Appendix B.3:
NorthConnect Adjustment to Route Study
Addendum Route Study Report

Co-financed by the European Union
Connecting Europe Facility

NorthConnect KS
Serviceboks 603, Lundsiden
N-4606 Kristiansand
Norway

Phone +47 38 60 70 00
Mail: post@northconnect.no
Web: www.northconnect.no

NorthConnect Adjustment to Route Study
Addendum Route Study Report
NorthConnect KS

Assignment Number: A100295-S00
Document Number: A-100295-S00-REPT-001

Xodus Group Ltd
The Auction House
63A George St
Edinburgh
EH2 2JG
UK

T +44 (0)131 510 1010
E info@xodusgroup.com
www.xodusgroup.com

Integrated Services
Total Field Development

Addendum Route Study Report

A100295-S00

Client: NorthConnect KS
Document Type: Report
Document Number: A-100295-S00-REPT-001

R02	19/01/2015	Issued for Client Review	JM/GC	ID	RH	
R01	05/12/2014	Issued for Client Review	EP	GC	ID	
Rev	Date	Description	Issued by	Checked by	Approved by	Client Approval

Table of Contents

EXECUTIVE SUMMARY

In 2012 NorthConnect KS (NorthConnect) commissioned Xodus to undertake a Desktop Route Study for a proposed High Voltage Direct Current (HVDC) cable connection between Scotland and Norway. The study identified and analysed potential route options between Peterhead in Scotland and Sima or Samnanger in Norway. Since that study it has become necessary to look for alternatives to the Scotland landfall and NorthConnect is investigating a site to the south of Peterhead near Longhaven. This present study was therefore commissioned to assist NorthConnect in integrating the new Scotland landfall location into the previously chosen route across the North Sea.

This study has taken into consideration a wide range of environmental and technical issues. Technical and environmental constraints have been mapped and visualised in GIS and constraints maps have been documented in this report. Through two workshop sessions, three potential routes were identified (Figure 5-1 Appendix C):

- Route Option 1 – A direct corridor route from original cable corridor route to landing point near Longhaven;
- Route Option 2 – A route option skirting to the north of potential Annex 1 environmental sensitivity;
- Route Option 3 – A southern corridor route option, avoiding the proposed Hywind offshore wind development site and various potential environmental sensitivities.

Overall Route Option 3, whilst avoiding areas of environmental sensitivity, was considered least favourable due to its length and because it would pass through areas of seabed which could pose technical installation difficulties.

Route Option 2 was identified as the preferred option, closely followed by Route Option 1. Whilst some potential environmental constraints were present along these two routes, these can be avoided or mitigated through survey and detailed design.

1 INTRODUCTION

1.1 Project Background

NorthConnect is a joint venture between four owner companies, i.e. Vattenfall (Sweden) and Norwegian power companies Agder Energi, E-CO and Lyse.

The NorthConnect Project aims to develop, construct and operate a High Voltage Direct Current (HVDC) cable connection between Norway and the UK by 2021. In 2012 NorthConnect KS (NorthConnect) commissioned Xodus Group (Xodus) to undertake a Desktop Route Study for a proposed High Voltage Direct Current (HVDC) cable connection between Scotland and Norway. The study identified and analysed potential route options between Peterhead in Scotland and Sima (Simadalen) or Samnanger in Norway. Since that study it has become necessary to look for alternatives to the Scotland landfall and NorthConnect is investigating a site to the south of Peterhead near Longhaven. This present study was therefore commissioned to assist NorthConnect in integrating the new Scotland landfall location into the previously chosen route across the North Sea.

1.2 Current Project Status

NorthConnect has completed the following studies to date:

> A pre-FEED (Front End Engineering Design) study which included a cable corridor routing appraisal, environmental screening and constraints mapping for a series of possible locations for the UK landing points, and CAPEX (capital expenditure) and OPEX (operational expenditure) estimations;

> A Desktop Survey and Route Engineering Study (Ref. 1) which included environmental and technical constraints mapping, route option screening and selection, cost modelling, programme scheduling, route positioning lists for detailed survey and technical specification for geotechnical, geophysical and environmental survey;

> A feasibility study to investigate Horizontal Directional Drilling (HDD) at a new UK landfall at Longhaven, south of Peterhead and Sandford Bay.

The project has also made progress in terms of selection of a Norwegian landfall at Simadalen.

1.3 Project Description

This addendum study was designed to provide a clear understanding of constraints and opportunities and to demonstrate negative and positive attributes of the revised Scotland landfall.

The overall aim of this study is to investigate the most appropriate cable route to the new UK landing point at Longhaven. This study aims at identifying the route which balances technical feasibility and economic viability whilst ensuring the least disturbance to people and the environment.

The purpose of this study is to extend the original desktop route engineering study (Ref. 1) with the following objectives:

> Establish and assess all the possible additional environmental and technical constraints;

> Determine the optimum proposed route to link with the new UK landing point option; and

> Document findings to reflect this route adjustment.

The key requirements of the desktop study are summarised as follows:

> Identification of potential obstructions and/or areas to avoid;

> Identification of other subsea cables, pipelines and infrastructure and crossing constraints;

> Review of technical/engineering constraints that may have an effect on the installation and/or operation of an HVDC interconnector cable;

- Identification of potential installation difficulties and recommendations on how to mitigate these;
- Execution of environmental constraint mapping for corridor and route selection;
- Identification and prioritisation of realistic cable routes;
- Calculation of cable route lengths;
- Cable corridor route assessment and selection;
- Production of maps highlighting cable corridor route options; and
- Preparation of recommendations based on outcome option screening and selection and residual risks.

This study considered a wide range of environmental, technical and economic constraints influencing the development of the NorthConnect interconnector project. This has been conducted as a constraint-driven option screening and selection exercise which included the identification and evaluation of alternative subsea cable route corridor options concluding with the identification of one or several 'preferred corridor options'.

This work has been undertaken in close collaboration with NorthConnect.

2 SCOPE OF WORK

2.1 Scope of Work

The scope of work includes the following activities:

- Data gathering and constraints mapping. Collection of baseline constraint information for the study area in relation to environmental factors, legislation and consents, and human factors;
- Analysis of mapped constraints in relation to projected connection point and technical components to derive broad cable route corridor options which will connect the potential landfall area options;
- Corridor route option screening and selection. Constraint information will include physical factors, environmental factors, human factors and any other features or operations that would represent a risk to the safe and efficient installation, operation or repair of a submarine HVDC interconnector;
- Work with NorthConnect to exchange data where required and support the identification of the optimum proposed route corridor option to link with new UK landing location; and
- Document findings and recommendations to reflect this adjustment to the original preferred corridor route.

2.2 Deliverables

Outputs from this study include:

- Addendum Route Study Report including recommendations for additional data gathering;
- GIS shape files of cable route to UK landfall location;
- GIS cable route and constraint maps; and
- Nearshore/landfall HDD survey specification.

2.3 Exclusions

Revision of Route Positioning Lists (RPLs) is not part of this scope of work.

2.4 Assumptions

All spatial data used in the study has been obtained through readily available commercial and free sources. No further detailed analysis of data such as shipping routes or fisheries areas has been commissioned.

With regards shipping and navigation, charted locations of anchorages and navigation features was used as provided in SeaZone Hydrospatial data. This study did not purchase recreational yachting route data or commission detailed analysis of shipping traffic data.

Fisheries spatial data used in the assignment was obtained from publically available Scottish Government and Marine Management Organisation data sources.

3 METHODOLOGY

3.1 Data Gathering and Constraints Mapping

The constraint mapping exercise as part of the corridor and route selection process provided a means of identifying, assessing and reporting environmental effects of the project.

Information was gathered from Xodus in-house sources, publically available data, and data from any other bodies approved by NorthConnect. This activity used as its basis updated information from the sources used by Xodus for the earlier desk study carried out for NorthConnect. This process was also considerably eased by knowledge gained of the locality during the course of EIA and geotechnical studies undertaken for the ongoing Hywind wind farm project which overlaps this NorthConnect study area.

Constraint mapping was performed as an iterative process conducted in parallel with cable route design to identify and avoid potential environmental interactions or marine stakeholder constraints, and to develop mitigation measures to be incorporated into the design, installation and operation of the NorthConnect subsea cable route. The objective of constraint mapping was to:

> Identify and assess potential effects on environment, including marine stakeholders; and

> Identify and assess potential technical constraints.

3.2 Data Sources

Project data including the location of the UK cable landing point, the HVDC/HVAC converter station and substation location, together with the HDD feasibility report (Ref. 2) and the cable technical data sheet was provided by NorthConnect to inform the study.

In order to carry out the constraints analysis, the various specialists listed the constraints to be included in the study. GIS data was then obtained from a variety of sources as required and as listed in Appendix A. Much of the marine charted data was purchased from SeaZone in the form of their Hydrospatial Base product, which combines data from various sources into one 'seamless' GIS data source. Data is licensed by half degree tile coverage and enough data was licensed to cover the area from the proposed landfall to the first turn in the existing cable route. From this GIS database, the data themes required for analysis were extracted and buffered as required.

Other data sources were used for data not present in Hydrospatial, for example environmental designation areas and oil and gas infrastructure data. These other data sources are also listed in Appendix A.

Where the same spatial features were present in both Hydrospatial Base and data sourced from the data issuing authority, for oil and gas pipeline data and cable data, the data from the issuing authority was used instead of the Hydrospatial Base. This is because the data in Hydrospatial Base is derived from S57 charted data, and therefore the spatial accuracy of the data is dependent on the resolution of the charted data, which for offshore areas is at smaller scale and hence lower resolution. The pipeline data from UKOilandGasData is more accurate and can be regarded as a more definitive data source. For offshore cables, cable location data provided by Kingfisher Information Service – Offshore Renewable and Cable Awareness (KIS-ORCA) was used in preference to the data representing the same cables within Hydrospatial Base. Where a pipeline or cable was present in Hydrospatial Base but not in the data from the more official data source, such as cables not provided by KIS-ORCA, it was retained within the dataset to ensure as much data was captured as possible.

Bathymetry data in the form of a digital terrain model (DTM) was required to perform a slope analysis, which was already available and licensed to Xodus.

The data required were gathered in ESRI file geodatabases using ESRI ArcGIS GIS software. The datum for all project data is WGS84 and where required the data was transformed to this datum using the appropriate transformation within ArcGIS. The projected coordinate system used was WGS84 UTM 30N.

Constraints were grouped by weighting and layered accordingly in an ArcMap map, which was used as the basis for workshop sessions investigating the constraints and identifying the routes through them.

An overview of data constraints, weightings and buffer distances can be found in Appendix A.

3.3 Type of Constraints

3.3.1 Environmental, Consenting and Permitting Constraints

Any route selected will be required to take into account environmental sensitivities to ensure, where relevant, that the integrity of any environmental designations are maintained during works. In addition, environmental factors may influence the feasibility and safety of the cable installation and operations.

The proposed route must be acceptable to the owners of the offshore seabed, the owners of the foreshore and military authorities. Any crossing proposals must be acceptable to the operators of existing cables and pipelines.

This study has considered opportunities to:

- Avoid known areas of environmental sensitivities (e.g. marine conservation areas, fishing grounds, and coastal nesting grounds);
- Assess suitability burial capability;
- Assess potential landing issues;
- Avoid areas where prevailing climatic or sea conditions (e.g. tides, currents and wave activity) will render installation or maintenance difficult or hazardous;
- Avoid disturbance to environmentally sensitive areas;
- Avoid disturbance to economically sensitive areas (ref. shipping lanes, recreation and tourism);
- Avoid military activity areas such as submarine exercise areas and artillery ranges;
- Ensure early communication/consultation with relevant (marine) stakeholders; and
- Assess planning, consenting and permitting risks and legal constraints.

3.3.2 Technical constraints

The proposed route has taken into consideration technical constraints such as the following:

- HVDC cables will have a diameter of 125 mm with a weight of 52 kg/m;
- The fibre optic cable will have a diameter of 24 mm with a weight of 1.6 kg/m;
- Cables will be buried along their entire length apart from where burial is not possible, i.e. at cable or pipeline crossings or in areas where seabed characteristics do not allow for cable burial;
- In sections where cable burial is feasible, subsea cables will be buried at a recommended depth dependent on soil conditions;
- In sections where cable burial is not achievable, subsea cables will be covered with rock placement to provide a protective layer;
- The need for rock placement should be minimised because of the excessive CAPEX and OPEX cost. It may be desirable to deviate the route significantly to minimise rock-dumping;
- A variety of installation vessels may be required due to the likely variable nature of the seabed along the corridor as well as specific installation requirements on the approaches to the landfall sites;
- The proposed route(s) must allow for sufficient space for the installation spread (e.g. area of 1000 m in length and 500 m in width) to operate;

- Marine cables will be laid in sections of a predefined length, dependent on cable characteristics, installation method and installation/cable-lay vessel capacity;
- Since more than one subsea cable is required, consideration shall be given as to whether these should be bundled together and laid into the same trench, or laid unbundled in separate trenches;
- Where subsea cables are to be laid unbundled in separate trenches, a separation distance of 50 m is recommended in water depths of more than 40 m to mitigate possible issues with compass deviations attributable to electromagnetic field generation. However, for cable repair considerations, further discussion with cable installation contractors should be undertaken to promote safe operational philosophies;
- Subsea cables could be laid further apart (i.e. with a greater separation distance) if local seabed obstructions apply;
- In areas defined as high risk for snagging, extra cable protection may be required;
- Cable joints will be installed between sections;
- Cable joints will be manufactured onboard the installation vessel;
- The location of cable joints will be dependent on the length of subsea cable that can be carried by the installation vessel in one load;
- The location of cable joints will be carefully chosen to permit installation, avoid areas of conflict and allow for future maintenance and repair activities;
- A transition or jointing pit will be required to connect the subsea cables and onshore cables at the landfall site;
- If more than one subsea cable is required, subsea cables may be bundled on the approach to landfalls;
- The preferred method of cable installation at the Longhaven UK landfall is to use HDD from onshore to pull the cable through a drilled conduit.

The revised routing study for the Longhaven approach has addressed and considered the following:

- Avoid sea-bed hazards;
- Avoid obstructions such as wrecks and dumping grounds;
- Avoid, where possible, difficult or hazardous areas, such as steep slopes, irregular rocks, boulders, debris;
- Avoid, where possible, sand waves, mega-ripples, rock, coral and areas with soft sediment (moving sea-bed);
- Avoid areas of geological instability such as earthquake zones and landslip areas (i.e. both submarine and terrestrial cliffs at the shore);
- Avoid, where possible, areas where it might be difficult to trench and bury cables;
- Avoid, where possible, other subsea cables (live/decommissioned) and pipelines;
- Avoid, where possible, areas of high marine activities such as shipping lanes, anchorages and fishing grounds;
- Avoid, where possible, areas where recovery of subsea cable for maintenance, repair and/or decommissioning would be difficult;
- Avoid areas of existing or planned marine development sites (oil and gas, wind, wave and tidal);
- Avoid areas sensitive to cable faults;
- Assess marine cable constraints;
- Assess cable installation constraints (e.g. minimise changes in direction and the approaches to shore of the cable routing);

- Assess appropriate means of cable protection (e.g. cable armour type, rock placement), if and where required;
- Assess cable burial depth and width required;
- Ensure safe distance from other marine infrastructure;
- Assess technical risk of offshore cable installation;
- Assess the feasible offshore exit locations of the long HDD conduit, in consideration of the location of a preferred entry point onshore in order to help understand the seabed constraints to drilling operations (e.g. seabed sediments, excavation requirements, rock outcrops); In considering the location of the HDD starting point onshore, assess the possible offshore exit hole locations in terms of seabed constraints to drilling operations (e.g. seabed sediments, excavation requirements, rock outcrops);
- Assess the subsea connection and cable protection philosophy between the point where the cable exits the trench to the HDD exit point offshore.

3.3.3 Economic Constraints

Economic viability has been identified as a key driver to corridor and route selection. Overall CAPEX costs will be derived from material, installation, maintenance and survey costs. OPEX cost is unlikely to be a key differentiator between individual route options and therefore has not been considered as a significant constraint.

The selected route must be financially viable, in terms of both installation and maintenance.

This study has considered opportunities to optimise cable corridor and route selection in order to:

- Minimise cable length;
- Minimise number of cable joints;
- Minimise amount of cable/pipeline crossings;
- Minimise need for cable protection;
- Optimise choice of installation method (in terms of cost and lead time);
- Maximise cable burial/trenching rates, i.e. look for cable routes through sea-bed which is easily ploughable; and
- Ensure the route allows the cables to be installed by as many vessels as possible to ensure competitive tendering.

3.3.4 Technical Safety and Risk Constraints

Technical health, safety and risk were identified as potential key drivers for the project. The selected route must be secure in terms of cable installation and operations. Therefore this study has assessed different options to:

- Avoid known areas of Unexploded Ordnance (UXO);
- Look for areas allowing for safe installation and operation (e.g. offshore conditions, water depth, soil conditions, existing infrastructure);
- Avoid busy shipping areas to minimise risk of collisions or interference with other vessels during installation;
- Ensure limited exposure of cables to other vessels or infrastructure;
- Ensure safe distance from other offshore infrastructure;
- Minimise amount of cable and pipeline crossings; and
- Ensure appropriate means of cable protection is provided.

3.4 Weighting of Constraints

Constraints along any route identified, need to be differentiated in terms of magnitude, sensitivity and significance. The weighting proposed for this study is the same as for the original DTS-RS study conducted in 2012 (Ref. 1), as follows:

> Hard Constraints (High) – Cable route constraint mapping must avoid or prevent sensitive areas which impose a significant risk to key drivers such as project consenting, technical safety, cost and schedule (e.g. conservation areas, steep slopes, areas Unexploded Ordnance). Any cable route considered should avoid areas introducing adverse effects which need to be offset. Costs related to offsetting related activities (e.g. environmental mitigation plan, environmental management) are usually significant and may impact economic viability. These areas will be marked as 'no-go' areas.

> Medium Constraints (Medium) – Cable route design must reduce the effects in sensitive areas which impose a reasonable risk to project consenting (e.g. cable/pipeline crossings, shipping lanes).

> Soft Constraints (Low) – Cable route design must minimise the effects in sensitive areas which impose a small risk to project consenting.

An overview of data constraints, weightings and buffer distances can be found in Appendix D.

3.5 Safety and Buffer Distances

Safety and buffer distances have been defined for offshore infrastructure (e.g. cables, pipelines and existing/future offshore development sites) and designated/sensitive areas (e.g. sites of conservation interest). These buffer distances have been incorporated as part of good practice in order to avoid collision risk and impact on the environment.

The buffer distances have been adopted in the GIS data as per details stated in Xodus Route Option Analysis Report delivered as part of the 2012 DTS-RS Desktop Survey and Route Engineering Study. Offshore Safety Zones, which are typically applied as legally enforceable 500 m buffers around sensitive infrastructure, were not buffered any further.

An overview of data constraints, weightings and buffer distances can be found in Appendix D.

3.6 Iterative Approach

3.6.1 Corridor Route Option Screening and Selection (Xodus Internal Workshop)

Broad cable route corridor options connecting the existing route to the new UK landfall area options (i.e. Longhaven) were identified during an internal project team workshop session. The constraints to be used in analysis were identified by environmental and subsea specialists.

Constraints data were then compiled into an ArcMap GIS map and colour coded and grouped by weighting. The constraints were layered as required and, by projecting the GIS on a large TV screen, the corridors were identified during workshop sessions as 'paths of least resistance' through the constraints. Each corridor section was digitised during the workshop and then 'fine-tuned' afterwards to remove any digitising errors incurred during the live workshop session.

Possible locations of onshore HVDC/HVAC converter station, HVAC substation and onshore cable route options have been addressed separately. However, this study briefly looked at landfall opportunities (e.g. access) and constraints (e.g. local tourist attractions, Longhaven Wildlife Reserve) that may have an effect on the overall routing strategy to connect with the offshore approach.

3.6.2 Corridor Route Option Screening and Selection (Workshop with NorthConnect)

A Client workshop was then held, the focus of which was to present the findings from the Xodus internal workshop to NorthConnect, prior to the preparation of this Addendum Route Study Report. The aims of this workshop were to:

- Investigate the offshore route feasibility of a new UK landing point near Longhaven;
- Establish and assess all the possible additional environmental and technical constraints;
- Determine the optimum proposed route to link with the new UK landing point option; and
- Document findings to reflect this route adjustment.

This was a constraint mapping exercise which balanced technical feasibility and economic viability whilst ensuring the least disturbance to people and the environment. The approach was similar to that in the previous DTS-RS but without VDRM (Value, Decision and Risk Management). However, reference was made to the original project drivers (or project success criteria), namely:

- Environmental;
- Planning and consenting;
- Economic viability;
- Technical suitability; and
- Programme schedule.

The on-screen GIS walkthrough, facilitated by Xodus, focussed on:

- Results from the previous Desktop Route Study (2012 DTS-RS);
- The onshore locations of the HVDC/HVAC converter station and HVAC substation;
- Access roads and work areas (converter station and HDD);
- Proposed onshore cable route;
- Offshore/onshore environmental constraints;
- Offshore/onshore technical constraints; and
- Corridor route options.

3.7 Addendum Route Study Report

Results from the analysis of mapped constraints were presented in a draft study report for NorthConnect to review. The results from the desk study are presented in a series of constraints maps with supporting assessment matrices. This ensures that all options are fully recorded with justification for the rejection or inclusion of different fully documented for future reference. The report provides information on the criteria used to evaluate route options and the subsequent ranking of individual routes. The report also includes clear recommendations for taking forward preferred options, including measures avoiding or minimising risk as the route is developed in more detail.

3.8 Codes, Standards, Legislation and Industry Guidance

Xodus has referred to DNV recommended practice DNV-RP-J301 Subsea Power Cables in Shallow Water Renewable Energy Applications (February 2014) (Ref. 3).

4 RESULTS FROM CORRIDOR ROUTE IDENTIFICATION WORKSHOPS

4.1 Xodus (Internal) Workshop

The internal workshop was held at the Xodus office in Edinburgh (13th November 2014) and was attended by the following:

- Iain Dixon (Xodus – Environmental Specialist);
- Jenna McGuinness (Xodus – Environmental Consultant);
- Greg Cook (Xodus – Subsea Principal Engineer); and
- Jim Hunter (Xodus – GIS Lead).

The workshop considered all available constraints and identified the following two corridor route options (see Figure 5-1 Appendices C):

- Route Option 1 – A direct corridor from the original cable corridor route to a landing point near Longhaven; and
- Route Option 2 – A route option skirting very slightly to the north in order to avoid an area identified by JNCC as potential Annex 1 reef habitat.

4.2 Workshop with NorthConnect

Xodus attended the external Client workshop with NorthConnect on the 24th November 2014 to present the findings from the internal workshop. This meeting was also held at the Xodus office in Edinburgh, and was attended by the following:

- Richard Blanchfield (NorthConnect – Deputy Project Manager/Head of Technical);
- Fiona Henderson (NorthConnect – UK Permitting Lead);
- Edwin Pauwels (Xodus – Project Manager);
- Iain Dixon (Xodus – Environmental Specialist);
- Greg Cook (Xodus – Subsea Principal Engineer); and
- Jim Hunter (Xodus - GIS Lead).

During the meeting, a third corridor route option was established. Route Option 3 – A southern corridor route option, avoiding the Hywind offshore wind development site and various potential environmental sensitivities (Figure 6-1, Appendix D).

Environmental and technical constraints were discussed for all three corridor route options. A quantitative assessment was conducted with the following conclusions:

- Environmental – Route Option 1 is the most direct and therefore shortest route, but crosses an area of potential Annex 1 reef habitat. Route Option 2 has a similar cable length (if slightly longer) compared to Route Option 1, but avoids the area of potential Annex I reef habitat. Route Option 3 avoids all known offshore environmental sensitive areas, but is significantly longer (by ca 20 km) compared to Route Options 1 and 2, therefore implying a greater disturbance of the seabed. Note that all route options, including Route Option 3, will by necessity pass through the Buchan Ness to Collieston Coast Special Protection Area (SPA) in order to have a landfall in the vicinity of Longhaven.
- Planning and Consenting – Route Option 3 implies six extra cable/pipeline crossings (compared to Route Options 1 and 2), with increased risk to marine stakeholders. As mentioned above this option poses greater disturbance to the seabed even though it avoids various potentially sensitive environmental areas. Route Option 2 is favoured above Route Option 1, as it avoids the potential Annex 1 reef habitat environmental constraint.

- Economic Viability – Route Option 3 is the least favourable candidate in terms of cable length and number of cable/pipeline crossings. Route Option 1 is slightly shorter than 2, and therefore considered most favourable.
- Technical Suitability – Route Options 1 and 2 are comparable in terms of technical suitability considering similar soil conditions and cable length. Route Option 3 is least favourable considering cable length, number of cable/pipeline crossings and higher risk of exposure to sand waves.
- Programme Schedule – Route Option 3 was considered least favourable due to cable length and number of cable/pipeline crossings. Route Options 1 and 2 were considered to be on a par.

Overall, general consensus was reached identifying Route Option 3 as the least favourable and Route Option 2 as the preferred option (closely followed by Route Option 1).

5 SUBSEA CABLE ROUTE ENGINEERING CONSIDERATIONS

5.1 Cable Characteristics

General information on cable characteristics was provided to Xodus by NorthConnect KS. A technical data sheet for the 500kV HVDC cable and URC-1 Fibre Optic cable from Nexans (cable manufacturer) can be found in Appendix C. It is understood that the NorthConnect HVDC link will comprise 2No. HVDC cables and 1No. fibre optic cable.

Each 500 kV high voltage cable is approximately 125 mm in outer diameter, weighs approximately 52 kg/m in air, and has a minimum bending radius of 3 m. The cable has a copper core, is insulated with water washed wood pulp HVDC cable paper impregnated with high viscosity cable oil for DC cables, is protected by two layers of steel cable armouring, and has a 3.3 mm lead alloy sheath.

The fibre optic cable is approximately 24 mm in outer diameter, weighs approximately 1.6 kg/m in air, and has a minimum bending radius of <1 m. The cable itself is a stainless steel tube containing up to 48 optical fibres and a copper conductor as an electrode. The cable is armoured with two layers of steel wire and sheathed with either a polypropylene or polyethylene material for the outer protection.

The HVDC cables will be installed unbundled (separate) or possibly bundled (together) depending on crossing arrangements, landfall requirements and electromagnetic impact on navigation, marine life or offshore infrastructure. In the previous study, it was indicated that compass deviations induced from the electromagnetic fields generated by unbundled cables need special consideration in water depths of <40 m in UK territorial waters if the cables are laid in a north-south direction. This was an issue raised for landfall approaches coming into the UK, but was unlikely to be a significant concern for this study as the cable route approach to a northeast UK landfall is unlikely to be aligned north-south due to the geography of the site (i.e. a north-south trending coastline). Further thought to bundling the cables at the landfall approaches could help mitigate such a concern. However, it is emphasised that such issues are for detailed design consideration when addressing the installation methodologies that follow on from this study. In that respect Xodus suggests that these issues should be addressed in future phases of the project in consultation with cable manufacturers and installation contractors to determine the best solution.

The fibre optic cable is likely to be laid separately from the HVDC cables to mitigate any risk of damage that may be caused from bundling the cables together. Therefore, the fibre optic cable may be laid into the same trench as one of the HVDC cables or be trenched separately for protection. The installation methodology will need a comprehensive risk assessment to determine the most appropriate trenching tool and the operational preference of the lay and trenching contractor.

During route design, special consideration has been given to (existing/future) offshore infrastructure, soil conditions, slope analysis, installation method, burial depth, crossing arrangements, scour protection and cable protection measures to protect the cables from failure during operations, and to ensure maximum availability during the project lifecycle.

It was initially assumed that a minimum 30 m cable separation would be a base case safe separation distance for installation activities (i.e. lay and trenching), as is commonly adopted in the offshore oil and gas and renewables industry to mitigate any risks associated with minor route deviations that can occur during operations. However, subsequent to the initial study in 2012, DNV has generated a new guideline for subsea power cable installation in shallow water for renewable energy applications (Ref. 3). The guideline does not suggest what specific distances should be adopted; however, for cables laid parallel to each other, it is recommended that due consideration should be given to the potential repair of a cable to work out a safe laydown distance. This is generally dependant on spatial requirements for the repair bight to be laid on the seabed, which will depend on water depth, repair vessel deck height, required deck length and crown radius of the bight. Additionally, further room may have to be foreseen for future intervention.

As the NorthConnect cables will be laid in water depths varying between 20 m to 800 m across the North Sea and within deep Norwegian fjords, a nominal 50 m cable separation distance is considered reasonable for planning purposes. This considers a 150 m wide installation corridor for 2No. cables, or 200 m for 3No. separate cables if the fibre optic cable is to be laid and trenched separately.

For cable failure and repair operations where the damaged cable is removed and extra lengths of the new cable are installed, specific and focussed survey should be undertaken to identify any seabed hazards in the laydown area where the extra length(s) are to be laid. It would be expected that repair of the outer cables would involve lay away from the centre cable so interference is avoided. Such issues regarding repair activities need special consideration and require further attention during the next phase of the project in discussion with cable designers and installation contractors.

For the UK landfall option, HDD is been considered at Longhaven. Two typical HDD installation methodologies for pulling the offshore cables to shore need to be considered: (worst case) three separate HDD holes and cable–pulls; or (more likely) two with the fibre optic cable bundled with one of the two power cables. The most appropriate methodology needs further investigation through a separate study in consultation with an HDD contractor and a potential cable manufacturer to determine which approach carries the least risk to cable installation damage, but which approach is also the most cost-effective solution.

5.2 Geotechnical and Geophysical Assessment

Xodus has used licensed publically available data from the BGS and knowledge of in-house survey data of geological and geotechnical conditions around the proposed landfall location at Long Haven Bay between Peterhead and Cruden Bay, both onshore and offshore to assess the main seabed issues that may potentially impact the proposed cable routing. The sections below present the data reviewed and how the geology was assessed to help determine the effects of route selection.

5.2.1 Available Information

Table 5-1 below lists the data used in the compilation of this report.

Document/ License No.	Title	Company/Author	Revision and Issue Date	Ref.
n/a	United Kingdom offshore regional report: the geology of the northern North Sea	Johnson, H., Richards, P.C., Long, D. and Graham, C.C. HMSO for the BGS	1993	4
n/a	United Kingdom offshore regional report: the geology of the central North Sea	Gatliff, R.W., Richards, P.C., Smith, K., Graham, C.C., McCormac, M., Smith, N.J.P., Long, D., Cameron, T.D.J., Evans, D., Stevenson, A.G., Bulat, J. and Ritchie, J.D. HMSO for the BGS	1994	5
2014/029	DigSBS250, DigQuat250	BGS	2014	-
2014/029, 2013/051	DigRock250	BGS	2014	-
n/a	Seabed Sediments – Peterhead (Sheet 57°N-02°W)	BGS	1984	6
n/a	Quaternary Geology – Peterhead (Sheet 57°N-02°W)	BGS	1986	7
n/a	Solid Geology – Peterhead (Sheet 57°N-02°W)	BGS	1982	8
o1055377	Hydrospatial (marine spatial data including charted data, wrecks, obstructions, buoys, cables, etc.)	SeaZone	2014	-
n/a	Oil & Gas Infrastructure	UKOilandGasData	2014	-
0100031673	Basemapping	Ordnance Survey	2012	-

Table 5-1: Available geological and geotechnical data

The geological and geotechnical appraisal is confined to the evaluation of data provided within these documents and sources, with the primary focus on the surficial seabed sediments and underlying Quaternary soil conditions, as these are of direct concern for lay and trenching activities.

5.2.1.1 Data Limitations

The offshore Peterhead area is covered by some general, but non-specific seabed data. By non-specific, the meaning is that the data available characterises only a broad range of seabed bathymetry and features rather than providing specific data for the cable route corridors under consideration. However, the data is still useful enough to get a general impression of seabed topography, seabed sediments and subsurface geology on which to develop an understanding of what site specific survey is required to reduce the uncertainty and risk associated with cable lay and trenching activities.

The SeaZone Hydrospatial and UKOilandGasData electronic datasets were used to generate the bathymetric contouring of the site and to understand the risk and constraint of wrecks and other known manmade features (e.g. dumping grounds, anchorage areas, buoys, obstructions, military areas, etc.) across the area. The Ordnance Survey data was used to map all onshore features such as topographic elevations, roads, urban areas, recreational ground, protected areas, etc., in combination with the site geology.

This study concentrates mainly on the offshore aspect of the cable routing; hence offshore/marine BGS data was purchased electronically to map the seabed geology. Four datasets (BGS digital data or seabed sediments, Quaternary Geology, and Solid Geology for Onshore and Offshore) were evaluated and cross-checked with more detailed information from hard copy 1:250,000 Peterhead sheets (Refs. 6, 7, 8) and offshore regional geology reports (Ref. 4, 5). The hard copy data provides more description on geological formations and of seabed sediment features sometimes not currently presented in the electronic data.

Additionally, the BGS provides sample station data through their web based offshore GeoIndex system that can identify relevant seabed coring data held by the BGS and of data that is owned by outside third parties, mainly oil and gas operators. The BGS data is usually a random distribution of sample stations across the seabed for general ground-truthing of their maps. The third party data is generally specific to a field development such as a pipeline route survey or where subsea and topside architecture has been installed (i.e. an oil or gas field). The data is scanned and provided as electronic core logs (e.g. grab samples, gravity cores, vibrocores, cone penetration tests (CPTs), boreholes, etc.).

It is known that some proprietary company survey data exists for some of the existing pipelines that come into the greater Peterhead area, that reports both geophysical and geotechnical site test information. Such data includes the geophysical interpretation of the seabed surface, i.e. sediments and features/bedforms, and of the shallow geology to bedrock contact, which is supported by some CPT/VC/PC/GC tests. This data is not referenced in this report or reproduced in any form, as it is proprietary data and cannot be used without gaining the appropriate permissions. However, the information contained within such documents has been used to gain a more informed interpretation of the seabed soil conditions.

For example, data along the Cruden Bay pipeline corridor indicates the seabed contains features such as sandwaves (large scale wave-like bedform features, typically > 100 m wavelength and being several metres high), megaripples (typically a ripple-like feature having a wavelength greater than 1 m or a ripple height > 100 mm), and longitudinal gravel patches, which correlates broadly with the BGS data. This helps give confidence that the coarser data sets from the BGS are still indicative of what to expect and hence is useful for this study.

5.2.2 Site Description

The following descriptions of seabed conditions relevant to the area of interest for this addendum study is presented in the following sections below. Appendix C presents the maps related to this assessment.

5.2.2.1 Bathymetry

Water depths from the point of where the new corridor route breaks from the initial route corridor vary from approximately 90 m below mean sea level near the Nexen Blackbird field development and shallows gradually west toward shore until about 3 – 4 km from the coast before the slope increases more sharply to a rocky shore.

Figure 5-1 “Bathymetry” in Appendix C presents a chart of the high level seabed bathymetry charted across the North Sea from Longhaven to where the revised routing joins the rest of the main cable corridor. This is supported by a slope plot to highlight how the bathymetry reflects seabed features over the wider area (see Figure 5-2 “Seabed Slopes” in Appendix C).

5.2.2.2 Seabed Features

Major seabed features expected along the proposed routes comprise:

> Megaripple fields and sand ridges between the Peterhead coast and the start of the large soft sediment basin known as the Witch Ground Basin;

> Pockmark fields, with occurrences of potential local authigenic carbonate features (MDAC) and potential shallow gas in connection with the very soft clays of the Witch Ground Basin, are expected in the eastern portion of the revised route;

> Localised linear gravel beds and patches of harder reef-like substrates are expected off the coast of Peterhead.

The megaripple and sandwave fields are obvious on Figure 5-2 “Seabed Slopes” in Appendix C, mainly in the south of the chart where Option 3 is routed. Such features are problematic for lay and trenching operations and hence may require significant route deviation if they are a feature to be avoided. Therefore, a detailed route survey will be required to understand the impact of such features to lay and trenching activities and to determine if any route deviations are required, if such hazards present a major risk to installation operations.

As indicated in Figure 5-3 “Seabed Sediments” in Appendix C, a number of potential crossing points have been identified along the proposed cable corridor routes, which is discussed more in Section 6.1.

For crossing design considerations, concrete mattress supports and rock placement protection are typical methods adopted to safely bridge and protect existing products on the seabed when a cable is laid over it (see Section 5.5). For trenching approaches to crossings, a transition distance (i.e. grading in/out from seabed level to full trench depth) of nominal length (typically 30 m) should be included for preliminary planning purposes. However, this can be refined by the installation contractor during an operations review prior to offshore activities and will be dependent on the chosen trenching/burial/protection technique selected.

5.2.2.3 Shallow Soil Conditions

As indicated earlier, coverage of the shallow seabed geology has been mapped geologically by the BGS based on geophysical interpretation and supplemented with some basic grab sampling of the seabed to ground-truth the data. Seabed sediments from the point of where the break in the original route occurs are expected to comprise predominantly superficial deposits of Holocene sands (sometimes gravelly), which generally occur as a very thin veneer blanketing the area (less than 0.5 m). Figure 5-3 “Seabed Sediments” in Appendix C presents the distribution of seabed sediments expected across the revised cable route corridors, as charted by the BGS.

Underlying the veneer, the BGS indicate that the Quaternary soils comprise Forth Formation sediments and potentially isolated patches of the Wee Bankie Formation (gravels), Witch Ground Formation (soft clays) and Coal Pit Formation (interbedded sands and clays). Based on geophysical records, the Quaternary sediments are relatively thin (up to 40 m thick) where they directly overlie basement bedrock, and this becomes progressively thinner west towards the coast where such sediments completely pinch out.

The sections below present more detail on each of the geological formations expected along the cable corridor routes.

Forth Formation

The Forth Formation consists a series of marine, glaciomarine, and fluviomarine facies (i.e. appearance and characteristics of the rock/soil unit reflecting its condition of origin, i.e. depositional environment), which comprises a series of fine to coarse sand and pebbly marine muds (silty clays) sediments. Offshore Peterhead, two facies are represented; the St. Andrews Bay and Largo Bay Members, but with the majority of the area being mapped as undivided (Refs. 5 and 7). This formation is considered to be laterally equivalent to the Witch Ground Formation that becomes more prevalent further east where the revised route joins the original route corridor. More specific pipeline route survey data indicate the Forth Formation in this area consists mainly of SAND with fine gravel, but changes into Witch Ground Formation type deposits further east (fine sands, silts and clays). The Forth Formation is expected to only occur as a thin soil unit across the wider area being only 2 – 3 m thick.

Witch Ground Formation

The Witch Ground Formation is expected to become more prevalent to the east of the revised cable corridor. Sediments generally comprise very soft to soft glaciomarine muds overlying an undulating erosive surface of older formations (Ref. 7), in this case the Coal Pit Formation. The BGS and other survey reports describe the sediments in this area to consist layered fine sands, silts and clays that are possibly pebbly and becoming more clayey with depth that often form infill channel features incised into the Coal Pit Formation.

Wee Bankie Formation

This formation is indicated to outcrop locally as rare discrete patches off the coast of Peterhead. It directly underlies the Forth Formation and is likely to only be a thin deposit as indicated by some geophysical route survey cross sections. The BGS indicate the formation is a till deposit comprising thin interbedded layers of sand and silty clay, and coarse sand and gravel deposits (Ref. 7). It is thought to lie directly over bedrock or over older ice-pushed Quaternary deposits, but is typically thin (< 5m thick). Closer to shore, it is expected to lie directly over bedrock.

Coal Pit Formation

The Coal Pit Formation is expected to underlie the younger geological units described above, but may not outcrop at the seabed within the zone of the revised cable route corridors. The BGS and route survey data indicate that the Coal Pit Formation forms an erosive contact with the sediments above and below it, typically being only 5 – 10 m thick. The formation itself is indicated to consist marine sands and pebbly glaciomarine muds and sands (Ref. 7).

The distribution of Quaternary soil formations expected to lie across the revised cable route section is presented in Figure 5-4 "BGS Quaternary Geology" in Appendix C and summarised in Table 5-2.

Geological Unit	Main Soil Type	General Description
Forth Formation, Upper	Sand	Medium dense to very dense fine SAND, locally gravelly
Forth Formation, Lower	Clay	Very soft to stiff slightly sandy CLAY, partings and layers of sand. Near the Scottish coast, includes the St Andrew's Bay member, soft to stiff laminated plastic CLAY with gravel.
Witch Ground Formation	Clay	Very soft to soft slightly sandy CLAY with fine to coarse gravel, can grade to SILT or to SAND soils at the margins of the Witch Ground Basin
Wee Bankie Formation	Till	Interbedded layers of dense SAND and stiff silty CLAY, with coarse sand and GRAVEL
Coal Pit Formation	Sand and Clay	Firm to very stiff CLAY and dense to very dense SAND

Table 5-2: Shallow soils expected in the UK sector

5.2.3 Bedrock Outcrops and Hard Substrata

The BGS has mapped the underlying offshore solid geology across the Peterhead area, which is presented in Figure 5-5 "Onshore and Offshore Solid Geology" in Appendix C.

In addition to this knowledge, the BGS has also mapped pre-Quaternary bedrock outcrops along the Peterhead coast, which is applicable to the landfall section at Longhaven (see Figure 5-6 "Coastal Bedrock Outcrops at Proposed Landfall" in Appendix C). As the map indicates, hard substrata are not reported offshore from a geological perspective as Quaternary sediments blanket the underlying bedrock geology. However, bedrock outcrops have been charted at two or three locations very close to shore within 1 km of the Longhaven landfall location, in addition to which the JNCC has identified the potential for rocky reef habitat to outcrop along the whole coastline within a kilometre or so from the shore (Figure 5-6). Finally, localised patches of harder seabed may occur which are not bedrock derived, e.g. gravel lag deposits and cemented reefs built by organisms. These are not mapped to any extent; therefore such areas will need to be identified from the route corridor survey.

5.2.4 Geohazards and Geotechnical Risks

A preliminary identification of possible geotechnical-related risks along the routes include:

- Seabed and sub-seabed boulders;
- Megaripples and sand waves;
- Pockmarks;
- Shallow gas;
- Gas-cemented hard ground (Methane Derived Authigenic Carbonate, MDAC);
- Local steep seabed gradients (e.g. sandwaves);

- Local areas of unstable/mobile sediments (e.g. megaripples, pockmarks);
- Bedrock (i.e. at the landfall);
- Offshore hard substrata (e.g. bedrock and cemented organic reefs);
- Gravel beds or lag deposits.

Additional risks include existing debris or dropped objects in areas of existing subsea infrastructure and local areas with strong bottom currents (e.g. around the megaripple/sandwave fields), and trawl/anchor scars, which indicate seabed interaction from man-made activities.

Such risks need to be confirmed by a site specific route corridor survey to gauge the level of risk such hazards have on final route alignment, cable installation, and further design considerations (e.g. crossings).

5.2.5 Trenchability

A preliminary review of expected soils within trench depth (typically up to 3 m below seabed) has been carried out to develop an initial classification of soil risk to trenching activities along the revised cable routes for the Longhaven approach. Please note that the assessment is only preliminary at this stage based on the limitations of available data, and before any route specific survey has been carried out. It is expected that significant local variations are possible in the shallow geology and that this uncertainty will only be identified during such a survey.

Based on the seabed geology and features described in Sections 5.2.2, 5.2.3, and 5.2.4, a summary of seabed conditions for each route option is given below in Table 5-3 to help assess the most appropriate trenching tool(s) for cable burial.

Route Corridor	Seabed Features	Geology (top 5m of soil profile)
1	> Bedrock exposure at the coast, which is likely to extend several hundred metres from the sea cliffs > A veneer of granular soils that blankets the route: gravelly SAND and slightly gravelly SAND > Route passes through a potential reef feature that is not mapped as a physical observation; listed as a potential MPA – to be confirmed by site survey	Shallow soil conditions are expected to comprise: > Fine to medium SAND with fine gravel of undivided Forth Formation > Dense Sand and Stiff Clay of the Coal Pit Formation expected ~43.5 km from Longhaven
2	> Bedrock exposure at the coast, which is likely to extend several hundred metres from the sea cliffs > A veneer of granular soils that blankets the route: gravelly SAND and slightly gravelly SAND > Route deviation to the north from 'Route 2' includes avoiding a potential reef feature that is not mapped as a physical observation; listed as a potential MPA	Shallow soil conditions are expected to comprise: > Fine to medium SAND with fine gravel of undivided Forth Formation - unlikely that the St Andrews Member expected this far north according to BGS charts > Possible local highs of sandy and gravelly clay tills (Wee Bankie Formation) may be encountered 15-20km from Longhaven > Dense Sand and Stiff Clay of the Coal Pit Formation expected ~45 km from Longhaven
3	> Bedrock exposure at the coast, which is likely to extend out several hundred metres from the sea cliffs > A more vairable veneer of granular soils that blankets the route: gravelly SAND, slightly gravelly SAND, and SAND > Sandwave/megaripple fields expected within 5 km from shore and further offshore at ~10-15 km from Longhaven > Route deviation to the south avoids any potential reef features charted within the desinated potential MPA that may appear along the route	Shallow soil conditions are expected to comprise: > veneer of granular soils (Holocene sands) and gravelly sands over fine to medium sand and silts and local shelly lags (Forth Formation) > Potential for an ara of ice-push Forth Formation sediments at ~40 km from Longhaven, which could be denser than the surrounding soils > A slither of Coal Pit Formation (Dense Sand and Stiff Clay) expected ~43 – 45 km from Longhaven. > Soft sandy CLAY of the Witch Ground Formation expected at ~56 km from Longhaven > Dense Sand and Stiff Clay of the Coal Pit Formation expected ~70 km from Longhaven

Table 5-3: Seabed Conditions Anticipated along each Cable Corridor – see maps in Appendix B for reference

5.2.5.1 Trenching Solutions

The previous study for the whole of the NorthConnect cable corridor from Peterhead to Norway indicated that the only trenching asset capable of burying the products as a stand alone tool would be a plough, specifically a heavy duty cable plough. This is still considered the most practical case if a single trenching asset type approach. However, it was also recommended that a trenching strategy that uses a combination of other tools should also be considered.

For the revised cable routing further south to Longhaven, a simplified risk based approach to trenching tool selection based on soil conditions within the top 2 – 3 m of the soil profile (i.e. within typical trench depth) is presented. This approach adopts an assessment that considers what soils are difficult to trench (i.e. high risk) and what are considered to be easily achievable (i.e. low risk), as presented in Table 5-4 below. Generally, the coarser the material the more difficult it is to trench. However, specialist tools should be considered for specific soils to make operations more effective and to manage the risk better.

Parameter	Very soft to soft CLAY	Firm to very Stiff CLAY	SAND*	GRAVEL
RISK	Low	Medium	Low to Medium	High

* Depends of soil density, i.e. loose sand is low risk, but dense sand is considered medium risk

Table 5-4: General soils risk to trenching operations within 2m – 3m depth of the soil profile

To present the typical types of subsea burial tool options available on the market today, a summary is given below:

- Ploughing – Ploughs are passive tools, which cut through the seabed and lift the soil out of the trench. They are pulled along the seabed from a vessel and are designed to cut either a V-shaped of slot-shaped trench. Of the various trenching techniques available, ploughs are the most suited to variable soil conditions and are better suited to relatively long sections of trenching. Cable ploughs in particular produce slot-shaped trenches that replaces the soil wedge during the ploughing process, to better protect the cable from damage by dragged or dropped objects.
- Water Jetting – Jetting tools excavate a trench by directing a jet of water at the trench face. In sand, the soil is fluidised and the cable can sink through this slurry, with sand settling out of suspension over the product as natural backfill. In soft clay, the jetting process cuts through the clay and spoil is carried out of the trench by the flow of water. Many of these tools also have greater independent mobility, as many are free-flying ROV based tools, to avoid seabed hazards, topographical constraints and to manoeuvre around existing subsea architecture. These tools are not suitable for stiff clay soil conditions or where cobbles/boulders are present.
- Mechanical Cutter Jetter – Mechanical trenching machines generally comprise a series of picks mounted on a chain or on a wheel. The soil is excavated by the picks and transported from the trench either by the chain, or in some cases by eductors. Mechanical cutting tools are more suitable for cutting seabed's comprising soft to stiff CLAY soils, and are less effective in sand, whereby jetting tools would be more efficient. However, such machines sometimes have a combined jetting and mechanical trenching capability to cover a range of soil types. It should be noted that mechanical cutters are not suited to gravelly soils or soils containing isolated or conglomerations of cobbles/boulders, and are equally not suitable in very soft clay seabeds due to potential sinkage and loss of traction. For planning purposes, track driven mechanical cutting tools are relatively slow and require high maintenance compared to other trenching options (i.e. ploughs and jetters).

Based on the anticipated soil conditions, soils risks, and trenching tool capabilities presented above, Table 5-5 presents possible trenching tool options considered most suited to the regional geology across the revised route corridors.

Approx. Distance from Longhaven (km)	Seabed Topography	Expected Shallow Soils	Soil Risks	Suitable Burial Solutions	Comment	Preliminary Trenching Risk Rating
0-40 (All Routes)	UK continental shelf, shallow water (generally < 100 m)	SAND, locally gravelly, over very soft to stiff CLAY	> Sand waves, megaripples, > Localised gravelly soils, > Seabed or buried cobbles and boulders	Plough, or Powerful Jetter (>1 MW) Mechanical combined cutting/jetting as alternative to the above	> Bedrock/hard substrate exposures closer to shore > Route specific survey required to determine if and where jetting methods could be feasible on sections of the route	Hard trenching High (remediation measures likely to be required closer to the coast)
40-80 (All Routes)	UK continental shelf, deeper water (generally > 100 m)	SAND over very soft to very stiff CLAY interlayered with loose to very dense SAND	> Sand waves, megaripples, > Localised gravelly soils, > Seabed and buried cobbles and boulders > Pockmarks and/or assoc. MDAC in Witch Ground Basin	Plough, or Powerful Jetter (>1 MW) Mechanical combined cutting/jetting as alternative to the above	> Large variation in thickness of seabed sands > Route specific survey required to determine if and where jetting methods could be feasible on sections of the route	Medium to Hard trenching Medium to High

Table 5-5: Preliminary Trenching Assessment of Revised Route Options (all routes)

The feasibility of combining water jetting with another tool for use in unjettable clay areas will require data from a route-specific survey (e.g. mechancial cutter with dual jetting capability). It is, however, likely that in light of the length of the route and the difference in performance speed between water jetting options and a cable plough, that a plough solution will prove to be a lower risk and be a more attractive solution economically.

Depending on the final required depth of lowering for the products, water jetting is evaluated to be suitable for product burial over the majority of the route, with the main limitation to the method being the occurrence of unjettable clay below the seabed sand veneer.

5.3 Cable Installation

Cable installation was discussed in the previous report, where cable lay for a project involving several hundred kilometres of cable lay activity would likely involve a Cable Lay Vessel (CLV) with significant cable carrying capacity, such as the C/S “Skagerrak” that holds a 7,000Te cable carousel/turntable. Currently there are only a few vessels in the world available to be able to install cables of significant distance to reduce mobilisations and lay schedules; therefore securing such vessels early is key to ensuring successful project delivery.

In combination with lay activities, trenching may be possible from the CLV provided the trenching tool is suitable for the expected soil conditions (i.e. simultaneous operations). However, if soil conditions dictate that a more specialist trenching tool should be used that cannot be mobilised onto the CLV, then a separate Trenching Support Vessel (TSV) will need to be mobilised to post-lay trench the cable. This may help reduce operational risks and costs in the long term as lay operations would not be tied to trenching operations, i.e. vessel schedules/activities can be more flexible to deal with delays/operational downtime between vessels.

As considered previously, a target burial depth of 1 m above top of product should be sufficient to protect the cable against most fishing gear interaction activities. Greater burial depths would only be required where there is a risk of deep anchor penetration from passing vessels; however such areas would normally be avoided during subsequent route optimisation screening phases.

In areas where trenching cannot be performed due to constraints, such as:

- soil conditions being too difficult to trench (e.g. gravel lag deposits);
- where seabed topography is too steep for a trenching tool to safely bury a product (e.g. large sandwaves);
- at pipeline/cable crossings and areas of other seabed infrastructure;
- in areas where bedrock is exposed at the seabed (e.g. near the coast at Longhaven),
- in shallow water potentially where wind, waves, tides can severely limit the operability of trenching tools;

Then the cables will need alternative protection such as rock placement or concrete mattressing. This is discussed further below in Section 5.5.

5.4 Landfall at Longhaven

Currently it is planned to use Horizontal Directional Drilling (HDD) techniques to bring the offshore cable to shore from a point around Longhaven. The HDD will likely be drilled from shore above the cliffs from a platform located safely behind the cliff edge, to exit several hundred metres offshore from the coast. Provisional HDD lengths of 800 m have been indicated by Technip (Ref. 2); however a separate study should be carried out by a suitably qualified HDD contractor to determine the best option for the site itself, as many more variables need to be considered for the technique.

The exit point offshore (i.e. where the HDD drill exits the ground at seabed) needs special consideration with regards to what subsea excavation/dredging is required and in what water depth. It is recommended to target a water depth of ~20 m below low tide and away from any rock substrata, so the vessel employed to survey the majority of the cable corridor can successfully acquire data without having to mobilise another nearshore/shallow draft vessel to complete the survey (i.e. as a separate activity). However, if this is not achievable for technical reasons (e.g. HDD distance is too long to reach 20 m water depth contour) then a nearshore survey (including intertidal areas) would need to be carried out to ensure the seabed has been qualitatively assessed for risks and constraints to installation activities. The nearshore survey would need to cover the seabed zone between the land based HDD entry point to the offshore exit point approximately 1 km offshore. This will likely require a separate mobilisation of a shallow drafted survey vessel that has the capability to access water depths of < 5 m and operate to within a safe distance from the sea cliffs and/or shallow beaches in Long Haven Bay.

It is expected that the nearshore area within 1 km of the coast will consist of a rocky seabed (see Section 5.2.3) with patches of coarse sediments; therefore, the survey should be set-up to best qualify the extent and nature of such conditions.

5.5 Cable Protection

Cable protection at landfalls and crossings along the routes can be achieved using several methods. Typically for subsea applications it is rock placement, with a minimum cover height of ca. 0.5 m above top of product and contoured to protect against fishing activity. Concrete mattresses can also be considered if fishing activity is not considered to be a high risk in a particular area; however these are often not a long term solution.

At landfall approaches, concrete tunnel structures or large diameter conduits could be utilised to protect the cables. However, this solution may be more cost-inefficient compared to rock placement.

5.6 Scour Protection

Scour protection of the cables can be achieved by either concrete mattresses or rock placement. Both techniques can be performed efficiently and placement achieved to a high positional tolerance. Not until detailed design phase can this be considered further; however, for this study it has been assumed that rock placement would be the most appropriate solution.

5.7 Cable and Pipeline Crossing Arrangements

Crossing design over existing pipelines and cables is generally site specific and tailored to the product to be crossed, which is heavily dependent on the requirements of the individual asset owners. However, typical crossing designs were considered for the initial study and the typical drawings are presented below in Figure 5-1 and Figure 5-2.

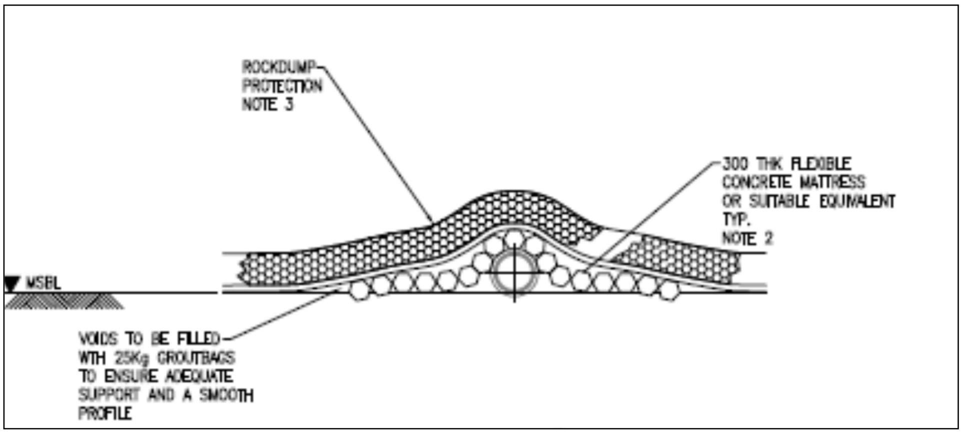


Figure 5-1: Section through a typical surface laid pipeline crossing

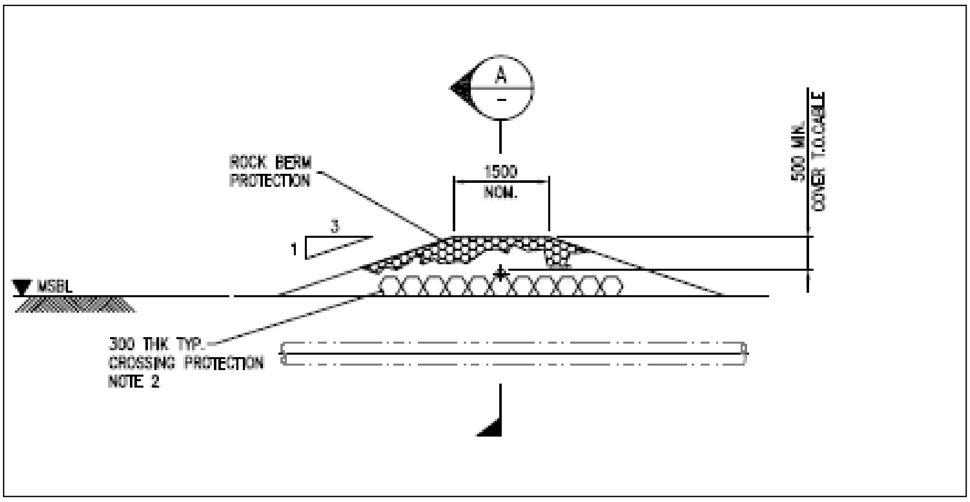


Figure 5-2: Section through a typical trenched and backfilled pipeline crossing

5.8 Thermal Properties of Seabed Soils

Thermal conductivity of seabed soils may have an impact on cable performance and should be considered by cable designers to ensure any effects have been addressed. Typical values for thermal conductivity of seabed soil types expected in the North Sea and for typical rock placement material are presented in Table 5-6 below.

Soil Type	Thermal Conductivity W/mK
SAND	1.5 - 2.5
CLAY	0.8 – 1.8
ROCK	2.0 – 2.5

Table 5-6: Typical thermal conductivity values for North Sea soils and rock placement material

6 PHYSICAL ENVIRONMENT AND ECOLOGICAL CONSIDERATIONS

This section outlines key physical, biological and socio-economic features of the Longhaven landfall and approaches, highlighting the constraints these may pose to the route options. The following topics are considered:

- Cable and pipeline crossings;
- Oil and gas infrastructure;
- Offshore renewable energy development sites;
- Commercial fisheries;
- Shipping, navigation and anchorages;
- Dredging, disposal and military practice areas; and
- Cultural heritage (marine and terrestrial);

Figures to accompany this section are referenced throughout and can be found in Appendix D.

6.1 Cable and Pipeline Crossings

Route Options 1 and 2 have two pipeline crossings and no cable crossings. However, the Hywind pilot offshore wind park project, approximately 23 km east of Peterhead, is currently in planning and this will have power export cables coming ashore at Peterhead (Figure 6-1 and 6-2). Depending on the relative timescales of this pilot wind park and the NorthConnect cable projects, there is therefore the potential for a cable crossing for Route Options 1 and 2.

Route Option 3 has three cable crossings and four pipeline crossings. This route will not interact at all with the proposed Hywind pilot wind park or its cable route to shore. Some of the existing cables and pipelines are located closely together and can be grouped into a single crossing arrangement to minimise environmental impact and optimise costs. Figure 6-1 in Appendix D shows the location and density of cables and pipelines within the study area.

Cables and pipelines were modeled as medium constraints due to cost of crossing arrangement as well as legal and financial risks involved. A buffer of 300 m was introduced for safety purposes.

Mitigation measures will include formal crossing agreements with cable and pipeline owners. Good communication and liaison with navigational stakeholders will be required.

6.2 Oil and Gas Infrastructure

There are two oil and gas wells and two plugged and abandoned wells within the study area. The route options have avoided existing oil and gas interests and have, where possible, avoided any areas of known future offshore development. The options maintain a minimum buffer distance between proposed cable routes and existing surface and subsurface infrastructure (Figure 6-1, Appendix D).

Oil and gas platforms and wells were modeled as hard constraints, i.e. no-go areas. These have been avoided by at least 500 m for safety purposes when drawing up each corridor route option. A buffer of 200 m was similarly applied around abandoned infrastructure.

The effects include potential interference with operations and maintenance activities of existing oil and gas infrastructure, planned decommissioning activities and installation of new oil and gas development sites.

6.3 Offshore Renewable Energy Development Sites

The Hywind offshore floating windfarm is the only offshore renewable development in the area (Figure 6-1, Appendix D) and is located 3,090 m north of route 3 and 7,608 m and 9,942 m south of Route Options 1 and 2.

Renewable energy development sites known to date were modeled as hard constraints, i.e. 'no-go' area. Such sites were avoided by at least 500 m for safety purposes when drawing up each route option.

The effects include potential interference with operation and maintenance activities of existing wind, wave or tidal infrastructure, planned decommissioning activities and installation of new wind, wave or tidal development sites.

6.4 Commercial Fisheries

The North Sea is an important area for commercial fisheries and the three route options cross inshore and offshore fishing grounds. The International Council for the Exploration of the Sea (ICES) has divided the waters around the UK into blocks to allow for recording and monitoring purposes. All three routes cross ICES rectangles 43E8 and 44E8. Figure 6-3 in Appendix D provides an indication of fishing density within the study area and each ICES rectangle and sub-rectangle.

This study has looked at opportunities to avoid fishing areas for important commercial species, avoid major fishing ports in the region, maximise cable burial, apply rock placement when cables cannot be buried and document cable installation method to allow for effective communication with fisheries.

Potential effects during installation, operations, repair and maintenance are:

- Displacement of vessels using mobile/static gear from the mobile exclusion zone around installation vessels;
- Creation of sea-bed obstructions of sections with unprotected cable for a period following installation;
- Disturbance/damage of certain species;
- Safety risk of exposed and/or unprotected cable;
- Cable protection at crossing obstructing mobile gear; and
- Disruption of inshore and offshore fishing activity during cable repairs and maintenance.

Fishing intensity is higher closer to shore with all three route options crossing areas of high usage with a 5 year mean of between 5,353 – 9,413 minutes. Usage further offshore decreases to between 61 – 1,620 minutes for routes 1 and 2 but whilst usage along Route Option 3 also reduces to these levels it does increase for a short distance in the south east (ICES 43E8-q2) to 1,621 – 3,217 minutes.

6.5 Shipping, Navigation and Anchorages

All proposed cable routes avoid or limit exposure to shipping and navigation areas. This study has considered opportunities to avoid and keep maximum distance from busy shipping areas by identifying navigational features, shipping routes and to avoid anchorage areas. Route Options 1 and 2 lie adjacent to the Peterhead harbour area and cross a recommended track for vessels entering or leaving the harbour. Route Option 3 does not cross any navigational features (Figure 6-2 in Appendix D).

Potential effects to shipping caused by compass deviation issues will be mitigated through detailed design. More detailed analysis will be conducted in terms of bundling versus unbundling, water depth and installation strategy at landfall to limit compass deviation to 2 degrees (as per UK specific requirement).

The potential effects to shipping and navigation include:

- Disruption of commercial shipping activity through the presence of cable installation, maintenance, repair and survey vessels;
- Collision risk with other vessels;
- Disruption of vessel anchoring;
- Fishing gear interactions and anchors dragging or snagging the cable; and
- Compass deviation on vessels navigating with magnetic compasses rather than GPS.

6.6 Dredging, Disposal and Military Practice Areas

Spoil ground areas have been identified near Peterhead landfall at Sandford Bay and near Peterhead harbour (Figure 6-2, Appendix D). However, all cable route options avoid these areas.

Former minefields, explosive dumping grounds and foul grounds were classed as no-go areas and avoided. Military practice areas were assessed as having medium sensitivity and buffer zones were not applied. None of the three route options cross any military practice areas.

6.7 Cultural Heritage

There are no designated wrecks for cultural heritage significance by Historic Scotland within the vicinity of the project area (Figure 6-1, Appendix D).

Wrecks have been identified along all routes options. However, all three route options avoid wrecks identified within the data sets provided by SeaZone by a margin of at least 200 m. Further mitigation will be applied as appropriate for any wrecks or obstructions revealed by survey work prior to detailed design and installation.

6.8 Coastal Defences

No coastal defences have been identified at the proposed landfall site.

6.9 Environmental considerations

6.9.1 Benthic environment

There are a number of wide scale sediment and habitat mapping programmes that have been conducted in UK, one of which is the JNCC UKSeaMap programme (Ref. 9). The programme provides an overview of the habitats likely to be present in areas of the North Sea and northern Scotland and builds upon previous datasets on sediment and habitats distribution from the MESH (Mapping European Seabed Habitats) programme. UKSeaMap predicts 'circalittoral coarse sediment' in inshore waters progressing to 'deep circalittoral coarse sediment' and 'deep circalittoral sand' further offshore (Figure 6-5, Appendix D).

From the predictive habitat mapping reported under UKSeaMap, the biotope 'circalittoral coarse sediment' is described as tide swept coarse sediments including coarse sand, gravel and shingle which are often unstable due to tidal currents and/or wave action. These habitats tend to be characterised by a robust fauna including infaunal polychaetes and bivalves (Ref. 10).

'Deep circalittoral coarse sediment' habitats cover large areas of the offshore continental shelf and consist of coarse sands and gravel or shell. These habitats are diverse and generally characterised by infaunal polychaete and bivalve species such as *Modiolus modiolus* (Ref. 10).

Fine or non-cohesive muddy sands make up the 'deep circalittoral sand' habitats offshore. Little data is available for such habitats but they are characterised by a diverse range of polychaetes, bivalves, echinoderms and amphipods (Ref. 10).

The predicted sediment composition along all three routes is largely similar consisting of mainly circalittoral coarse sediments and deep circalittoral sand. All could potentially harbour features that would be considered constraints to cable routing, such as Annex I reef habitats; for example *Modiolus* beds and *Sabellaria* reefs could occur in this region.

In addition, as noted above in Section 5.2.3, bedrock outcrops (Annex I reef habitat) have been charted at two or three locations very close to shore within 1 km of the Longhaven landfall location, in addition to which the JNCC has identified the potential for rocky reef habitat (either bedrock or areas of boulders) to occur along the whole coastline within a kilometre or so of the shore (Figure 5-6). Therefore, the potential for rocky habitat to be encountered along the route options is high inshore, but diminishes with distance offshore.

However, only a site-specific benthic environmental survey would be able to determine the presence or absence of any areas of high sensitivity, and therefore no constraints or buffers were applied as a result of the predictive habitat mapping data.

6.9.2 Fish spawning and nursery grounds

Herring *Clupea harengus* and sandeel (several species in the family Ammodytidae) spawning grounds cover all of the study area and therefore all routes cross these grounds (Ref. 11 and Ref. 12).

Herring

Herring are a principal prey item for several larger fish species, marine birds and mammals, and occur throughout Scottish waters including the North Sea. They deposit their sticky eggs on a variety of substrates ranging from boulders, rock, small stones, coarse sand, shell fragments, macrophytes and man-made structures such as lobster pots but gravel is widely considered to be the preferred spawning substrate (Ref. 13 and Ref. 14). Herring are particularly sensitive because they spawn in well-defined areas across a small timeframe based on geographic location. In the context of the current study, herring spawn in September/October.

Sandeel

As major predators of zooplankton, sandeel play a key role in the North Sea food-web and are the principal prey of many top predators including other demersal fish, marine mammals and birds (Ref. 15; Ref. 16; Ref. 17; Ref. 18; Ref. 19; Ref. 20; Ref. 21; Ref. 22; and Ref. 23).

Sandeel are particularly sensitive because they spawn in very specific habitats favouring seabed habitats containing a high proportion of medium and coarse sand with and low silt content (Ref. 24). Overall, sandeels are considered to be rare in sediments where the silt content is greater than 4%, and absent where the silt content is greater than 10% (Ref. 24). Sandeel are most active in late spring/early summer, during which time they move freely, on a diurnal basis, between the seabed and the water column. During autumn and winter, sandeels lie dormant in the sediment except for a brief midwinter emergence to spawn (Ref. 25).

Herring and sandeel spawning grounds were modeled as medium constraints due to the specific habitat requirements both species need. A site-specific benthic environmental survey would be able to determine any areas of likely herring spawning ground within the route corridor (based on an assessment of sediment type from photographs and laboratory analysis). No buffer zones were applied to the spawning grounds.

An area which is crossed by Route Option 1 is identified by JNCC as potential Annex I ‘sandeel grounds’. Additional information is not available on this habitat and its sensitivity is unclear. Only detailed benthic surveys would be able to determine whether any sensitive habitats or species are present within the route corridors.

Effects on these species can be minimised through seasonal working (autumn and winter), if practicable as sea states may not permit winter working.

6.9.3 Offshore conservation

There are several offshore conservation designation and proposed designations within the study area (Figure 6-4, Appendix D).

The Turbot Bank Marine Protected Area (MPA), located approximately 7,675 m to the east of Route Option 3, is designated for the protection of sandeels.

Route Options 1 and 2 pass through the southern extremities of the proposed Southern Trench nature conservation MPA. SNH submitted its proposal for consideration of this MPA to Marine Scotland in July 2014. The proposed MPA has benthic interests in the Southern Trench underwater valley feature in the Moray Firth, and the waters off Fraserburgh produce frontal zones with strong horizontal gradients in surface and/or bottom temperatures. These features also make it an important area for white-beaked dolphin and minke whale.

MPAs were modelled as medium constraints.

There are several areas within the study area in addition to the ‘sandeel grounds’ mentioned previously which have been identified by JNCC as areas of potential Annex I habitats. Little information is available to detail the characteristics of these areas and it is understood that JNCC is reviewing this data which will be republished at the end of 2015. These areas, classed as Potential Annex I habitats: Reef; Not Reef; and Fluid Seeps are shown in Figure 6-4 (Appendix D).

6.9.4 Coastal and terrestrial conservation

Statutory designations

There are three coastal statutory designations at the landfall site: the Buchan Ness to Collieston Special Area of Conservation (SAC) designated for vegetated sea cliffs; the Buchan Ness to Collieston Coast Special Protection Area (SPA) designated for aggregations of breeding seabirds which extends 2 km offshore; and the Bullers of Buchan Coast Site of Special Scientific Interest (SSSI) designated for aggregations of breeding seabirds, geomorphology and maritime cliffs. All three route options pass through these designations.

The closest terrestrial designation is the Hill of Longhaven SSSI located approximately 4.6 km north-west from the onshore works. This site is designated for quaternary geology and geomorphology.

All coastal and terrestrial designations have been modelled as medium constraints with a 500 m buffer applied.

In addition to statutory designations, a number of grey seal haul-out areas have been identified along coast. These have been modelled as a medium constraint and a 500 m buffer applied.

Protected species

A data search was undertaken by the North East Scotland Biological Records Centre (NESBReC) to identify protected and notable species in the area. Sandwich tern *Sterna sandvicensis,* golden plover *Pluvialis apricaria,* hen harrier *Circus cyaneus,* barnacle goose *Branta leucopsis,* peregrine *Falco peregrinus* and merlin *Falco columbarius* were the only European protected species recorded. No protected mammal species were recorded.

No constraints for protected species (other than those associated with SPAs) were identified during the desk study.

7 CONCLUSIONS

Based on the technical constraints presented, Route Option 2 was found to be the most favourable option. Route Option 3, whilst avoiding areas of environmental sensitivity, was considered the least favourable option due to the longer cable length and route through areas of seabed which would be technically difficult for installation activities and therefore pose a greater project risk.

All routes cross the Buchan Ness to Collieston Coast SPA. Route Options 1 and 2 cross the Southern Trench MPA and, in addition, Route Option 1 crosses the potential Annex I habitat identified as 'sandeel grounds'. Route Option 3 crosses no other designations.

From a technical perspective, the re-routing south from Sandford Bay to Longhaven does not add any more seabed constraints to the proposed cable corridor options, other than at the nearshore approach to Longhaven. Offshore seabed sediments and shallow soil conditions are expected to be similar across all three routes based on the regional geology of the site, hence trenching tool selection (i.e. ploughing) has not changed since the initial study in 2012. Seabed features are also expected to be similar; however, cable Route Option 3 may be more susceptible to sand wave fields.

The cable approach to shore at Longhaven is different from the initial study considered at Sandford Bay, where the geography and shore geomorphology are significantly different. At Sandford Bay an open-cut trench landfall was considered technically acceptable up the beach area. However, at Longhaven the shore is dominated by steep rocky cliffs and small, narrow gravel/cobble beaches, which are not conducive to such techniques. Therefore, HDD has been suggested, whereby the onshore tie-in is expected to be made offshore at an appropriate exit point on the seabed. The shore risk is effectively removed by HDD, as the drilling technique avoids any interaction with the sea cliffs and/or beaches. However, rocky outcrops and hard substrata offshore should be avoided in the selection of the HDD exit point, as such areas may present a seabed risk for tie-in operations with the offshore cable (e.g. lay and trenching activities).

In terms of crossing other marine infrastructure, cable Route Options 1 and 2 will not include any more crossings than the initial routing to Sandford Bay. However, cable Route Option 3 will have to make extra crossings (6) over the Cruden Bay pipelines before re-joining the main cable corridor.

The proposed HDD landfall connection does not affect the routing study. It is considered that the HDD exit point offshore should target a water depth that is suitable for both the offshore survey vessel and the main cable-lay vessel (~20 m) to carry out operations unhindered. The advantage of this would be to minimise the need and use of multiple survey/lay spreads to achieve a combined cable and landfall installation.

8 RECOMMENDATIONS

The following recommendations are proposed for further work on the NorthConnect routing study, to include this re-routed segment to Longhaven in combination with the rest of the cable route to Simadalen. The recommendations are as follows:

A **detailed seabed survey** is required to confirm sea bed conditions, hazards, and risk to cable installation. Based on the results of the detailed survey, a micro-routing study should be carried out at key locations, e.g. crossings, repair areas, significant seabed geohazards, The most probable cable route can then be finalised before detailed route design. Additionally, the detailed route survey data is essential to confirm appropriate installation methods, burial depth and level of cable protection in different areas along the cable route selected.

Digital data from the detailed route survey will require detailed analysis of geotechnical and geophysical constraints (e.g. pockmarks, rock exposures, debris, mounds, ridges, sandwaves, mega-ripples, and soil types). The data will also reveal obstacles (e.g. boulders, uncharted wrecks) which will need to be captured and avoided during detailed route design.

Further to the routing, study a **Burial Risk Assessment** should be carried out. Burial depth or trench depth should be optimised based on data from detailed survey and risk based assessment as a means of minimising cost. We recommend a detailed trenching study for the proposed routes to refine the trenching rate adopted within the earlier desk top study is still appropriate.

An **UXO survey** should also be commissioned to investigate the area and establish the level of risk involved. Any unwanted object will need to be removed by NorthConnect before any further activities can be performed.

Formal Crossing Agreements with cable and pipeline owners of existing seabed assets, and good communication and liaison with navigational stakeholders and local fisheries, will be required. NorthConnect should engage with relevant stakeholders to inform them about the intended route and obtain early feedback through initial consultations. Any feedback on constraints, pinch points or potential showstoppers should be used as input to detailed route design.

- In addition to the above, early engagement with cable and pipeline owners is recommended to formalise crossing design and fine-tune installation strategy and refine project costs. The legal side of the crossing arrangements will require attention to detail. It is recommended that Oil & Gas UK, the oil and gas industry trade body, is consulted. Subsea Cables UK is the central forum for all cable operators in the UK (formerly the UK Cable Protection Committee). It is recommended that effective engagement is made with this group too.
- Cable repeaters should be addressed during crossing arrangement discussions with cable owners. Detailed route design should capture exact location of cable repeaters and adopt minimum distance requirements.
- During route detailed design, engagement with cable installation companies should confirm recommendations of cable installation methods (i.e. subsea and landfall), cable burial depth and cable/scour protection stated in this report. Early supply chain engagement will allow for positioning within the supply market, create strategic partnerships and help secure production capacity and vessel availability.

A detailed **topographic survey along the proposed land route** option(s) is required to find the best place for where the long HDD drilling operation would be set-up. A survey of the shoreline with respect to cliff edges and safe distances away from hazardous ground would also be required. As part of this survey, definitive landownership boundaries and positive identification of environmental/cultural constraints of the site will need to be charted to spatially assess the limitations to such construction activities.

For the exit location of the HDD drill/conduit, the offshore export cable route survey should include provision for carrying out a **detailed bathymetric survey** at the proposed site to enable route optimisation during the detailed design phase. Ideally the survey should include identifying any major obstructions that would affect the marine operations for cable laying and the potential for cable trenching offshore and near shore toward the HDD exit point.

Obtaining detailed geotechnical data is paramount for successful HDD cable landfall construction. The scope of the geotechnical work should address the shore-based drilling operation and the probable depth and length of the HDD profile from the onshore entry point to the exit location offshore. For the onshore scope, an understanding of the soil cover overlying the rock (i.e. thickness, strength and material properties), and the competency and strength of the rock itself, 2 - 3 boreholes drilled onshore at the proposed HDD site may be required. Additionally, trial pits or flight augering into the soil overburden should be considered to observe the *in situ* soil and corroborate the borehole data.

With the above in mind, obtaining **early contractor engagement** would be beneficial with respect to the following:

- Discussions with contractors on methods, land access and occupation requirements during construction, access requirements for drill set-up and/or winch, and to confirm overall site feasibility for the landfall works. Developing an interface between the offshore phase of work and the onshore scope of HDD would identify the limits/constraints for the cable lay vessel to link the connection point to shore. Additionally, a specific site evaluation can then be used to provide indicative construction costs and schedules to further support the final site selection process, before committing to a preferred method and/or contractor;
- Liaison with installation companies should also confirm safety distance for trenching near existing cables and pipelines as it will define safety constraints for crossing arrangements. These constraints will need to be addressed during discussions with cable/pipeline owners and design of individual crossing arrangements; and
- Engagement with cable manufacturers will be required to assess production rates and understand potential constraints. Another project objective is to align cable manufacturing and cable installation schedules to optimise supply chain (i.e. sourcing, manufacturing, transport and installation) and project financing.

Consultation with the regulator is advisable to ensure that sampling for all required sensitivities is included in the offshore benthic survey specification. The study area is in general considered important as herring spawning ground, and there may be a requirement to include a herring spawning ground assessment in the survey.

9 REFERENCES

1 Xodus Group Ltd. Desk Top Survey and Route Engineering Study – Route Option Analysis Report. Doc. No. A-30722-S04-REPT-002 Rev A01. Issued 21/09/2012.

2 Technip Offshore Wind Ltd. NorthConnect HVDC Interconnector - NorthConnect Landfall Option Study. Doc. No. TOWL 1076 RT ENG 001 Rev 1. Issued 18/12/13.

3 DNV-RP-J301. Subsea Power Cables in Shallow Water Renewable Energy Applications. Feb, 2014

4 BGS (1993). Johnson, H., Richards, P.C., Long, D. and Graham, C.C. United Kingdom offshore regional report: the geology of the northern North Sea. HMSO for the BGS.

5 BGS (1994). Gatliff, R.W., Richards, P.C., Smith, K., Graham, C.C., McCormac, M., Smith, N.J.P., Long, D., Cameron, T.D.J., Evans, D., Stevenson, A.G., Bulat, J. and Ritchie, J.D. United Kingdom offshore regional report: the geology of the central North Sea. HMSO for the BGS.

6 BGS (1984). Seabed Sediments – Peterhead (Sheet 57°N-02°W).

7 BGS (1986). Quaternary Geology – Peterhead (Sheet 57°N-02°W).

8 BGS (1982). Solid Geology – Peterhead (Sheet 57°N-02°W).

9 JNCC (2010). UKSeaMap Interactive Map - predictive mapping of seabed habitats available from http://jncc.defra.gov.uk/page-2117 [Accessed 20/11/14].

10 Connor D.W., Allen J.H., Golding N., Howell K.L., Lieberknecht L.M., Northern K.O. and Reker J.B. (2004). The Marine Habitat Classification for Britain and Ireland Version 04.05 JNCC, Peterborough ISBN 1 861 07561 8.

11 Coull, K., Hohnstone, R. and Rogers, S. (1998). Fishery sensitivity maps in British Waters. Published and distributed by UKOOA Ltd. Available from http://cefas.defra.gov.uk/media/29947/sensi_maps.pdf [accessed 21/11/2014].

12 Ellis, J., Milligan, S., Readdy, L., Taylor, N. and Brown, M. (2012). Spawning and nursery grounds of selected fish species in UK waters. Sci. Ser. Tech. Rep., Cefas, Lowestoft, 147 56 pp.

13 Drapeau, E. (1973). Sedimentology of herring spawning grounds on Georges Bank. ICNAF Res. Bull 10: 151-162

14 Rogers, S. & Stocks, S. (2001). North Sea Fish and Fisheries. Technical report for Strategic Environmental Assessment (SEA). 72pp.

15 Collins, M. and Pierce, G. (1996). Size selectivity in the diet of Loligo forbesi (Cephahlopoda: Loliginidae). Journal of the Marine Biological Association of the United Kingdom 76, 1081-1090.

16 Mills, D., Hadoke, G., Shelton, R. and Reid, J. (2003). Atlantic Salmon Facts. Atlantic Salmon Trust booklet. Prepared in 1986 revised in 2003.

17 Greenstreet, P., McMillan, J. and Armstrog, E. (1998). Seasonal variation in the importance of pelagic fish in the diet of piscivorous fish in the Moray Firth, NE Scotland: a response to variation in prey abundance? ICES Journal of Marine Science, 55: 121-133.

18 Wright, P. and Kennedy, F. (1999). Sandeel biology and its implications to management. Fisheries Research Services Report Number 12/99 Proceedings of a workshop held at FRS Marine Laboratory Available online at http://www.scotland.gov.uk/Uploads/Documents/Coll1299.pdf [accessed 21/11/2014].

19 ICES (2005). Report of the Planning Group on North Sea Cod and Plaice Egg Surveys in the North Sea (PGEGGS), 10 -12 May 2005, Lowestoft, UK. ICES CM 2005/G:11. 85pp.

20 ICES (2006). ICES CIEM ICES Fish Map – Herring. Available online from: http://www.ices.dk/marineworld/fishmap/ices/pdf/herring.pdf [Accessed 09/05/2014].

21 ICES (2008). North Sea-Ecosystems overview. ICES Advice 2008. Book 6.

22 ICES (2010). Report of the Herring Assessment Working Group for the Area South of 62n (HAWG), 15 - 23 March 2010, ICES Headquarters, Copenhagen, Denmark. 688 pp.Inger, R., Attrill, M., Bearhop, S., Broderick, A., Grecian, W., Hodgson, D. Millis, C., Sheehan, E., Votier, S., Witt M and Godley, B. (2009). Marine renewable energy: potential benefits to biodiversity? An urgent call on research. Journal of Applied Ecology, 46: 1145-1153.

23 McConnell, B., Hall, A. and Fedal, M. (1999). Seal foraging and sandeel distribution In Wright, P.J. and Kenedy, F.M., (1999).

24 Holland G., Greenstreet, S., Gibb, I., Fraser, H. and Robertson, M., (2005). Identifying sandeel Ammodytes marinus sediment habitat preferences in the marine environment. Marine Ecology Progress Series, 303, 269-282.

25 Greenstreet, P., Holland, G., Guirey, E., Armstrong, E., Fraser, H. and Gibb, I. (2010). Combining hydroacoustic seabed survey and grab sampling techniques to assess “local” sandeel population abundance. ICES Journal of Marine Science, 67 (5), 971-984.

APPENDIX A DATA LIST

Weighting	Constraint	Data provider	Buffer (where applicable)
High	Offshore SAC	JNCC	n/a
High	Anchorage Area	Seazone Hydrospatial Base	n/a
High	Anchorage Area point location	Seazone Hydrospatial Base	500 metres
High	Aquaculture Area	Seazone Hydrospatial Base	n/a
High	Aquaculture point location	Seazone Hydrospatial Base, Marine Scotland	500 metres
High	Restricted Area	Seazone Hydrospatial Base	n/a
High	Offshore Safety Zone	UK OilandGasData	n/a
High	UK O&G Surface infrastructure	UK OilandGasData	500 metres
High	UK O&G Subsurface infrastructure (active)	UK OilandGasData	500 metres
High	UK O&G Subsurface infrastructure (abandoned)	UK OilandGasData	200 metres
High	Bedrock areas	Seazone Hydrospatial Base	n/a
High	JNCC Potential Reef areas	JNCC	n/a
High	Former Minefield	Seazone Hydrospatial Base	n/a
High	Explosives Dumping Ground	Seazone Hydrospatial Base	n/a
High	Foul Ground	Seazone Hydrospatial Base	n/a
High	Foul Ground point location	Seazone Hydrospatial Base	500 metres
High	Wrecks & Obstructions	Seazone UKHO Wrecks Database	200 metres
High	Navigation Installation	Seazone Hydrospatial Base	200 metres
Medium	JNCC Potential Annex I Reef areas	JNCC	n/a
Medium	JNCC Offshore SAC 500m Buffer	JNCC	500 metres
Medium	JNCC SPA with Marine Components	JNCC	n/a
Medium	SSSI	SNH	n/a
Medium	Sandeel spawning grounds	CEFAS	n/a
Medium	Sandeel spawning grounds	CEFAS	n/a
Medium	Herring spawning grounds	CEFAS	n/a
Medium	Traffic Regulation Schemes	Seazone Hydrospatial Base	n/a
Medium	Military Activity Area	Seazone Hydrospatial Base	n/a
Medium	Marina	Seazone Hydrospatial Base	n/a
Medium	Bathing Waters	SEPA	n/a
Medium	Licence areas 20/2a and 21/10	UK OilandGasData	n/a
Medium	Pipelines	UK OilandGasData, SeaZone Hydrospatial Base	300 metres
Medium	Cables	KIS-ORCA, Seazone Hydrospatial Base	300 metres
Medium	Indicative Hywind Pilot Park Project cable route	Digitised from Hywind Scoping Report cable route	300 metres
Medium	Spoil Ground	Seazone Hydrospatial Base	n/a
Medium	Dredged Areas	Seazone Hydrospatial Base	n/a
Low	SPA 500m Buffer	JNCC	500 metres
Low	SSSI 500m Buffer	SNH	500 metres
Low	UK Discovery Fields	UK OilandGasData	n/a
Low	Restricted Areas	Seazone Hydrospatial Base	n/a
Low	Harbour Area	Seazone Hydrospatial Base	n/a
Low	Ferry route,recommended route	Seazone Hydrospatial Base	300 metres
n/a	Slope analysis	Xodus derived from Marine Themes DEM	n/a
n/a	UK VMS Fishing activity	MMO	n/a
n/a	Sediment, bedrock and Quaternary Geology	BGS	n/a

APPENDIX B CABLE DATA SHEETS

REDACTED: CONTENT OUT OF DATE

APPENDIX C TECHNICAL CONSTRAINTS

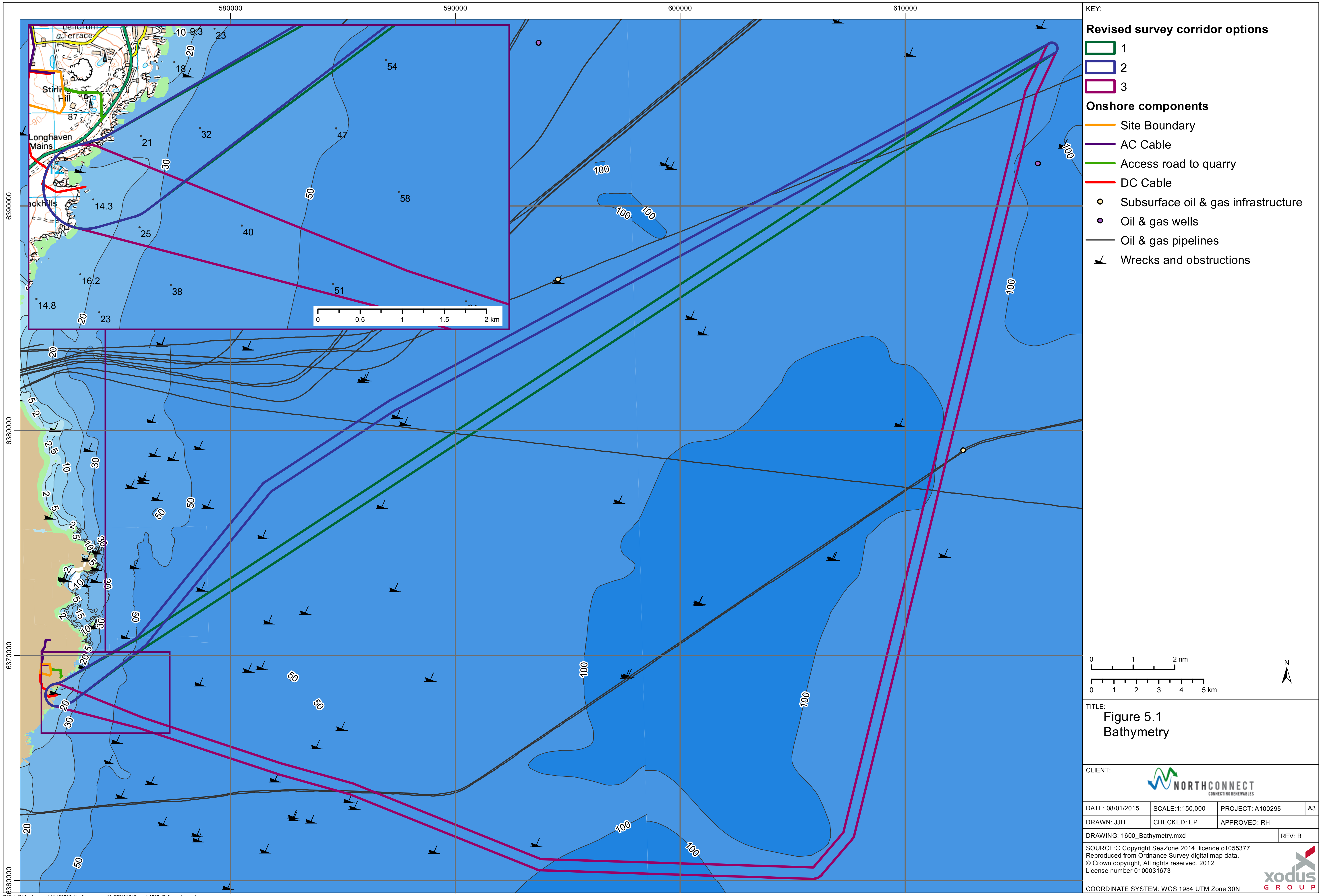
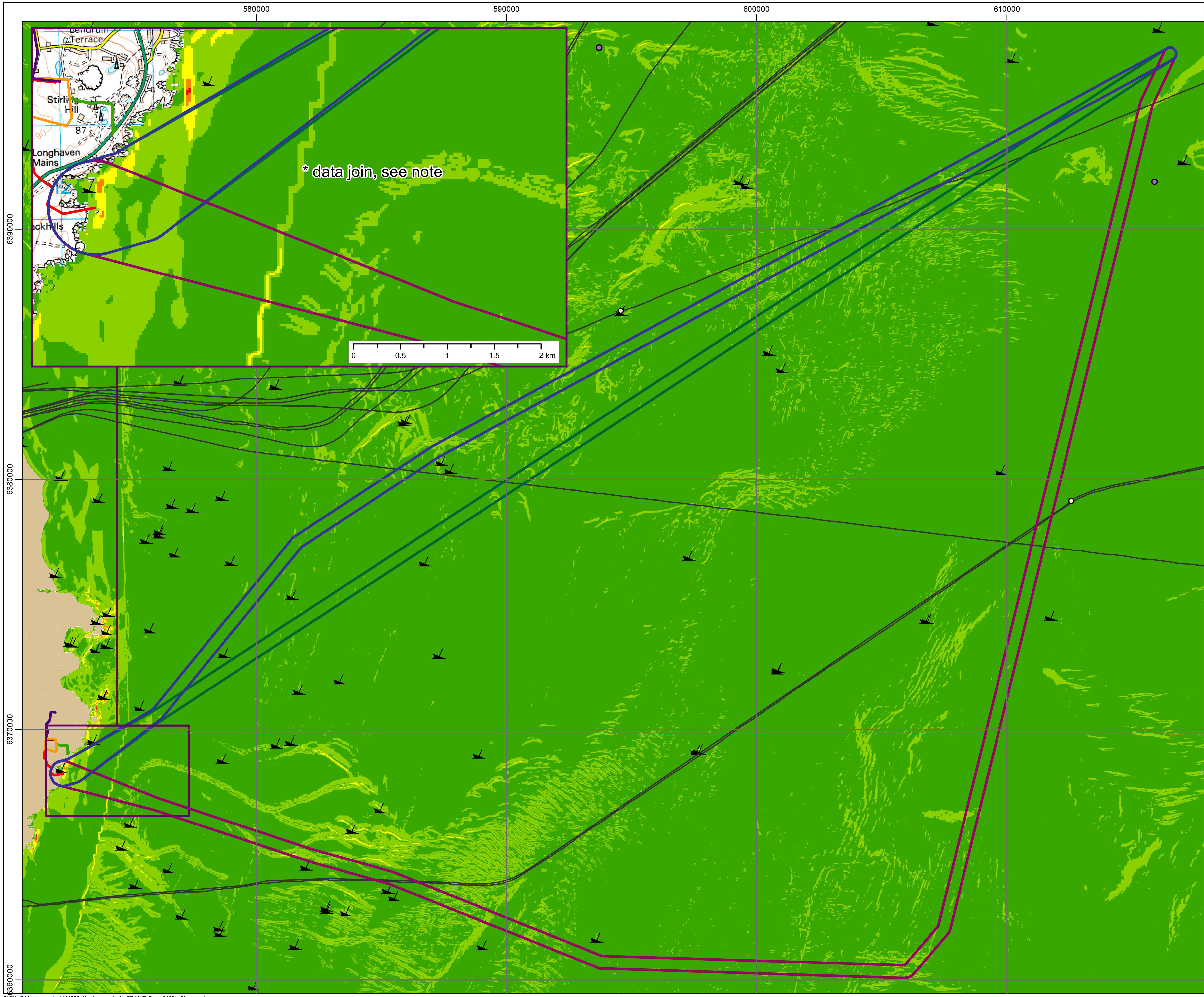


Figure 5.1
Bathymetry

PATH: G:\Assignments\A100295_Northconnect_JH_EP\MXD\Report\1600_Bathymetry.mxd



KEY:

Revised survey corridor options
- 1
- 2
- 3

Onshore components
- Site Boundary
- AC Cable
- Access road to quarry
- DC Cable
- Subsurface oil & gas infrastructure
- Oil & gas wells
- Oil & gas pipelines
- Wrecks and obstructions

Slope (degrees)
- 0 - 1
- 1 - 5
- 5 - 10
- 10 - 15
- >15

* Note that slope values inshore from this zig zag join between datasets are derived from charted data and not survey derived bathymetry

0 1 2 nm

0 1 2 3 4 5 km

N

TITLE:

Figure 5.2
Seabed slopes

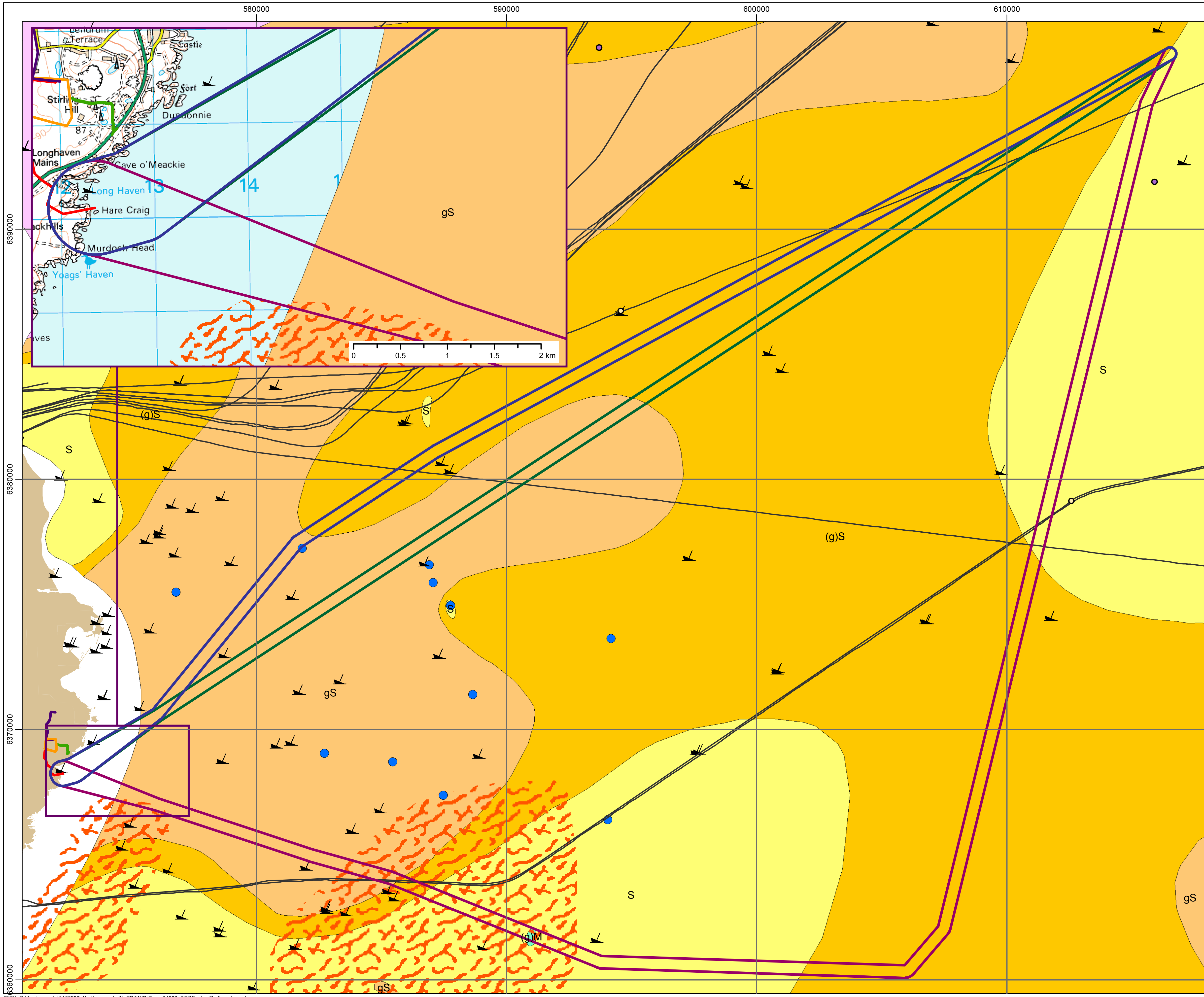
CLIENT: NORTHCONNECT CONNECTING RENEWABLES

DATE: 04/12/2014	SCALE:1:150,000	PROJECT: A100295	A3
DRAWN: JJH	CHECKED: EP	APPROVED: RH	
DRAWING: 1601_Slope.mxd			REV: B

COORDINATE SYSTEM: WGS 1984 UTM Zone 30N

xodus GROUP

PATH: G:\Assignments\A100295_Northconnect_JH_EP\MXD\Report\1601_Slope.mxd



KEY:

Revised survey corridor options
- 1
- 2
- 3

Onshore components
- Site Boundary
- AC Cable
- Access road to quarry
- DC Cable
- Subsurface oil & gas infrastructure
- Oil & gas wells
- Oil & gas pipelines
- Wrecks and obstructions
- BGS sample stations
- Areas of sandwaves

Seabed Sediments
- Slightly gravelly mud (g)M
- Sand S
- Gravelly sand gS
- Slightly gravelly sand (g)S
- Sandy gravel sG

0 1 2 nm
0 1 2 3 4 5 km
N

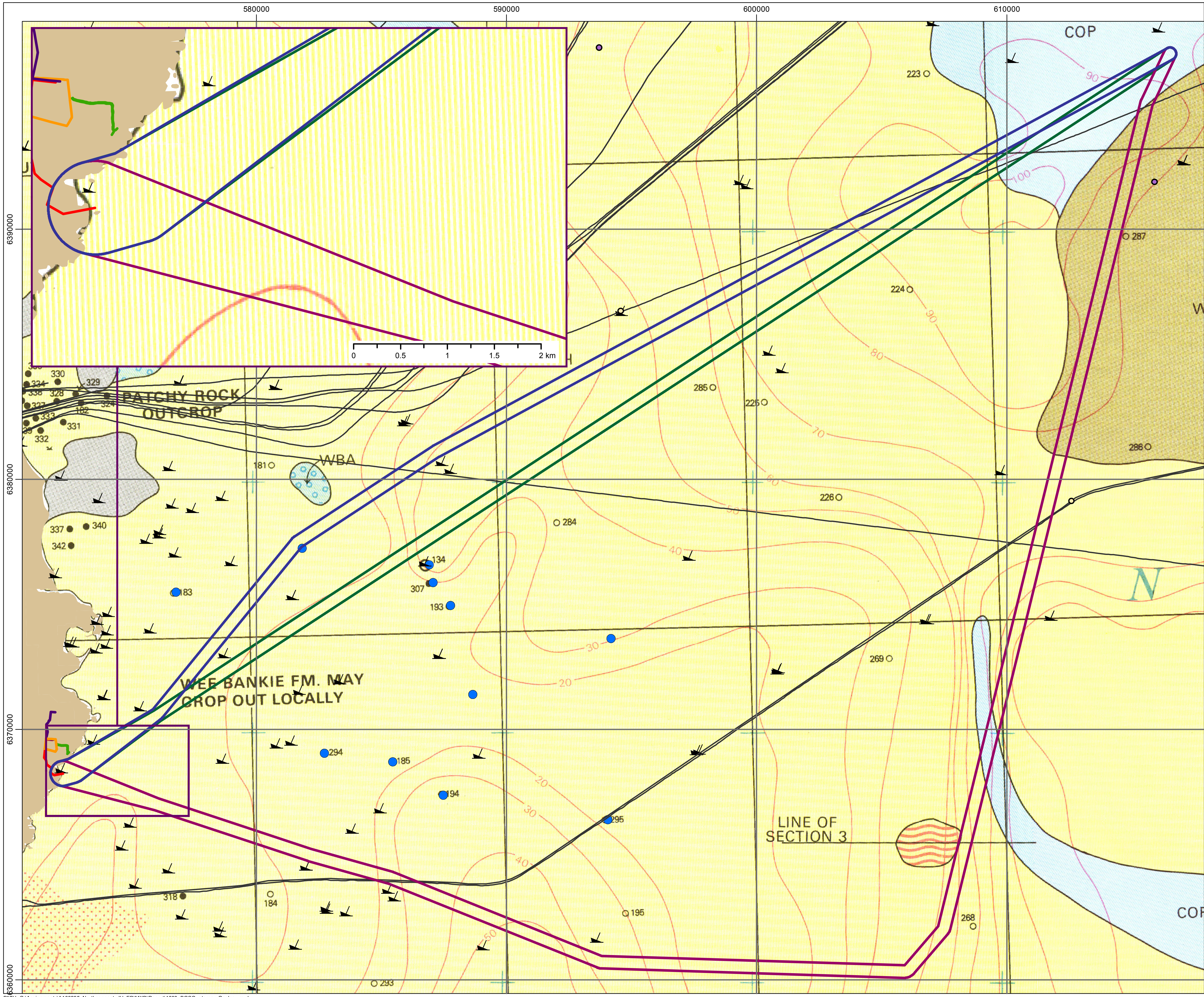
TITLE:
Figure 5.3
Seabed sediments

CLIENT: NORTHCONNECT CONNECTING RENEWABLES

DATE: 08/01/2015	SCALE:1:150,000	PROJECT: A100295	A3
DRAWN: JJH	CHECKED: EP	APPROVED: RH	
DRAWING: 1602_BGSSeabedSediments.mxd			REV: B

COORDINATE SYSTEM: WGS 1984 UTM Zone 30N

PATH: G:\Assignments\A100295_Northconnect_JH_EP\MXD\Report\1602_BGSSeabedSediments.mxd



KEY:

Revised survey corridor options

- 1
- 2
- 3

Onshore components

- Site Boundary
- AC Cable
- Access road to quarry
- DC Cable
- Subsurface oil & gas infrastructure
- Oil & gas wells
- Oil & gas pipelines
- Wrecks and obstructions
- BGS sample stations
- Vibro Core
- Shallow Sediment Core

Quaternary geology

- Forth Formation
- Witch Ground formation
- Wee Bankie Formation
- Coal Pit
- Pre Quaternary (bedrock)
- Sediments at depth disturbed by ice-push during Weichselian times
- St Andrews Bay Member (Forth Formation)
- Isopachs showing Quaternary thickness over bedrock in metres

0 1 2 nm

0 1 2 3 4 5 km

N

TITLE:

Figure 5.4
BGS Quaternary geology

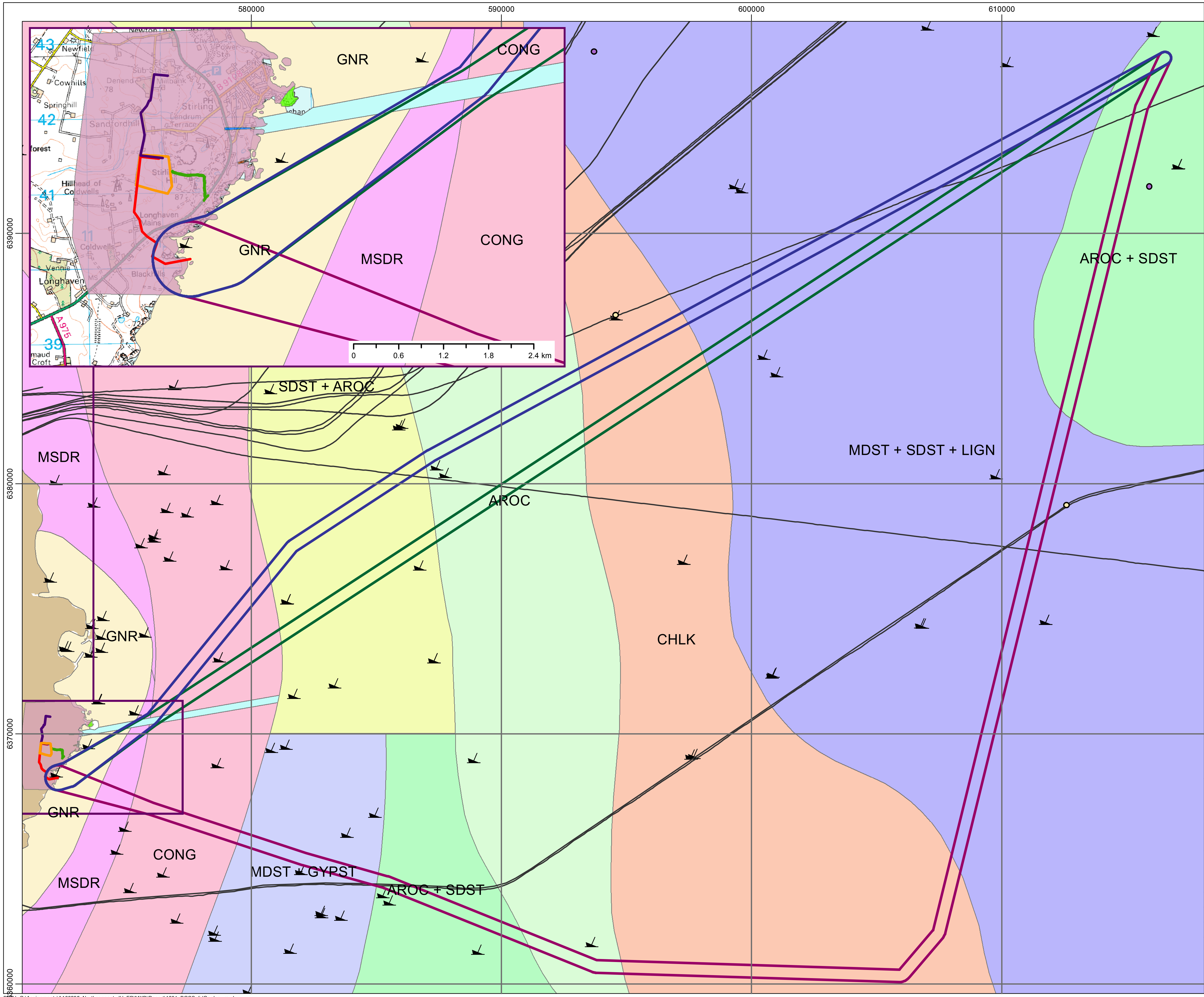
CLIENT: NORTHCONNECT CONNECTING RENEWABLES

DATE: 04/12/2014	SCALE:1:150,000	PROJECT: A100295	A3
DRAWN: JJH	CHECKED: EP	APPROVED: RH	
DRAWING: 1603_BGSQuaternaryGeology.mxd			REV: B

COORDINATE SYSTEM: WGS 1984 UTM Zone 30N

xodus GROUP

PATH: G:\Assignments\A100295_Northconnect_JH_EP\MXD\Report\1603_BGSQuaternaryGeology.mxd



KEY:

Revised survey corridor options

- 1
- 2
- 3

Onshore components

- Site Boundary
- AC Cable
- Access road to quarry
- DC Cable
- Subsurface oil & gas infrastructure
- Oil & gas wells
- Oil & gas pipelines
- Wrecks and obstructions

Onshore bedrock

- Qtz-Microgabbro
- Felsite Dyke Suite
- Lamprophyres Dyke Suite
- Peterhead Granite

Marine bedrock

- Chalk
- Conglomerate
- Granitic - rock
- Metasedimentary rock
- Mircogabbroic - rock
- Mudstone and Gypsum-stone
- Mudstone and Sandstone (undifferentiated) and Lignite
- Rock, Siliciclastic, Argillaceous
- Rock, Siliciclastic, Argillaceous and Sandstone (undifferentiated)
- Sandstone (undifferentiated) and rock, Siliciclastic, Argillaceous

0 1 2 nm

0 1 2 3 4 5 km

N

TITLE:

Figure 5.5
Onshore and Offshore Solid Geology

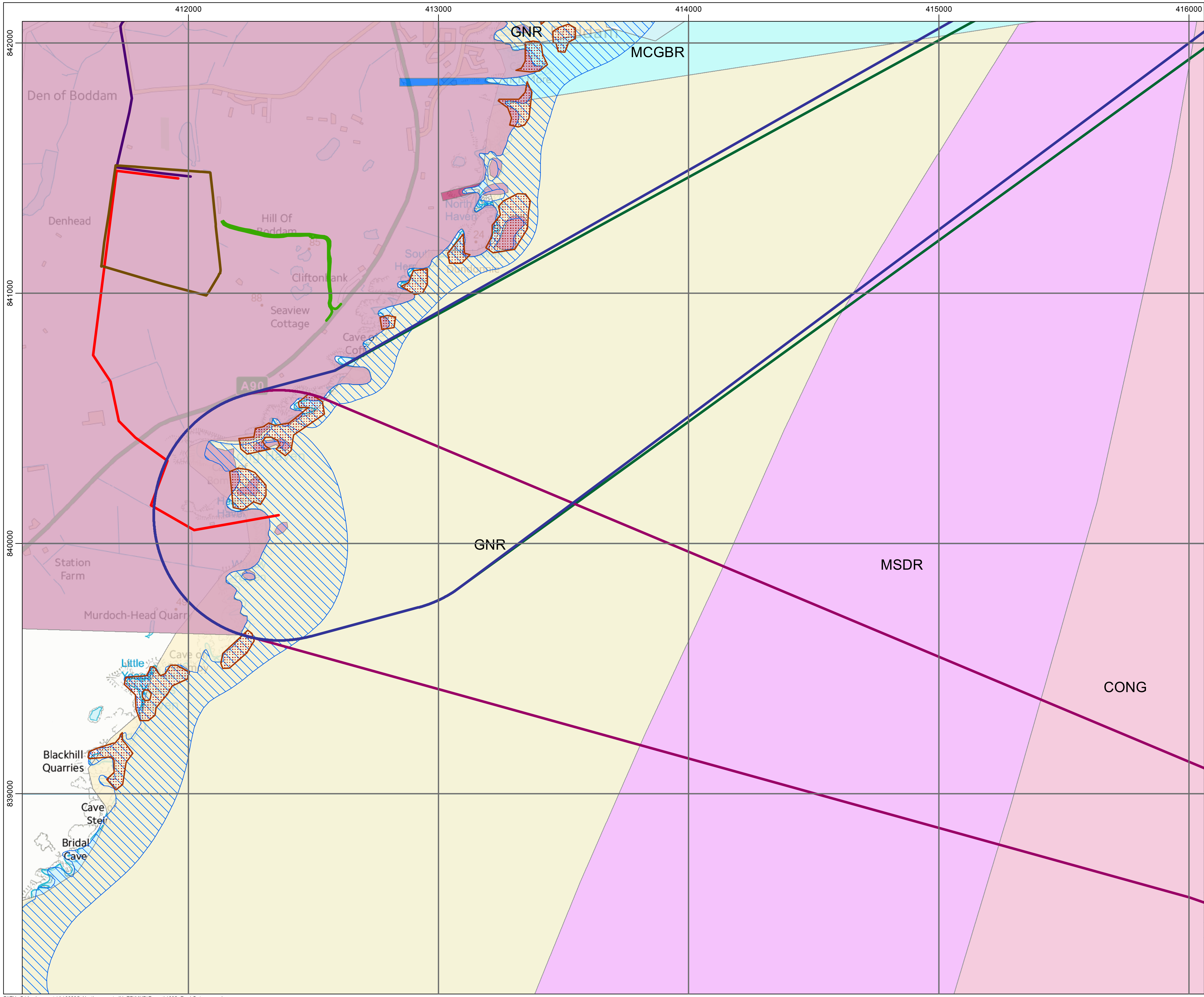
CLIENT: NORTHCONNECT CONNECTING RENEWABLES

DATE: 05/12/2014	SCALE:1:150,000	PROJECT: A100295	A3
DRAWN: JJH	CHECKED: EP	APPROVED: RH	
DRAWING: 1604_BGSSolidGeology.mxd			REV: B

COORDINATE SYSTEM: WGS 1984 UTM Zone 30N

xodus GROUP

PATH: G:\Assignments\A100295_Northconnect_JH_EP\MXD\Report\1604_BGSSolidGeology.mxd



KEY:

Revised survey corridor options

- 1
- 2
- 3

Onshore components

- Site Boundary
- AC Cable
- Access road to quarry
- DC Cable
- Charted bedrock
- Potential reef (JNCC potential Annex I)

Onshore bedrock

- Qtz-Microgabbro
- Lamprophyres Dyke Suite
- Peterhead Granite

Marine Bedrock

- Conglomerate
- Granitic - rock
- Metasedimentary rock
- Mircogabbroic - rock

0 0.1 0.2 nm
0 100 200 300 400 500 m
N

TITLE:
Figure 5.6
Coastal bedrock outcrops at proposed landfall

CLIENT: NORTHCONNECT CONNECTING RENEWABLES

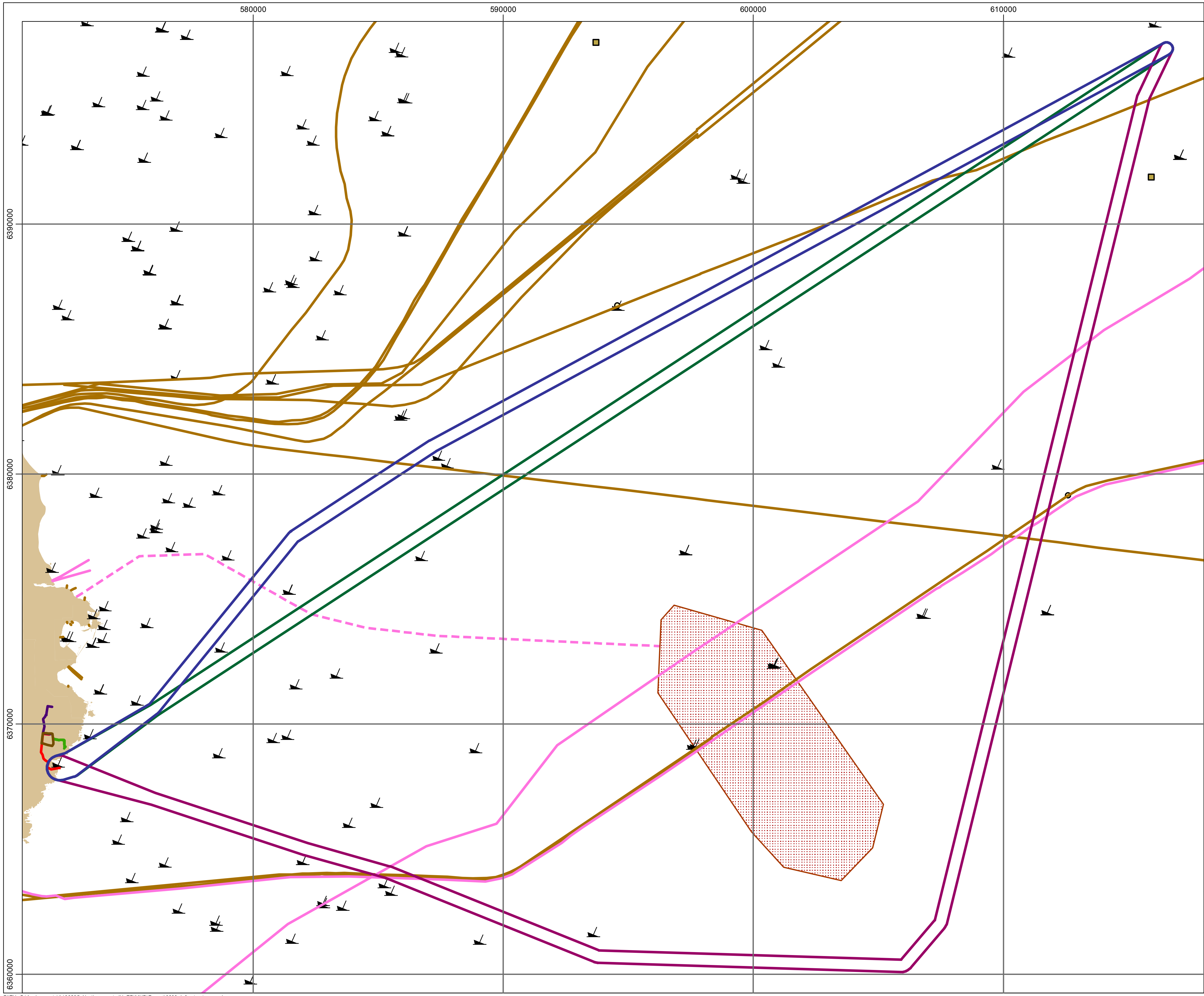
DATE: 05/12/2014	SCALE:1:15,000	PROJECT: A100295	A3
DRAWN: JJH	CHECKED: EP	APPROVED: RH	
DRAWING: 1605_RockOutcrop.mxd			REV: B

COORDINATE SYSTEM: British National Grid

xodus GROUP

PATH: G:\Assignments\A100295_Northconnect_JH_EP\MXD\Report\1605_RockOutcrop.mxd

APPENDIX D ENVIRONMENTAL CONSTRAINTS



KEY:

Revised survey corridor options

- 1
- 2
- 3

Onshore components

- Site Boundary
- AC Cable
- Access road to quarry
- DC Cable

Existing infrastructure

- Cable
- Pipeline
- Subsurface oil & gas infrastructure
- Plugged & Abandoned well
- Wrecks and obstructions

Hywind Scotland Pilot Park Project

- Area for Lease
- Indicative Hywind Scotland Pilot Park Project cable route

0 1 2 nm

0 1 2 3 4 5 km

N

TITLE:

Figure 6.1
Infrastructure within the study area

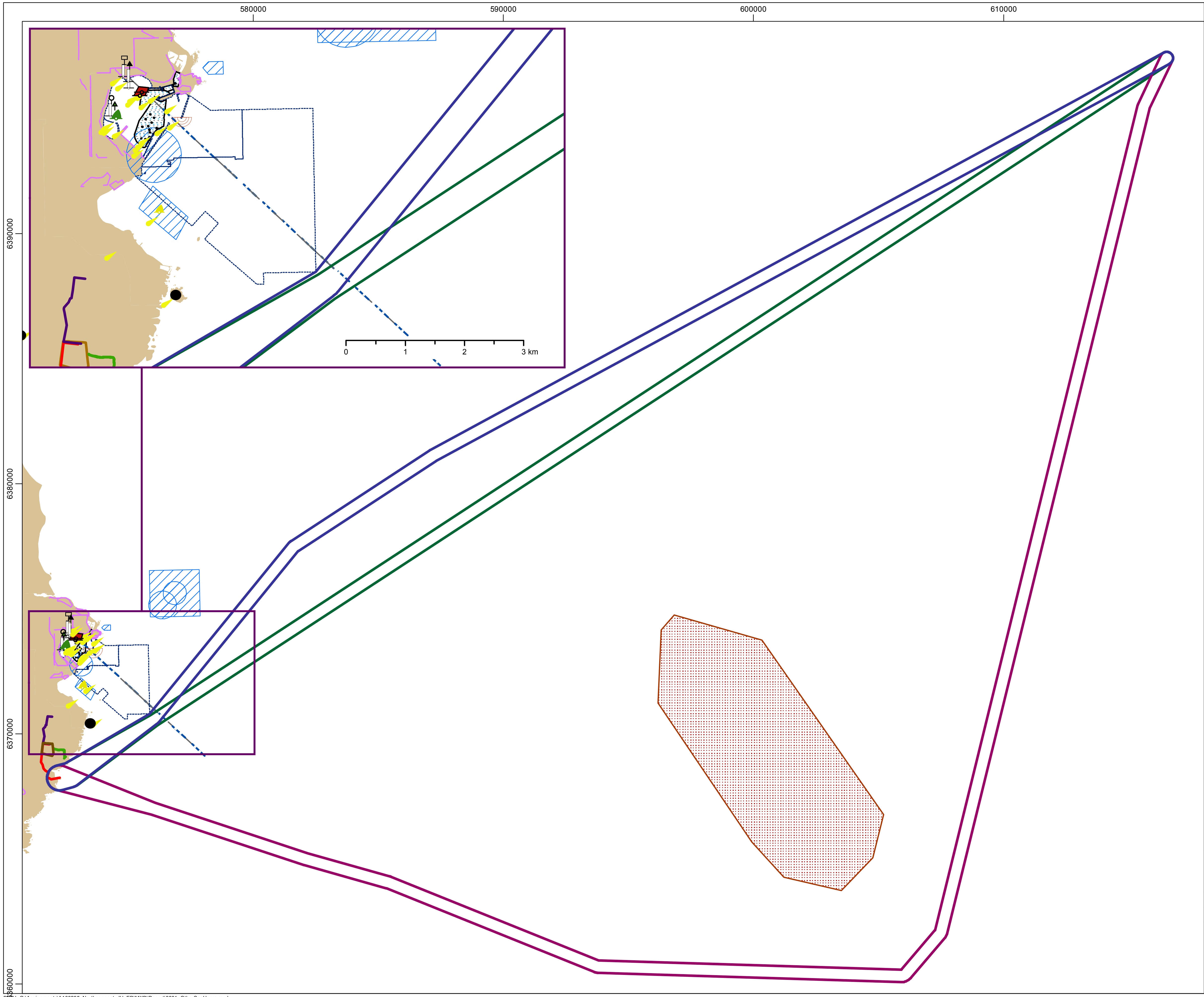
CLIENT: NORTHCONNECT CONNECTING RENEWABLES

DATE: 08/01/2015	SCALE:1:150,000	PROJECT: A100295	A3
DRAWN: JJH	CHECKED: EP	APPROVED: RH	
DRAWING: 0600_Infrastructure.mxd			REV: B

COORDINATE SYSTEM: WGS 1984 UTM Zone 30N

xodus GROUP

PATH: G:\Assignments\A100295_Northconnect_JH_EP\MXD\Report\0600_Infrastructure.mxd



KEY:

Revised survey corridor options

- 1
- 2
- 3

Onshore components

- Site Boundary
- AC Cable
- Access road to quarry
- DC Cable

Other sea users

- Beacon
- Buoy, special purpose/general
- Fog signal
- Light
- Topmark-cone, point up
- Topmark-sphere
- Topmark-triangle (point up)
- Topmark-triangle (point down)
- Radar transponder beacon
- Buoy, lateral - Port
- Buoy, lateral - Starboard
- Harbour area
- Administration area
- Navigation line
- Recommended track
- Crown Estate Area for Lease
- Dredged area
- CEFAS disposal sites

0 1 2 nm

0 1 2 3 4 5 km

N

TITLE:
Figure 6.2
Other sea users
within the study area

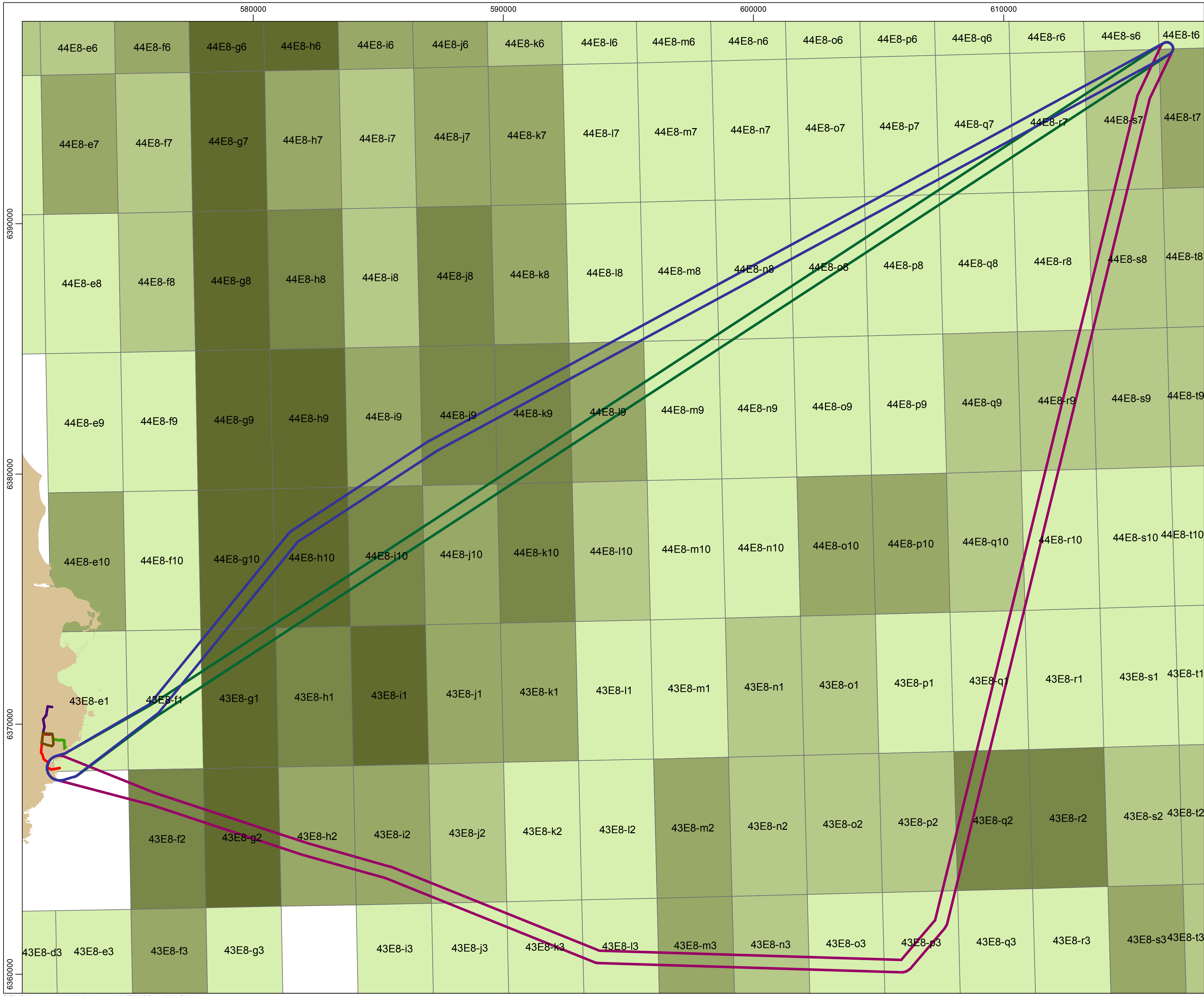
CLIENT: NORTHCONNECT CONNECTING RENEWABLES

DATE: 08/01/2015	SCALE:1:150,000	PROJECT: A100295	A3
DRAWN: JJH	CHECKED: EP	APPROVED: RH	
DRAWING: 0601_OtherSeaUsers.mxd			REV: B

COORDINATE SYSTEM: WGS 1984 UTM Zone 30N

xodus GROUP

PATH: G:\Assignments\A100295_Northconnect_JH_EP\MXD\Report\0601_OtherSeaUsers.mxd



PATH: G:\Assignments\A100295_Northconnect_JH_EP\MXD\Report\0602_Fishing.mxd

KEY:

Revised survey corridor options

- 1
- 2
- 3

Onshore components

- Site Boundary
- AC Cable
- Access road to quarry
- DC Cable

Mean time in minutes, 2009 - 2013

- 61 - 721
- 722 - 1620
- 1621 - 3217
- 3218 - 5352
- 5353 - 9413

0 1 2 nm

0 1 2 3 4 5 km

N

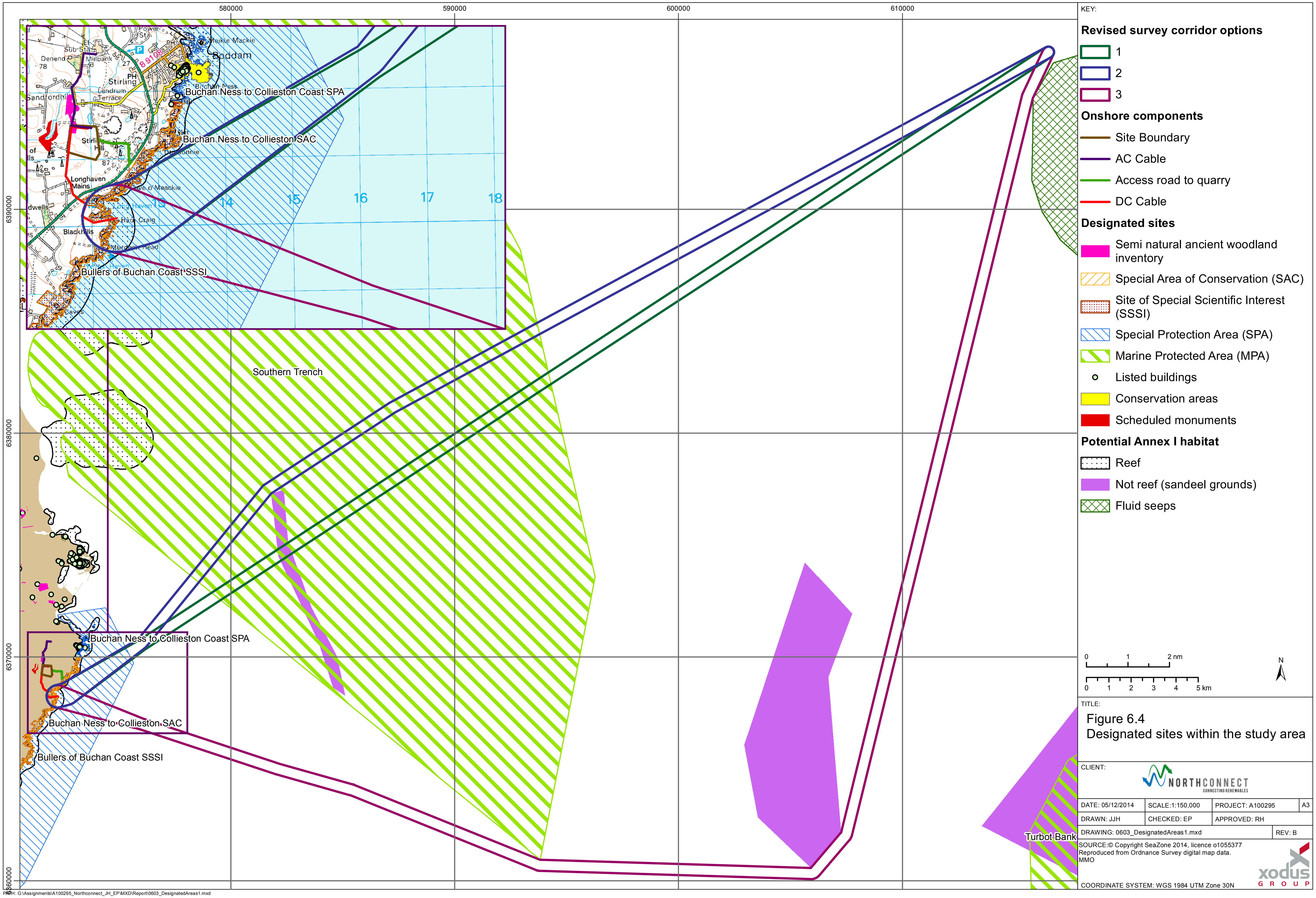
TITLE:
Figure 6.3
Mean fishing intensity within the study area from VMS data, 2009 - 2013

CLIENT: NORTHCONNECT CONNECTING RENEWABLES

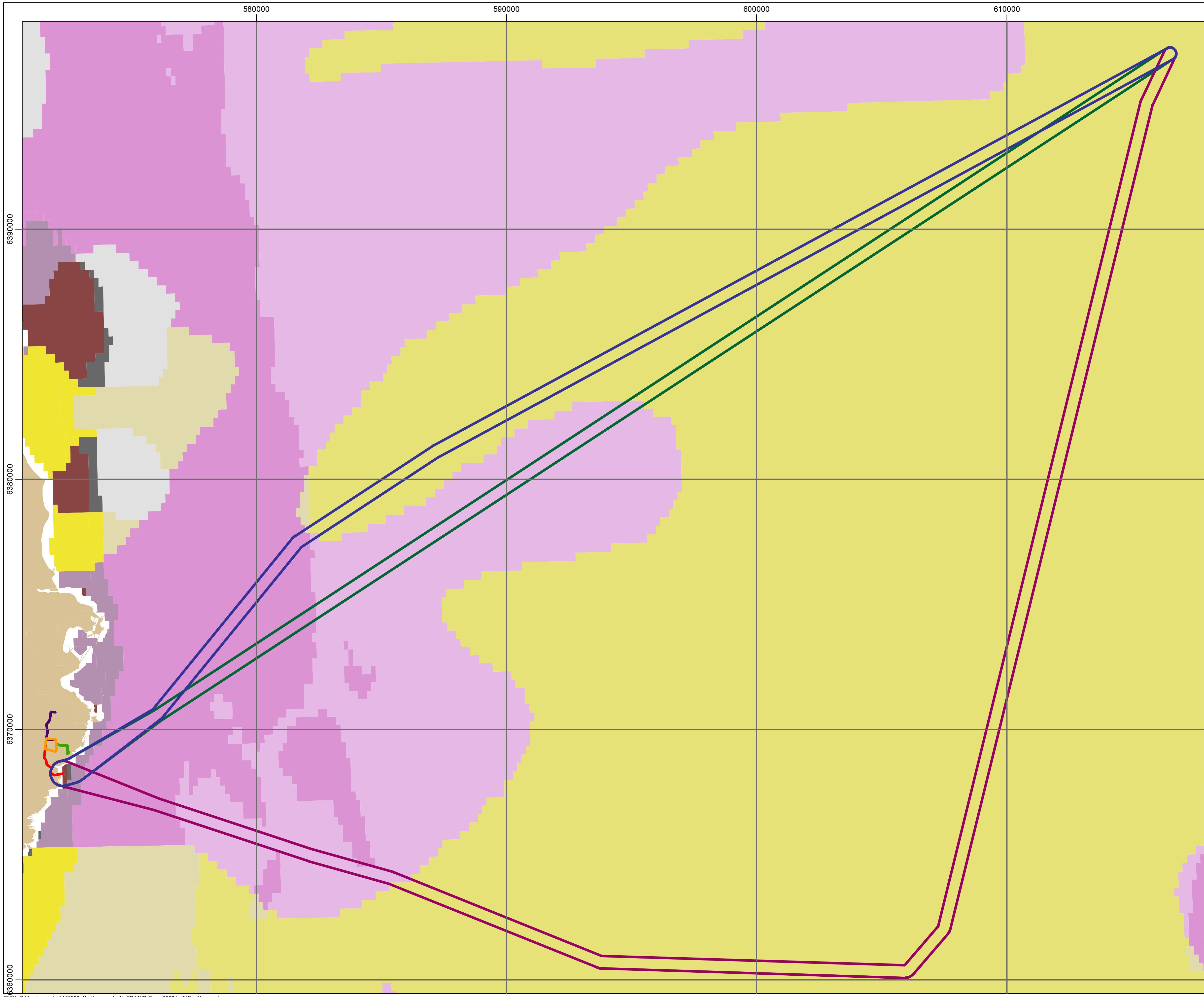
DATE: 08/01/2015	SCALE:1:150,000	PROJECT: A100295	A3
DRAWN: JJH	CHECKED: EP	APPROVED: RH	
DRAWING: 0602_Fishing.mxd			REV: B

COORDINATE SYSTEM: WGS 1984 UTM Zone 30N

xodus GROUP



TITLE:
Figure 6.4
Designated sites within the study area



KEY:

Revised survey corridor options

- 1
- 2
- 3

Onshore components

- Site Boundary
- AC Cable
- Access road to quarry
- DC Cable

UK SeaMap predicted habitat

- A3.1: Atlantic and Mediterranean high energy infralittoral rock
- A3.2: Atlantic and Mediterranean moderate energy infralittoral rock
- A4.2: Atlantic and Mediterranean moderate energy circalittoral rock
- A5.13: Infralittoral coarse sediment
- A5.14: Circalittoral coarse sediment
- A5.15: Deep circalittoral coarse sediment
- A5.23: Infralittoral fine sand or A5.24: Infralittoral muddy sand
- A5.25: Circalittoral fine sand or A5.26: Circalittoral muddy sand
- A5.27: Deep circalittoral sand

0 1 2 nm

0 1 2 3 4 5 km

N

TITLE:

Figure 6.5
UK SeaMap predicted habitat

CLIENT: NORTHCONNECT CONNECTING RENEWABLES

DATE: 05/12/2014	SCALE:1:150,000	PROJECT: A100295	A3
DRAWN: JJH	CHECKED: EP	APPROVED: RH	
DRAWING: 0604_UKSeaMap.mxd			REV: B

COORDINATE SYSTEM: WGS 1984 UTM Zone 30N

xodus GROUP

PATH: G:\Assignments\A100295_Northconnect_JH_EP\MXD\Report\0604_UKSeaMap.mxd