LLŶR FLOATING OFFSHORE WIND PROJECT

Llŷr 1 Floating Offshore Wind Farm

Environmental Statement

Volume 6: Appendix 3B – Offshore Geological Desk Study

August 2024

Prepared by: Llŷr Floating Wind Ltd

FLOVENTIS ENERGY

Document Status

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Approval for Issue

Prepared by	AECOM
Prepared for	Llŷr Floating Wind Limited
Approved by	Jay Hilton-Miller

Glossary of project terms

Term	Definition
The Applicant	The developer of the Project, Llŷr Floating Wind Limited.
Array	All wind turbine generators, inter array cables, mooring lines, floating sub-structures and supporting subsea infrastructure within the Array Area, as defined, when considered collectively, excluding the offshore export cable(s).
Array Area	The area within which the wind turbine generators, inter array cables, mooring lines, floating sub-structures and supporting subsea infrastructure will be located.
Floventis Energy	A joint venture company between Cierco Ltd and SBM Offshore Ltd of which Llŷr Floating Wind Limited is a wholly owned subsidiary.
Landfall	The location where the offshore export cable(s) from the Array Area, as defined, are brought onshore and connected to the onshore export cables (as defined) via the transition joint bays.
Llŷr 1	The proposed Project, for which the Applicant is applying for Section 36 and Marine Licence consents. Including all offshore and onshore infrastructure and activities, and all project phases.
Marine Licence	A licence required under the Marine and Coastal Access Act 2009 for marine works which is administered by Natural Resources Wales (NRW) Marine Licensing Team on behalf of the Welsh Ministers.
Offshore Development Area	The footprint of the offshore infrastructure and associated temporary works, comprised of the Array Area and the Offshore Export Cable Corridor, as defined, that forms the offshore boundary for the S36 Consent and Marine Licence application.
Offshore Export Cable	The cable(s) that transmit electricity produced by the WTGs to landfall.
Offshore Export Cable Corridor (OfECC)	The area within which the offshore export cable circuit(s) will be located, from the Array Area to the Landfall.
Onshore Development Area	The footprint of the onshore infrastructure and associated temporary works, comprised of the Onshore Export Cable Corridor and the Onshore Substation, as defined, and including new access routes and visibility splays, that forms the onshore boundary for the planning application.
Onshore Export Cable(s)	The cable(s) that transmit electricity from the landfall to the onshore substation.
Onshore Export Cable Corridor (OnECC)	The area within which the onshore export cable circuit(s) will be located.
proposed Project	All aspects of the Llŷr 1 development (i.e. the onshore and offshore components).
Onshore Substation	Located within the Onshore Development Area, converts high voltage generated electricity into low voltage electricity that can be used for the grid and domestic consumption.
Section 36 consent	Consent to construct and operate an offshore generating station, under Section 36 (S.36) of the Electricity Act 1989. This includes deemed planning permission for onshore works.

AECOM

LLyr Offshore windfarms and Cable routes

Geological Desk study

Floventis Energy

Project number: 60669422

21 March 2022

Delivering a better world

Quality information

Prepared by	Checked by	Verified by	Approved by
Dr. Arre Verweerd Associate Director Geophysics	Costanza Cagnina GIS Graduate Consultant	Tim Newton Associate ESIA Consultant	Frank Fortune EIA Technical Director-Offshore Wind

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Prepared for:

Floventis Energy

Prepared by:

Dr. Arre Verweerd
Associate Director Geophysics
M: 07786 626 249
E: arre.verweerd@aecom.com

AECOM Limited
12 Regan Way
Chetwynd Business Park
Nottingham NG9 6RZ
United Kingdom

T: +44 (115) 907 7000
aecom.com

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ABBREVIATIONS

BGS	British Geological Survey
DTI	Department of Transport and Industry
GIS	Geographical Infromation System
LAT	Lowest astronomical tide (m)
MBES	Multibeam Echosounder
MCA	Marince Character Area (Natural Resources Wales)
ODN	Ordnace Datun (Newlyn)
OSGB36	Ordnance Survey National Grid refernce system 1936
OWF	Offshore Wind Farm
SAC	Special Area of Conservation
UTM	Universal Transverse Mercator
UXO	Unexploded Ordnance
WGS84	World Geodetic System 1984
WMS	Web Map Server
QGIS	Quantum Geographical Information System

1. Executive Summary

Floventis Energy commissioned a geological desk study from AECOM across the proposed cable routes and Llŷr windfarm development zone.

Most of the data used in this desk study is of considerable age, and although from reputable sources (such as peer reviewed scientific articles, BGS,DTI and Admiralty) and of reasonable spatial density, care must be taken in using this information. It is important to obtain a current geophysical dataset of the study area, to correlate with the existing historical data,

Llyr development zone:

The bathymetry of the Llŷr development zone can be described as a relatively flat seabed, at an approximate depth of -68m LAT, with rather little seabed features

In general the seabed of the study area can be characterized by a relatively thin layer (less then 1m) of coarse sediments on cretaceous (chalk)/ Jurassic (mud/sandstone) bedrock and potentially glacial till. The sediments are relatively undifferentiated, classified as coarse sand-gravelly sand-sandy gravel. The western zone of the Llŷr development appears to have a smaller grainsize and is classified as sand.

Cable routes:

Sediment cover across the cable routes, either north or south show a very similar pattern as the Llŷr development zone, a relatively thin, coarse sediment cover. The southern route appears to cross more coarse sediments for the majority of its length than the northern route, which has a more sandy nature. Close to the southern cable landing (Barnstaple Bay), the sediment cover increases to several meters and more fine sediments (sandy, gravelly clay) are encountered. The bathymetry of the southern route show a gradual increase of seabed depth from shore to the deeper waters in the centre of the Bristol Channel.

The northern route shows more bathymetrical changes, especially close to the Welsh coast where several peaks (10m height) and throughs are observed. Several known rocky outcrops exist approximately 6 km offshore. A zone of increased sediment thickness and presence of sand waves is present, at a similar latitude as the sand waves described in the Outer Bristol Channel study, but only limited modern data exists for this area.

Recommendations:

Based on the findings of this study, it is deemed important to update the existing data sets by a geophysical and geotechnical investigation, to update information on:

- Sediment thickness within the Llŷr development zone and cable routes by a combination of sub-bottom profiling and vibrocores
- Sediment types/regimes form sidescan sonar and MBES backscatter analysis supplemented with grainsize analysis from grab samples or vibrocores on the Llŷr development zone
- Vibrocores together with thermal resistivity probes to characterize the seabed along the vibrocores

Based on the finding in the desk study, the sediment thickness of the Llŷr development zone might be insufficient for a drag anchor design and piled or gravity base foundations should be considered.

2. Introduction

1.1 General Information

Floventis Energy Ltd. commissioned AECOM Ltd to undertake a geological desk study of the proposes Llŷr 1 and Llŷr 2 Offshore Windfarms and cable routes, located within the Bristol Channel. The study will consist of a written report as well as a QGIS project database of the area under investigation.

1.2 Aim of this Study

This study will provide an overview of the geological features, marine habitats and human activity of the proposed areas. The information in this report is compiled form public domain datasets, report, maps and online information. All information is compiled, digitized and interpreted by AECOM Engineers in various AECOM UK offices. A list of references of information used is included in Section 2 Of this report.

The report excludes a study of UXO risk in the study area.

The area under investigation is located in the outer approaches of the Bristol channel/ Celtic Sea , west of the Island of Lundy (see Figure 1) and is comprised of two development areas (Llŷr 1 and Llŷr 2) and two options for the cable route, one north toward Wales (cable landing zone near Milford Haven, Pembrokeshire) and the second one, with a south-easterly heading towards Northam in Devon.

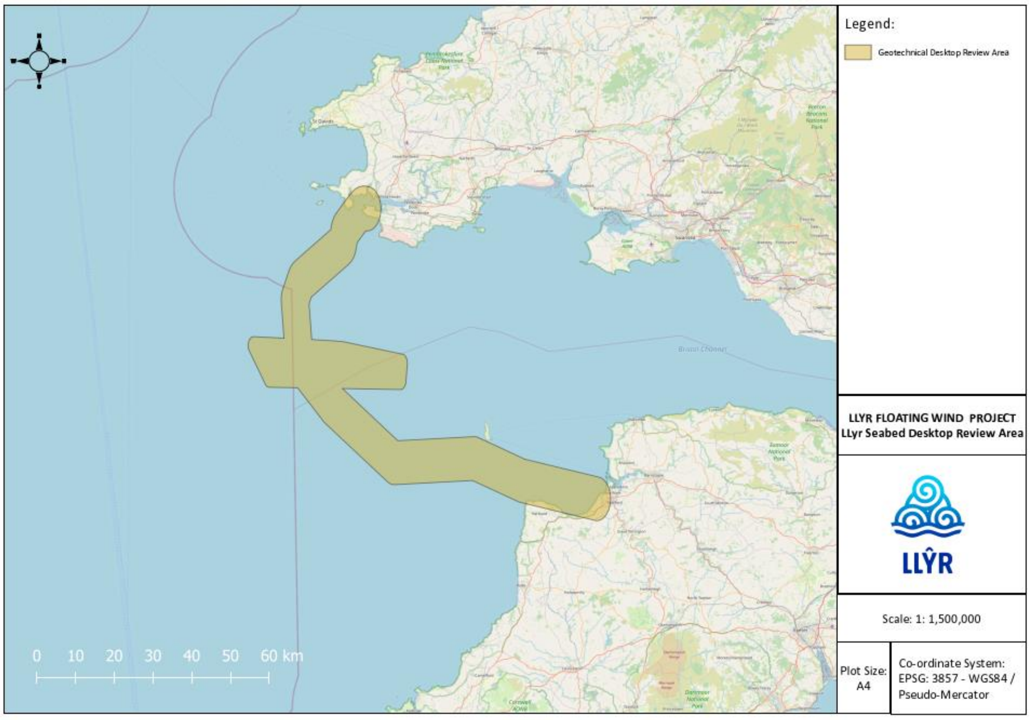

Figure 1: Llŷr Offshore wind fam (image and shape files provided by Floventis Energy)

1.3 Content and structure of this report

The study is organized in eight chapters, and presents both factual (publicly available) data, interpretive information and recommendations for follow-up detailed survey; the conclusion will also include a risk and mitigation register. All discussions in this report will refer to either figures included in the report body or maps provided in pdf format in Appendix B. A digital delivery of all compiled information is included as a QGIS project, in Appendix A.

3. Available Data

Only limited data is available of the study area, and most is based on research from the end of the 20^{th} century. Although data and images presented in this report are of reputable sources (governmental organisation, British Geological Survey and peer-reviewed scientific articles), care must be taken not to overinterpret the results, due to changes in technology and data analysis procedures.

2.1 Online GIS Databases

Data from the following online sources was used to populate the QGIS project presented in Appendix A and used to create the maps found in Appendix B. The following WMS Web Map Servers (WMS) were used:

- BGS
- EMODnet (Bathymetry, Geology and Human Activities)
- DEFRA
- Data.Gov.Wales

2.2 BGS Reports and Maps

In addition to the available digital datasets, several documents and maps from the BGS[1] have been included in this study and were digitized to be included in the GIS project:

- The sea-bed sediments around the United Kingdom, BGS Research report SB/90/1
- United Kingdom Offshore Regional report: The Geology of Cardigan Bay and the Bristol Channel
- Bristol Channel Sheet 51N 04W Sea Bed sediment & Quaternary, Scale 1:250 000
- Lundy Sheet 51N 06W, Sea Bed sediments Scale 1:250 000
- Outer Bristol Channel Marine Habitat Study – 2003 Investigations and Results J.W.C James, S.L Philpott, G Jenkins, A.S.Y Mackie, T Darbyshire and E.I.S Rees Keyworth, Nottingham British Geological Survey 2004
- Geology of Britain Viewer, BGS Keyworth, Nottingham [online] https://mapapps.bgs.ac.uk/geologyofbritain/home.html
- British Geological Survey. 2020. The BGS Lexicon of Named Rock Units [online]. Keyworth, Nottingham. Available from https://www.bgs.ac.uk/technologies/the-bgs-lexicon-of-named-rock-units/.

[1] British Geological Survey, Keyworth, Nottingham

2.3 Government and Industry Guidelines/Standards

The following documents were used as reference and guidance documents for this study:

- Standard Ground Investigation- Minimum requirements for geotechnical surveys and investigations into offshore wind energy structures, offshore station and power cables- Bundesamt fuer Seeschifarhrt und Hyfrographie-2014
- Guide to an offshore wind farm -Updated and extended, BVG Associates 2018 on behalf of the Crown Estate and the Offshore Renewable Energy Catapult, 2019
- JNCC (2015) SAC Selection Assessment: Bristol Channel Approaches / Dynesfeydd Môr Hafren. January 2016. Joint Nature Conservation Committee, UK
- UK.Lundy SAC https://sac.jncc.gov.uk/site/UK0013114
- DTI Strategic Environmental Assessment Area 8, superficial geology and processes. British Geological Survey Commissioned Report, TAPPIN, D R., MASON, T. and ROCKS, K., 2007 CR/07/075.
- DTI Offshore Energy Strategic Environmental Assessment Programme Technical Report on the Other Users of the SEA8 Area, Metoc PLC 2007, report No R1673 REV1
- DTI Strategic Environmental Assessment Area 8 (SEA8)- Geology and Sediment Processes Compiled by: Deborah Tyrrell, 2004

2.4 Scientific Articles

The following scientific articles were used in the analysis and figures have been reproduced in this report.

- “Topographic features of the Bristol Channel sea-bed: a comparison of SEASAT (synthetic aperture radar) and side-scan sonar images” P.T. Harris, G.M. Ashley, M.B. Collins and A.E. James, Int. J. Remote Sensing, 1986
- “Bristol Chanel Sediment Regime”, B. Cooper, Marine Sandwave Dynamics, International Workshop Lille, 2000
- “The north-westwards continuation of the Sticklepath Fault: Bristol Channel, SW Wales, St. Georges Channel and Ireland”. A. Ruffell, Geoscience in south-west England, 2002
- “The Sticklepath-Lustleigh fault zone: Tertiary sinistral reactivation of a Variscan dextral strike-slip fault”. S. Holloway and R.A. Chadwick, Journal of the Geological Society, 1986.
- “Pembrokeshire Superficial Deposits and Habitats”. B. John, An Historical Atlas of Pembrokeshire, ed D.W. Howel (2019).
- ”Evidence for the importance of small faults on block rotation”, D.C.P. Peacock, M.W. Anderson. A. Morris, and D. Randall, Tectonophysics 1998
- “Old Red Sandstone facies of the Pembroke peninsula, south of the Ritec fault” B.P.J Williams, J.R.L. Allen, J.R.L.,J.D. Marshall, and M.G. Bassett. Geological Excursion in Dyfed, South-west Wales, 1982

2.5 Atlantic Array Survey Reports

Between 2007 and 2013 several companies investigated the development of a 1.2GW offshore windfarm in the Bristol channel called Atlantic Array (see Figure 2). After several years of investigations and submission of a planning application in June of 2014 by RWE the project was shelved due to substantial technical challenges and issues in RWE's home market in Germany.[2] Some of the reports and datasets collected during the development phases of Atlantic Array have been made available in the public domain on https://www.marinedataexchange.co.uk/. For this study the following documents have been included:

- Channel Energy Limited Atlantic Array Offshore Windfarm- Geotechnical Investigations and Laboratory tests Report 1-Boreholes and DTH CPT. GEO project 33837, 2011 GEO
- Channel Energy Limited Atlantic Array Offshore Windfarm- Geotechnical Investigations and Laboratory tests Report 2-laboratory tests. GEO project 33837, 2011 GEO
- RWE NPOWER Renewables, Atlantic Array-Cornborough range Cable Landfall- Feasibility Desk study- Metoc 2010
- Channel Energy Ltd. Outer Bristol Channel, Atlantic Array Offshore Windfarm Geophysical Survey-Survey Report, 2010 Gardline Geosurveys Ltd.
- Channel Energy Ltd. Outer Bristol Channel, Atlantic Array Offshor Cable Route Geophysical Survey-Survey Report, 2010 Gardline Geosurveys Ltd.

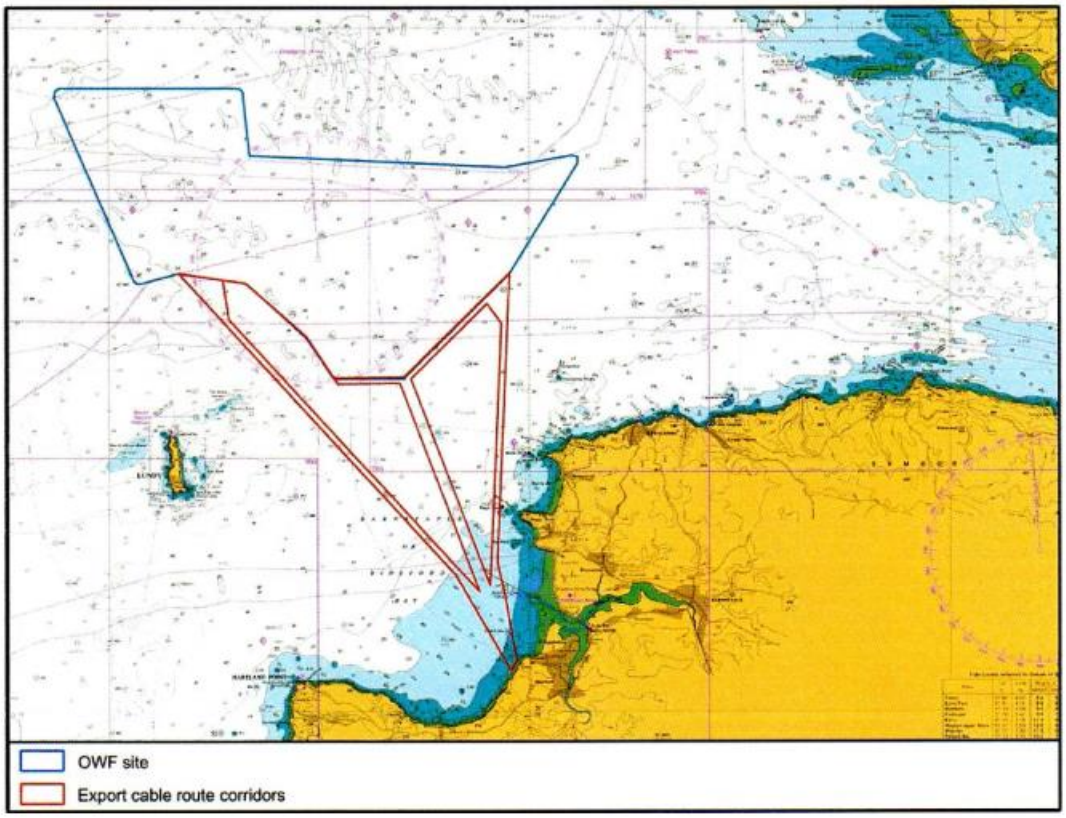

Figure 2: Atlantic Array site and cable route extents (after GEO)

[2] After "Analysis: Why did RWE decide to drop Atlantic Array", November 2013, J. Quilter, https://www.windpowermonthly.com/article/1223085/analysis-why-rwe-decide-drop-atlantic-array

4. Engineering Focus

This desk study will focus on a variety of geological and anthropogenic features, compiled in narrative, maps and a GIS project file (digital delivery). Apart from the assessment of different elements, recommendations for future work and a risk register will be included.

3.1 Llŷr 1 & Llŷr 2 Offshore Windfarms

For the offshore wind turbines, Floventis Energy is planning on a floating turbine design, and therefore the focus for the study will lie on the specific hazards and constraints around anchor types (drag anchor, suction buckets, driven and grouted piles, gravity base).

A summary of the geology to approximately 100 m below ground will be included for the Llŷr development zone (Llŷr 1 & Llŷr 2) as well as seabed conditions for the site, comprised of elements such as:

- Presence of seabed obstructions (boulder fields, shipwrecks, existing cable and pipeline routes)
- Presence of geological risks (outcropping rocks, buried paleo channels, active fault lines and earthquakes)
- Presence of geotechnical risks (soft soils, shallow gas)
- Assessment of seabed mobility
- Assessment of suitable foundations

3.2 Cable routes

For the cable routes the focus will be on the top 10m of the seabed, and will include elements such as:

- Seabed obstructions (see above)
- Military and Environmental exclusion zones
- Shipping lanes and anchorage points

5. Bathymetry and Seabed Morphology

The bathymetry of the study area can be found in Map 1 in Appendix B, from this dataset several representative profiles are extracted for discussion in this section (see Figure 3).

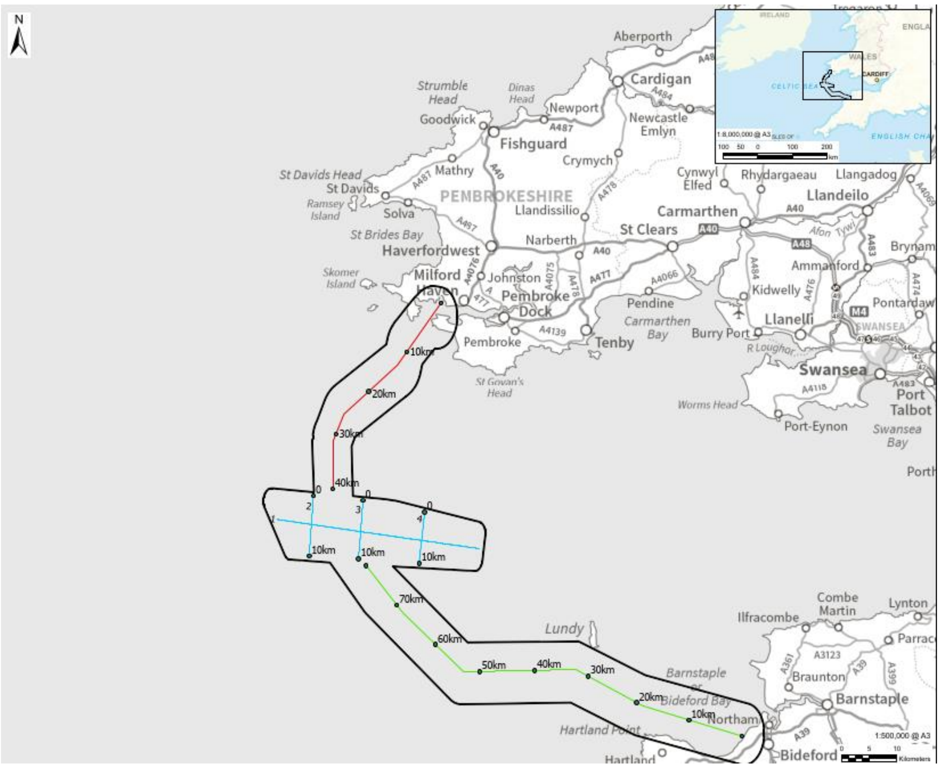

Figure 3: Location of Bathymetry profiles (blue = development zone, red = north, green = south cable route)

4.1 Llŷr Development Zone

Four profiles have been extracted for the Llŷr development zone, an east-west profile (profile 1) through the central area of the zone and three north-south profiles (profile 2,3,4).

Figure 4: East-West Bathymetry Llŷr 1 & 2 with intersection points of the north-south profiles

General bathymetry of both Llŷr 1 and 2 sites is relatively flat (Figure 4), seabed depth is approximately 68m below Lowest Astronomical Tide (LAT). Towards the east of the sites, there is a slight decrease is seabed depth, to approximately 62m below LAT. The western portion shows a slight increase in depth to around 70m.

Four profiles were extracted from the database to represent the bathymetry of the Llŷr 1 & 2 sites: one along the longitudinal direction and three transverse profiles

As can been seen from Figure 4 , the majority of the east- west profile across the site shows very little variation, at an approximate depth of 68 m below LAT. The far west of the profile is slightly deeper (-70m), but the slope is rather flat (from -70m to -68m LAT a 1:0.003 slope). The Eastern portion of the survey area shows more relief, with several increases of seabed elevation, to a level of -62m at the far east of the development zone.

Similarly in the north south profiles (Figure 5), little seabed topography is observed, other than a general increase in depth of several meter in the southern 2-3 km of the study area.

Overall the whole study area shows a relatively flat signature with an average depth around 68m below LAT.

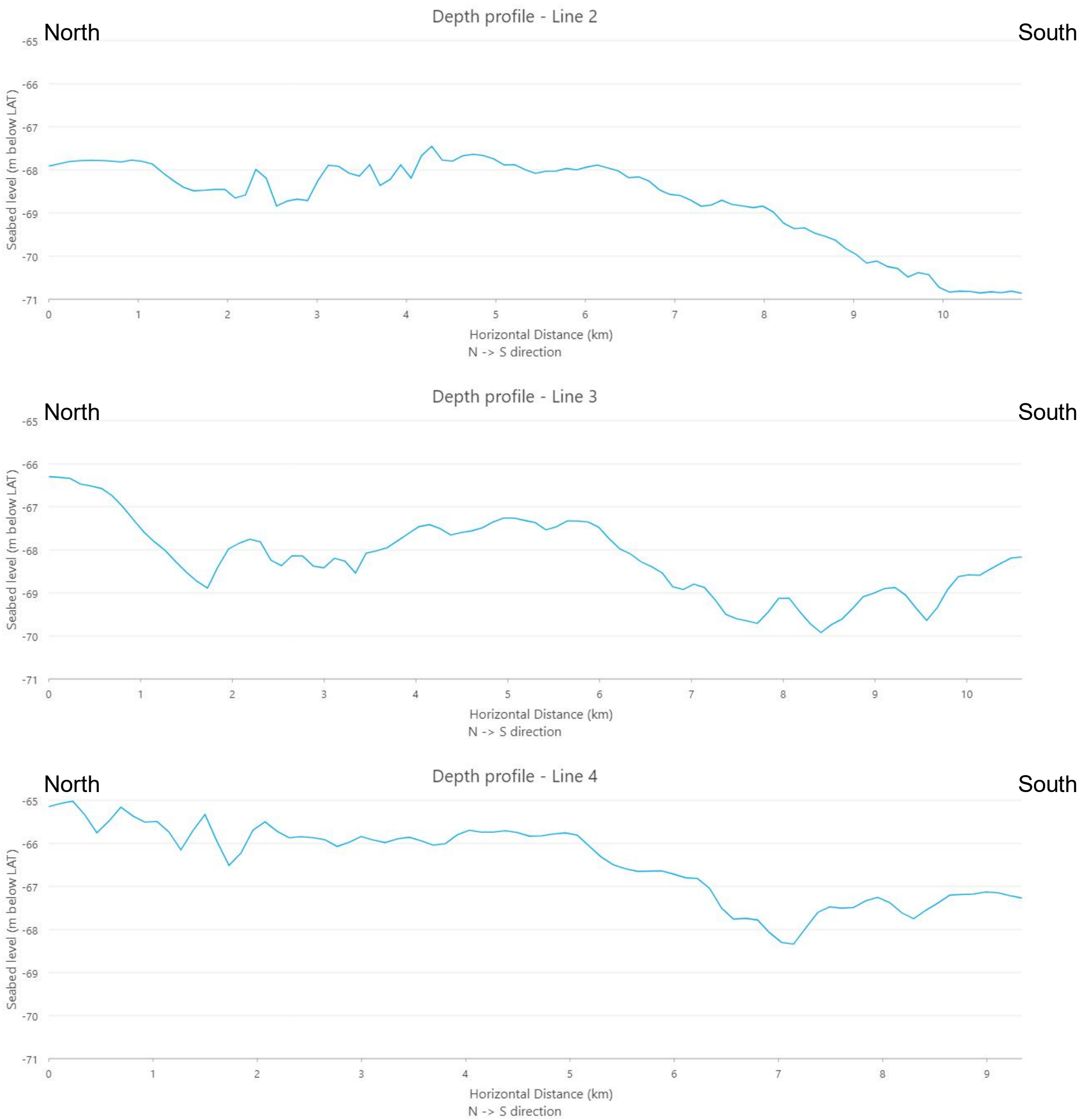

Figure 5: North South Bathymetry Llŷr 1 & 2 (three profiles)

4.2 Cable routes

For the cable routes a profile in the centre of the study areas was extracted (see Figure 3 for locations).

The northern route (Figure 6) shows more relief than the southern route (Figure 7), where a general, relatively smooth increase in depth can be observed. The southern route shows after the initial decrease from the coastline, a plateau around 20m below LAT for the first 12 km form shore, before relatively quickly increasing to a depth of 50m below LAT and more.

Figure 6 Northern route bathymetry

Figure 7: Southern route bathymetry

The northern route shows several peaks in the seabed, where over a length of 18km from shore topographic features are observed decreasing the depth of the seabed with up to 10m.. No gradual decrease is observed as was in the south route, apart from the last 8 km of profile toward the location of the Llŷr development zone.

4.3 Seabed Morphology

The seabed of the survey area is dominated with rather large grained sediments, typically gravels and medium to coarse sands (see Maps 2, 3 and 4 in Appendix B). A generalized seabed thickness and bed form map can be found in Figure 8 below.

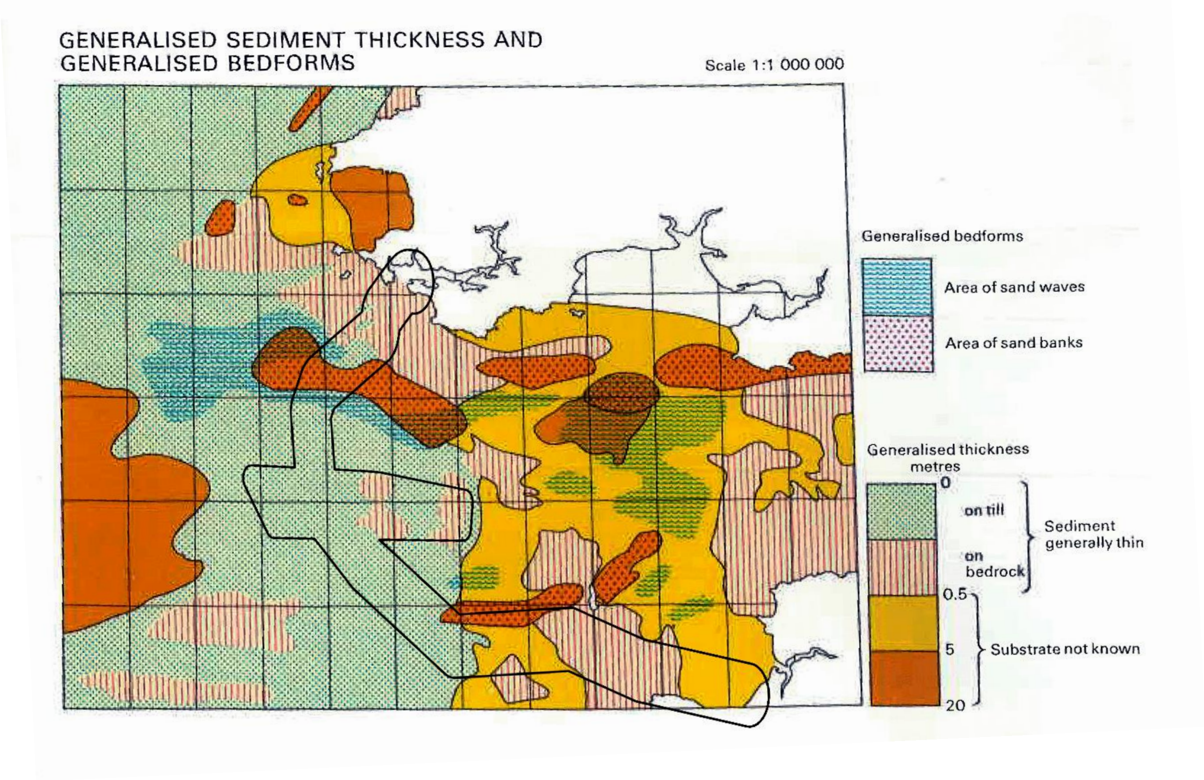

Figure 8: Generalised Sediment Thickness and generalised bedforms (BGS Lundy map sheet)

Seabed morphology of the majority of the study area is rather limited, due to only a thin layer (potentially mobile) of sediment thickness overlying glacial till or directly on bedrock.

Along the northern route a band of thicker sands and associated sand waves is located, approximately 9 km out of the coastline.

Small patches of substrate classified as mud and rock/boulders are present in the study area (Map 2 of Appendix B). The largest area of mud can be found on the cable landing area on the southern landing zone, where the area south of Bideford is classified as Mud and the northern half classified as Sand.

Rocky outcrops can be found around Lundy, and make up the Lundy SAC, extending more to the North and East of the island than the south, where it is included in the cable route. Also in the north some isolated spots of exposed bedrock are indicated. No information on the type of rock is available but these isolated features have been encountered in 9 separated locations by historical BGS surveys.

4.4 Atlantic Array and other sources

No direct indication of seabed features was available in the public domain, the study area has not been covered by other investigations. The area directly to the east of the study area has seen detailed investigations (Figure 9), mapping the seabed character from an environmental perspective and as part of the Atlantic Array development (Figure 2). As can be seen from Figure 8, there is a continuous band of sand waves from this eastern zone across the northern cable route, which could include similar sand wave features.

It is very unlikely the large sand waves are present in other sections of the study area, due to the coarser nature of the material present and the expected thin nature of the sediment cover. There also is no evidence in the bathymetry data of the presence of large sand waves.

An interpreted seabed features map was developed by Gardline Geoscience of the Atlantic Array development zone (Figure 10). Both investigations show a very similar image, of a thin layer coarse sediments overlying bedrock for the majority of the areas surveyed. The Sub-bottom profiling data collected by Gardline show a sediment thickness of 5-8m between sandwaves and up to approximately 20m at sandwaves in the north-northwest of the areas surveyed.

Towards the east and south, closer to the Llyr development zone the sediment cover is described as a siltly sand veneer (<0.5m thickness). The eastern part of the survey area is also marked with frequent boulder/protrusions of bedrock (with heights over 1m above the seabed). Based on the seismic dataset the reflector identified as bedrock is estimated at <2m below the seabed for the east and southern portion of the Atlantic Array survey area (using a fixed velocity of 1700 m/s)

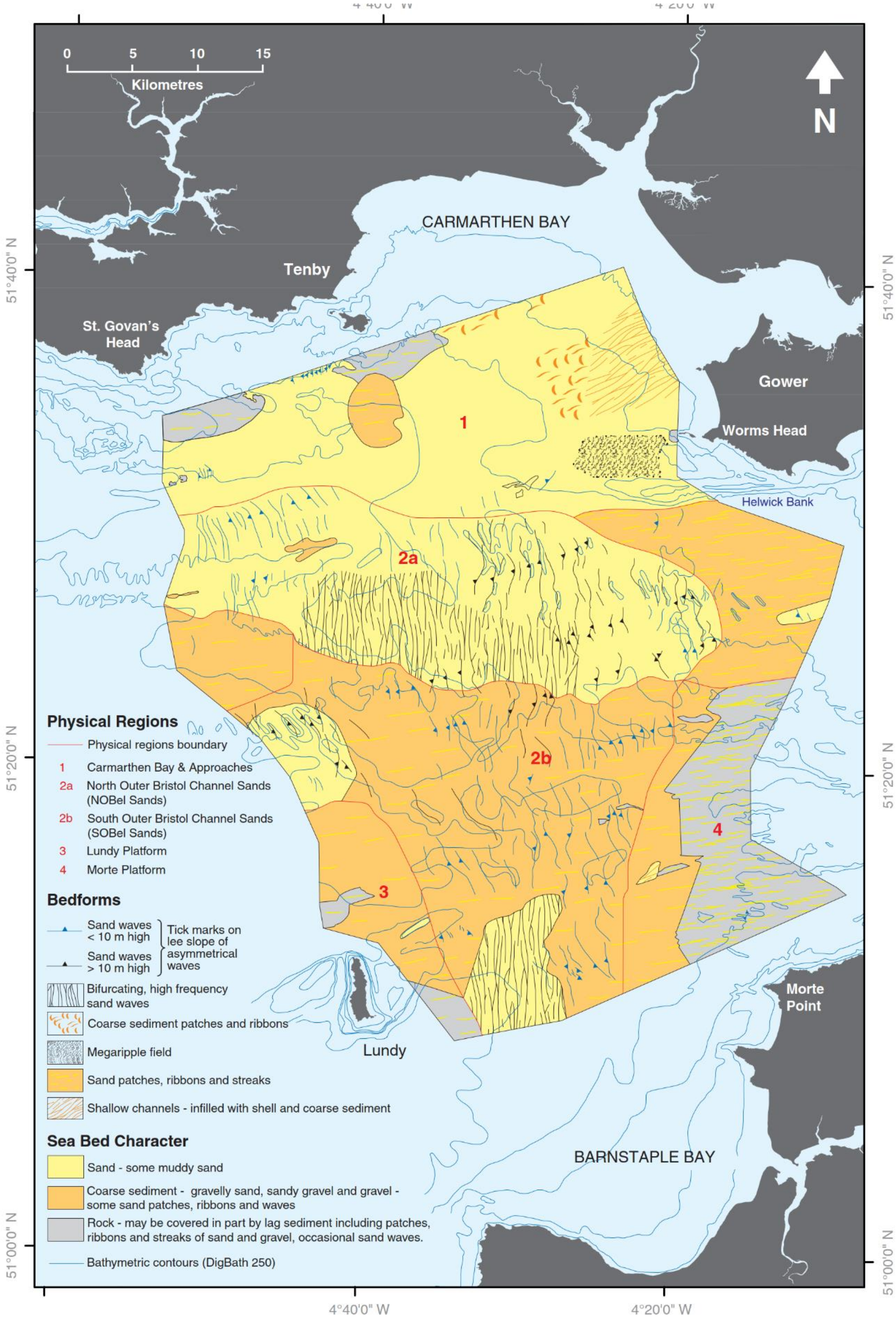

Figure 9: Seabed Characteristics Outer Bristol Channel (James et al)

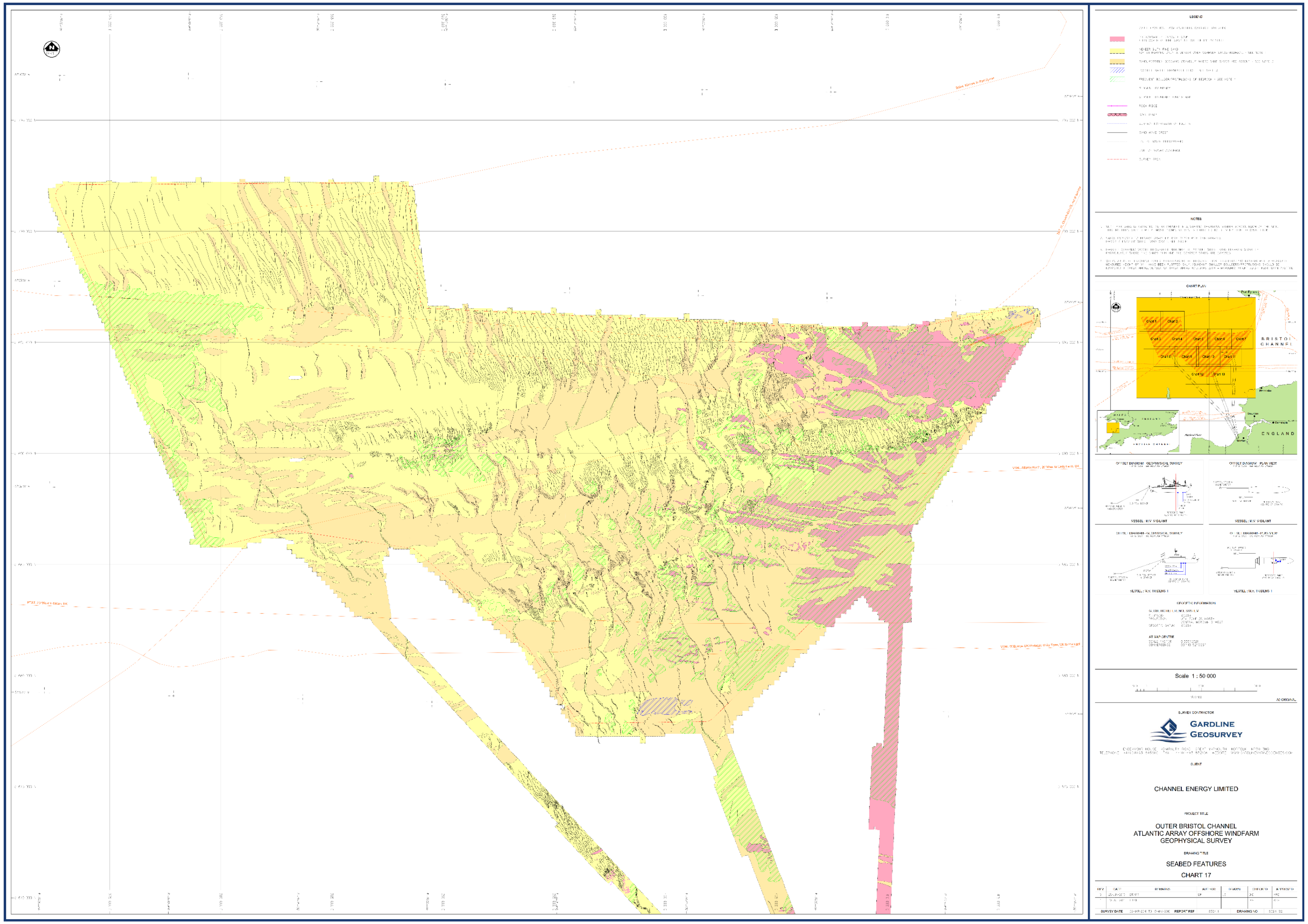

Figure 10: Atlantic Array Seabed feature map (after Gardline Geosurvey)

4.4 Sediment movement

As part of a government funded research programme examining the potential of Marine Aggregate Resources a conceptual sediment transport model was developed for the Severn estuary and the Bristol channel (Figure 11).

Sediment movement follows different regimes along the study area, near shore regions of the cable route are experiencing an easterly direction of transport, whereas the central portion a westerly direction. Overall transport speeds are likely limited, due to the coarse nature of the sediments along the study area.

Outcome of this study show the following general properties for the Outer Bristol channel sandwave areas, located adjacent to the study area:

- Wavelength: 100 to 150m
- Crest height: 10 to 15m
- Peak spring flow: 1.4m/s (ebb)
- Local depth: 30 to 40m
- Tidal range : 7.2 spring, 3.2m neap

The largest sandwaves in the Outer Bristol Channel, located directly to the east of the survey area have crest heights of more than 15m with megaripples superimposed on top of the sandwaves. Modelling the sediment transport process by the action of waves and tides indicates that the net transport direction across the area of sandwaves is maintained under all conditions, including opposing Atlantic storms.

The following general characteristics for sandwave areas were concluded in the report.

- New sandwaves form slowly;
- Locations of sandwave fields are precise and lasting;
- Morphology of sandwave fields are stable because they are in general equilibrium with their local hydrographic environment. During reduced tidal streams (neap tides) and calm conditions sandwaves will favour growth (given sediment supply) or maintain their existing form. This is balanced by periods of erosion during storms.
- The movement of isolated sandwaves is poorly understood at this moment in time due to limited data coverage and lack of repeat surveys.

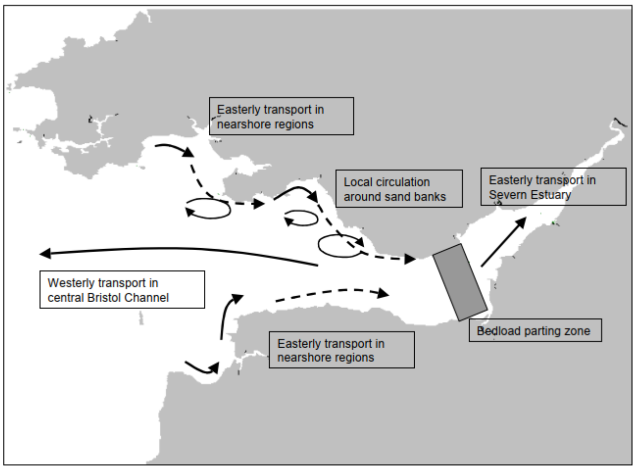

Figure 11: Conceptual model of sand transport in the Bristol channel (after Cooper, 2000)

Harris et al discusses a comparison between three different investigations east of the survey area. An Admiralty survey from 1977 was compared to analysis of synthetic aperture radar SEASAT images and a side-scan survey in 1983.

A profile was extracted from each data set (Figure 12 and Figure 13), and the location of the sand wave crests was compared (for the 1977 and 1983 side-scan surveys height of the crests was analysed as well).

It can be seen for Figure 13 that in the 6 years between the 1977 and 1983 surveys the location of the crestlines of the main features has remained relatively stable, especially in the western portion of the profile, although the height of the crest shows some variation.

No modern MBES datasets or repeat surveys are available for the study area to corroborate these findings.

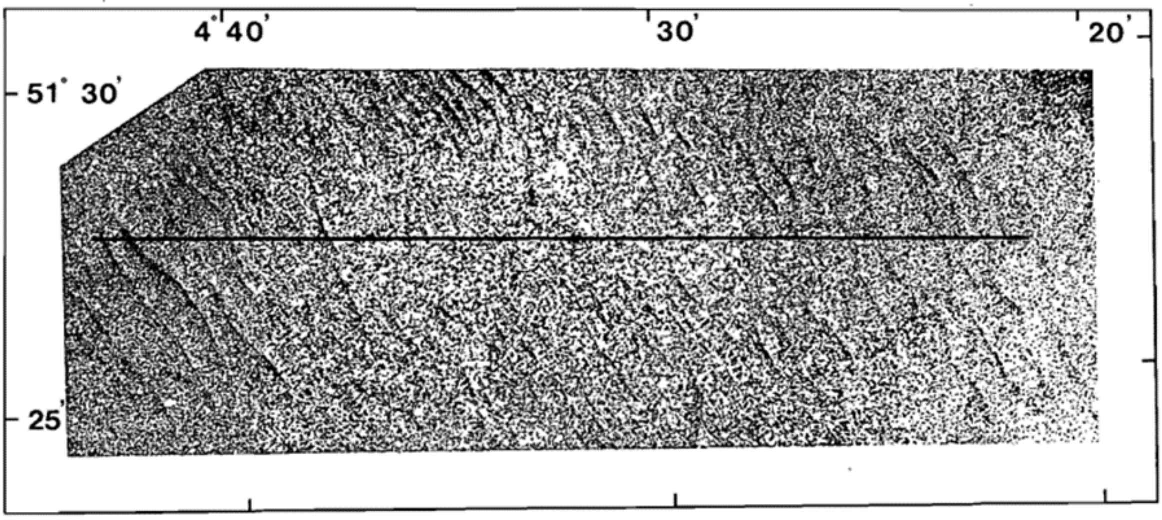

Figure 12: SEASAT SAR image of the outer Bristol Channel sandwave field, showing profile used in comparison (after Harris et al, 1986)

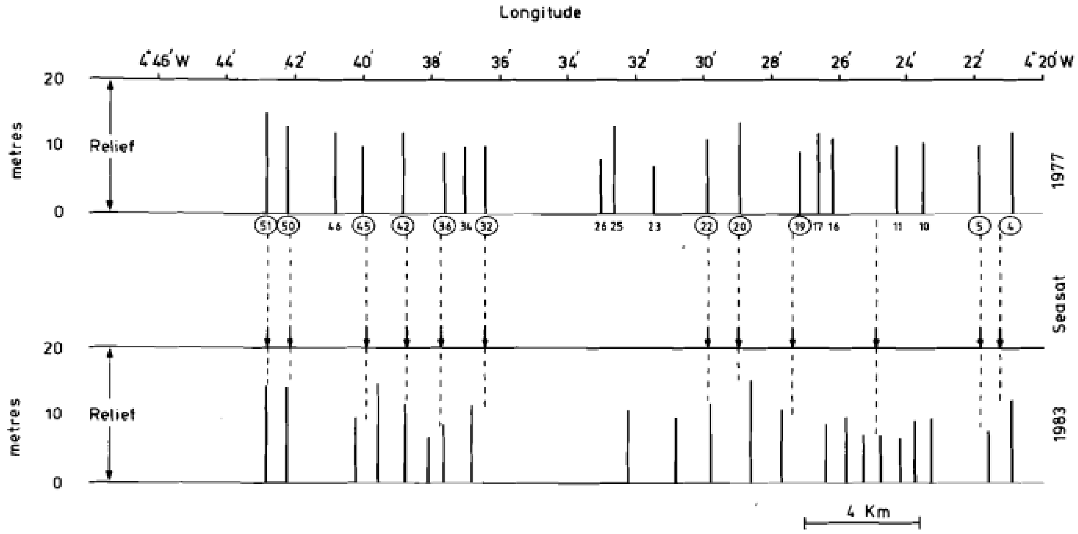

Figure 13: Plot of crest location of sandwaves >6m in the Outer Bristol Channel, comparing side-scan sonar and SEASAT data sets. Comparable crestlines are indicated with the encircled numbers (after Harris et al, 1986).

6. Geological Setting

5.1 Basement Geological Setting

The structural setting of the basement of the Bristol Channel is dominated by the Caledonian and Variscan fold belts. Both major Orogenic domains meet at the south coast of Wales, at the Variscan Thrust front (see Figure 14). This structure follows an approximately east-west strike, dipping relatively steep towards the south.

Towards the western end of the Bristol Channel, around the Island of Lundy some northwest-south east trending faults are observed, bounding the Lundy Horst structure (see Figure 21). Most of these faults to the west of the island of Lundy are relatively small scale, but to the east a large named fault, the Sticklepath-Lustleigh fault is observed extending from the south coast of Wales across Devon to the English Channel.

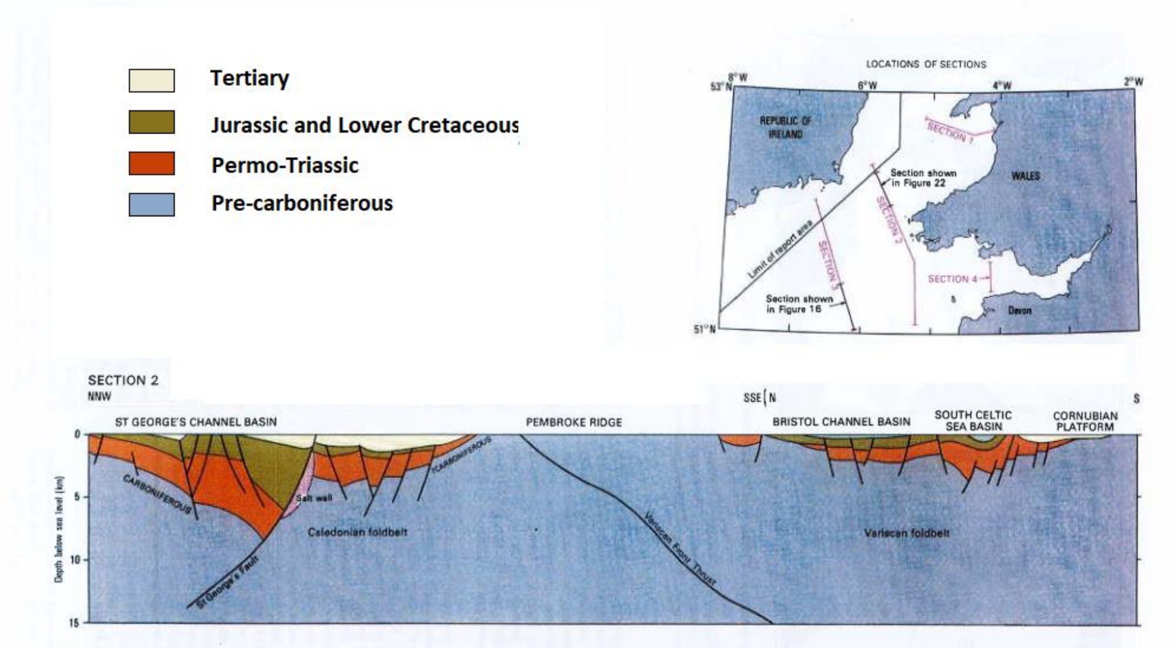

Figure 14: Large scale structural setting Study Area (after BGS regional report)

5.2 Cable Landing

5.2.1 Northern cable landing zone

The bedrock geology of the Pembrokeshire cable landing zone (Figure 15) is dominated by the Milford haven subgroup, part of the wider Old red sandstone supergroup. The group consists of hard red calcareous marls interspersed sporadically by green and red sandstones and red marls and breccia to the South.

In the eastern edge of the proposed landing zone, along the Angle peninsula, a syncline striking East west exposes ridgeway conglomerate, also part of the old red sandstone group. The younger Skrinkle sandstone and Black rock subgroup and gully oolite formation units are found in the centre of the syncline. North of St Anne’s head, the geology becomes more complicated with sedimentary and volcanic deposits belonging to various units outcropping in a band striking East West, bounded by the Musslewick fault to the North and the Wennal fault to the South (Williams et al 1982). The volcanic deposits belong to the Skomer volcanic group consisting of subaerial lava flows with breccias, conglomerates quartzites and red clay rocks. Whilst the sedimentary deposits consist of quarzitic sandstones of the Gray sandstone group and shales, mudstones, and limestones of the Coralliferous group.

The soils in the area (Figure 16) are typically thin, mostly free draining, acid in areas overlying the old red sandstone and base rich where underlain by carboniferous limestone (John 2019). Along the coast, marine beach deposits are found, whilst along low-lying areas, tidal flat deposits comprising sand silt and clay dominate. Glacial till deposits are found on St Anne’s head, whilst areas of blown sand are found on the Angle peninsula to the East. However, the superficial deposits are sporadic and in general the bed rock geology dominates the area.

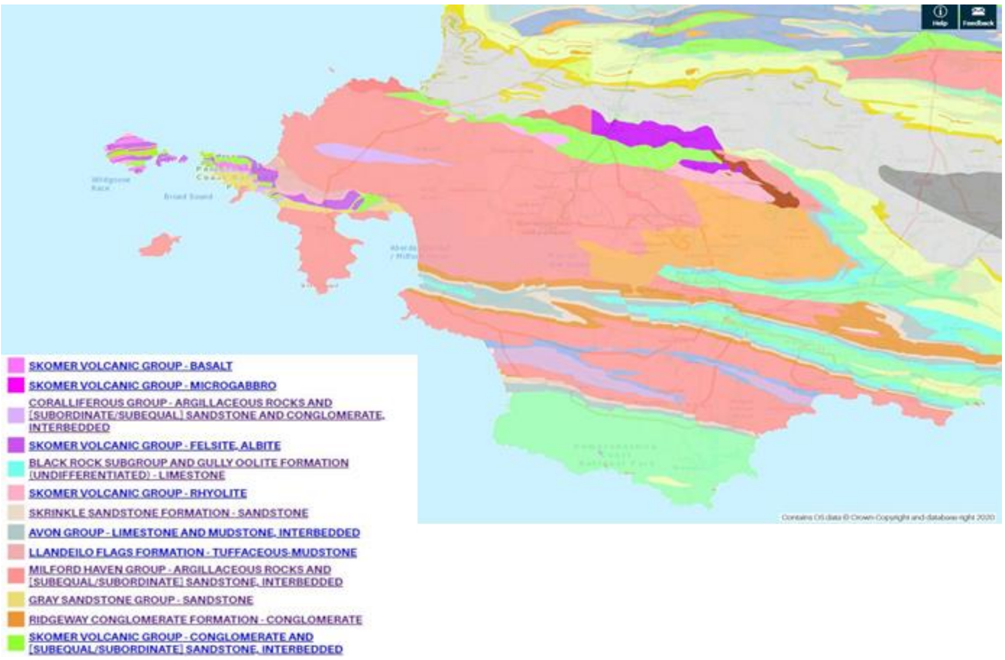

Figure 15: Bedrock geology cable landing North

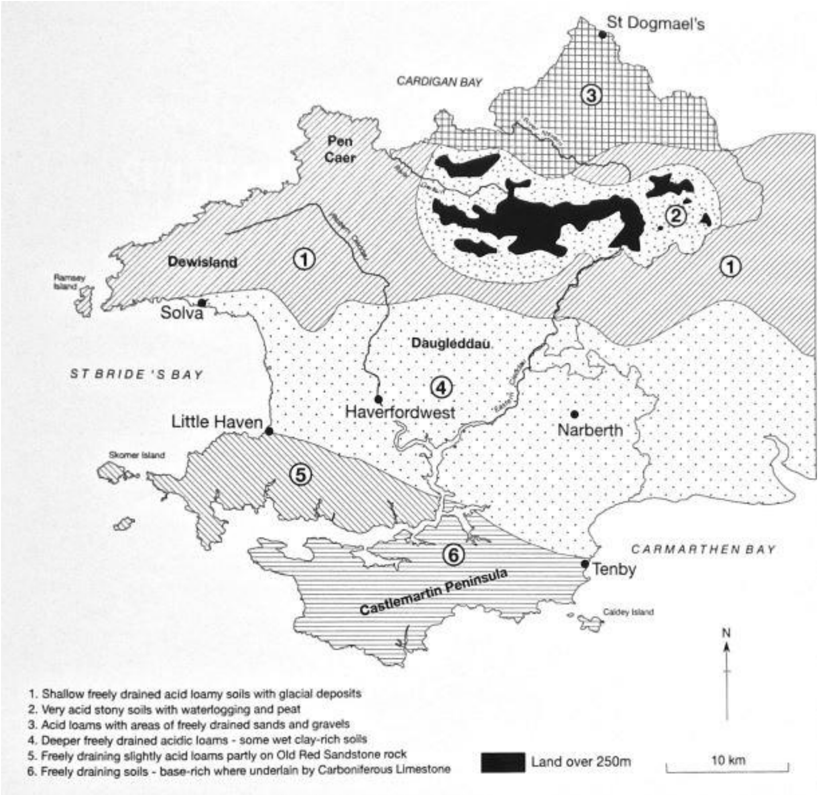

Figure 16 Soil types of Pembrokeshire (after John, 2019)

5.2.2 Southern cable landing zone

The geology of the Devon cable landing area is dominated by the Bude formation (Figure 17), this formation with ages between 319ma and 309ma predominantly consists of grey thick bedded sand stones and mudstones. In addition, bands of black sulphurous shales also appear within the formation. This outcrops at the coast between Westward Ho! and Clovelly where the underlying Crackington formation outcrops, extending to the Western extents of the proposed landing zone.

The Crackington formation consists of rhythmically bedded, dark blue-grey mudstones and grey sandstones and siltstones. The percentage of sandstone varies between 20-75% vertically and geographically. In the uppermost part of the formation, destratified beds and scattered ironstone nodules are present.

Figure 17: bedrock Geology of the southern cable landing (after BGS geoindex)

Between Westward Ho! and Bideford, small linear outcrops of the Bideford formation appear in an area where the Bude formation dominates, these outcrops strike roughly East west. The Bideford formation consist of mudstones interbedded with sandstone and siltstone and has an age of between 318ma-319ma, this sits between the Bude and Crackington formations stratigraphically.

Minimal Superficial deposits are found in the area (typically only several meters in thickness), with marine beach deposits found along the coast and alluvium of varying grain sizes present in valleys and low-lying areas. The estuary of the rivers Taw and Torridge in the North of the cable landing zone provide thicker surficial clay and sand deposits.

The Sticklepath-Lustleigh fault bisects the landing area, striking NW-SE, dextral strike slip fault with a total throw of 10km that has been active since the post Permian age (see also Figure 21).

5.2.2 Atlantic Array cable landing zone

During the development of the Atlantic Array offshore windfarm, the proposed cable landing zone was near the town of Bideford as well, and can be seen as typical for the coastline. A shoreline desk study and geophysical survey report are available for this area and will be reproduced in this section.

The alignment sheet of the cable landing zone (alignment sheet 10) of the Gardline Cableroute report is reproduced as Figure 18.

It shows the coastline to be composed of rock/rocky mud and sandstone outcrops(Bideford formation), with only a thin layer of sand (typically 1m or less in thickness). Within the top sand layers, some internal reflectors are observed, which are likely due to gravelly or bands of more coarse sand. Below the mobile top layer, a basal sand and gravel layer is identified, overlying the bedrock. Several borehole are available[3] in the Metoc report, indicating a total thickness of coarse sediments between 0 and 2.8m

3

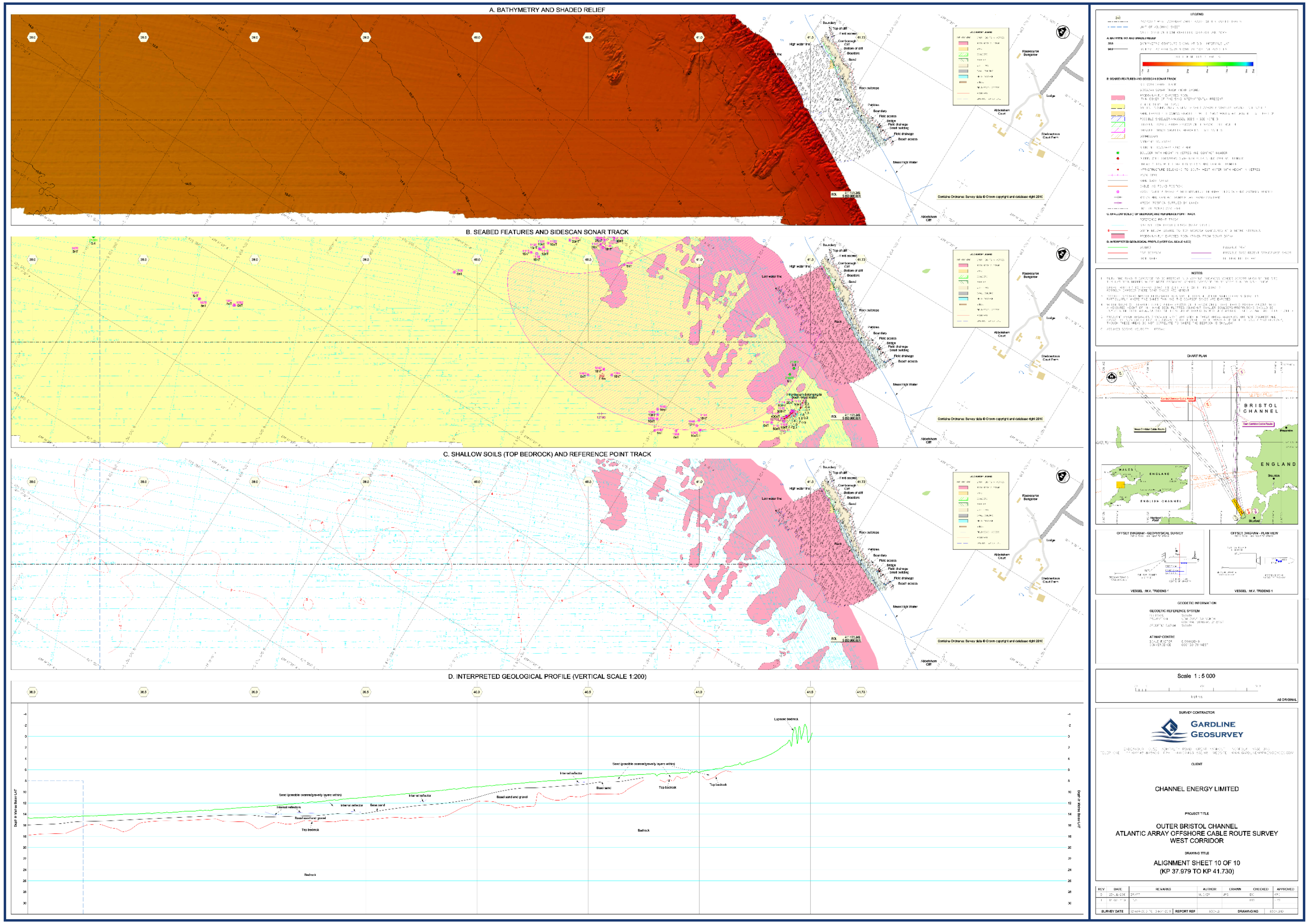

Figure 18: Atlantic Array Cable landing zone (after Gardline Geosurveys)

5.3 Bristol Channel Bedrock Geology

The bedrock of the survey area is comprised of Permo-Triassic (Figure 19) and Jurassic-Cretaceous units (Figure 20) , very limited younger rocks can be found in the area based on the available offshore drilling data. The Permo-Triassic sedimentary rocks of the Bristol basin consist of Mudstones from the Mercia Mudstone and Penrath group, with thickness up to 2000 m encountered in boreholes.

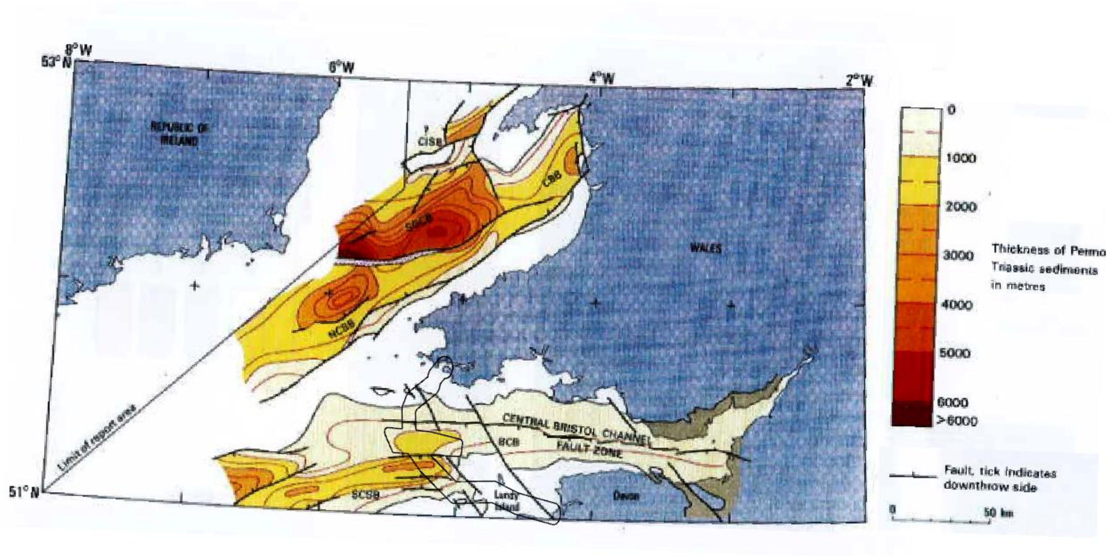

Figure 19: Thickness of Permo-Triassic bedrock geology (after BGS regional report)

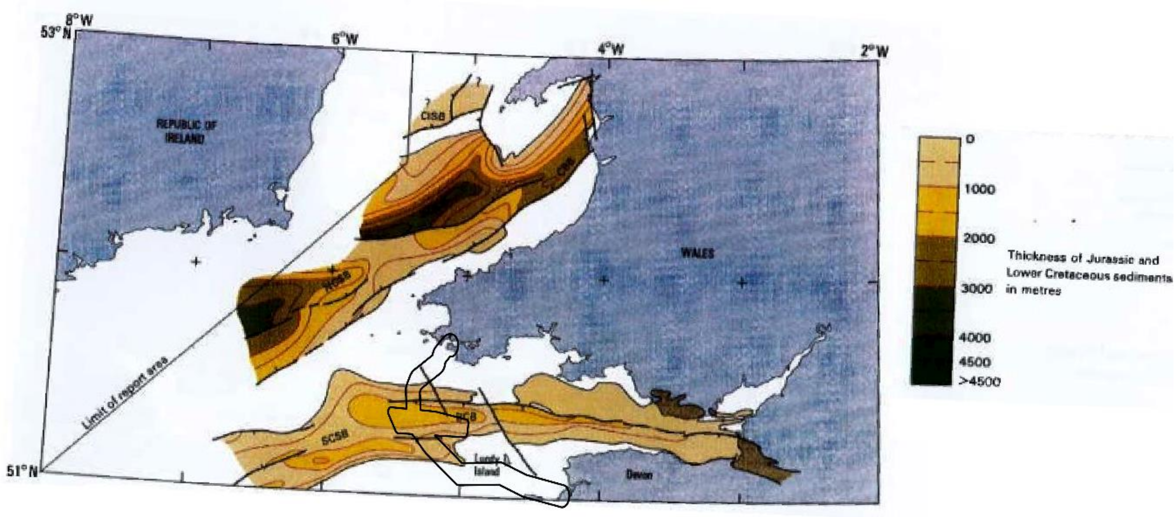

Figure 20: Thickness of Jurassic-Cretaceous bedrock geology (after BGS regional report)

The Jurassic and Cretaceous rocks provide the most recent bedrock across most of the survey area and is comprised of mud stones (Purbeck Facies) of Jurassic age and sand/silt and mud-stones (Wealden Facies) of the lower cretaceous. The upper cretaceous consist of chalk facies with a thickness of up to 1 km.

During the Tertiary age the island of Lundy was formed as part of the British Tertiary Volcanic Province and is the only geological feature of this age. The granite of the Lundy island originated from partial mantle melts, on the south eastern side of the island slate is observed. Both granite and slates have been intruded by a dike swarm.

A major fault (Sicklepath-Lustleigh) is located east of Lundy, with a north-west/south east direction (see Figure 21). The fault is of Permian age and still some low magnitude seismicity along this fault is still possible.

The fault extends into the Bristol channel, passing east of Lundy and extending to Wales where it meets the coast near Buckspool (Ruffel 2002, Holloway & Chadwick 1986). Due to the strike slip morphology of the fault, only a throw of bedrock units of approximatley10 km is observed.

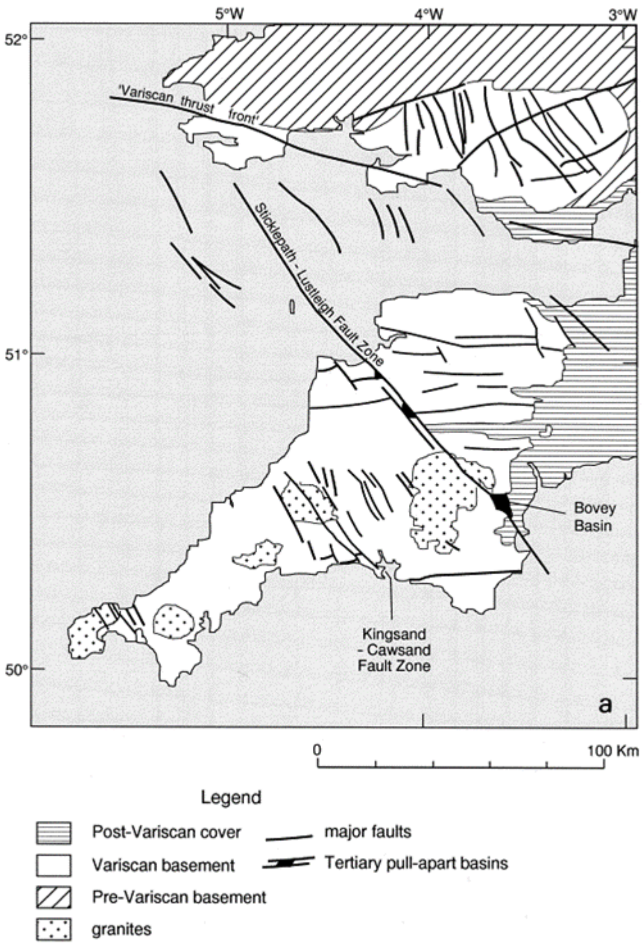

Figure 21 Location of Sticklepath - Lustleigh fault (after Peacock et al 1998)

5.4 Seismic Activity

The seismic activity of the Sicklepath-Lustleigh fault and other faults in the area is very low, only a few low magnitude seismic events have been recorded in past. Map 5 in Appendix B shows the records held by BGS for the survey area.

5.5 Seabed Sediments

5.5.1. Llŷr Development Zone

Seabed sediments of the survey area (Maps 2,3 and 4 in Appendix B) are relatively thin, only rarely reaching a thickness of 20 m (see Figure 22). Most of the sediments in the area are rather coarse (medium-coarse sands, with a large gravel fraction >30%).

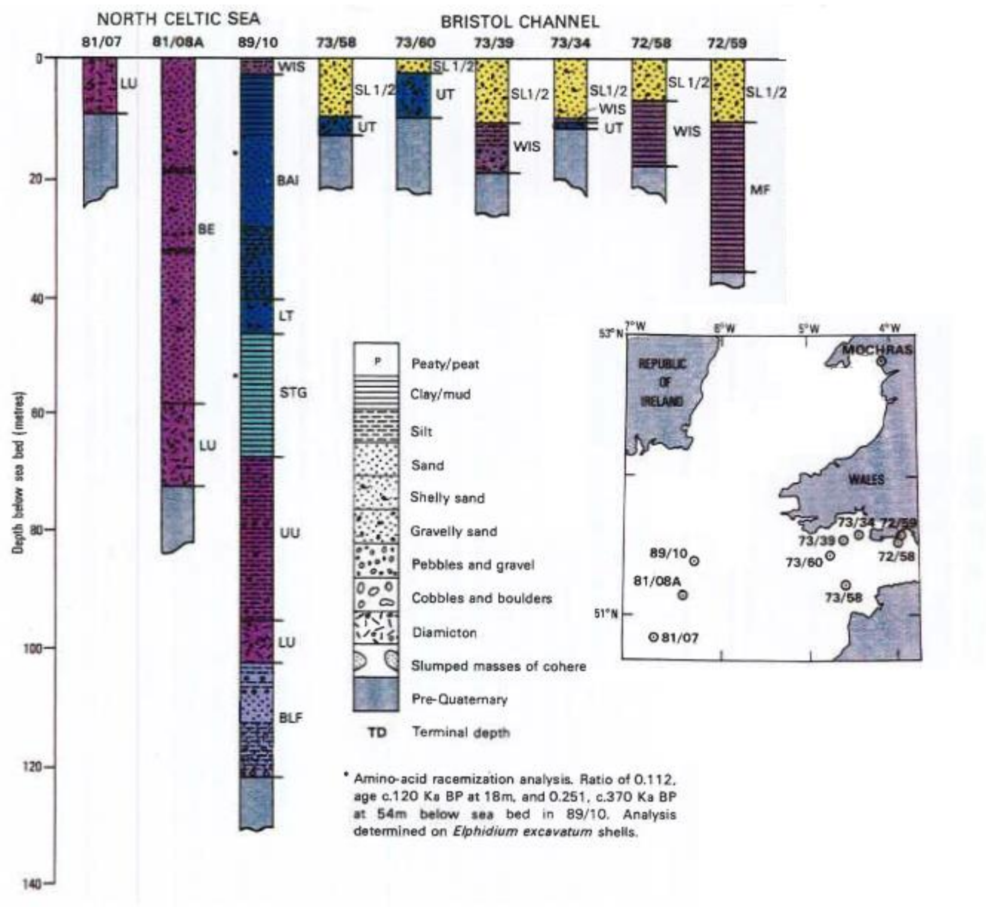

Figure 22: Shallow offshore drilling boreholes, representative for the study area (adapted after BGS regional report)

The seabed itself consists of gravelly sand on the eastern side of the study area, gradually reducing in grainsize to more sandy material (see Figure 2,3 and 4 in the Appendix) towards the west. Some isolated pockets classified as muddy sand or sandy mud are present in the easter side of the study area.

Only large spaced grabsample and borehole information is available, which only allows for a generalized estimate of seabed sediment and thickness (see Figure 8). In general sediment thickness is assumed minimal across the site, with values up to 0.5 m reported in most places. No indicators of organic material were found in the desk study, and the limited sediment thickness makes the study area unfavourable for shallow gas risk,

5.5.2 Cable Routes

The sediments of the southern cable route are more coarse than on the northern cable route. The majority of the southern cable route is classified as sandy Gravel, with only the near shore Barnstaple Bay area (from approximately 15 km out of the coastline) showing sand cover. Similarly to the Llŷr windfarm locations, the sediment cover for the majority of the cable route is minimal. With only a thin layer of coarse sediments on top of bedrock for most of the route. The southern portion of the south cable route where the sediments change from gravel-sandy gravel to more sandy and even muddy material, the sediment cover thickens to several meters

The northern leg of the cable route shows a more sandy nature out in the Bristol channel with more coarse material (gravelly Sand) near the coastline of Wales (< approximately 13 km). Some rocky outcrop is present near the welsh coastline as well. .

Also in the northern cable route a band of thicker sediment is found, with potential for sand waves (Figure 8),

7. Anthropogenic and Natural Features

This section details seabed features and a general discussion about the study area. All information is presented in the maps in the appendix and as layers in the QGIS database. Most of these features are also marked on the Admiralty chart for the area (1178 Bristol Channel Approaches and 1179 Bristol Channel), these maps were scanned and presented in Figure 6 for reference.

6.1 Subsea Cables

Several subsea cables cross the study area and cable routes, all of them fibre-optic subsea cables, the table below shows cable descriptions, locations are given in Map 7 (Appendix B) And the QGIS database.

Cable ID	type	owner	Cable landing 1	Cable landing 2
Solas	communication	Vodafone/Eir	Oxwich Bay (UK)	Kilmore Quay (Ireland)
EXA Express	communication	EXA Infrastructure	Brean (UK)	Halifax NS (Canada)
Tata TGN (2 cables)	communication	Atlantic Tata Communication	Highbridge (UK)	Wall Township NJ USA (2x)
Tata TGN-Western Europe 1	communication	Tata communication	Highbridge (UK),	Seixal (Portugal)
Tata TGN-Western Europe 2	communication	, Tata communication	Highbridge (UK),	Bilbao (Spain)
Pan European Crossing (UK-Ireland),	communication	Lumen	Bude (UK)	Balinesker, (Ireland)

Table 1: Subsea cable information

6.2 Shipwrecks

Based on the Admiralty shipwreck data base several wrecks are present in the study area. Locations of the known shipwrecks are indicated on Map 8 in Appendix B and compiled in Table 2.

wreck_id	name	type	Latitude	Longitude	depth	Seabed texture	tonnage
12192	ADUR II	tug	51°, 1', 47.82"	-4°, 32', 58.019"			
12193	UNITY	trawler	51°, 2', 13.8"	-4°, 16', 46.139"	7	sand	
12207			51°, 5', 1.800"	-4°, 38', 4.020"			
12213	foul ground	Fisherman's Fastener	51°, 6', 35.760"	-4°, 58', 42.900”			
12251	SOUTH AUSTRALIAN	sailing vessel	51°, 12', 48.48"	-4°, 36', 9.480"	35	pebbles	1078
12266	AMIRAL ZEDE	steam ship	51°, 20', 1.679"	-4°, 30', 4.080"		sand	5980
12268	SOVEREIGN (POSSIBLY)	sailing vessel	51°, 20', 1.679"	-4°, 50', 3.960	49		1224
12273	FAGERNES	steam ship	51°, 23', 55.680"	-4°, 3', 40.200"	27		3204
12309	IONIAN	steam ship	51°, 36', 8.580'	-4°, 57', 27.900"			8268
12310	JUTA	steam ship	51°, 37', 12.839"	-4°, 38', 47.279"	18	sand	1559

wreck_id	name	type	Latitude	Longitude	depth	Seabed texture	tonnage
12335	OTWAY	sailing vessel	51°, 34', 49.619"	-4°, 55', 51.900'		rock	
12336	HMS TORMENTOR	destroyer	51°, 38', 7.559"	-4°, 47', 3.960"		rock	1096
12400	PROVIDER (POSSIBLY)	beam trawler	51°, 15', 0.779"	-4°, 44', 25.020"		sand	27
17371	foul ground	Fisherman's Fastener	50°, 0', 43.200"	-4°, 7', 12.06"		sand	
17385			50°, 1', 25.200"	-4°, 46', 59.82"	69	sand	
17398	foul ground	Fisherman's Fastener	50°, 2', 14.16'0'	-4°, 53', 7.800"			
17425	foul ground	Fisherman's Fastener	50°, 3', 32.16'0'	-4°, 41', 45.9"			
17430	STANLAKE (POSSIBLY)	steam ship	50°, 3', 38.16'0'	-4°, 55', 9.779"	50		1742
17504		steam ship	50°, 6', 26.220"	-4°, 55', 37.5"	50	mud/sand/ shells	
17543	EAST POINT	cruiser (merchant)	50°, 8', 17.160"	-4°, 3', 31.08"			5234
17569	SHOAL FISHER	motor vessel	50°, 9', 56.700"	-4°, 48', 57.000"	47	mud	698
17594	AUSTRALBUSH (POSSIBLY)	steam ship	50°, 12', 7.800"	-4°, 5', 14.94"	49.15		4398
17609	ROSEHILL	steam ship	50°, 14', 7.5--"	-4°, 41', 13.559"	43.5	mud	1050
17698			50°, 21', 28.98-"	-4°, 9', 21.54"	4.64	gravel	
17777			50°, 44', 21.059	-4°, 48', 35.280"	39	rock	
17797	foul ground	Fisherman's Fastener	50°, 46', 40.920"	-4°, 56', 5.8799"			
17819	DALEGARTH FORCE (PROBABLY)	steam ship	50°, 50', 58.860"	-4°, 42', 28.92"	20		684
17860	RFA GREEN RANGER	tanker	50°, 58', 43.799"	-4°, 32', 10.021"			3500
17865			50°, 59', 31.800"	-4°, 37', 28.0199"			
17901	THALASSA	fishing vessel	50°, 1', 44.220"	-4°, 3', 46.08"		sand	33
17922	ARUN VENTURER	fishing vessel	50°, 6', 38.16-0'	-4°, 38', 15.9"	60		13
17945	CHRISANDE	fishing vessel	50°, 53', 1.859"	-4°, 50', 3.899			42
17953	IASGAIR	fishing vessel	50°, 7', 16.380"	-4°, 57', 26.100"	46	sand	

Table 2: Known shipwrecks in study area

6.3 Military Exclusion Zones

No Military exclusion zones are present in the study area, but off the coast of Pembrokeshire several conventional munitions dumps are located. Military firing practice areas are also present at the northern section of the cable route (see Map 6 in Appendix B).

6.4 Shipping Lanes and Marine Traffic

There is considerable marine traffic along the Bristol Channel, with the ports of Bristol, Newport, Cardiff, Barry, Port Talbot and Swansea located to the East of the study area. The major UK port of Milford Haven is located at the North cable landing zone, along the Milford Haven waterway. The port includes the Pembroke Refinery, South Hook and Dragon LNG terminals with the associated large bulk carrier shipping.

An anchorage point for Milford Haven is located in the entrance of the Milford Haven Waterway, which will need to be avoided by any subsea cable.

Traffic of large bulk carriers (Tata steel in Port Talbot) and the two container ports around Bristol (Portbury and Avonmouth) is to be expected to cross the study area. In general shipping traffic is low-medium for the study area (see Map 8 in the Appendix) and concentrated in two lanes. Only Milford Haven is qualified as “high traffic” 100+ total ships in cell for 1 hour/square km/ month.

6.5 Dredging, Sand Winning and Spoil Dumps

No current dredging/ marine aggregate areas are located within the study area (Map 10 in Appendix B), four zones of former dredging spoil dumping are located in the study area, although the origin and amount of material dumped is unknown:

- Outside the Milford Haven Waterway a small dumbing ground is located (approximately (3.972.600 m2)
- The cable route outline touches on another small area of spoil dumb, approximately 15 km off the Pembrokeshire coast (210,310 m2).
- In the south-west corner of the Llŷr development zone a larger zone is located (67 190 600 m2)
- North of Harland Point on the southern cable route another dumping ground is located (42 872 500 m2) .

6.6 Natural Habitat Exclusion Zones

Several natural habitat exclusion zones are present across the study area (Map 11 in Appendix B).

Around the Island of Lundy a Special Area of Conservation (SAC) is located (SAC EU code UK0013114), primarily due to the presence of a reef habitat.

Lundy is a granite and slate reef system and is selected for its outstanding representation of reef habitats in south-west England. Lundy Island is exposed to a wide range of physical conditions as a result of differing degrees of wave action and tidal stream strength on sheltered and exposed coasts and headlands. This range of physical conditions, combined with the site’s topographical variation, has resulted in the presence of a unusually diverse complex of marine habitats and associated communities within a small area. The reefs of Lundy extend well over 1 km offshore and drop steeply into deep water in some areas. The variety of habitats and associated species on the reefs is outstanding and includes, for example, a large number of seaweeds and many rare or unusual species, including Mediterranean-Atlantic species representing biogeographically distinct communities at, or very close to, their northern limit of distribution. In particular, fragile long-lived species, such as the soft coral, sea-fan a variety of erect branching sponges, are found in deep, sheltered conditions, particularly on the east coast of the island. All five British species of cup-coral are found here, including the scarlet and gold star-coral and the sunset cup-coral.

A second SAC is being proposed (pSAC status) for the Bristol Channel Approaches, covering a large portion of the survey area (see Map 11 Appendix B)

This SAC will cover the presence of harbour porpoise and the area is within the top 10% of high density population for both winter and summer season, recognized by the Joint Cetacean Protocol (JCP). A local study suggests porpoises in the pSAC prefer the coarser seabed sediments over fine (likely due to the presence of sand eels as a food source).

The proposed northern cable landing zone is part the Milford Haven National Park (MCA-21), comprising the sheltered ria (drowned river valley) of Milford Haven including the upper stretches of the Daugleddau estuaries. The whole estuary network is one of the best examples of a ria system in Britain. It forms a significant part of the Pembrokeshire Marine SAC which is European protected for its wide variety of marine habitats and communities. Nationally rare saltmarshes, water sheltered bedrock and muddy inter-tidal areas, shingle beaches and 'pills' provide habitat for sea wormwood and marsh mallow– a nationally scarce species. Milford Haven Waterway SSSI also covers the whole of the MCA, nationally important for its geology, ancient woodland, rare and scarce maritime plants as well as nationally important numbers of migratory waterfowl and otter.

6.7 Other Development Zones

The Pembrokeshire Demonstration Zone is a new wave energy site located off the South Pembrokeshire coastline. Wave Hub Limited is the seabed leaseholder (see Map 9 in Appendix B).

The zone comprises a 90 square km area of seabed with water depths of approximately 50 metres and a wave resource of 19 kW/m. It is located between 13-21kms offshore and has the potential to support the demonstration of wave arrays with a generating capacity of up to 30MW for each project. A 400 kV transmission line will provide connection to the mainland.

8. Recommendations for Surveys and Site Investigations

7.1 Geophysical Surveys

Due to the limited current information available the preliminary geophysical survey of the study area will need to be considerable, consisting of:

- Sub bottom profiling (mapping bathymetry and sediment cover thickness)
- Multibeam Echo sounding(including backscatter analysis), mapping detailed bathymetry and backscatter analysis will aid in sediment identification based on reflectivity
- Side Scan sonar (mapping seabed objects and seafloor)
- Magnetic survey (mapping shipwrecks/metallic obstructions, UXO and subsea cables)

During the geophysical survey seawater sound velocity profiles (SVP) should be obtained at least once every 12 hrs.

An UXO desk study is required to assess the risk of UXO along the cable routes and development zones, to be supplemented by the magnetic survey results to provide a detailed map of potential UXOs.

Deliverables of the geophysical survey should include an interpreted seabed category type based on backscatter and sidescan sonar findings. This map will be important to update the existing geological maps from 1978. Special attention should be given to the sub bottom profiling survey, a high resolution survey is required to accurately resolve the likely thin sediment cover found on a larger portion of the study area,

Once a better understanding of the sediment thickness and distribution of different categories of seabed (based on the geophysical data) is established a geotechnical campaign can be planned, targeting specific anomalous features and general seabed conditions to be correlated with the geophysical maps for an updated, final seabed category map.

7.3 Geotechnical site investigation Llŷr 1 & 2

Due to the expected thin sediment cover, the geotechnical survey could be limited to a vibrocore and grabsample campaign, actual offshore drilling can be done in a second campaign if drilled pile foundations are deemed the most suitable anchoring type.

Seabed CPTs will be very useful, to characterize the soil behaviour type (amongst other parameters), although the gravelly nature of the seabed could give rise to an increased amount of refusals.

7.4 Geotechnical Site investigation Cable routes

Vibrocores outfitted with a thermal resistivity heatflow probe rather than a borehole investigation are deemed to be sufficient for the cable route investigation. It is important to include in-situ thermal resistivity measurements to the rather than only relying on laboratory testing.

9. Conclusion

Based on the review of available information on the seabed conditions of the survey area a summary of expected seabed conditions have been provided in this report. Although in general the data density is reasonable there is a clear lack of current data. Most results presented here are from late from the late 1970s and early 1980s. And although only information of reputable sources has been used (such as peer reviewed scientific articles, BGS,DTI and Admiralty) it cannot be ignored that the information used is over 40 years old and might not be recorded or interpreted to current standards of geotechnical and geophysical investigations.

In general the seabed of the study area can be characterized by a relatively thin layer (less then 1m) of coarse sediments on cretaceous bedrock (chalk) or glacial till. The sediments are relatively undifferentiated, classified as coarse sand-gravelly sand-sandy gravel. The western zone of the Llŷr development appears to have a smaller grainsize and is classified as sand. Thickness of the sediment cover is minimal, likely less than1m on most of the development zone.

Based on the available bathymetry data the Llŷr development zone can be described as a relatively flat seabed, at an approximate depth of -68m LAT, with rather little seabed features (although information is scarce). Directly to the east of the study area, significant investigations have been done in an Outer Bristol Channel Marine habitat survey. The seabed conditions here show large, stationary sand waves with a north-south strike, it can be assumed the more sandy regions of the study area could follow similar conditions.

Sediment cover across the cable routes, either north or south show a very similar pattern as the Llŷr development zone, a relatively thin, coarse sediment cover. The southern route appears to cross more coarse sediments for the majority of its length then then northern route, which has a more sandy nature. Close to the southern cable landing (Barnstaple Bay), the sediment cover increases to several meter and more fine sediments (sandy, gravelly clay) are encountered. The bathymetry of the southern route is a steady decrease from shore to the deeper waters in the centre of the Bristol Channel.

The northern route shows more bathymetrical changes, especially close to the Welsh coast several peaks and throughs are observed. Several known rocky outcrops exist approximately 6 km offshore. A zone of increased sediment thickness and presence of sand waves is present, at a similar latitude as the sand waves described in the Outer Bristol Channel study, but only limited modern data exists for this area.

Based on the findings of this study, it is deemed important to update the existing data sets by a geophysical and geotechnical investigation, to update information on:

- Sediment thickness along the Llŷr development zone and cable routes
- Sediment type to supplement the available data

Due to the expected thin, coarse sediment cover, it is unlikely drag anchors or suction buckets would be suitable for anchors, assuming a chalk or glacial till bedrock, driven piles either as a stand alone or in combination with a gravity base could provide a suitable anchor type for the study area. A more exotic anchor type such as “torpedo” or Omni-Max[4] anchors could be considered if the bedrock proves to be weak chalk. This type of anchors offers a relatively quick, economical alternative where a 100-120mT anchor is installed as free fall under gravity to embed itself in the seabed. Although typically used as Deepwater mooring systems, these systems could be adapted for the approximately 70m water depth of the development zone. For the penetration of these anchor types, a bedrock of weak chalk (low-medium density) is likely required, it is unlikely these types will be suitable for mud- and sandstone bedrock.

A risk and mitigation register are included in Table 3 below, based on the findings of this desk study and effects on possible foundation toe and location of the cable route.

[4] Developed by Delmar Vryhof, Houston USA/ Schiedam, The Netherlands

Geohazards & Constraints	Description	Mitigation	Foundation type affected						
			Drag Anchors	Suction Buckets	Pile (Steel driven)	Pile (Drill & grouted)	Gravity Base	Gravity Base + Pile (Steel driven)	Gravity Base + Pile (Drill & grouted)
Isolated pockets of soft ground (Llŷr site)	• Soft ground comprising clay and organic material present in BGS maps	• One isolated (single grabsample) of muddy Sand known on BGS map. • Detailed geophysical ground investigation, to further map presence of soft sediments based on SSS and backscatter MBES, followed by targeted geotechnical campaign to validate. • Foundation design to account for areas of soft or very soft ground conditions		Y	Y	Y	Y	Y	Y
Shallow Gas	• Risk of ground support collapse due to shallow gas	• Generally geology is unfavourable for the presence of shallow gas due to thin sediment cover • When interpreting the sub-bottom profiling data, look for signs of shallow gas (bright spots in reflectors)							
Sand wave/ripple marks (larger ripples to east of site)	• Not observed in current data set, but only limited information available Large sand waves are present directly east of the study areas • Potential scouring	• Eastern zone appears to be covered by relatively stationary waves • Repeat bathymetry surveys (especially before & after major storm events) to allow mapping of areas of sand waves and potential rate of movement • Based on the bathymetrical assessment, potential for scour around foundation to be assessed and included in foundation design	Y	Y			Y		
Boulders/ objects on seabed	• Presence of natural obstruction • Presence of dredging spoils on south west corner of Llŷr OWF	• Limited information available at this stage, MBES & SSS surveys needed • Adapt turbine locations or foundations	Y Foundation Not Possible	Y	Y Foundation Not Possible		Y		
Limited sediment thickness (OWF)	Across a large portion of the planned OWF very limited sediment thickness is observed	• High resolution Sub bottom profiler required in combination with SSS for outcrop detection. • Limited sediments can disqualify drag anchors and suction buckets	Y Foundation Not Possible	Y Foundation Not Possible	Y	Y	Y	Y	Y
Coarse Sediments	Majority of sediments in study area are classified as coarse sand/gravelly sand	• Foundation design tailored to coarse seabed sediments, rather than fine	Y	Y Foundation Not Possible	Y	Y		Y	Y
Limited sediment thickness (Cable route)	Across large portion of cable route very limited sediment thickness observed	• High resolution Sub bottom profiler required in combination with SSS for outcrop detection. • Limited sediment thickness will influence transmission cable burial	Cable route						
Man-made features	• Major communication cables through study area • Munitions dumps in northern area • Shipping lanes & Anchoring point Milford Haven	• Mag survey to map location of cables • Munitions dumps are no longer actively used, can avoid by proper route planning • No fairways are present in the study area, moderate-low shipping density except for Milford Haven and associated anchorage point. • Proper cable route planning required to mitigate risk	Cable route						

Heterogenous ground conditions	The northern cable route approaching Milford haven show a variety of seabed substrate, including rocky outcrops	• Detailed geophysical and geotechnical survey	Cable route
Earthquake risk	Sticklepath - Lustleigh fault present in the area	• Risk deemed low, fault systems are not very active, and magnitude of earthquakes associated with faults is low	GENERAL RISK
Environmental	• National Park in North cable landing • Lundy SAC • Planned SAC across large portion of study area	• Contact and discuss with responsible government bodies	GENERAL RISK

Table 3: Hazard assessment and potential mitigation techniques

Appendix A QGIS Project (digital)

Appendix B MAPS (pdf)

General

Map 1: Bathymetry with contour lines

Geology

Map 2: Seabed Sediments 1:250k

Map 3: Seabed substrates

Map 4: Scanned Seabed map

Map 5: Earthquake risk

Human activities

Map 6: Admiralty Charts 1178 and 1179

Map 7: Telecommunication stations and schematic routes

Map 8: Average vessel density 2017 + wrecks

Map 9: Ocean energy sites + windfarms

Map 10: Dredge soil dumping + dumped munitions+: Aggregate extraction areas

Conservation & ecology

Map 11: SAC, MCA, National Park