GREEN VOLT

Technical Appendix 4.1

Landing Point Feasibility Study

Offshore EIA Report: Volume 2

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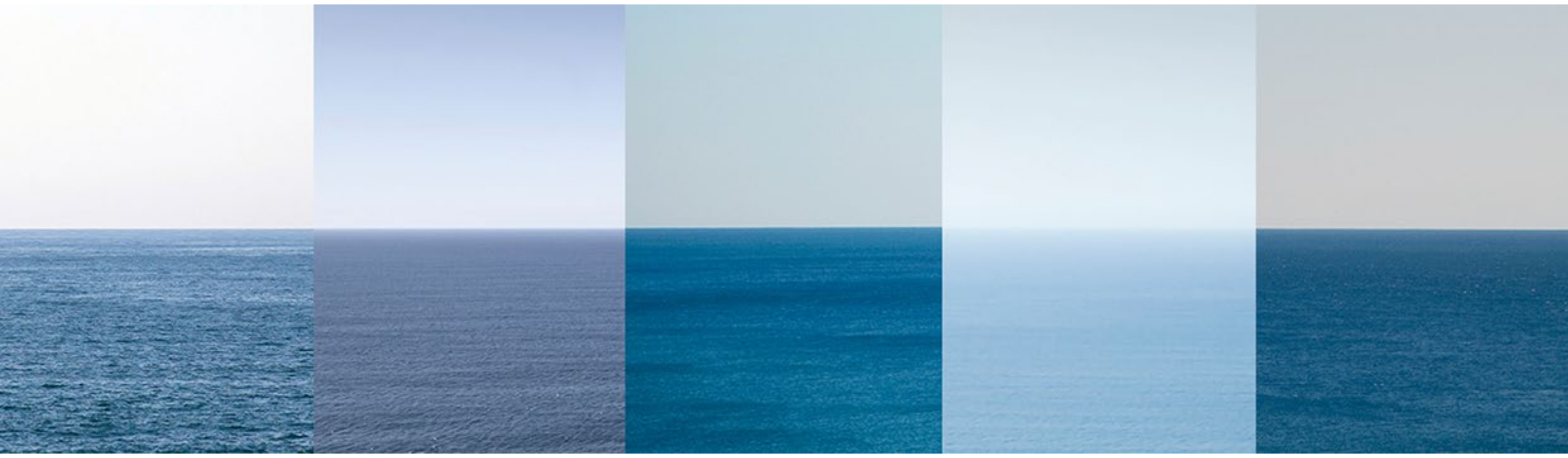

Green Volt Export Cable

Landing Point Feasibility Study

For Flotation Energy

PRJ108335-GEO-RP-02 Client Reference

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DOCUMENT ISSUE RECORD

Rev	Date	Status	Prepared by	Reviewed by	Approved by
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DOCUMENT CHANGE RECORD

Rev	Section(s)	Page(s)	Brief Description of Change
1			Original Issue to Client
2	Throughout		Removal of Boddam Options, add NorthConnect Parallel Option

DOCUMENT HOLD RECORD

Section(s)	Page(s)	Brief Description of HOLD

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1. SUMMARY

Flotation Energy are developing the Green Volt floating offshore wind project to decarbonise the Buzzard oil and gas field, NNE of Aberdeen, Scotland. As part of the development, there will also be an electrical connection to shore, to export excess energy to grid, and to also take energy from the grid when and if needed.

This study examines the feasibility of shore landing the cables, at predetermined sites provided by Flotation Energy. The study establishes the viability of each option in terms of access and site area, constraints, geological and geotechnical conditions and HDD drill length feasibility. The study also examines the nature of the immediate nearshore area, particularly in terms of water depth and construction access to the HDD exit pit, and the potential to secure the cables through burial in the seabed.

Multiple sites have been deemed to be feasible by this study, which has also been taken into account for offshore route survey planning.

Following offshore routing and DTS work, this Rev2 version of the report removes the originally considered Boddam landfall options and includes a new option for landfall at the planned NorthConnect HVDC project landfall.

2. INTRODUCTION

2.1 Green Volt Floating Offshore Wind Farm

Flotation Energy are developing the Green Volt floating offshore wind project to decarbonise the Buzzard oil and gas field, NNE of Aberdeen, Scotland. As part of the development, there will also be an electrical connection to shore, to export excess energy to grid, and to also take energy from the grid when and if needed.

The onshore grid connection is planned with a new substation at New Deer, 24km West of Peterhead. The onshore routing and substation location has been investigated by Greencat Renewables [1] and has resulted in a number of potential cable landing locations at St Fergus and Collieston Coast.

2.2 Scope of Work

The purpose of this study is to review the potential cable landing options from an offshore cable routing and technical feasibility perspective including, but not limited to:

- Geological and geotechnical conditions
- Potential for nearshore burial
- HDD feasibility, including drill length
- Constraints – both natural and anthropogenic
- Access to HDD construction and launch areas

The outcome of this study will then inform the initial trajectory and route of the cable from shore, which will in turn be used to guide cable route survey efforts out towards the 12nm limit.

2.3 Terminology and Definitions

Abbreviation	Definition
AfL	Agreement for Lease
BGS	British Geological Survey
CLB	Cable Lay Barge
CLV	Cable Lay Vessel
HDD	Horizontal Directional Drill
LAT	Lowest Astronomical Tide
Mya	Million years ago
nm	Nautical Mile
ODN	Ordnance Datum Newlyn

Abbreviation	Definition
OS	Ordnance Survey
SNH	Scottish Natural Heritage
UKHO	United Kingdom Hydrographic Office

Table 1: Abbreviations

3. DATA ADEQUACY REVIEW

3.1 Data Sources

The following data has been provided by Flotation Energy:

1. Greencat Renewables, Buzzard Offshore Wind Farm: Substation and Jointing Pits. Options Review and Field Report. C4642-1234 Version 1. August 2021.
2. Flotation Energy, Spatial data pack for Green Volt containing site-specific and open-source datasets, C1127G01_02_SpatialDataPack
3. Flotation Energy, Green Volt Development Area, Green_Volt_Dev_Area_WGS84_Z30N.shp
4. Flotation Energy, Indicative export cable corridor, Ettrick_Export_Buffer_v2_dis_WGS84_Z30N_1
5. Flotation Energy, Indicative HDD compounds, provided as individual shapefiles: Boddam Joining Point 1.shp, Boddam Joining Point 3.shp, Boddam Joining Point 4.shp, SF Joining Point 1.shp, SF Joining Point 2.shp, SF Joining Point 2.shp, SF Joining Point 3.shp
6. NorthConnect. HVDC Cable Infrastructure – UK Construction Method Statement. NCGEN-NCT-X-RA-0002. Revision 1, August 2018.
7. United Kingdom Hydrographic Office (UKHO), Admiralty Chart 2182C: North Sea – Northern Sheet
8. NorthConnect. Horizontal Directional Drilling (HDD) Feasibility Report. NCFFS-NCT-Z-RS-0001. Revision 0, August 2018.

The following data has been gathered by Global Maritime as part of this study:

9. British Geological Survey, Geoindex and Georecords Boreholes: NK14SW1017/E9, NK15SW3, NK15SW4, NK15SW5, NK14NW4, NK14SW16925-10,12,13
10. British Geological Survey, Geoindex, 1:250k Offshore Bedrock and Superficial Geological Mapping and 1:50k Onshore Bedrock and Superficial Mapping, https://map.bgs.ac.uk/arcgis/services/Offshore/Products_WMS/MapServer/WmsServer, (accessed 25/01/22)
11. British Geological Survey, 1:50 000-scale geological maps of Scotland (WMS), https://map.bgs.ac.uk/arcgis/services/BGS_Detailed_Geology/MapServer/WMSServer? (accessed 25/01/22)
12. National Library of Scotland, Ordnance Survey Aberdeenshire Sheet XXIII.SW, Edition of 1928
13. Environment Agency, LIDAR Composite DTM (1m resolution), updated 10th December 2021
14. United Kingdom Hydrographic Office (UKHO), HI1155 Todhead Point to Bosies Bank bathymetric survey, March – June 2009, https://datahub.admiralty.co.uk/portal/apps/webappviewer/index.html?id=1d001f91ed114a5996e953b5cdd62b06
15. United Kingdom Hydrographic Office (UKHO), M3972 Approaches to Peterhead bathymetric survey, November 2000, https://datahub.admiralty.co.uk/portal/apps/webappviewer/index.html?id=1d001f91ed114a5996e953b5cdd62b06
16. EMODnet, European Digital Terrain Model (DTM) of Europe, 2020 release, https://portal.emodnet-bathymetry.eu/

17. Royal Society for the Protection of Birds (RSPB), Important Bird Areas (IBA), RSPB_IBAs_2020_4326_210723
18. Royal Society for the Protection of Birds (RSPB), Reserves boundaries, RSPB_Reserves_Boundaries_20210625_m_27700_210723
19. Scottish Government, Gardens and Designed Landscapes, ScottishGovt_Gardens_and_Designed_Landscapes_m_2020_27700_270721
20. Scottish Government, Special Areas of Conservation, ScottishGovt_SAC_SCOTLAND_m_2020_27700__210622
21. Scottish Government, Conservation Areas, ScottishGovt_Conservation_Areas_m_2020_27700_27072021
22. Scottish Government, Special Protection Areas, ScottishGovt_SPA_SCOTLAND_m_2020_27700_210622
23. Scottish Government, Sites of Special Scientific Interest (SSSI), ScottishGovt_SSSI_SCOTLAND_m_2020_27700_210726
24. Scottish Government, Listed Buildings, ScottishGovt_Listed_Buildings_points_m_2020_27700_210727
25. Scottish Government, Scheduled Monuments, ScottishGov_Scheduled_Monuments_m_2020_27700_210727
26. Scottish Natural Heritage, RAMSAR, EUEV_SNH_RAMSAR_SCOTLAND_210506
27. Scottish Natural Heritage, Local Nature Reserves, EUEV_SNH_LNR_SCOTLAND_210506
28. Scottish Natural Heritage, Ancient Woodland Inventory (AWI), EUEV_SNH_AWI_SCOTLAND_210506
29. Scottish Natural Heritage, Geological Conservation Review Sites, EUEV_SNH_GCR_SCOTLAND_210506
30. OpenStreetMap contributors, Planet dump 25/01/22. Retrieved from https://planet.openstreetmap.org
31. Crown Estate of Scotland (CES), Energy Infrastructure Agreements, EUST_CES_Energy_Infrastructure_Agreements_220210

3.2 Data Adequacy and Gaps

Data adequacy, with regards the needs and perspectives of this study only, are summarised in **Error! Reference source not found.** below with commentary and a traffic light qualitative assessment.

Data Type	Source	Comment	Adequacy
Project boundaries	[3], [4]	Boundaries provided for the wind farm area and indicative offshore export corridor. Onshore project boundary is still being defined and is therefore not required for this scope.	
HDD compound	[5]	Indicative compounds provided in shapefile format	
Bathymetry	[14], [15], [16]	UKHO "Todhead Point to Bosies Bank" survey at 4-8 m resolution covers the offshore study area from approximately 40 mLAT, and is	

Data Type	Source	Comment	Adequacy
		therefore of limited use for the landfall assessment. The Boddam landfall is partially covered by ungridded UKHO bathymetric survey of the approaches to Peterhead from 2000. Nearshore areas are infilled with EMODnet bathymetry	
Elevation	[13]	1m resolution LiDAR dataset from 2021 covers the entire study area	
Existing infrastructure	[2], [7], [30], [31]	Open source data on marine cables, pipelines and oil and gas infrastructure supplied in initial project data pack, cross referenced against admiralty charting. Existing terrestrial infrastructure reviewed against OpenStreetMap. Subterranean assets have not been considered at this stage.	
Onshore Geology	[11]	High level geological characteristics, combined with existing BGS sample records where available, are seen as sufficient for this stage of development. Detailed site investigation is recommended at any preferred or potential onshore works locations.	
Offshore Geology	[10]	High level geological characteristics are seen as sufficient for this stage of development. Detailed site investigation is recommended at any preferred or potential HDD exit and entry locations	
Geotechnical	[9]	High level geological characteristics, combined with existing BGS sample records where available, are seen as sufficient for this stage of development. Detailed site investigation is recommended at any preferred or potential onshore works locations.	
Environmental designations	[2], [17], [18], [20], [21], [22], [23], [26],	Boundaries for designations provided in shapefile format	

Data Type	Source	Comment	Adequacy
	[27], [28], [29]		
Cultural and landscape designations	[2], [19], [24], [25]	Boundaries and points in shapefile format	

4. CABLE LANDING POINT REVIEW

Greencat Renewables have performed an onshore focussed study to identify potential onshore joint bay and substation locations [1]. This assessment has been based upon access, environmental and cultural constraints and existing onshore infrastructure.

The study has focussed on shoreline areas to the north and south of Peterhead in order to identify onshore jointing pits for the cables. These locations are briefly reviewed here, in addition to other coastline options, prior to assessment for feasibility from a construction and offshore engineering perspective.

4.1 St Fergus

In total, 3 potential jointing pit and HDD launch locations have been identified, south of St Fergus.

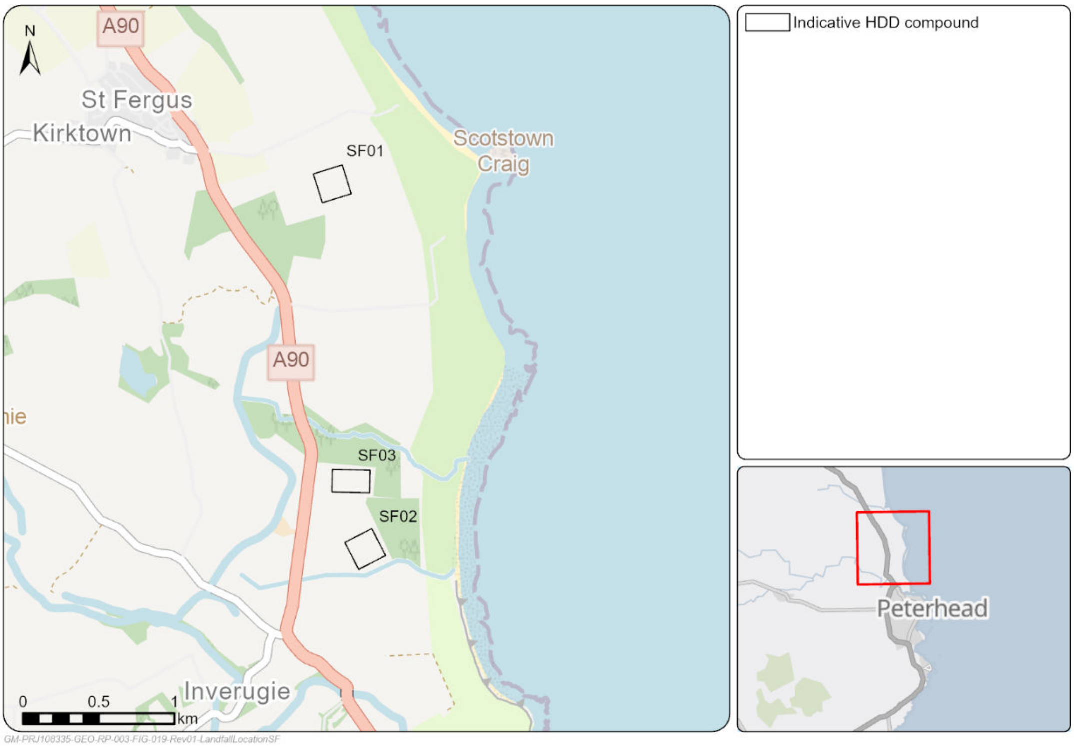


Figure 1: St Fergus Landfall Area

All three options provide for ample HDD compound areas on readily accessible arable land. The topographic elevation to be negotiated by HDD operations between launch and offshore exit are feasible, with a notable absence of significant cliffs. The identified jointing areas are positioned such that the HDD exit pit can be located significantly offshore, within the technical limits of what is generally considered with HDD. This provides for ease of construction vessel access and ensures that the cable exit at seabed is outwith the immediate nearshore high energy environment.

Other areas are constrained by existing land use and are not suitable, including otherwise favourable coastline at Craigewan Links due to the presence of a golf course.

4.2 NorthConnect Parallel

There is only one potential HDD launch location due to corridor length limitation for the NorthConnect Parallel alternative.

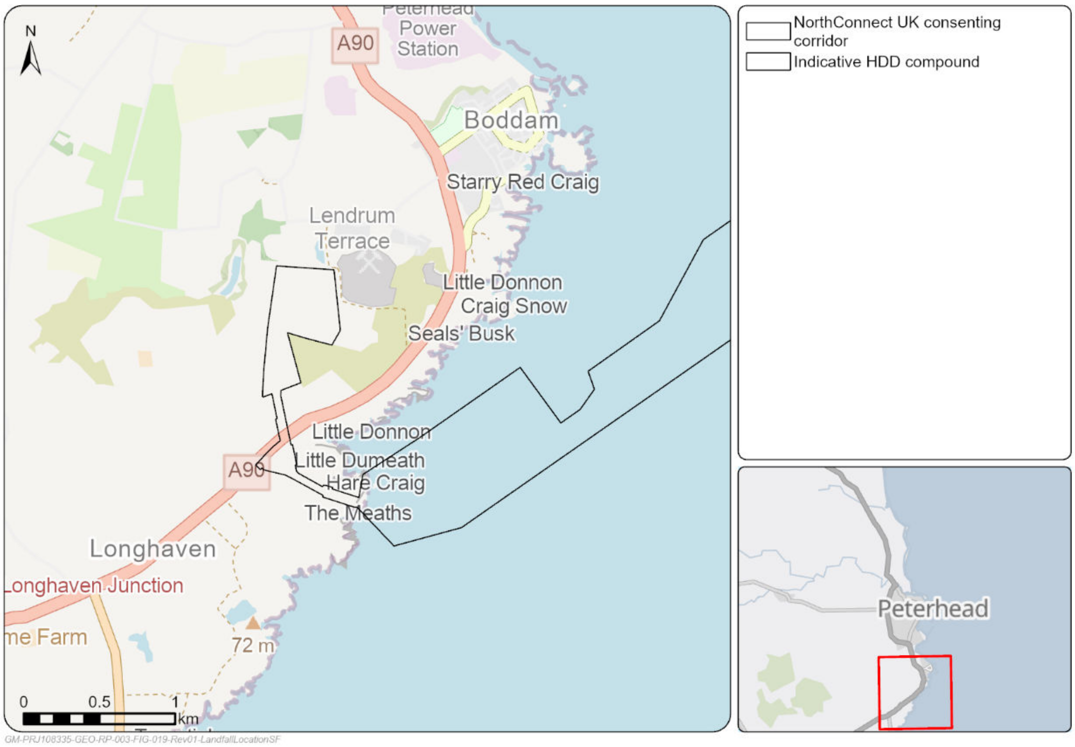


Figure 2: NorthConnect Landfall Area

The topography of the jointing area is dominated by steep coastal cliffs up to 55m high. However, the cliffs at the east side of the proposed HDD launch site are up to 25m high, with some of the shallowest gradients along this stretch of coastline. The cliffs are covered by SSSI, SPA, and SAC environmental designations. Therefore, HDD would minimise the environmental impacts on these areas. HDD is also a technically appealing option in this location due to its short length requirement to reach suitable water depths offshore for vessel access; and good access to A90 through two fields.

4.3 Peterhead

The town of Peterhead does not provide any feasible options for the launch of HDD operations, because of existing land use. Siting a HDD launch location immediately West of Peterhead would leave an infeasible HDD drill length.

4.4 Boddam and South

Boddam village, and the power station immediately North, occupies the land area between the A90 and the coastline. HDD launch areas within and immediately around Boddam are not possible because of residential land use.

To the north of Boddam is Sandford Bay, which was identified by Greencat as a potential landfall option due to its favourable physical characteristics [1]. Sandford Bay has subsequently been included in the planned Eastern Link 2 Agreement for Lease (AfL) boundary – a proposal to install a sub-sea high-voltage direct current (HVDC) cable from Sandford Bay, at Peterhead, to Drax in England – meaning additional cable landfalls in this area are now unlikely [31].

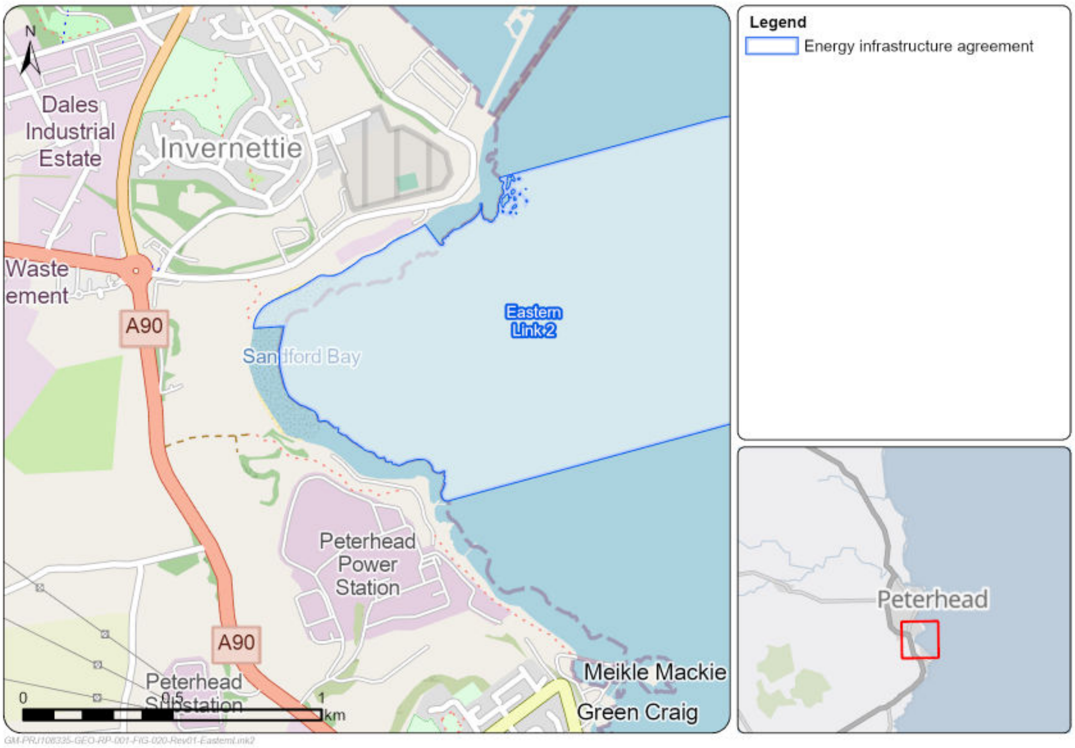


Figure 3: Eastern Link 2 Agreement for Lease at Sandford Bay

Further South, potentially suitable land for HDD launch areas exist between the A90 and the coastline but the coastline is attributed with a variety of designations including scheduled monuments (Boddam Castle), ancient monuments (Canmore), geological conservation review sites, SAC's, SPA's and SSSI's. Furthermore, the coastline is characterised by substantial cliffs which would add complexity to HDD engineering and design.

Other than the 'NorthConnect Parallel' option, the coastline South of Boddam is not deemed suitable.

4.5 Summary

The work performed by Greencat has identified potential jointing areas and HDD launch locations. Amongst these options, those at Boddam have been discounted, due to the subsequent planned and there are preferences from an engineering perspective amongst the remaining options.

Areas of coastline outwith those identified by Greencat do not provide viable opportunities for the launch of HDD operations and the jointing of cables, with the exception of the NorthConnect Parallel option, which is in addition to those identified by Greencat.

5. SITE CONDITIONS

5.1 St Fergus Option 1

5.1.1 Topography, Bathymetry and Land Use

The proposed jointing pit is located in a relatively flat field used for the grazing of cattle, immediately south of South Scotston farm buildings which also include a single residential dwelling. The jointing pit lies at an elevation of approximately 6mOD with the topography rising to 10mOD shorewards up to a noticeable break in topography, east of which the elevation falls towards the links and dunes systems at the coast where the topography once rises again into dune features.

Immediately East of the proposed jointing pit, along the probable HDD alignment, is indicated a telecommunication mast on OS mapping at grid reference NK11296 51791. A conventional mast is not present at this location which according to aerial photography is now a pond which is fenced off from surrounding fields. A further mast structure is indicated immediately adjacent to a road leading down to St Fergus Links at grid reference NK11033 52118. This latter location corresponds with a large security fenced compound, but no conventional mast is present. The nature of these mast features should be confirmed with a site walkover.

In the nearshore area, the seabed shelves gradually such that the 5mLAT bathymetric contour is reached 780m from the beach. Thereafter, the bathymetry deepens markedly, attaining 10m and 15mLAT at 1.0 and 1.18km from shore respectively.

Figure 4: St Fergus Option 1 Elevation

Figure 5: St Fergus Option 1 Aerial Imagery

5.1.2 Environmental Designations

The area is not subject to any environmental designations.

5.1.3 Cultural and Landscape Designations

The area is not subject to any cultural or landscape designations.

5.1.4 Geology and Geomorphology

The stratigraphic succession at the proposed HDD launch location comprises Quaternary lacustrine deposits overlying the Devensian Hatton Till Formation, underlain by rockhead comprising Semipelite, Pelite and Psammites of the Neoproterozoic Crinan and Tayvallich Subgroups.

Between the launch location and the shoreline, the uppermost soils transition through blown sand and a thin band of marine beach deposits which hug the coastline. Areas of Made Ground are also noted. Underlying these upper soils, are the same Hatton Till and metasediments as at the HDD launch location.

Between the proposed launch location and the existing coastline is a linear BGS feature denoting the presence of a palaeo shoreline.

At the shoreline, a rock outcrop is present and named Scotstown Head. Geological mapping shows the presence of Silurian granite and microdiorite dykes. These dykes, and associated offshoots, may be anticipated to be generally more prevalent in the immediate area.

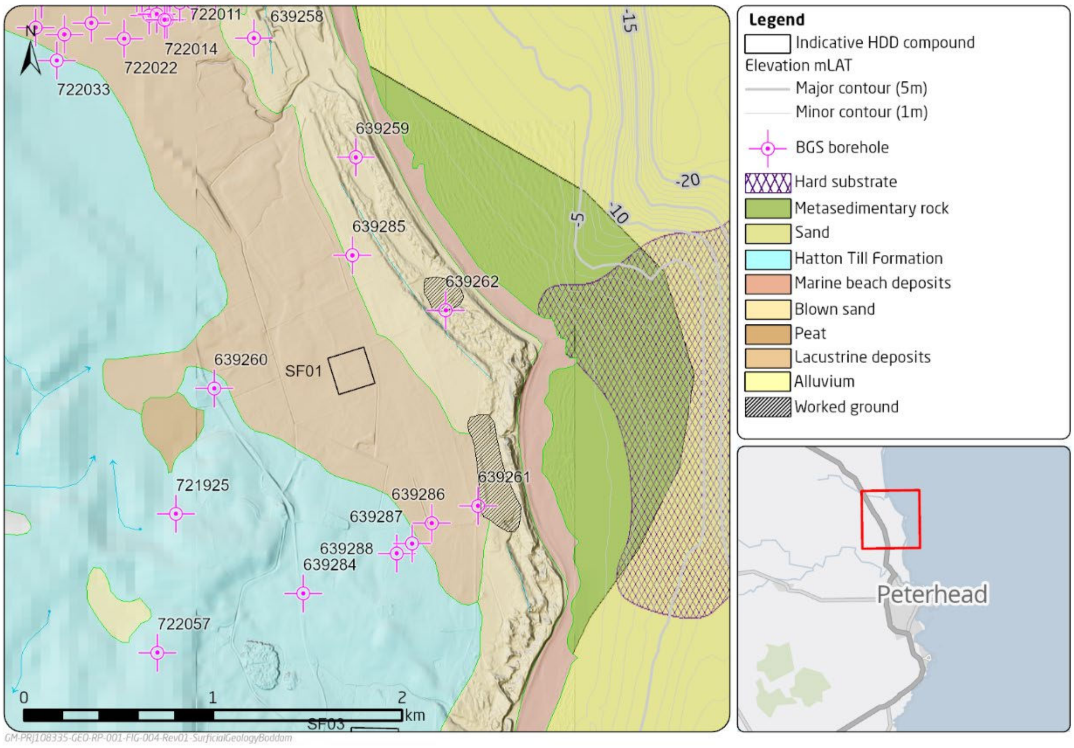


Figure 6: St Fergus Option 1 Superficial Deposits

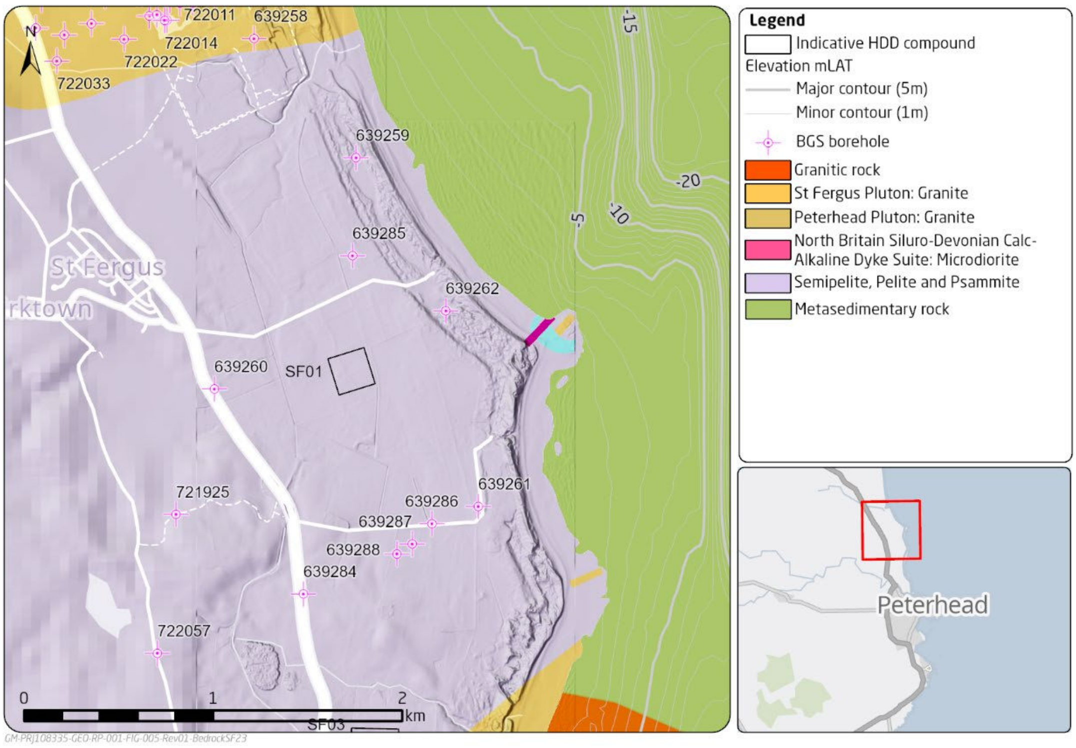


Figure 7: St Fergus Option 1 Bedrock

5.1.5 Geotechnical

Three geotechnical records from the BGS [9] bound the proposed launch location in a triangular formation (NK15SW3/4/5). Each of the geotechnical records are 500-1000m distant from the proposed HDD launch location.

Borehole NK15SW3, West of the launch location and adjacent to the A90, records 7.2m of glacial till (compact clay, sandy laminae, well rounded clasts) overlying glaciolacustrine deposits (laminated, clayey silt, well rounded pebbles) to borehole termination at 18.0m below ground level.

Borehole NK15SW4, 1km Southeast of the launch location, records 1.3m of blown beach sand overlying 9.5m of 'alluvium' (probably lacustrine) comprising clay with rare fine sand lenses and well rounded pebbles. Below this, the borehole enters glacial till typified by firm sandy clay with rare sand lenses and common angular to rounded clasts of a variety of igneous and metamorphic rocks.

Geotechnical record NK15SW5 is a simple pit, located 500m East-Northeast of the launch location. This recorded blown sand to 4.3mbgl, underlain by beach deposits (sandy gravel) to the base of the pit at 5.6mbgl.

The geotechnical records confirm the geological mapping but also disclose the presence of a glaciolacustrine deposit within the glacial till sequence. The recent and uppermost lacustrine deposits are anticipated to be normally consolidated, soft to firm, whereas the glacial till and associated internal glaciolacustrine unit may be anticipated to be normally to overconsolidated and generally stiff in consistency.

Sand lenses in both the lacustrine and glaciolacustrine units have the potential to contain overpressurised pore water, leading to flowing sand conditions. Hard clasts, up to boulder size, should be expected throughout the glacial till units.

The geotechnical records did not intersect the underlying rockhead. However, given the geological description, these rocks may be assumed to be moderately strong to strong, layered and with a low-grade metamorphic texture.

Figure 8 below depicts an idealised stratigraphy at the St Fergus 1 option location, determined with reference to the BGS records available. There is some significant uncertainty about the depth to principal stratigraphic interfaces, not least the depth to rockhead. Rockhead does exist in part at the Scotstown Head shoreline, at 0mOD, some 5-6m below the jointing pit elevation.

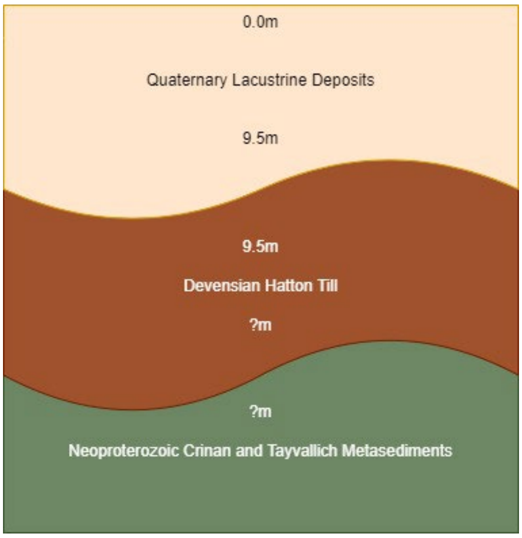


Figure 8: St Fergus Option 1 Idealised Stratigraphy

5.2 St Fergus Options 2 and 3

5.2.1 Topography, Bathymetry and Land Use

Option 2 and 3 jointing pit locations are situated immediately West of commercial forestry in open arable farmland, 290m and 150m East of the A90 respectively. Option 2 location is gently sloping to the South-Southeast and Option 3 is flat.

The topography shorewards is very similar to that of St Fergus Option 1 with a notable shore-parallel depression marking the palaeo-shoreline at the back of the current dune system.

A shallow seabed gradient results in the 5m bathymetry contour being reached approximately 630m from the shoreline, with the 10m and 15m contour reached at 1km and 1.4km respectively. Beyond the 15m water depth contour, the bathymetry increases markedly, gaining an additional 15m in water depth over 500m.

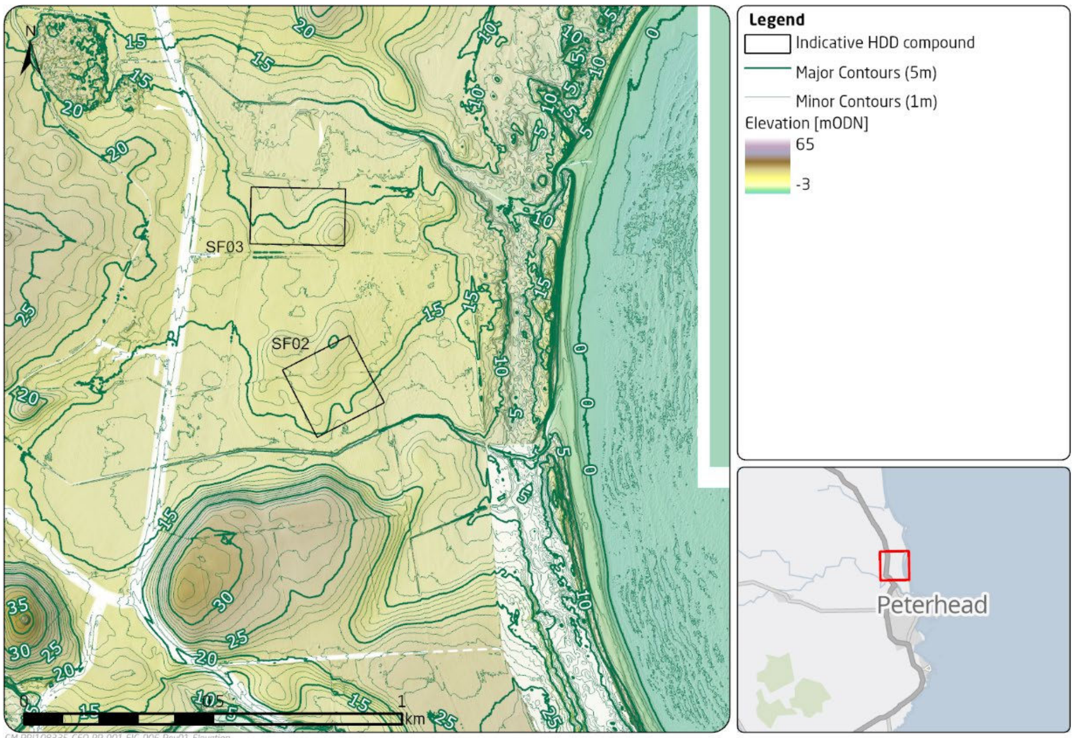


Figure 9: St Fergus Options 2 and 3 Elevation

Figure 10: St Fergus Options 2 and 3 Aerial Imagery

5.2.2 Environmental Designations

The locations of Options 2 and 3 are not subject to any environmental designations.

5.2.3 Cultural and Landscape Designations

The locations of Options 2 and 3 are not subject to any cultural or landscape designations

5.2.4 Geology and Geomorphology

The stratigraphic succession at these proposed jointing locations comprises the Hatton Glacial Till, underlain by bedrock. The solid geology in the vicinity of jointing pit options 2 and 3 are complex; the northernmost option 3 is located within the Neoproterozoic Crinan and Tayvallich Metasediments, whereas option 2 to the south is located at the intersection between the Forest of Deer and Peterhead Granite plutons.

Between the jointing pit locations and shore, the Peterhead Granite pluton subcrop extends northwards such that any HDD bore from these locations will intersect granitic bedrock.

The BGS Quaternary mapping [10] identifies a relict shoreline feature along the probable HDD path and corresponding with a shore-parallel topographic depression between the coastal dune system and farmland to the West.

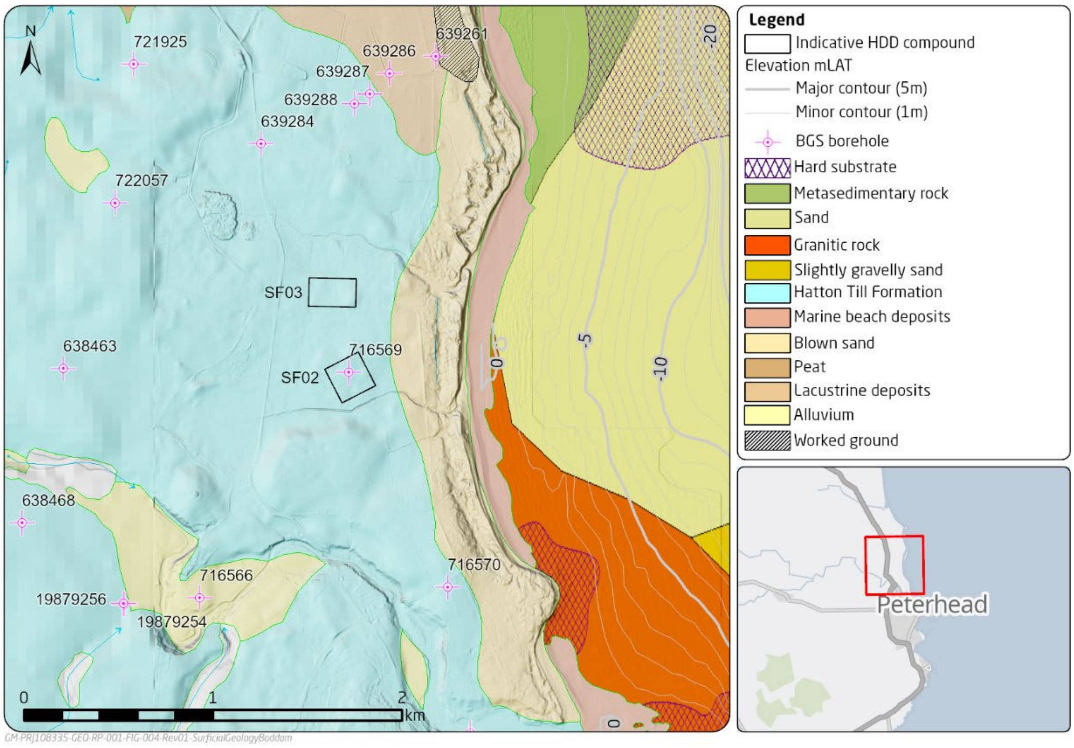


Figure 11: St Fergus Options 2 and 3 Superficial Deposits

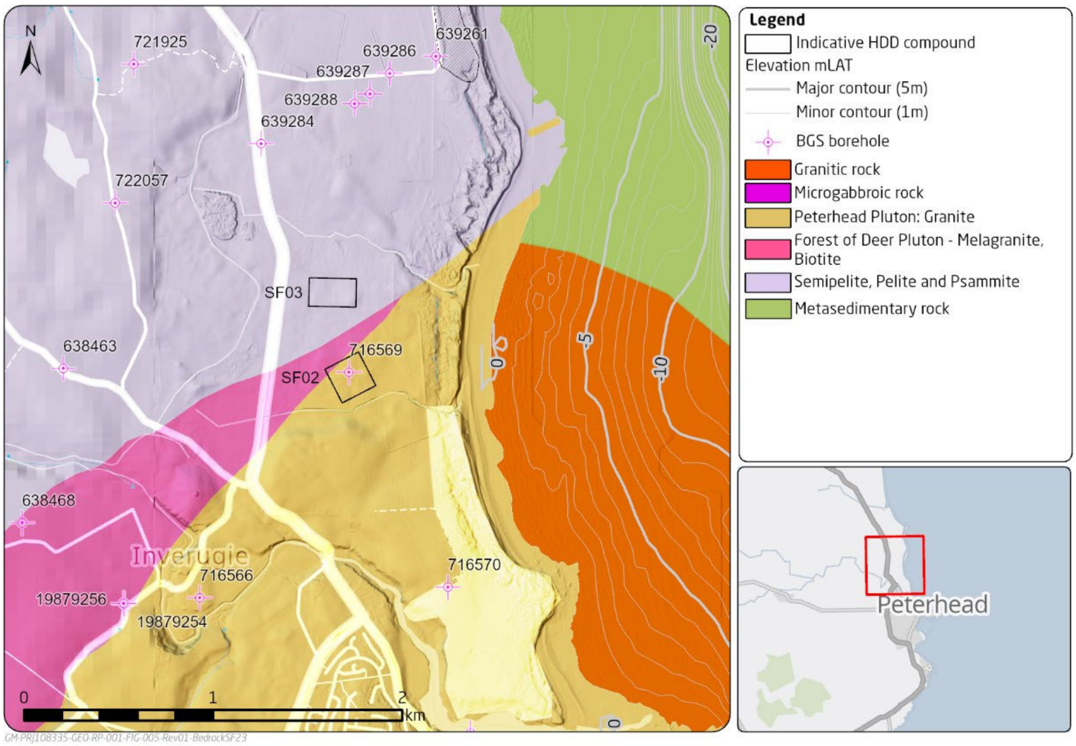


Figure 12: St Fergus Options 2 and 3 Bedrock

5.2.5 Geotechnical

One geotechnical record is available from the BGS [9] immediately adjacent to option 2; borehole record NK14NW4.

This borehole record discloses a succession of Hatton Till, including a glaciolacustrine sub-unit, from ground level to 10.9m. Rockhead is recorded at this level, comprised of the Caledonian Peterhead Granite pluton.

The Hatton Glacial Till is recorded as stiff sandy and silty clay, with clasts of igneous and metamorphic lithologies. The glaciolacustrine sub-unit is noted to be laminated and with bands of fine sand.

The granite was not penetrated substantially by the borehole. The granite was recorded as weathered, coarse grained and pink which is typical of the Peterhead Granite Pluton.

The Forest of Deer Granite, which is typically very biotite mica rich, has not been intersected by the geotechnical borehole.

The Option 3 location is indicated to be underlain by Semipelite, Pelite and Psammites of the Neoproterozoic Crinan and Tayvallich Subgroups [9], but to be very close to the contact with both the Forest of Deer and Peterhead Granites. This should be confirmed by site investigation.

The stratigraphy at the option 2/3 locations is presented in Figure 13 below.

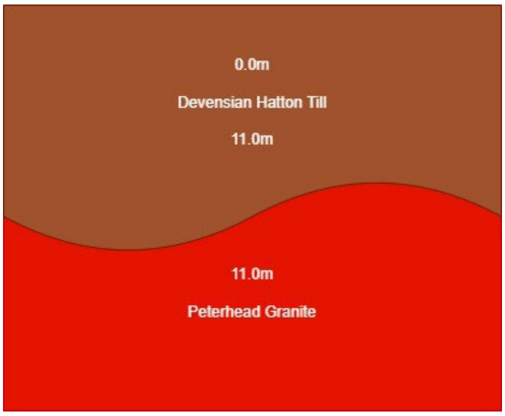


Figure 13: St Fergus 2 and 3 Stratigraphic Profile

5.3 NorthConnect Parallel

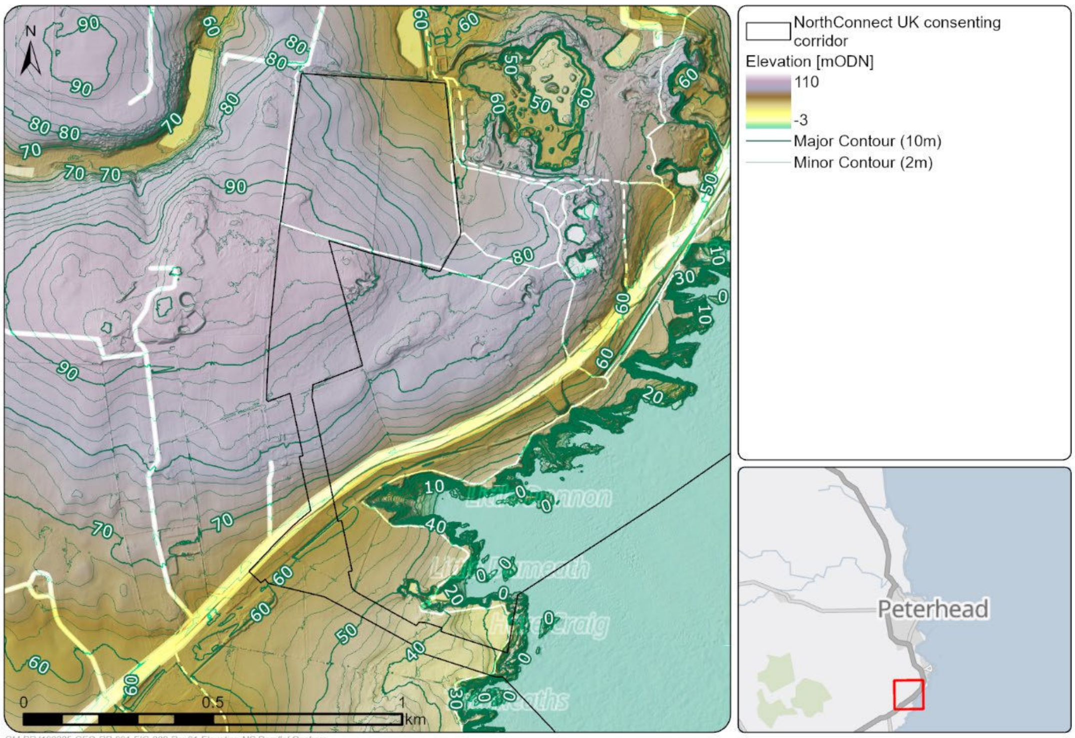
5.3.1 Topography, Bathymetry and Land Use

The topography of the jointing area is dominated by steep coastal cliffs up to 55m high. However, the cliffs at the east side of the proposed HDD launch site are up to 25m high, and form some of the shallowest gradients along this stretch of coastline. The potential HDD site is on gently sloping ground, at approximately 1 in 15, away from the A90 to the southeast. The gradient increases on the western edge as approximately 1 in 3. In contrast, the area is surrounded by the cliffs both to the north and south, which are near vertical with one section of the northern cliffs appearing to be undercut. [8]

A HDD in this location would benefit from reduced distance to reach the marine environment, and good access to A90 through two fields. The fields are mostly well drained with boggier areas around gates.

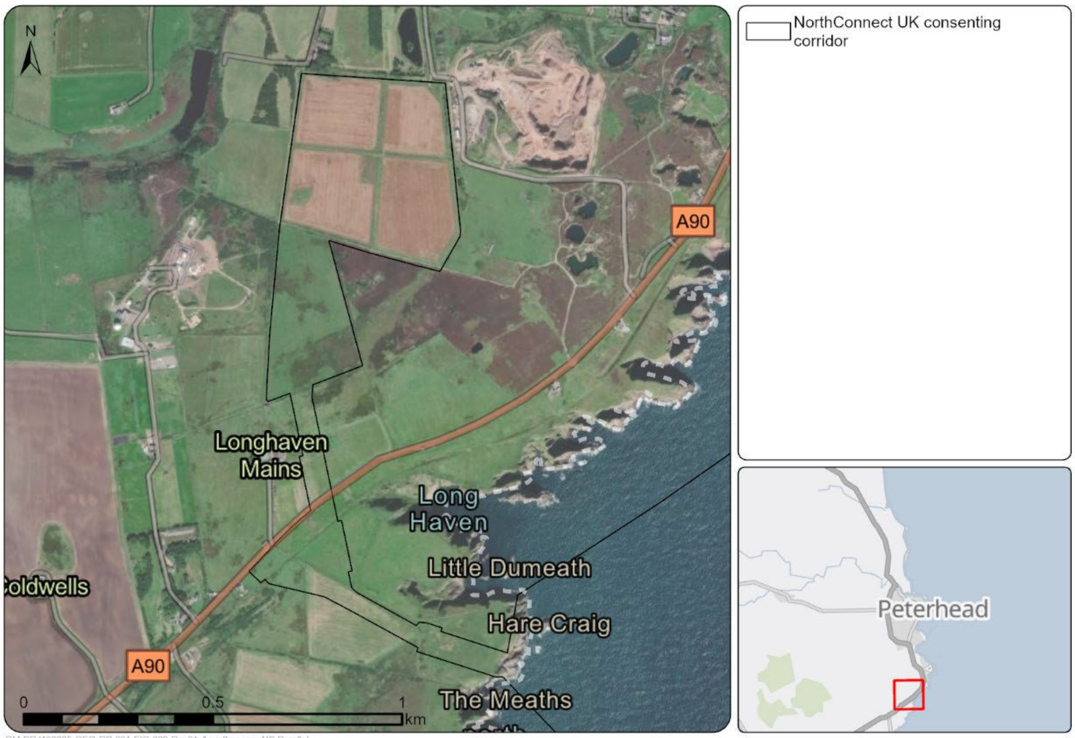
Gradient of the seabed between 0 and 5m LAT appears to be relatively shallow, with the 5mLAT bathymetry contour reached at 425 m away from the cliff. Beyond this, the water depth increases more rapidly with the 10m and 20m bathymetry contours being reached at 670m and 1080m from the cliff respectively.

The jointing area is grassed, probably used for grazing, and it is easily accessible through the gate, although the area around the gate is boggy. There is a slightly raised stony lineament in the middle of the area which might be an abandoned stone fence but there is no evidence on the historical mapping. The land is already permitted for HDD landing of the NorthConnect HVDC project and so benefits from this future planned land use.



GM-PRJ108335-GEO-RP-001-FIG-008-Rev01-Elevation NC Parallel Onshore

Figure 14: NorthConnect Parallel Onshore Elevation



GM-PRJ108335-GEO-RP-001-FIG-009-Rev01-AerialImagery NC Parallel

Figure 15: NorthConnect Parallel Aerial Imagery

5.3.2 Environmental Designations

The Buchan Ness to Collieston Coast OSPAR Marine Protected Area bisects Longhaven Cliffs and extends to both the north and the south. The qualifying interest of this designation is through the support of large numbers of seabirds. Also, the Longhaven Cliffs are covered by SSSI, SPA, and SAC environmental designations.

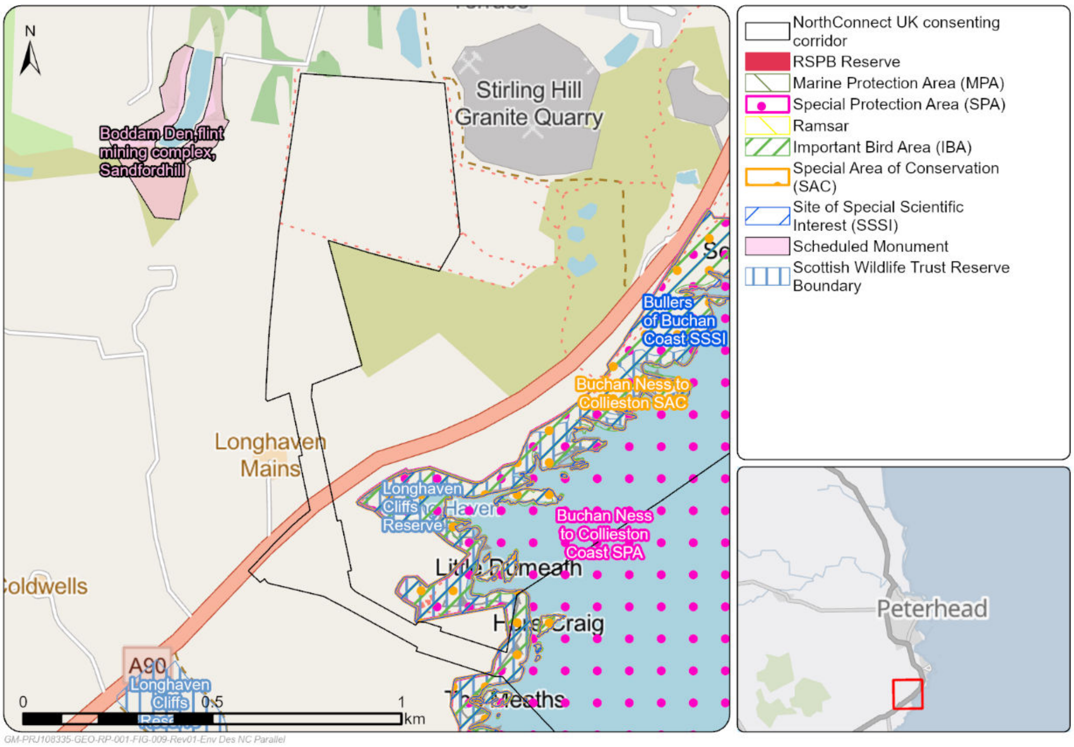


Figure 16: NorthConnect Parallel Environmental and Cultural Designations

5.3.3 Cultural and Landscape Designations

The proposed jointing area location is not subject to any cultural or landscape designations. However, there is a scheduled monument to the northwest of the compound.

5.3.4 Geology and Geomorphology

The proposed jointing location contains only a thin layer of superficial deposits which is expected to be 1-3 m thick over solid bedrock at the land side and thin loose Holocene sediments overlying dense sand and Glacial Till in the areas near potential HDD landfalls (marine side). BGS mapping indicates that the HDD site is underlain by Granite of the Peterhead Pluton and is of Silurian (416 – 444 Ma) age. The local soil profile is exposed at a number of places along the cliff edges and around the margins of the former quarry workings to the northwest of the HDD site. There are no specific geomorphological features noted in the area.

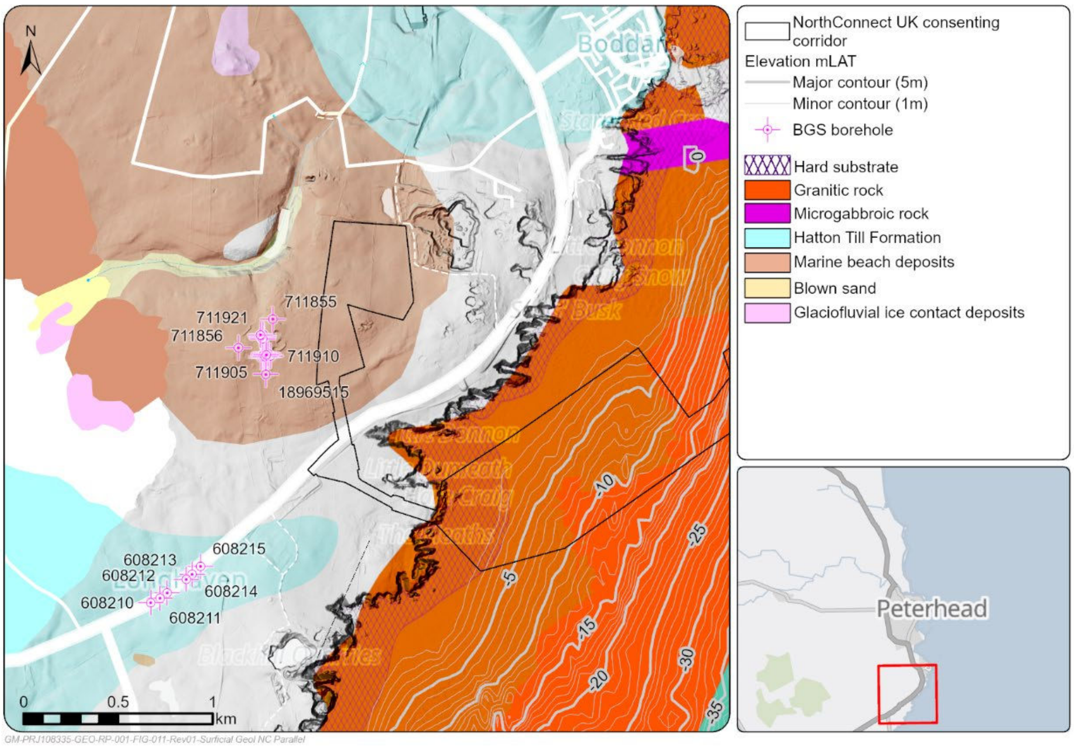


Figure 17: NorthConnect Parallel Superficial Geology

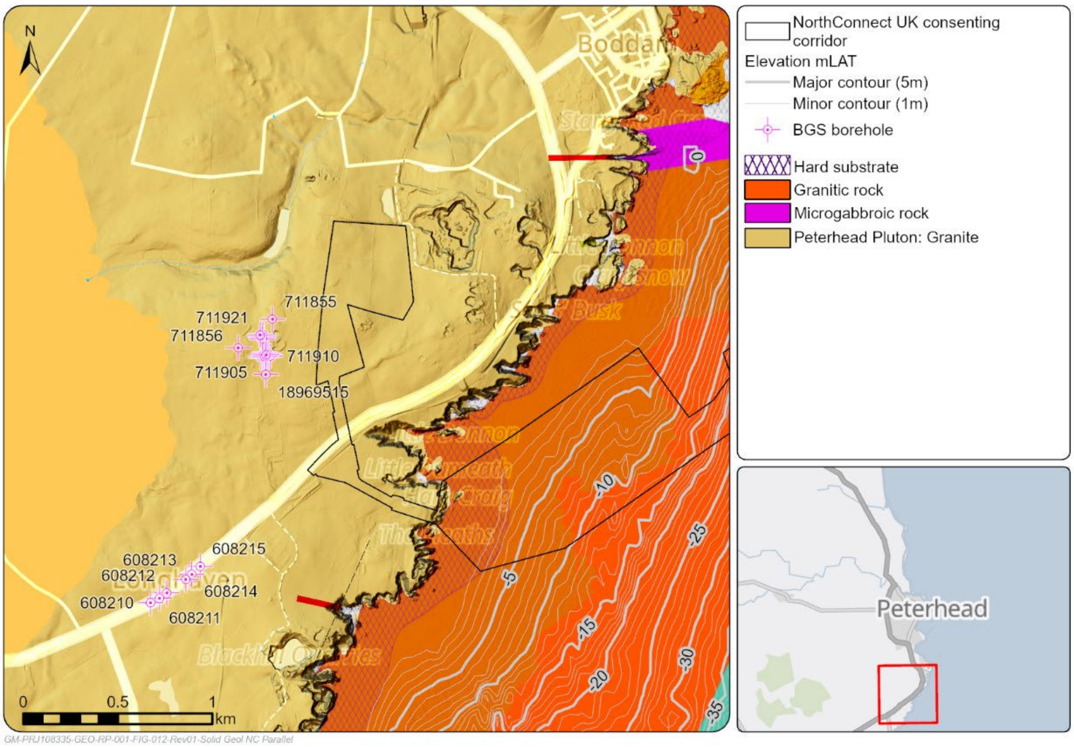


Figure 18: NorthConnect Parallel Bedrock

5.3.5 Geotechnical

Superficial deposits compromise of a thin (0.3 – 0.5 m) humic layer overlying silty SAND with Gravel. With depth, the gravel component is likely to increase in size and percentage as the soil transitions to rock. Towards the base of superficial deposits there are likely to be cobbles and boulders formed from weathered granite corestone.

BH201 indicates that the HDD locations will probably encounter soft slightly gravelly CLAY, with occasional boulders in the top 2 m of ground. Underlying this will be of cobbles and boulders of granite with some sand, representing a weathered profile, underlain by competent rock, with more highly weathered zones associated with jointing and faulting.

The Unconfined Compressive Strength (UCS) of the fresh granite is potentially 200Mpa or higher. Granite in the weathered fault zones might be as low as 40MPa depending on the degree of weathering.

An idealised stratigraphy is presented in Figure 19 below.

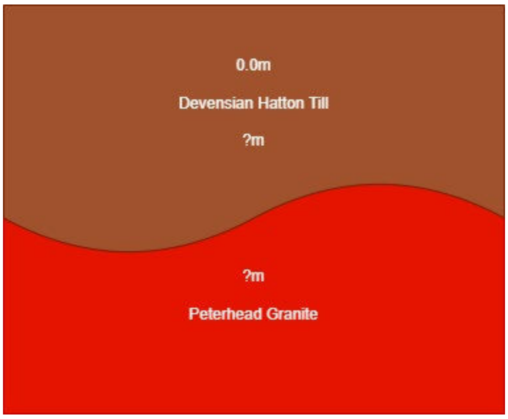


Figure 19: NorthConnect Parallel Idealised Stratigraphy

6. CABLE LANDING AND HDD FEASIBILITY

6.1 General

Both open-cut trenching and HDD (or other trenchless techniques such as Direct Pipe) may generally be considered as viable cable landing options. However, in the case of the Green Volt project, a combination of elevation change, shoreline land use and habitat considerations means that open-cut trenching is not viable.

6.1.1 Horizontal Directional Drilling (HDD)

HDD methods are the most common trenchless method and involve installing a steel or plastic (high density polyethylene) conduit in individual or parallel HDD installations. This method of construction is typically used to install pipes and conduits in areas not amenable for trenched construction, including water bodies, highways, railroads, runways, environmentally sensitive areas, and shorelines/landfalls. Assuming proper design and good HDD construction practices, the HDD method allows for the installation of subsea cables at shore landing, with minimal impact to the surrounding environment.

The installation methodology of a cable by HDD can be summarised by three primary stages:

1) Creating a Pilot Drill – A steerable drill bit creates a pilot hole along the pre-determined trajectory from the launch site, which is generally sited onshore. Steering is computer controlled by a surveying tool on the drill string behind the drill bit. Drilling mud is pumped in to lubricate and cool the drill bit and remove cuttings. Steel casing will likely be required for the first section of the bore in order to hold the bore open effectively for the multiple passes required for drilling and reaming.
2) Reaming – Successively bigger reamer tools are attached into the drill pipe (which runs continuously through the hole with pipes added/removed at each end) and passed along the bore to enlarge the hole to the required diameter, with cuttings removal and hole support supplied by bentonite slurry.
3) Installing a Duct – The duct is pushed through the completed and cleaned hole by pushing it through from the launch point, or in some cases where onshore space is limited, from the offshore site by pulling a prefabricated duct into the landfall though the bore by the drilling machine and drill string. The duct will be sealed with a messenger wire in place and made stable on seabed with mattresses or rock bags temporarily until the cable product can then be pulled though the completed duct.

The above HDD installation methodology is well known, with several contractors across the industry with the required installation experience. From this experience, it is documented that there are three major considerations for HDD operations, notably length, curvature and elevation change across the bore, to be regarded. As these increase the pull force required to pull the duct though the completed hole increases. Pull force is limited by both the HDD equipment and the tensile strength of the duct before damage occurs, although it is possible to mobilise specialist jacking systems to push-jack the conduit into the entry hole. Drill and reaming forces can be potentially reduced by conducting some or all the HDD operations from an offshore jack-up barge, albeit increasing expense significantly.

The depth of cover for a given HDD installation is dependent on several factors. Of these factors, the most important include the properties of the overlying geotechnical materials, the resistance these materials provide to the required installation-induced drilling fluid pressures, and spatial or clearance requirements between the HDD bore and existing utilities and structures. Horizontal curves can be incorporated into the bore profile to align the installation to avoid buildings and structures if present between HDD pit and shoreline. The angle of the required deflection should be kept as small as possible.

It should be noted that maximum installation length is anticipated to be 1.5 km due to typical limitations associated with cable and duct pull in requirements, though this may vary project-to-project. Some long HDDs have been completed in the offshore industry of up to 2 km, and up to 5 km in exceptional circumstances onshore with large, 400Te rated HDD rigs.

6.1.2 Trenchless Installation Considerations

Water Depth at Punch-Out

For this assessment, an exit point (punch out) of the bore at the -5m LAT line offshore was initially assumed, a depth of water in which most cable lay barges (CLB) can operate. Given the bathymetric profile along this section of coast, standing a deeper draft cable lay vessel (CLV) off at the -10mLAT contour and floating a cable into the HDD duct is also considered viable.

Considering punch out at -5mLAT will mean shorter bores, and cost and time savings. Given the bathymetric profile and the ability to stand-off a CLV at a relatively short distance, this approach is considered for the project as it de-risks the HDD completion. However, some additional cost may be anticipated to be passed on to the cable installation works, in terms of using specialist CLB’s, or additional effort in managing a cable float-in.

The potential for longer HDD’s is not discounted at this stage, which could achieve punch-out in -10mLAT water depth, enabling a CLV to directly access the HDD exit point for cable pull in. Such approaches introduce additional risk and cost to the HDD operations which may not be necessary. More detailed assessments with project-specific bathymetry and ground data will enable a judgement to be made.

Thermal Considerations

The Thermal properties of the ground containing a buried cable are a significant consideration to avoid overheating damage. Thermal conductivity and heat capacity of the surrounding soil, overburden thickness, the presence or absence of cooling groundwaters and the ability of groundwaters to circulate to remove heat are all factors.

Liaison with HDD / Direct Pipe contractors is required to determine the minimum cover depths for installation operations given the anticipated geology. Conversely, should the bore profile be restricted by soils then heating concerns need to be considered with respect the cable conductor size and in the worst case an oversized conductor might be required for the bore section.

Site Requirements

The landfall site must be designed to comprise the jointing pit and HDD operations for two export cables. For a typical large HDD installation involving the installation of a single conduit, the staging area for the entry side of the crossing is recommended to be approximately 100 m by 60 m. For multiple conduits, such as required here, the width of the staging area needs to be increased to accommodate each entry location. For the two required conduits, with a horizontal separation of 20 m, the shore-parallel dimension of the compound is likely to increase to 70-80m.

Maintaining a shore-perpendicular dimension of the compound at 100m enables more efficient pipe handling and build out in longer length. Available land, and associated landuse, landward of the HDD compound should also be considered. If very long HDD's are required, it is likely that the ducting would need to be pushed in from the launch pit in large, continuous lengths of several hundred metres at a time. Site layout needs to be considered to potentially permit this arrangement. Figure 20 below depicts a potential site layout for two HDD rigs.

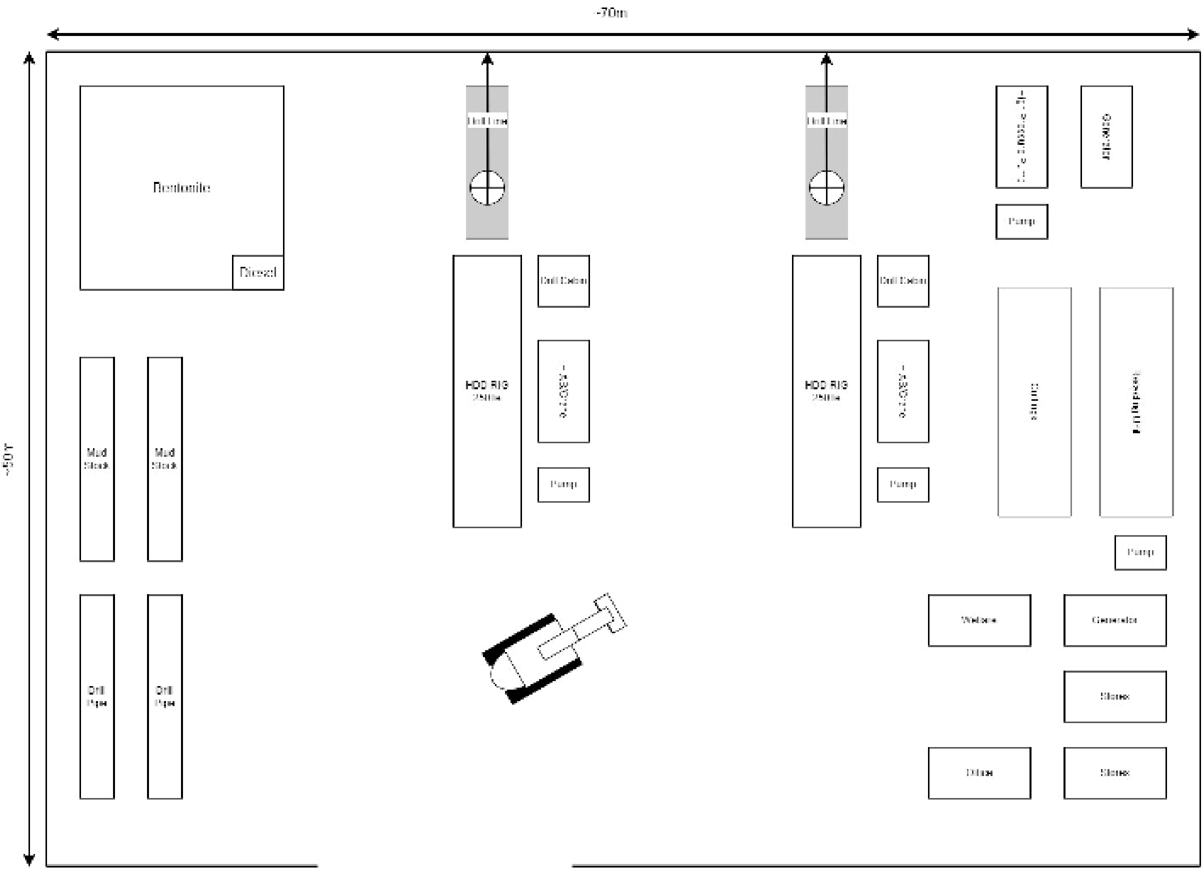


Figure 20: Potential HDD Site Layout

Cable Spacing

Detailed routing and definition of cable spacing is subject to route specific geophysical and geotechnical survey.

After exiting the HDD bore, cables should attain a minimum separation of 50 m within the export cable corridor. Ideally, this separation should be 75-100m to allow for ease of

IMR activities. In the nearshore section (e.g., at the bore exit), the separation can be reduced to approx. 35 m for the individual punch outs. This is to give sufficient working area on the seabed around the duct, and not cause any inefficiency, however that should be reviewed.

As the cables approach landfall via HDD ducts and reach the jointing bay area (e.g., at the entry points), the separation can be further reduced to approx. 20m. Again, largely led by the requirement for working area around the drill entry points and the eventual pad for the landfall joint.

The above constraints will need to be accommodated with a detailed RPL during a full routing exercise following common practice rules such as minimum curvature radius.

6.2 St Fergus Option 1

Site Area

The site area is within flat farmland with good access from the A90. The jointing bay location itself is of ample size to accommodate the HDD operations. Inland of the jointing bay location, there is a further 300m of open farmland which could be secured for longer lengths of conduit piping to be set up and handled into the HDD.

The site area is suitable for HDD drilling and jointing pit operations.

Drill Length and Trajectory

In order to reach the -5mLAT depth contour, a drill length of approximately 1.3km is required, within the capabilities of widely available HDD drill rigs in the market. At the upper bound of conventional rig capabilities, the -10mLAT contour may also be reached with a drill length of approximately 1.5km.

The site area lies at an elevation of 6mOD, giving an approximate elevation change of 11m from entry to exit pit. This is not problematic over the planned drill length.

Onshore Geological and Geotechnical Conditions

Post-glacial lacustrine deposits are expected at surface, at perhaps up to 10m thickness. This unit is likely to require casing, due to it’s less consolidated nature and presence of sand lenses which are likely to contain overpressurised water. The casing length is likely to be in the order of 60-70m may be expected.

Underlying the lacustrine deposits are glacial tills. These soils are anticipated to be generally stable in the HDD bore, although are likely to contain boulders of igneous and metamorphic origin.

Rockhead exists at the shoreline, but has not been intersected by any local boreholes. It may therefore be anticipated to be present along the HDD bore. The metamorphic rock is likely to be strong and competent, forming a stable bore, but the rock structure, including joints, faults and metamorphic texture should be investigated in detail to determine the potential for hydrofracture. Igneous dykes are present in the immediate vicinity and should be anticipated within the trajectory of the HDD bore. These dykes are likely to be stronger than the metamorphic country rock, but may also have generated preferential fluid pathways leading to zones of enhanced weathering.

The geological and geotechnical conditions require careful consideration at this location but are not considered particularly problematic for a well planned and executed HDD operation.

Nearshore Geological and Geotechnical Conditions

The immediate nearshore area is characterised by intermittent soil cover and large areas of exposed rock at seabed. Burial potential is anticipated to be extremely limited within the rock which will be difficult to cut, even with a mechanical trencher. To maximise the chances of attaining cable protection through burial, the cable route centreline must be deviated to the north, around an area of mapped rock at seabed. This results in a constrained route, aligned closely to the Fulmar to St Fergus pipeline.

The nearshore geological constraints result in a longer cable route and limitations to cable burial potential. As a result of these factors, St Fergus Option 1 may be considered unfavourable.

6.3 St Fergus Option 2 and 3

Site Areas

The site areas are within arable farmland with good access from the A90 at Lunderton Cottages. Option 3 area is relatively flat, with a small incline of 3-4m in the southeast corner. Option 2 area occupies a shallow, South-Southeast dipping slope of 1.5°. Inland of both options, there is a significant amount of open farmland available which could be used for handling longer conduit lengths.

Both site areas are suitable for HDD drilling and jointing pit operations.

Drill Length and Trajectory

In order to reach the -5mLAT depth contour, a drill length of approximately 1.1km and 1.3km is required for Options 2 and 3 respectively, within the capabilities of widely available HDD drill rigs in the market. At the upper bound of conventional rig capabilities, the -10mLAT contour may also be reached with a drill length of approximately 1.6km.

The site areas lie at an elevation of approximately 18mOD, giving an approximate elevation change of 23m from entry to exit pit. This is not problematic over the planned drill length.

Onshore Geological and Geotechnical Conditions

Both options lie within an area of Hatton Glacial Till at surface. This glacial till is anticipated to continue to rockhead, but to be quite heterogenous, incorporating minor sand lenses, glaciolacustrine layers and significant boulders. Whilst the glacial till is anticipated to form a relatively stable bore overall, sand lenses with high pore water pressure has the potential to cause bore collapse and instability. Boulders will cause slower drilling progress. Both of these factors should be considered in drilling and drill fluid design.

Rockhead is encountered in the vicinity at 11.0m below ground level, comprising Peterhead Granite where it is intersected by a borehole [9]. In the area more generally, rockhead is comprised of the Peterhead Granite, Forest of Deer Granite and Semipelite, Pelite and Psammites of the Neoproterozoic Crinan and Tayvallich Subgroups [9]. The exact nature and relationship of these rock types should be confirmed with site survey. Whilst the rock types anticipated should form a clean and stable HDD bore, the nature of weathering and contact metamorphism effects should be confirmed, in addition to the potential for any preferential fluid flow pathways through faults or contact between the different rock types.

The onshore geological and geotechnical conditions are not anticipated to cause any problems for a properly planned and executed HDD operation.

Nearshore Geological and Geotechnical Conditions

The nearshore area exists immediately to South of a mapped rock outcrop at seabed. The seabed itself is indicated to comprise of Forth Formation, underlain by Wee Bankie Formation. The nearshore area exists inside of the 10m Quaternary depth contour, and so soil cover may be expected to be limited. Rockhead is likely to comprise Peterhead Granite in the immediate nearshore area, with negligible burial potential.

Some burial potential is therefore afforded in the nearshore area, which may be considered favourable for St Fergus Options 2 and 3. It will be important to quantify the thickness of soil cover and burial potential with route specific geophysical and geotechnical survey.

6.4 NorthConnect Parallel

Site Areas

Site area is located between A90 and Longhaven Cliffs. Access to the site is from the A90 through two fields. The fields are mostly well drained with boggier areas around the gates. They are likely to provide good access once topsoil has been stripped and laid with geofabric and hardcore or gravel. Potential locations of HDD crossings beneath the A90 and the former railway are located approximately 500 m inland from the landfall location.

The HDD site area is located mostly level ground, there is only a gentle slope to the east, at approximately 1 in 15. The western edge of the potential site is formed by steeper slope of approximately 1 in 3. [8]

Potential HDD alignments should balance the available depth of cover beneath the intertidal/gutter of nesh area, maintaining a sufficient lateral distance from the cliffs south of the site, alignment for onward cabling toward the substation, and favourable conditions at the marine exit point.

Drill Length and Trajectory

The proposed NorthConnect HDD design is 409.10m in length, with entry elevation approximately +38m ODN and exit elevation -28m ODN (26m below LAT). The entry angle is 17° in order to maximise the depth beneath the coastal land, which is at the upper end of normal HDD rig setup angles. It is intended to ensure depth is reached as quickly as possible, reducing the overall length of the HDD, achieving an adequate depth of cover and maintaining a angle close to that of the cliff profile.

The exit point is chosen to keep the HDD length to a minimum as well as exit at a suitable angle for duct installation and onward cabling. Also, the vertical curve radius of 400m is within the limits of both the drilling equipment and the expected ducts. [8] These approaches and strategies are reasonable and could be adopted for the Green Volt HDD landing.

Onshore Geological and Geotechnical Conditions

The site contains only a thin layer of superficial deposits. It is expected to be 1-3 m thick over solid bedrock and potentially up to 5 m depth above weathered shear zones.

In the field there is expected to be a thin (0.3 - 0.5m) humic layer overlying silty SAND with gravel. With depth, the gravel component is likely to increase in size and percentage as soil transitions to rock. Towards the base of the superficial deposits there are likely to be cobbles and boulders formed from weathered granite corestone, representing a weathered profile, underlain by competent rock, with more highly weathered zones associated with jointing and faulting.

Results from BH201 indicate that the HDD locations will probably encounter soft sandy slightly gravelly CLAY, with occasional boulders, in the top 2m of ground. Underlying this will be 4m of cobbles and boulders of granite with some sand. The geophysical information from Resistivity Line 1 matches the results from BH201.

Nearshore Geological and Geotechnical Conditions

The MMT 2016 LOTA marine geophysical and geotechnical survey [8] identified a sequence of thin loose surficial Holocene sediments (silt sand and gravel) overlying dense sand and Glacial Till in the areas near potential HDD landfalls. At the probable HDD exit points, the Holocene sediments are identified as silt and fine sand, while in the centre of the survey area near the shoreline it is identified as sand and gravel with ripples. Additionally, BGS mapping indicates that the HDD site is underlain by Granite of the Peterhead Pluton and is of Silurian (416 – 444 Ma) age.

It should be noted that the continuation of the granite offshore is an assumption; there is no direct evidence of the bedrock material beyond Hare Craig. However, locally there are granite outcrops offshore (e.g., Skerry Rock, 500m offshore from Boddam) and the BGS offshore index mapping shows the granite bedrock extending to 1.75km from shore. Granite continuing to the possible HDD exit location 250m from the shoreline is therefore considered to be very probable.

6.5 Summary

The landfall locations proposed have been comparatively evaluated and are summarised in Table 2 below.

Option	Onshore Geo	Offshore Geo	Drill Length	Site and Constraints	Overall
St Fergus 1					

St Fergus 2					
St Fergus 3					
NorthConnect Parallel					

Table 2: Landfall Suitability Summary

St Fergus 1 requires a circuitous route to avoid nearshore rock outcrops and the targeted areas of nearshore seabed soils may also not offer reliable burial potential.

St Fergus 2 and 3, and the NorthConnect Parallel option, all offer viable and attractive opportunities for cable landing based upon the information available to this study.

7. CONCLUSIONS

Proposed jointing bay and HDD locations have been proposed by Flotation Energy and assessed by Global Maritime from a practicality, constraint and technical feasibility perspective. Each of the sites have been considered separately, although reported together where appropriate.

All potential landfall sites are considered feasible, although with their own particular considerations.

St Fergus 2 and 3 are favoured landing point options, because of the negligible topography, favourable geological conditions and attainable HDD drill length. These options also permit a relatively direct route offshore towards the 12nm boundary. NorthConnect Parallel is also feasible, with a shorter HDD drill length, but greater elevation difference to account for in HDD design. The offshore route for NorthConnect Parallel would seem to offer some burial potential but is less direct than that of St Fergus 2 and 3. The NorthConnect Parallel option does offer the benefit of being located adjacent to the NorthConnect planned HDD, which is already permitted. It is felt that this may alleviate some of the concerns around environmental and cultural designation constraints in this area.

At this stage, the project may continue to consider these sites in parallel, maintaining a plurality of options and thus managing landfall risk.

Other jointing pit and HDD locations may also be considered in future, for example to the immediate west of the golf course, to the south of St Fergus 2 and 3. These options can be considered in future and should be accounted for in any planned offshore survey campaigns.

APPENDICES

APPENDIX A BGS BOREHOLE RECORDS

APPENDIX A BGS BOREHOLE RECORDS

A.1 St Fergus Option 1

Institute of Geological Sciences
IMAU Sand and Gravel Borehole Log Form

NK 15 SW 3	NK 1010 5159	North Kirkton Farm, St Fergus	Block D

Surface level	+7.0m (+23 ft)

Ground water level +2.0m

250mm and 200mm percussion

September 1977

Waste	18.0+

LOG

~~COMMERCIAL~~

Geological Classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Till	Clay, red to red-brown, mottled in parts, compact, with sandy laminae and clasts of well rounded granite and platy schist	6.9	7.2
Glaciolacustrine deposits	Silt, clayey, micaceous, laminated, grey-brown to red-brown, with rare well rounded pebbles of granite	10.8+	18.0

GLOBAL MARITIME

IMAU Sand and Gravel Borehole Log Form

NK 15 SW 4	NK 1149 5097	North Kirkton Farm, St Fergus	Block D E

Surface level	+ 10.8 m (+35 ft)
Ground water level +9.9 m	
150 mm and 200 mm percussion	
September 1977	

Overburden	0.2
Mineral	1.3
Waste	15.0+

LOG

Geological Classification	Lithology	Thickness m	Thickness ft	Depth m	Depth ft
	Soil, sandy, dark brown	0.2		0.2	
Blown sand	Sand Sand: fine to medium, subangular to subrounded, quartz with feldspar and shell fragments, beige	1.3		1.5	
Lake alluvium	Clay, mid-grey, mottled in part, with rare fine sand lenses and rare well rounded pebbles.	9.5		11.0	
Till	Clay, sandy, grey-brown, with angular to rounded clasts of basic igneous and metamorphic rocks and quartz	2.5		13.5	
	Clay, firm, reddish brown, with common angular to subrounded clasts of pink granite and metamorphic rocks.	2.3		15.8	
	Clay, sandy, grey-brown, with clasts of gneiss becoming common towards base.	0.7+		16.5	
	Borehole abandoned due to slow progress in stony till				

IMAU Sand and Gravel Borehole Log Form

NK 15 SW 5	NK 1132 5200	St Fergus Links Sand Pit, St Fergus	Block E

Surface level	+ 7.2m (+ 24 ft)

Water struck at + 1.8m

Sampling by hand

May 1978

Overburden	0.3
Mineral	5.3+

LOG

COMMERCIAL IN CONFIDENCE

Geological Classification	Lithology	Thickness m	Depth m
	Soil, peaty	0.3	0.3
Blown sand	a) Sand: medium with some fine, subrounded, quartz, yellow	4.3	4.6
Post-Glacial Beach deposits	Sandy gravel, with pebble band at top Gravel: cobble and coarse with fine, well rounded gneissose rocks, felsite and shells Sand: medium with some fine and coarse, sub- to well rounded, quartz and shell, yellow-orange	1.0+	5.6

A.2 St Fergus Options 2 and 3

MAU Sand and Gravel Borehole Log Form

NK 14 NW 4	NK 1103 4930	Lunderton Farm, Peterhead	Block D

Surface level	+18.4 m (+60 ft)
Water not struck	
250 mm and 200 mm percus sion	
November 1977	

Waste	10.9
Bedrock	0.3+

LOG

Geological Classification	Lithology	Thickness m	Thickness ft	Depth m	Depth ft
	Soil, clayey, grey-brown	0.4		0.4	
Till	Clay, mottled, red-brown, becoming stiff at depth, with subangular to subrounded clasts of granite, schist and quartz	3.8		4.2	
Glaciolacustrine deposits	Silt, clayey, sandy at top, red, stiff in parts, with bands of fine sand and red-brown laminated clay	3.8		8.0	
Till	Clay, sandy, greenish grey, with numerous clasts, often well rounded, of quartz, schist and weathered granite.	2.9		10.9	
Caledonian	Granite, weathered, coarsely crystalline, pink	0.3+		11.2	

GREEN VOLT

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