a vertical installation tolerance of 0.3m for the remedial and crossing rock berms. For the nearshore rock berm at Noss Head, which consists of larger material, the tolerances for the inner part differ from the outer part due to different size material being used. Clear communication towards rock placement operator is necessary to make sure any exceedance in maximum tolerance do not compromise the reduction in water depth.

Protection Type	Height from seabed	Shallowest water level (mLAT)	Name of location	% water depth reduction
Burial by jet trenching	0	N/A	N/A	0
Burial by jet trenching including a worst case remedial work	Cable diameter+post-lay rock+tolerance= 0.125+0.6+0.3=1.025m	21	KP 2	4.9%
No trenching due to bedrock	Cable diameter+post-lay rock heigh+tolerance= 0.125+0.6+0.3=1.025m	36	KP 7	2.9%
Crossing Type 1: Mattress+ post lay berm	Mattress thickness + cable diameter+ post lay rock height+ tolerance = 0.3 + 0.125 + 0.6 + 0.3 = 1.325m	65.41	Crossing SHEFA 2 Seg 9	2.0%
Crossing Type 2: Pre-lay + post lay berm	½ exposed pipe + pre-lay rock +vertical tolerance +cable diameter +Post-lay rock height +vertical tolerance = 0.38 + 0.5 + 0.3 + 0.125+0.6+0.3= 2.205m	75.55	Crossing 30¨Piper to Flotta Oil	2.9%
Crossing Type 3: Cable protection System (CPS)	Outer diameter = 0.318m	34.36	Horse Mussel Bed	0.9%

Protection Type	Height from seabed	Shallowest water level (mLAT)	Name of location	% water depth reduction
Near shore rock berm Noss Head:				
Inner Part of Nearshore Rock Berm, Noss Head*	Worst case pop – out above seabed (including cable diameter) +rock berm above cable +vertical tolerance= 2.5+1.30+1.30=5.1m Base case pop – out above seabed (including cable diameter) + rock berm above cable + vertical tolerance = 1.0+1.30+1.30=3.6m	20.6	Close to HDD Exit Point, approx. KP 251.900	Worst case scenario: 25% Base case scenario: 18%
Inner Nearshore Rock Berm, Noss Head*	Cable diameter +rock berm +vertical tolerance =0.125+1.30+1.30=2.725	23.6	End inner part berm, approx. KP 251.636	12%
Outer Part of Nearshore Rock Berm	Cable diameter + rock berm+ vertical tolerance =0.125+0.8+0.8=1.725	23.6	Start outer berm approx. KP 251.636	7.3%
Outer Part of Nearshore Rock Berm	Cable diameter + rock berm+ vertical tolerance =0.125+0.8+0.8=1.725	34.0	End outer berm approx. KP 250.880	5.1%
Nearshore rock berm Weisdale Voe				
Nearshore Rock Berm, Weisdale Voe	Cast-Iron half-shells outer diameter rockberm + vertical tolerance = 0.336+0.3+0.3 = 0.936	10.0	PE-Pipe exit point, KP 0.15	10.25%
Nearshore Rock Berm, Weisdale Voe	Cast-Iron half-shells outer diameter + rockberm + vertical tolerance = +0.336+0.3+0.3 = 0.936	13.9	KP 0.75	6.7%

Table 7.1: Water Depth Reductions

*) The inner part of the nearshore rock berm may include a CPS, but this will have no effect on the total height of the rock berm.

Early engineering shows the nearshore berm at Noss Head between KP 250.880 and KP 251.900 has a total length of 1020m.

It should be noted that the pop out at Noss Head 2.5m high pop out is due to the pop being in the face of the cliff. The navigable depth is actually at the top of the ‘cliff’, so having a rock berm that extends halfway up or to the top of the cliff, isn’t actually reducing the navigable depth.

Reviewing the AIS data available for the nearshore Noss Head area, over a time span of 2 years (31 October 2018- 31 October 2020) it can be seen that smaller vessels with a shallow draught are sailing in this area. Smaller vessels with a very limited draft, largest seen are all 10m or less, such as crew boats / passenger vessels, pleasure boats and pilot vessels are also seen crossing the cable corridor at the planned berm location.

Comparing to activities further away from shore, especially outside the Noss Head MPA, the vessel activities near HDD exit point can be seen as marginal. No large deep draught vessels such as tankers, offshore construction vessels or similar sizes which would be affected by the depth reduction has been reported in the 2-year timespan for this area.

8 Further Investigations

8.1 Survey Planned for 2021

A pre-lay survey with focus on UXO mapping and confirming crossing locations is planned for May-June 2021 [08].

The survey is planned as a geophysical survey with geotechnical survey as an option.

If deemed necessary, HMB survey can also be included.

For nearshore cable route at Weisdale Voe a geophysical survey and UXO survey is planned with geo-technical survey as an option [08].

Reference is made to the CMS Section 7 “Offshore Works – Pre-lay and UXO Survey” for further details.

8.2 Pre-cable Lay Preparation Work

Prior to cable lay, activities performed such as boulder clearance and PLGR will give the opportunity to further assess the cable route.

Document
Final reporting of boulder clearance work
Final reporting of crossing preparations
Final reporting of PLGR -CP1
Final reporting of PLGR -CP2/3

Table 8.1: Route Clearance Reporting

9 As-Built Data and Documentation

As-Built Report and data shall be provided to the marine licensing authorities on completion on the cable protection works.

Document
Noss Head Nearshore As-Built Final Report
Weisdale Voe Nearshore As-Built Final Report
As-Trenched Final Report & Data CP1 (KP246.5-KP155)
As-Built Rock Placement Final Report & Data CP1
As-Trenched Final Report & Data CP2 (KP57-KP0)
As-Built Rock Placement Final Report & Data CP2
As-Trenched Final Report & Data CP3 (KP57-KP155)
As-Built Rock Placement Final Report & Data CP3
Final As-Built Cable Route Report & Data

Table 9.1: As-Built Data

Further details of the as-built data can be found in the Construction Method Statement, Section 14 [08].

Table of Modifications

Rev.	Date	Prepared by	Description
A	2020-12-11	Sondenaa, Elisabeth	First issue of document
B	2021-01-29	Sondenaa, Elisabeth	Second issue after received comments
C	2021-02-25	Kerkhoff, Duncan	Updated after comments received
D	2021-03-18	Sondenaa, Elisabeth	Updated after comments received, second review-cycle
E	2021-04-19	Sondenaa, Elisabeth	Updated after comments received, engineering review-cycle

10 Appendix 1 CBPP Overview Charts

Refer to document

1AA0428474 CBPP Overview Charts, (NKT, 2021)