



Geotechnical Support Services - Hywind Scotland Offshore Pilot Park Geotechnical Desk Study Report Statoil ASA

Assignment Number: A100142-S01
Document Number: A-100142-S01-REPT-001

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Integrated Services
Total Field Development



Geotechnical Desk Study Report

A100142-S01

Client: Statoil ASA

Document Type: Report

Document Number: A-100142-S01-REPT-001

A01	02/04/15	Issued for Use	AT	LF	LF	
R02	09/07/2013	Client Comments Incorporated	GCO	CGO	SED	
R01	03/07/2013	Issued for Client Review	GCO	CGO	SED	
Rev	Date	Description	Issued by	Checked by	Approved by	Client Approval



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1 INTRODUCTION

Statoil has been awarded exclusivity rights for the seabed in the area of the Buchan Deep which lies 25 km to the east of Peterhead on the Aberdeenshire coast covering an area of approximately 60 km² as illustrated in Figure 1. The Pilot Park will be located either to the north or south of the BP Forties C to Cruden Bay Pipeline which runs through the Exclusivity Area from northeast to southwest.

The 30 MW (maximum) Pilot Park will consist of 5 turbines that will be up to 6 MW in size. The turbines will have a maximum height of 101 m with a rotor diameter of up to 154 m maximum and a draft of 80 m.

The turbines will be located between 720 m and 1,500 m apart and will be attached to the seabed by a three-point mooring spread (illustrated in Figure 1.7). Depending on seabed conditions, the moorings will be secured with the most suitable type of anchor. The anchor types currently under consideration include torpedo anchors, suction anchors, fluke/drag embedment anchors, and possibly driven pile anchors (note the latter is subject to environmental consents, and hence may not be a practical solution). It is likely that three anchors will be required per turbine, but it is possible that some anchors can be shared between two or more turbines. The mooring lines are likely to be composed of chains with a diameter extending out from the Hywind turbines to approximately 800 m – 1,000 m.

The total footprint of the Pilot Park including the mooring system will be approximately 6.7 km² maximum [TBC]. The exact size of Pilot Park area will be dependent on the actual spacing and location of the anchors and mooring lines. The export cable corridor will be 25 to 30 km in length connecting to a landfall in the Peterhead area. The final location of the landfall is still to be determined.

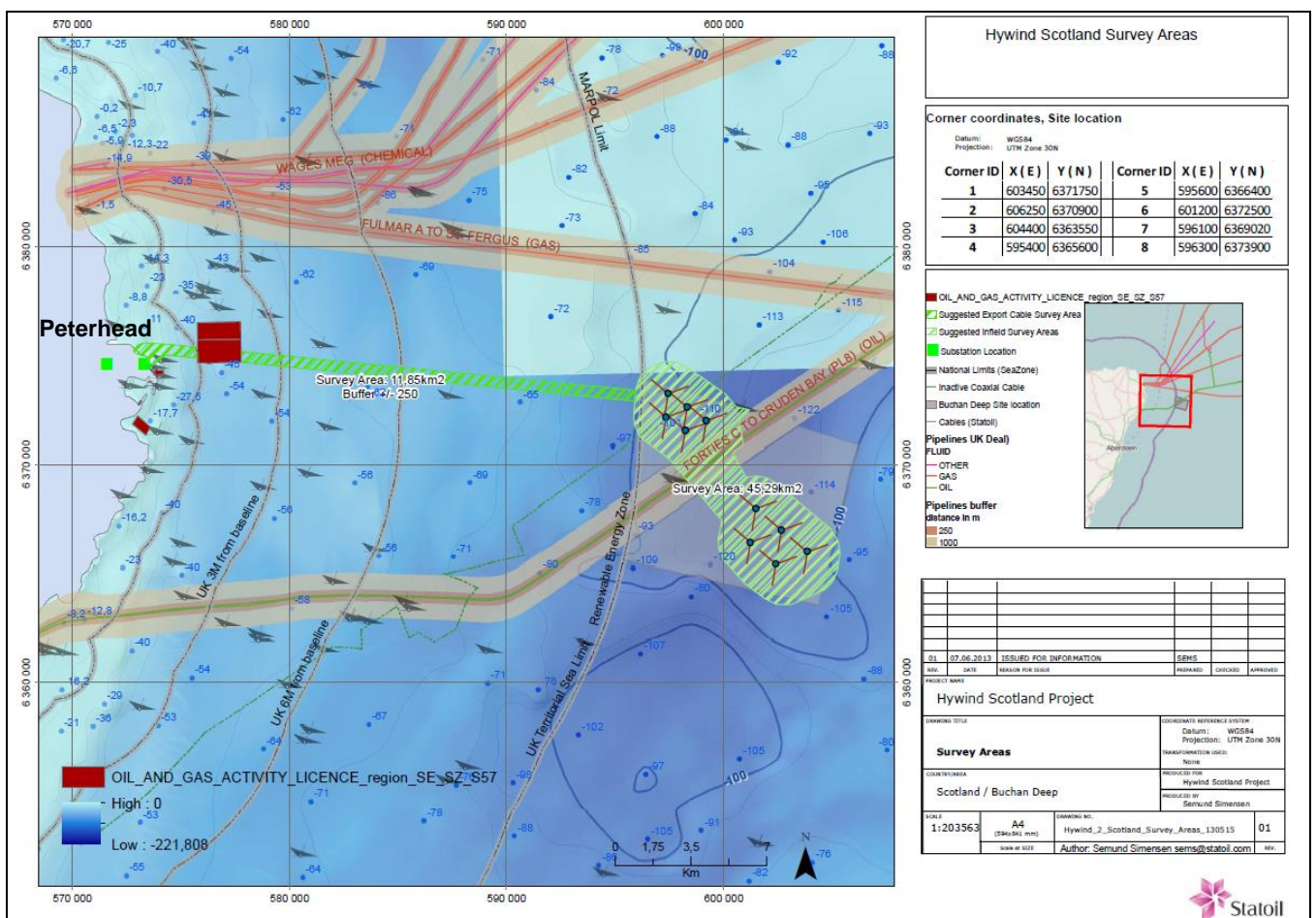


Figure 1: Proposed Hywind Scotland Offshore Windfarm project



Statoil has commissioned Xodus to undertake an Environmental Impact Assessment (EIA) of the Pilot Park Project. In addition to this assignment, Statoil has also requested a desk study of seabed conditions across the proposed Hywind development area (i.e. both parts of the exclusivity zone) and along the proposed export cable route.

2 SCOPE OF WORK

The scope of work for this report is as follows:

- > Carry out a desk study to identify and collate all existing geophysical and geotechnical seabed data for the Pilot Park development area and export cable route(s);
- > Evaluate existing Statoil seabed data and identify where further data is required, or that can be sourced from 3rd party sources;
- > Understand the limitations of the data with respect to the Pilot Park development area and the uncertainty/risk associated with this limitation; and
- > Present the data in GIS to understand seabed constraints to the Pilot Park development area and to the export cable routing to the landfall location.

In conclusion of this report the author may participate in a review meeting in Oslo at Statoil's offices to summarise the findings of the study. A time and date is to be confirmed with Statoil.

The desk study was initiated using all currently available site and seabed data at the proposed Hywind Scotland location to review and assess surface and subsurface seabed conditions. As part of this study, additional data has been purchased from recognised data sources. This information has been supplemented where possible with data held in existing Xodus and Statoil in-house databases.

The following definitions for the Hywind Scotland field development and the geographical definition of the study area applied to this desk study is given below with reference to Figure 2.

- > Hywind Scotland Exclusivity Area/Pilot Park – area where the proposed windfarm turbine array(s) are to be located (red box)
- > Hywind Scotland Study Area – the greater area between Peterhead and the eastern extent of the Exclusivity Area assessed in this study (black box border)
- > Hywind Scotland Export Cable Route– nominal 1000m wide corridor that links the Hywind Scotland offshore site to the landfall options in Peterhead (green cross-hatched zone)

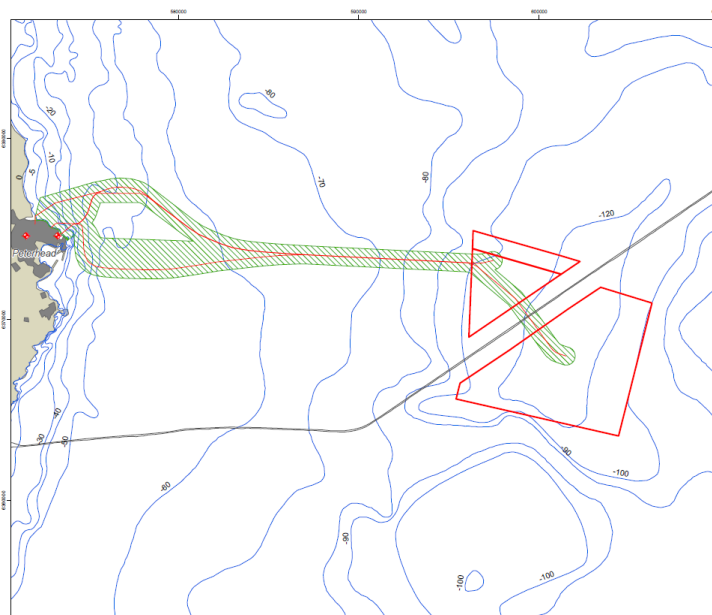


Figure 2: Definitions of study and development areas used in this report



In addition to the findings presented in this report, Xodus are to investigate and provide recommendations on the following:

- > Carry out a route selection study of the preferred cable route (North or South options) based on the available data;
- > Present possibilities of narrowing down the proposed site survey area;
- > Identify which areas in the BP Forties to Cruden Bay Pipeline exclusivity zone are best suitable for anchoring;
- > Perform a landfall selection study on the preferred location based on the site assessment.

The above scope will be presented in a follow up assessment for the cable route; however in review of the data undertaken by this study, some general comments will be presented in the conclusions section, Section 7.

2.1 Objectives

The objectives of the study are as follows:

- > Understand the seabed geology of the site including the type and extent of seabed sediments, shallow geology (quaternary geology) and bedrock geology;
- > Identification of seabed features and potential obstructions to installation activities across the windfarm development site and the along the export cable route;
- > Identification of other subsea cables, pipelines and infrastructure that may cross the cable route and that may lie within the development site;
- > Perform comparative constraint mapping with various data sets (e.g. BGS data maps with samples station data) across the whole development and cable corridor site;
- > Production of map based drawings highlighting the above geology and constraints to the field development and cable route characteristics; and
- > Establish uncertainty on data to then go on to identify where further is required and if any specialist survey requirements should be considered based on the reviewed data (e.g. UXO surveys).

This study is to make a first pass review of existing data in the hope of being able to fulfil the objectives stated above. However, this will be limited to the state of the available data and what information each source of reference contains.

It should be noted, the ultimate aim and objective to feed into a geophysical survey which Statoil are planning for the Pilot Park development area and preferred cable corridor during Q3 2013. The purpose of the geophysical survey is to provide site specific data on the seabed and sub-seabed features, in particular the shallow geology, and to provide benthic habitat data within the development area and along the export cable corridor.

The survey coverage will be over approximately 60 km² with a 500m width corridor for the export cable route (i.e. ± 250 m of the preferred route centreline). It is understood that no survey activities will take place within 500 m of the BP pipeline.

2.2 Abbreviations and Definitions

BGS	British Geological Survey
BH	Borehole
CPT	Cone Penetration Test
EIA	Environmental Impact Assessment
GC	Gravity Core



GIS	Geographic Information System
LAT	Lowest Astronomical Tide
PC	Probe Core
SPT	Standard Penetrometer Test
TBC	To Be Confirmed
UK	United Kingdom
UXO	Unexploded Ordnance
VC	Vibrocore



3 AVAILABLE INFORMATION

Table 3-1 below lists the data used in the compilation of this report.

Document No. / License No.	Title	Company/Author	Revision and Issue Date	Ref.
EK001-208503	Marine Themes (marine spatial data including charted data, wrecks, obstructions, buoys, cables etc)	Oceanwise	2013	1
n/a	Oil & Gas Infrastructure	UK DEAL	2013	2
n/a	SPA, SAC and Ramsar designated site GIS data	JNCC	2013	3
n/a	SSSI designated site GIS data	SNH	2013	4
n/a	Basemapping	Ordnance Survey	2013	5
unknown	Bathymetry contours	TCarta	unknown	6
n/a	Existing cable locations	KISCA & Statoil	2013	7
n/a	Hywind project area, cable route and survey corridors	Statoil	2013	8
2013/051 DB A	DigBath250	BGS	2013	9
2013/050 A	DigSBS250	BGS	2013	10
2013/050 A	DigRock250	BGS	2013	11
2013/050 A	DigQuat250	BGS	2013	12
n/a	Seabed Sediments - Peterhead (Sheet 57°N-02°W)	BGS	1984	13
n/a	Quaternary Geology - Peterhead (Sheet 57°N-02°W)	BGS	1986	14
n/a	Solid Geology - Peterhead (Sheet 57°N-02°W)	BGS	1982	15
n/a	The Geology of the Central North Sea	BGS	1994	16
n/a	Forties Field Cruden Bay Pipeline Survey (Revised Route)	Hunting Surveys Ltd	1973	17
FEP-A-PO-PT-3023	Pipeline Alignment Charts and Isopach maps of sediment cover over bedrock for BP Petroleum Development Ltd	GeoTeam UK Ltd.	Sept 1989	18
n/a	Forties to Cruden Bay 36" Replacement Oil Export Pipeline – Summary of Expected Seabed and Shallow Geological Soil Conditions Along Proposed Lay Route.	EXE Survey Unit / Geotechnics Branch, BP Engineering	March 1989	19

Table 3-1: Client Supplied and Published Data



3.1 Data Limitations

The Hywind Scotland Pilot Park development 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 area of seabed bathymetry and features rather than providing specific data for the project under consideration. However, the data is considered 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 Pilot Park construction activities.

The Oceanwise Marine Themes and UK Deal electronic datasets [Refs. 1 and 2] were used to generate the bathymetric contouring of the site and to understand the risk and constraint of wrecks and other known features (e.g. dumping grounds, anchorage areas, buoys, obstructions, military areas, etc.) across the area. JNCC and SNH datasets [Refs. 3 and 4] were used to understand environmental constraints to the site both onshore and offshore. The Ordnance Survey data [Ref. 5] was used to map all onshore features such as topographic elevations, roads, urban areas, recreational ground, protected areas, etc. Further data from TCarta was used to cross-reference the bathymetry data [Ref. 6] and Statoil provided GIS data specific to the project itself [Refs. 7 and 8].

This study concentrates mainly on the offshore aspect of the Pilot Park development area, as future work on the onshore landfall aspects will be performed at a later date. Therefore, offshore/marine BGS data was purchased electronically to map the seabed geology. Four datasets [Refs. 9, 10, 11, 12] were evaluated and cross-checked with more detailed information from the hard copy 1:250,000 Peterhead sheets [Refs. 13, 14, 15] (Solid Geology, Seabed Sediments, Quaternary Geology) and offshore regional geology reports [Ref. 16]. The hard copy data provides more description on geological formations and of seabed sediment features sometimes not currently presented with 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, CPTs, boreholes, etc.). The data relevant to the Pilot Park development area is owned by BP which has kindly released such information to Statoil for use in this study.

The BP data within the Hywind Scotland Study Area is mainly related to geological and geotechnical site testing for the Forties C to Cruden Bay 36" Oil Export Pipelines (PL721 and PL8) carried out in 1973 [Ref. 17], and reassessed later in 1989 [Ref. 18, 19]. These reports present geophysical interpretation of the seabed surface, i.e. sediments and features/bedforms, and of the shallow geology to bedrock contact. This data is supported by some VC tests which show some basic offshore tests data such as moisture content, soil density (SPT values) and shear strength tests. Other BP data toward the Peterhead coast is unspecified as to why the tests were performed there, however the information is useful for this study.

Review of each BP report is presented below to indicate what each document contains:

- > [Ref. 17] presents alignment charts along the original proposed Forties to Cruden Bay Export Pipeline Route for work carried out by Hunting Surveys Ltd. in 1973. These charts present interpretive soil data of surface seabed conditions and shallow subsurface geological stratigraphy, with some VC/PC sampling. No report has been provided to accompany the charts. The relevant alignment sheets located near the Hywind Exclusivity Area are Profile Sheets 4 and 5, which are presented in Appendix A.
- > [Ref. 18] presents alignment sheets along the revised proposed Forties to Cruden Bay Export Pipeline Route for work performed by GeoTeam UK Ltd. in 1989. These sheets provide interpretative soil data of surface seabed conditions, seabed features, and shallow subsurface geological stratigraphy. However, no geotechnical test data is presented or a report to accompany the data interpretation. The relevant alignment sheets around the Hywind Scotland Pilot Park development area are Sheets 4b, 5b and 6b, which are presented in Appendix A.

- > [Ref. 19] is a summary report that presents written descriptions of alignment sheets describing expected soil conditions along the Forties to Cruden Bay Export Pipeline Route by the BP EXE Survey Unit in 1989. This report reviews data from the 1973 pipeline route surveys and presents Vibrocore (VC) and Probe Cone (PC) test sample station logs with basic soil test data. The sample station logs have been requested from BP, but has not been released for evaluation in this report. However, prior to receiving this data, the sheets of interest are contained in the descriptions for Revised Sheets 4 to 6, which are presented in Appendix A.

From review of the data, [Ref. 17] seems to be first pass site investigation along the original export pipeline route corridor, where analogue geophysical methods (i.e. single/multibeam echosounder, shallow seismic) were used to define seabed topography and shallow subsurface stratigraphy, which was concurrently ground-truthed with Vibrocore (VC) and Probe Cone (PC) testing every 1 – 2 km along the route. In comparison [Ref. 18] provides a more recent survey for a revised export route alignment (see Figure 3 below), and provides alignment sheets in a different format, but contains more information about seabed features such as sandwaves (large scale wave-like bedform features, typically > 100 m wavelength and being several metres high), megaripples (typically a ripplelike feature having a wavelength greater than 1 m or a ripple height > 100 mm), longitudinal gravel patches, and interpreted geology that correlates with BGS data. Geotechnical sample stations are indicated on the sheets, but data logs are not presented on the alignment sheets nor in any accompanying report. Only qualitative descriptions of the soil units are presented.

However, [Ref. 19] presents a description of seabed topography and shallow soil interpretation of each of these sheets for the revised route to align with [Ref. 18]. Unfortunately the relevant test stations conducted near the Hywind Scotland Exclusivity Area are not included in the report (see Figure 3 below). The available VC and PC test logs, show qualitative soil description with some offshore test data (SPT blow counts, probe test loads, water content, and shear strength) and 6No. Particle Size Distribution sheets from laboratory analysis within the top 1 m of the seabed.

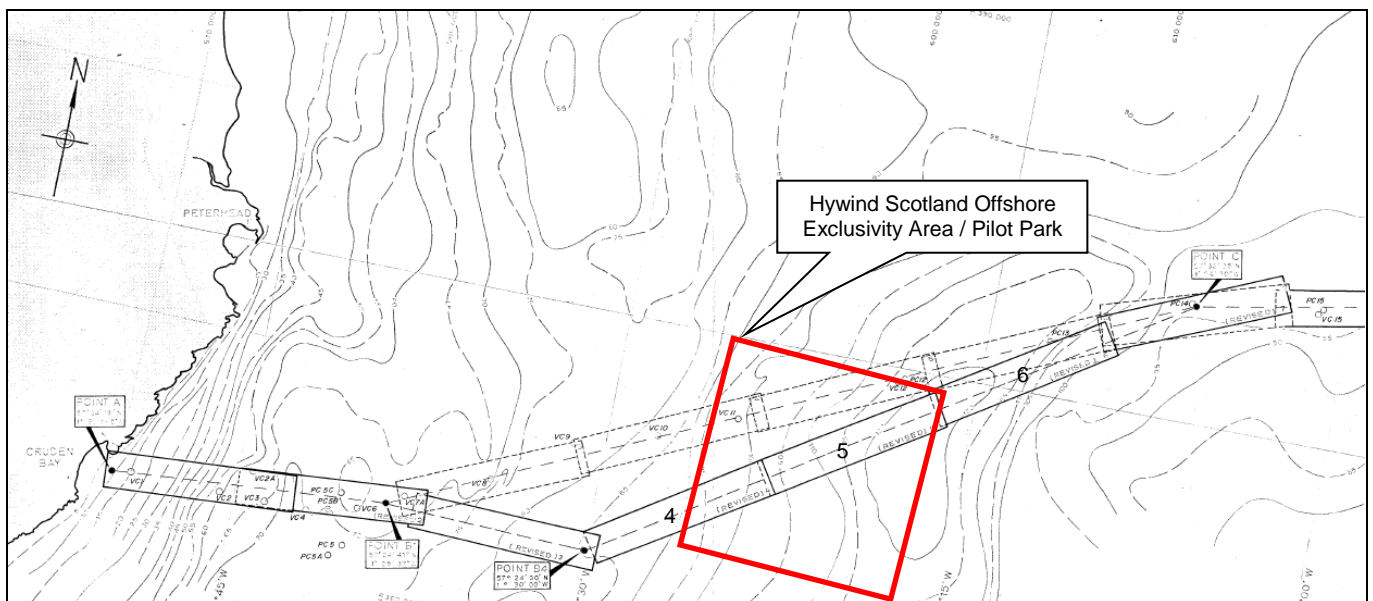


Figure 3: Extract of revised Forties to Cruden Bay 36" Export Pipeline Route [Ref. 19]

It is noted that other BP data within the Hywind Scotland Study Area and which is more relevant to the proposed export cable route exists, but has yet to be provided by BP. The relevant report as listed in [Ref. 19] is as follows:

- > Terresearch Ltd., 1973. Seabed Investigation for North Sea Forties Field Pipeline for BP. Report No. S.22/555.



4 SITE DESCRIPTION

4.1 Bathymetry

Water depths across the Hywind Scotland Pilot Park development area are indicated to range between 95 m and 120 m below LAT within the Buchan Deep area (see Figure A1 in Appendix B). The seabed shallows westward toward Peterhead gradually, till about 3 – 4 km from the coast where it the slope increases slightly.

4.2 Development Constraints

The Xodus EIA study has used data provided from [Refs. 1, 2, 3, 4, 5, 6, 7] to identify where constraints to the proposed field development and export cable route lie. This information has been plotted in GIS to show the spatial distribution of seabed hazards and environmentally sensitive zones with respect to the Pilot Park development area, as represented in Figure A2 in Appendix B.

As the layout chart indicates the Pilot Park development area contains 1 No. recorded wreck in the eastern corner of the northern part. Another wreck is indicated on the Forties to Cruden Bay 36" pipelines (Anne-Meke shipwreck [Ref. 18]); however, this feature remains outside the development area. No other environmental constraints are identified within these zones.

As the export cable route heads toward the proposed Peterhead landfall locations, north of the harbour, it passes through an area identified by the Joint Nature Conservation Committee (JNCC) as a 'Nature Conservation Marine Protected Area (MPA) Proposal Area'. However, this site has not yet been designated and it has been identified by the JNCC that further assessment work will be required before this area can recommended for designation as an MPA. At present, this area does not present any constraints to cable installation. However, the potential for this area to be of potential environmental importance / sensitivity will need to be taken into consideration as part of final route selection.

The main constraints located along the cable corridor tend to be those located closer to shore, including:

- > A large dumping ground approximately 1 km northeast of Peterhead harbour (dredging spoils from the harbour);
- > An area marked as foul ground/obstruction just south of the dumping area; and
- > 4 - 5 No. shipwrecks.

Figure 4 is an extract from Figure A2 in Appendix B that shows the proposed export cable route being re-routed as options around these features, except for the marine protected area as this zone is still to be assessed. In the following sections, seabed sediments, seabed features and underlying geology are assessed with the above routeings to understand if further geohazard type constraints will affect the indicated cable corridors and to determine the likely soils across the area for construction/installation and cable protection type activities.

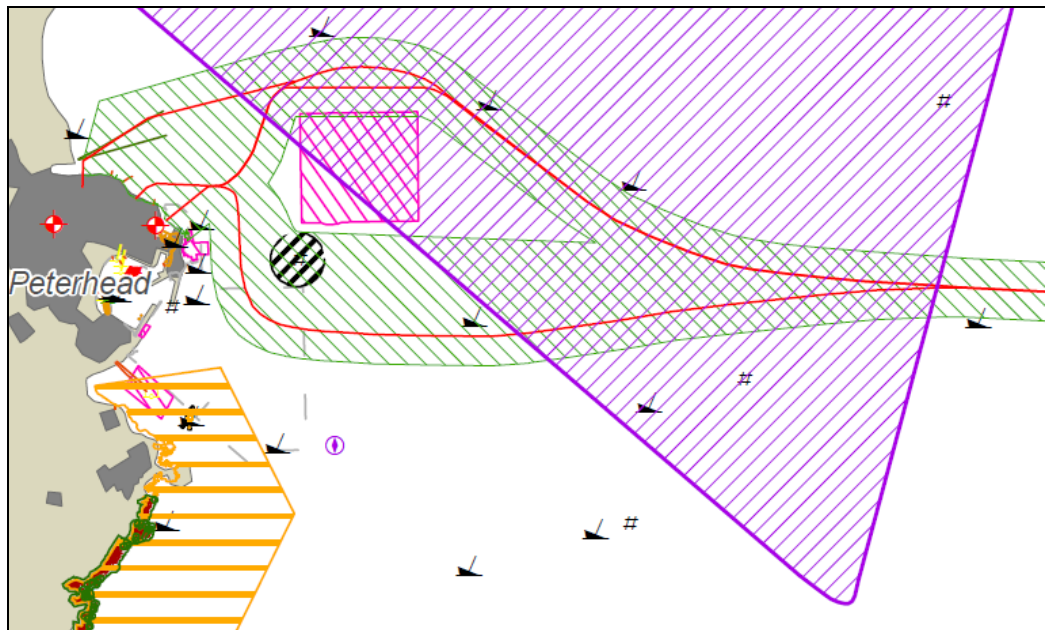


Figure 4: Extract from Figure A2 of constraints affecting the export cable route near Peterhead

4.3 Crossings and Seabed Infrastructure

Several crossings have been identified to exist within the Hywind Scotland Study Area. In terms of the Pilot Park development area, the only potential crossing will be the Forties C to Cruden Bay 36" and 32" oil export pipelines (a number of parallel pipelines, some in use and some disused), which pass through the Hywind Scotland Exclusivity Area splitting it into two parts (see Figure 1). Currently these pipelines have a 2 km buffer zone (PL721 and PL8) surrounding them as indicated in Figure 1, but this may be subject to change.

A number of potential crossing points have been identified along the cable corridor. The UTM positions of the crossings are based on the proposed cable routes indicated by Statoil. This data along with reported statuses as listed in [Refs. 1, 2], are presented in Table 4-1 below. Note the coordinate system used is WGS 1984 UTM Zone 30N.

Crossing	Easting (m)	Northing (m)	Buried/Unburied ¹	Status
BT Coaxial Cable Aberdeen to Bergen	597414.37	6372203.93	Buried?	Inactive
36" PL721 Oil Pipeline	599410.14	6370137.68	Unburied?	Active
32" PL8 Oil Pipeline	599380.03	6370178.99	Unburied?	Active
Cable 1 ²	597054.44	6372505.81	Undefined	Not in use
Cable 2	572171.67	6375770.54	Undefined	Not in use



Cable 3	573243.13	6376448.52	Undefined	Not in use
Cable 4	572894.64	6376244.99	Undefined	Not in use
Telephone Cable (Fibreoptic)	599448.34	6370085.28	Buried?	Permanent

Notes:

¹ No data available, but suggestions indicated with ‘?’

² Cable crossing to be treated with caution, based on GIS interrogation

Table 4-1: Crossings for the proposed cable routes as presented in Figures A1 to A5, Appendix B

For crossing design considerations concrete mattress supports and rockdump protection are typical methods adopted to safely bridge and protect existing products on the seabed when a cable is laid over it. For trenching considerations on approaches to crossings, a transition distance (i.e. grading in/out from seabed level to full trench depth) of nominal length (typically 30 m) is to be included. 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 REGIONAL GEOLOGY

5.1 General

Coverage of the Hywind Scotland Study Area has been mapped geologically by the British Geological Survey (BGS) [Refs. 9, 10, 11, 12] that is supplemented with some very basic grab sampling of the seabed to confirm the geophysical interpretation. The seabed sediments comprise predominantly superficial deposits of Holocene sands (sometimes gravelly), which generally occur as a very thin veneer blanketing the area (less than 0.5m). Underlying the veneer, the BGS indicate that the Quaternary soils comprise Forth Formation and Wee Bankie/Witch Ground Formation deposits over Coal Pit Formation. Based on geophysical records, the Quaternary sediments are relatively thin (up to 40 m thick) within the Pilot Park development area where they directly overlie basement bedrock and thin west towards the coast where they completely pinch out.

The distribution of the various soil units identified in the surveys, and their general nature are described in Section 5.2 below, with more detailed discussion of the site specific geology in Section 6.

5.2 Geological Formations

5.2.1 Superficial Sediments (Holocene)

Superficial sediments, typically < 0.5m thick, blanket the seabed across the Hywind Scotland Study Area. These sediments generally consist of gravelly shelly sands and occasional muddy sands [Refs. 10, 13], which are likely to be derived from the underlying Quaternary sediments. Areas of reworking of such sediments are thought to be related to the development of sand waves and sand ridges [Ref. 16] as indicated in Figure 5 below.

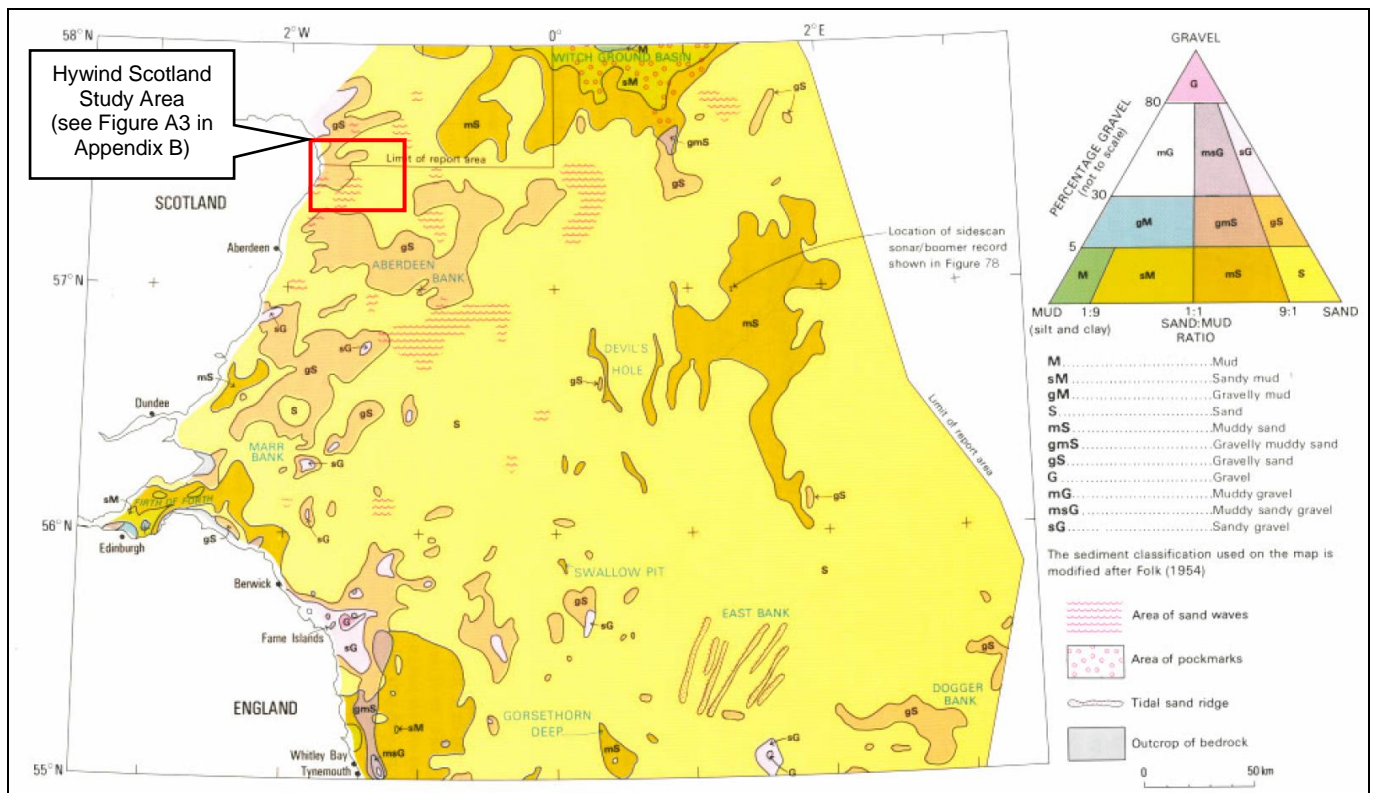


Figure 5: Seabed sediment and bedform distribution in the central North Sea [Ref. 16]. Reproduced by permission of the British Geological Survey. CP13/060.



A seabed sediment distribution map for the Hywind Scotland Study Area and export cable route is presented in Figure A3 of Appendix B.

5.2.2 Quaternary Deposits

A Quaternary Geology map of the Hywind Scotland Study Area is presented in Figure A4 of Appendix B. The sections below discuss the geological formations expected to be present within the site for further evaluation in Section 6.

5.2.2.1 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 consist a series of fine to coarse sand and pebbly marine muds (silty clays) deposits. Within the Study Area, two facies are represented; the St. Andrews Bay and Largo Bay Members, but with the majority of the Study Area being mapped as undivided [Refs. 12, 14]. This formation is considered to be laterally equivalent to the Witch Ground Formation that becomes more prevalent further east. The BP data [Refs. 17, 18] indicate the Forth Formation in this area is mainly 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 site being only 2 – 3m thick [Ref. 14].

5.2.2.2 Witch Ground Formation

The Witch Ground Formation is not indicated to be present in the Hywind Scotland Study Area from the BGS data, as it is probably underlying a thin cover of the Forth Formation. However, it has been interpreted to be present by the subsurface stratigraphic units indicated on the cross-sections along the Forties to Cruden Bay pipeline [Refs. 18] toward the east of the Pilot Park development area. Sediments generally comprise very soft to soft glaciomarine muds overlying an undulating erosive surface of older formations [Ref. 14], in this case the Coal Pit Formation. [Ref. 18] describes the sediments in this area to consist layered fine sands, silts and clays that are possibly pebbly becoming more clayey with depth that often form infill channel features that have incised into the Coal Pit Formation.

5.2.2.3 Wee Bankie Formation

This formation is indicated to outcrop locally as rare discrete patches across the Study Area. It directly underlies the Forth Formation and is likely to only be a thin deposit as indicated in interpreted geophysical cross sections in [Ref. 18]. The BGS indicate it is a till deposit comprising thin interbedded layers of sand and silty clay, and coarse sand and gravel deposits. It is thought to lie directly over bedrock or over older ice-pushed Quaternary deposits. The closer to shore, it is expected to lie directly over bedrock. BP seismic data interpretation indicates the unit is thin (< 5m thick) based on the geophysical cross sections [Ref. 18].

5.2.2.4 Coal Pit Formation

The Coal Pit Formation is also not indicated to be present as an exposed formation on the BGS data, again because it is not interpreted to outcrop locally being covered by deposits of the Forth, Witch Ground and Wee Bankie Formations. Cross sections presented in [Ref. 18] indicate that the Coal Pit Formation forms an erosive contact with the sediments above and below it, seemingly being only 5 m – 10 m thick. The formation itself is indicated to consist marine sands and pebbly glaciomarine muds and sands [Ref. 14].

5.2.2.5 Aberdeen Ground Formation

The Aberdeen Ground Formation is indicated to underlie the above Quaternary deposits across the area, sometimes being locally absent [Ref. 14]. This formation is indicated to directly overlie pre-Quaternary bedrock as an irregular contact where it forms an onlap sequence toward the coast where the younger sedimentary deposits pinch out. Sediments generally comprise glaciomarine muds sands and gravels [Ref. 14].



5.2.3 Basement (bedrock)

The basement bedrock underlying the much younger Quaternary deposits comprise a sequence of indurated sedimentary and igneous rock sequences dating between Paleocene and Devonian age [Refs. 11, 15, 16]. This sequence grows older westward toward the Peterhead coast. The depth to the bedrock interface is irregular, with deep areas lying southeast and northeast of Peterhead. However, directly east of Peterhead in the Pilot Park development area, bedrock is indicated to be within 20 m of the seabed, before dropping away to greater depths east of this point.

A Solid Geology/Bedrock Geology map of the Hywind Scotland Study Area and export cable route is presented in Figure A5 of Appendix B. Note hard substrates have also been recorded around some coastal areas to indicate where exposure of rock has been mapped offshore.



6 SEABED FEATURES AND SOIL DATA

6.1 Seabed Features

Seabed features roughly marked by the BGS around the Hywind Scotland Study Area (see Figure 5) indicates large scale bedforms such as sandwaves, pockmarks and outcrops of bedrock. Such features have been drawn on Figure A3 in Appendix B to see if they impact on the proposed development area, but these are shown to lie southwest of the Pilot Park development area and south of the cable route; hence these are not anticipated to be a hazard, but such features should be confirmed during the site specific survey. It is observed that the sandwave features appear to be related to the lobe of sand sediments that extend along the Forties to Cruden Bay pipeline route, which are not indicated to be present along the proposed cable route option(s).

No other obvious geohazard features, including hard substrates around the landfall locations (Figure A5), are indicated from the BGS data.

In review of more specific seabed survey data from the BP data reports along the Forties to Cruden Bay pipeline route, the seabed conditions described are as follows:

- > The seabed consists a veneer of silty fine SAND (Holocene) that is sometimes locally absent exposing the soft CLAY underneath (either Forth Formation (west) and/or Witch Ground Formation (east));
- > The general sandy seabed is megarippled, but these become 'ill defined' eastwards (i.e. flat and featureless);
- > Larger scale sandwave features lie in the western area of the pipeline route (possibly located in the western margin of the Hywind exclusivity area) with wavelengths of 10 – 12 m, heights above seabed of 1 – 3 m, and crest direction typically trends NW-SE;
- > Linear gravel lag deposits that trend NNE-SSW are located in discrete areas across the pipeline route;
- > Soft clays of the Witch Ground Formation may outcrop locally in the easterly portion of the Hywind area, where the sand veneer is not as thick;
- > Numerous trawl/anchor scars and a ship wreck (identified as the Anne-Meke) are identified within the pipeline route survey corridor. The trawl/anchor scars are more predominant in the easterly portion of the Hywind area where the Witch Ground Formation is expected;
- > Very few single point objects are identified.

Based on the above, the seabed around the Hywind Scotland Study Area and along the proposed export cable route is expected to have some hazard features (e.g. sandwaves, megaripples, and gravel lag deposits), which will need to be considered for any anchoring assessments of the turbines and for lay/burial of the cable.

6.2 Shallow Soils

The shallow soil profile across the Hywind Scotland Study Area is summarised in Table 6-1 below. It has been developed from an integrated interpretation of the available geophysical and geotechnical data, in combination with the wider regional geology from the BGS maps.

It is expected that the shallow soil conditions will mainly consist of silty SAND of both Holocene and Forth Formation type soils. However, there may be localised outcrops of soft CLAY from the Witch Ground Formation in the eastern area of the Hywind Pilot Park development area. Underlying the Forth Formation in the west is a thin layer of TILL of the Wee Bankie formation, that is indicated to pinch out against Witch Ground Formation in the east.

All of the above units are shown to directly overlie SANDS and MUDS of the Coal Pit Formation, which to be widespread across the site. This unit in turn overlies MUDS, SANDS and GRAVELS of the Aberdeen Ground Formation that rests directly on basement bedrock.



Soil Unit	Depth Below Seafloor (m)		Soil Description	Formation
	From	To		
Holocene	0.0	< 0.5	Silty SAND	Holocene ¹
I	0.5	1.0 – 2.0	SAND with fine gravel	Forth ²
II	0.5	5.0 – 10.0	Layered fine SANDS, SILTS, CLAYS	Witch Ground ³
III	2.0	5.0	TILL with thin layers of sand, clay and gravel	Wee Bankie ⁴
IV	5.0	15 - 20	SANDS and pebbly MUDS and SANDS	Coal Pit ⁵
V	20	30	MUDS, SANDS and GRAVELS	Aberdeen Ground ⁶

Notes:

¹ Depth is variable depending on presence of sandwaves

² Often difficult to differentiate with Holocene material

³ Becomes more predominant in the east of the Hywind Offshore Exclusivity Area more as infill erosion channels that have incised into the underlying Coal Pit Formation

⁴ Laterally discontinuous, occurring only in the west of the Hywind area

⁵ Occurs as an irregular unit in terms of thickness, but is common across the whole development area

⁶ Little data available that discusses its confirmed presence, but expected to directly overlie the basement bedrock

Table 6-1: Expected soil profile across the Hywind Scotland Study Area

Descriptive logs of BGS sample station data identified within the Hywind Scotland Study Area (see locations of each in Figures A3 and A4 in Appendix B) are presented in Appendix C. These logs are mainly from Gravity Cores (GC) with one station being from a borehole (BH). The GC descriptions contain very limited information and generally only confirm that clean, sometimes gravelly, SAND lies at the seabed and this is generally underlain by 'sticky' very soft to soft CLAY. The borehole log (BH 72/31) suffers from gaps in sample recovery, but indicates 8 m of sticky, quite soft boulder CLAY with few pebbles from the seabed and from 21 to 33 m depth this material continues, but becomes hard and compact below 24 m. Bedrock appears to occur at 34.5 m below seabed. No geological formation names or soil boundaries have been assigned to the log

VC and PC logs from [Ref. 19] either side of the revised Forties pipeline routing indicated in Figure 3 are presented in Appendix C. It should be noted that VC/PC logs between 7 VC A and 14 PC are not included in [Ref. 19]. These tests were performed along the original pipeline route, but not discussed in this report and hence not presented. These logs confirm a loose to dense SAND veneer over a very soft to firm clayey SILT/silty CLAY with shell fragments and traces of gravel. Basic soil properties from these logs are presented in Section 6.3.

6.3 Geotechnical Engineering Parameters

For wind turbine design considerations of the mooring anchors, the soil profile presented in Table 6-1 requires confirmation with a geotechnical sampling programme to derive relevant soil design parameters for the identified soil units and obtain a better understanding and definition of the actual depth to bedrock. To achieve this, a borehole survey should be undertaken at each mooring anchor location or alternatively a deep push CPT to bedrock, accompanied with shallow CPT/VC sampling across the array area.

Some basic engineering properties from the available geotechnical test data presented in [Ref. 19] and from general geotechnical values assigned to geological formations in [Ref. 14] are given below Table 6-2. However, caution is recommended in the use of these parameters as the BP data is 40 years old and requires confirmation with further sampling and corroboration using modern methods/standards of data collection and interpretation and reporting. The BGS data is only general and should be secondary to any site specific sampling performed.

It should be noted that no geotechnical data is available for the deeper soil units from within the study area; hence only general BGS data is considered for Units IV and V.



Soil Unit	Description	Water Content w_c (%)	Undrained Shear Strength S_u (kPa)	Angle of Internal Friction, ϕ (°) ¹	Plasticity
Holocene	Loose silty SAND	-	-	30	-
I	Loose SAND with gravel	-	-	30 - 35	5 - 45
II	Layered fine SANDS, SILTS, CLAYS	15 - 50	5 - 50	25 - 30	5 - 35
III	TILL with thin layers of sand, clay, gravel	10 - 40	40 - 300	-	10 - 50
IV	Firm to very stiff pebbly MUDS and dense SANDS	-	100 - 150	35	-
V	Very stiff to hard MUDS, SANDS and GRAVELS	-	>300	-	-

Notes:

¹ Values estimated based on descriptions

Table 6-2: Geotechnical engineering parameters for trenching evaluations

For cable stability and trenching and burial considerations along the export cable route, only sediments occurring within the top 5 m of the soil profile are evaluated to determine the most appropriate parameters for design evaluations and trenching tool selection. Based on the available data this evaluation considers soils from the Holocene, Forth, Witch Ground and Wee Bankie Formations that all lie within 5 m of the seabed surface. Basic engineering parameters required for such assessments are given above in Table 6-2, but more definition of material along the cable route is required to understand the shallow soil stratigraphy and how this varies laterally along the route.



7 CONCLUSIONS AND RECOMMENDATIONS

The main conclusions from the geotechnical desk study are follows:

- > An evaluation of seabed conditions and soil stratigraphy has been carried out across the Hywind Scotland Study Area, which extends from the coast to the north of Peterhead out to approximately 32 km at the easternmost extent of the Hywind Scotland Exclusivity Area/Pilot Park.
- > Various data sources have been obtained to map seabed information in GIS to evaluate environmental and infrastructural constraints to the proposed development and to understand seabed geology across the site. For the geotechnical aspect of this study, the available data has been sourced from the BGS and from BP who has conducted tests offshore Peterhead for pipeline routing options in the 1970's. No other data from 3rd party sources has been identified that could be included in this study, hence data is very limited.
- > There is very little geotechnical sampling data across the Hywind Scotland Study Area and which is not specific to the Pilot Park development area or the export cable route. The BGS sample stations are random and contain very limited information. The BP data is confined to pipeline route studies, with the only data provided to date being located along the Forties to Cruden Bay oil export pipeline route corridor that separates the Hywind site. Other data has been identified that is more relevant to the proposed export cable route; however this data has yet to be provided.
- > The BGS data indicated the site is blanketed by a thin veneer of Holocene sand, slightly gravelly sand and gravelly sand. Areas of sandwaves are identified by the BGS to the south of the cable route and outside the Hywind Scotland Pilot Park.
- > BP data collected along the Forties to Cruden Bay oil export pipelines confirms the BGS interpretation of seabed sediments and seabed features, where silty SAND with shells and sometimes fine gravels blanket the area. Bedform features include larger scale sandwaves to the west of the site where water depths shallow to shore, megarippled sands, and linear but discontinuous gravel lag deposits. Manmade features such as trawl/anchor scars are more common in the eastern area of the site within Buchan Deep.
- > The regional geology of the area indicates that 5No. Quaternary soil units lie beneath the Holocene veneer, which include the Forth, Witch Ground, Wee Bankie, Coal Pit and Aberdeen Ground Formations. These layered units vary laterally in thickness and are also laterally discontinuous, meaning the soil profile is not consistent across the site. Generally the Quaternary deposits are approximately 20 - 30 m within the Hywind Scotland Pilot Park but shallow west towards shore as the formation form an onlap sequence directly over basement bedrock.
- > The basement bedrock consists of indurated sedimentary and igneous rocks from the Paleogene to the Devonian, with the age of such increasing westwards to shore. The boundary with the overlying Quaternary soils is an erosional contact that is very undulating.
- > Very little geotechnical data is available to consider for foundation design or for cable stability design evaluations, and/or trenching evaluations. Basic soil properties have been presented from the available data; however these should be treated with caution for any design considerations. This data is to be revised upon review of site specific survey, to confirm and/or supersede the values presented.

With respect to the Hywind Scotland field development and cable route, some general comments are made with regard to the review undertaken:

- > A cable route selection study is to follow on from the results presented from this study, and the constraints identified from the EIA. However, as a result of some of the environmental constraints found as part of the EIA mainly around the landfall approach, it is understood the cable route requires further interrogation to progress the project. Therefore, the route selection study is delayed until these issues have been resolved to make a more informed assessment.



- > Based on the above assessment, there is currently no possibility to narrow down the proposed site survey area, without having a definitive field layout agreed, or preferred cable route selected. At present all options are still being considered, so there are no specific areas that can be targeted to reduce the survey scope.
- > In terms of which areas are best suitable for anchoring within the Pilot Park exclusivity zone, little can be recommended based on the very limited available seabed data other. A high level comment would be that all areas seem suitable for drag embedment anchors and driven pile anchors. But because the loads being considered for the anchored mooring system are very high (> 5000 kN), a gravity based solution is probably not feasible. Additionally, there is no enough deep soil data or test data with detailed geotechnical engineering parameters to consider torpedo piles, or suction piles with any confidence. For safe and efficient driven pile solutions, these also require detailed test data and soil profile data to at least 30 - 40 m below seabed. The current sample station data sets from the BGS and BP are very sparse and shallow (up to 5 m depth), with only the geophysical interpretation giving an understanding into what could be lie beneath the seabed, but this has very little ground-truthing. Therefore, a recommendation into presenting the most suitable anchoring solution cannot be commented on until more site specific data with test results presenting engineering parameters becomes available.
- > In addition to this review, a landfall selection study is to be undertaken after a site walkover of the cable landing options is performed. This was to occur on 11th July 2013, however this has been postponed. Therefore, this study has been delayed until a new date is proposed.

It is understood a geophysical and benthic site survey will be performed in Q3 2013 across the Hywind Scotland Pilot Park development area and along the preferred export cable route to investigate seabed and sub-seabed conditions. Optional scopes for archaeological and UXO surveys may be added if the need becomes more important. The survey is aimed to map and identify the shallow geology, seabed features, local topography, hazards, and benthic habitats of conservation importance, across the area to improve to better understand the holistic constraints to the proposed development and what effect these may have to construction activities planned for the site.

Upon review of the results of the geophysical survey, a geotechnical survey will be undertaken at a later date to target specifically where site sampling should be performed to support/ground-truth the geophysical interpretation of the site and obtain engineering parameters relevant to foundation design. The following recommendations are presented for such a survey to reduce seabed uncertainty of the site:

- > Shallow geotechnical sampling with CPTs, VCs, up to 5 – 6 m depth below seabed should be carried out within the Pilot Park development area (i.e. at each anchor deployment location) and along the export cable (approx. every 1 km) to confirm soil stratigraphy and to determine engineering parameters for design considerations. The aim would be to ground-truth the geophysical data and develop a more confident ground model of the greater development area.
- > Depending on the preferred anchoring solution for the chosen mooring system of the floating turbines, deeper BHs and/or deep push CPTs to 30 - 40 m depth below seabed may be required at the mooring anchor locations to obtain good quality soil profile data for detailed design considerations, especially if piles are selected.
- > The requirement for geotechnical data along the cable route would be used for cable design analysis, e.g. stability and cable protection assessments and to develop and confirm cable protections strategies, based on the interpreted geology along the route. From here costs and schedules for operations can be developed based on tool availability and from performance predictions. Or alternatively consider other protection options, e.g. rockdump, where trenching is unachievable such as in areas of shallow rock outcrops.
- > Additionally, if further BP data comes available at a later date then review of this information can be incorporated into any subsequent revisions of this report.

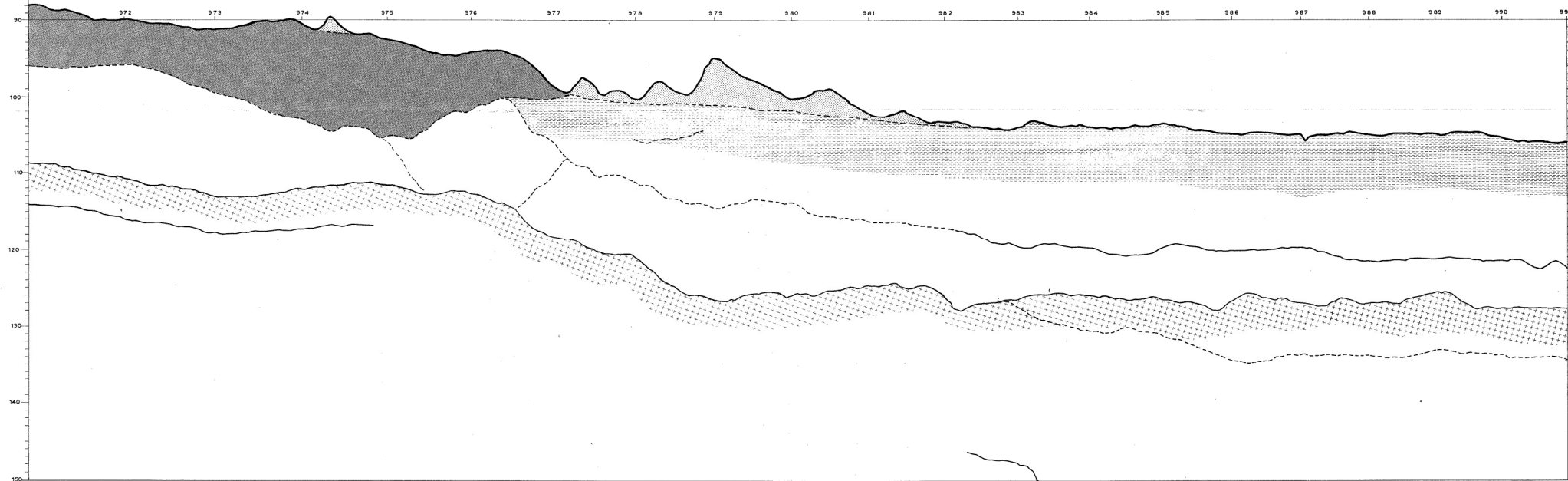
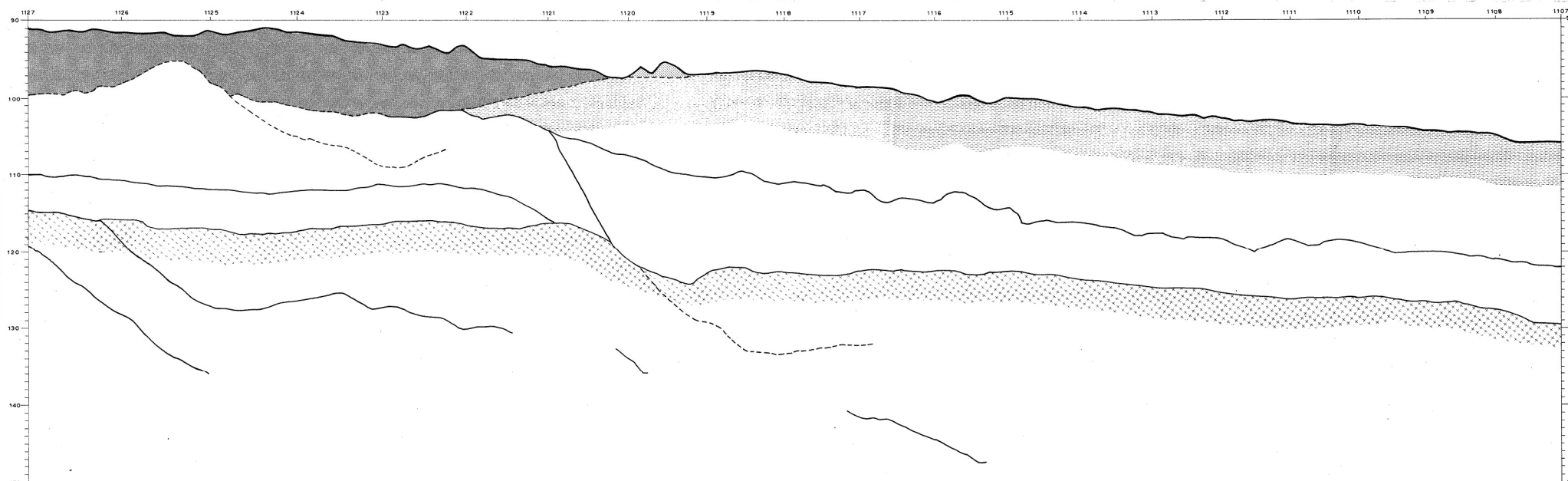
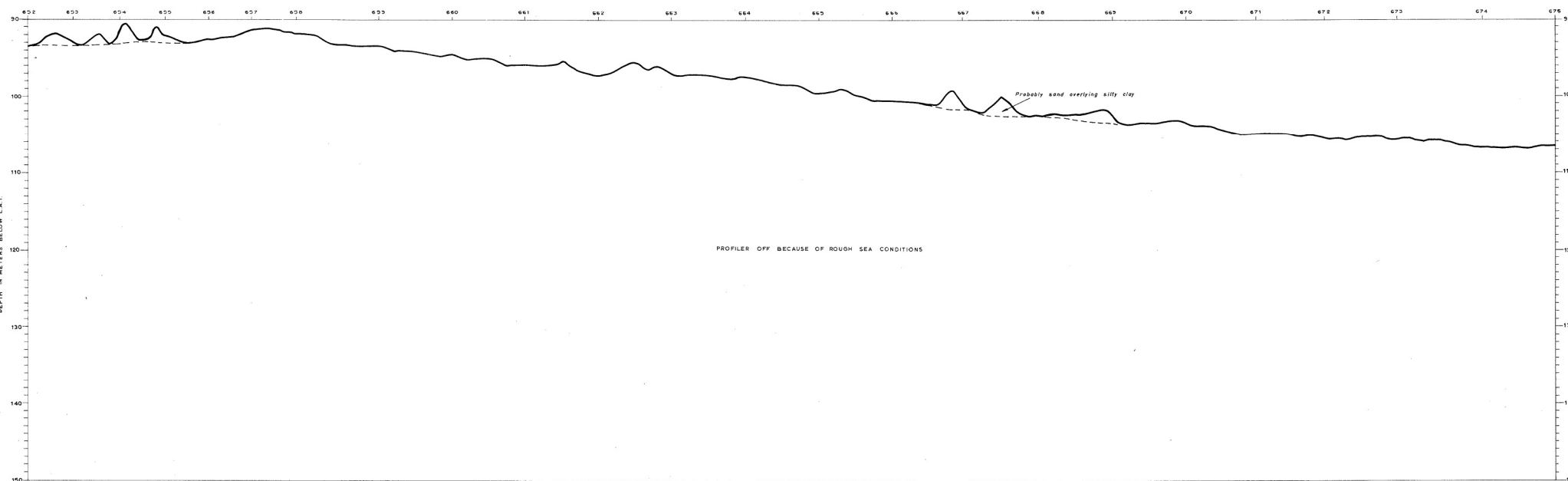
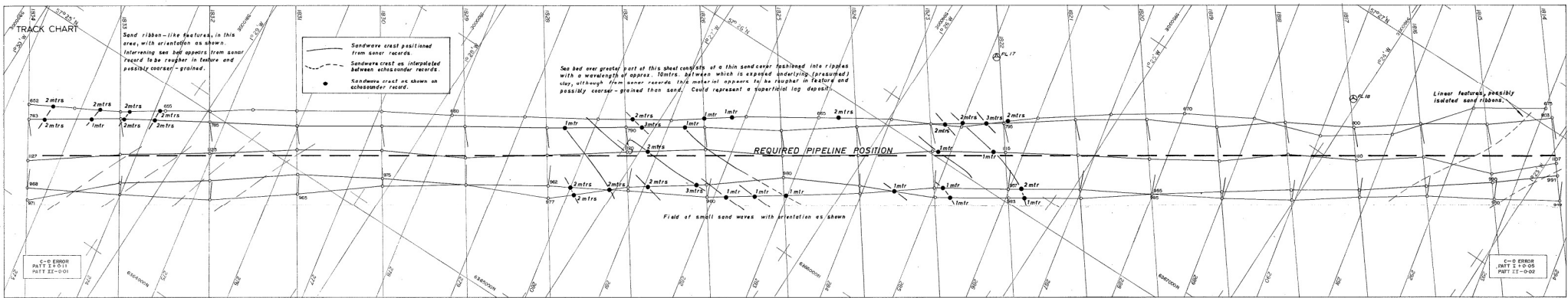
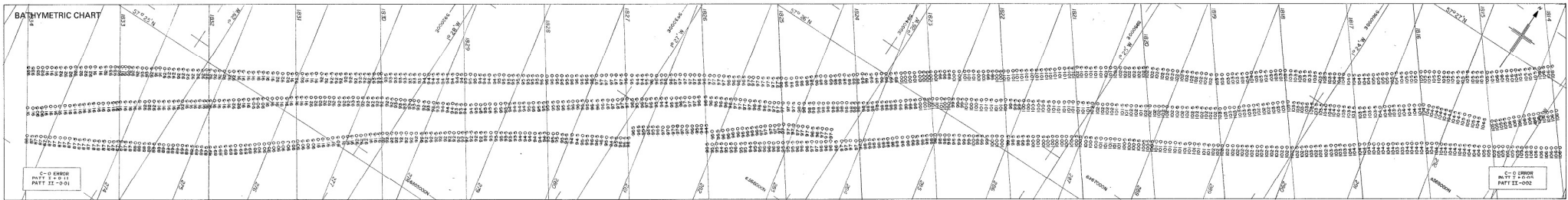


8 REFERENCES

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- 2 UK DEAL, 2013. Oil & Gas Infrastructure
- 3 JNCC, 2013. SPA, SAC and Ramsar designated site GIS data
- 4 SNH, 2013. SSSI designated site GIS data
- 5 Ordnance Survey, 2013. Basemapping
- 6 TCarta, Unknown Date. Bathymetry contours
- 7 KISCA & Statoil, 2013. Existing cable locations
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- 11 BGS, 2013. DigRock250
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- 18 GeoTeam UK Ltd., Sept 1989. Pipeline Alignment Charts and Isopach maps of sediment cover over bedrock for BP Petroleum Development Ltd.
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APPENDIX A GEOTECHNICAL DATA EXTRACTS





B.P. PETROLEUM DEVELOPMENT LTD
BRITANNIC HOUSE
MOOR LANE
LONDON EC2Y 9BU.



HUNTING SURVEYS LTD.
ELSTREE WAY
BOREHAMWOOD
HERTFORDSHIRE.
TEL 01-953 8181

- LEGEND
- Ships Track & Fix Position
 - Underwater Photo Location
 - Self Recording Current Meter Position (S.R.C.M.)
 - Direct Reading Current Meter Position (D.R.C.M.)
 - Percussion Core Position
 - Vibrocoring Position
 - Obstruction observed on P.D.R./Sonar
 - Admiralty Position of Wrecks - not observed
 - Sandwave Crest with steeper side
 - Fix - Showing Direction of Side Scan Sonar

FORTIES FIELD - CRUDEN BAY PIPELINE SURVEY (REVISED ROUTE B1 - B4 - C)

SCALE 1:10,000

SURVEYED BY HUNTING SURVEYS LTD.
IN CONJUNCTION WITH MARINE SCIENCES GROUP
B.P. RESEARCH CENTRE, SUNBURY, MIDDLESEX.
DATE OF SURVEY: MARCH - APRIL 1973

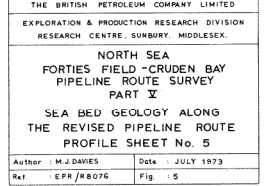
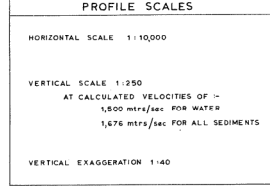
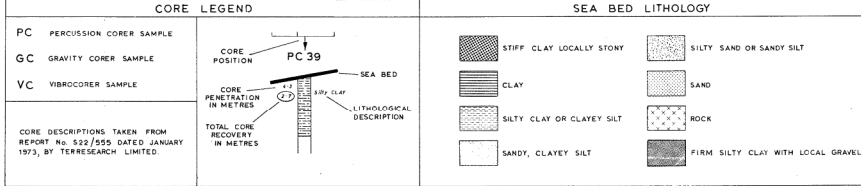
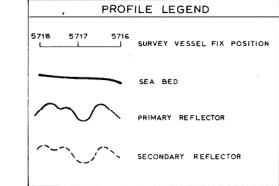
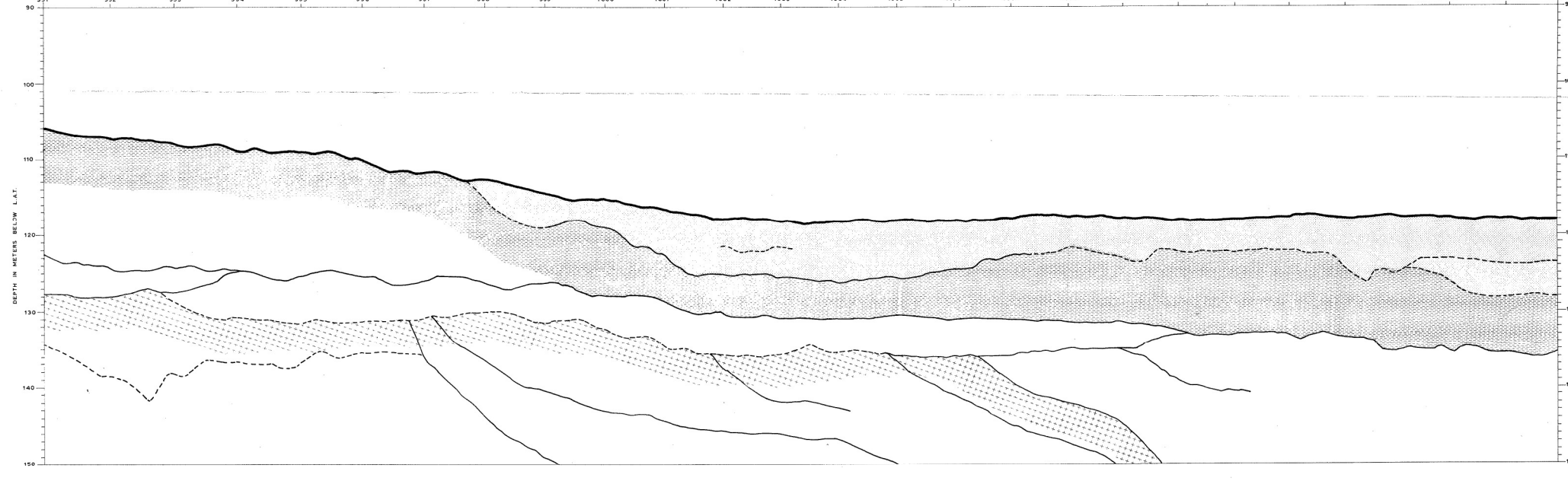
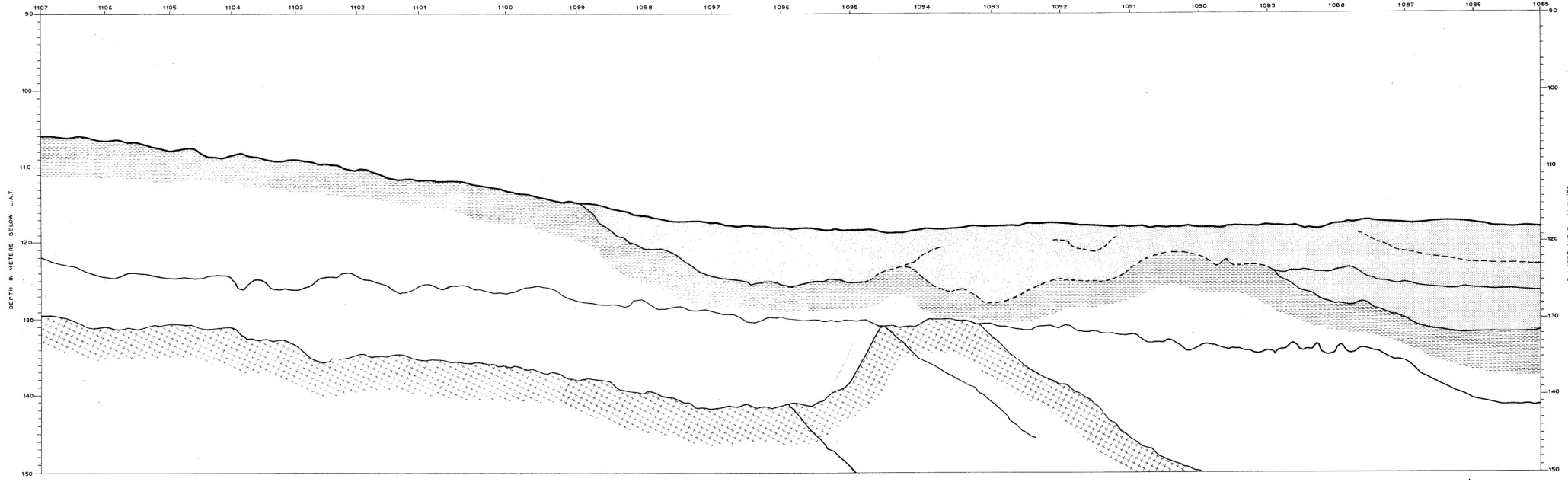
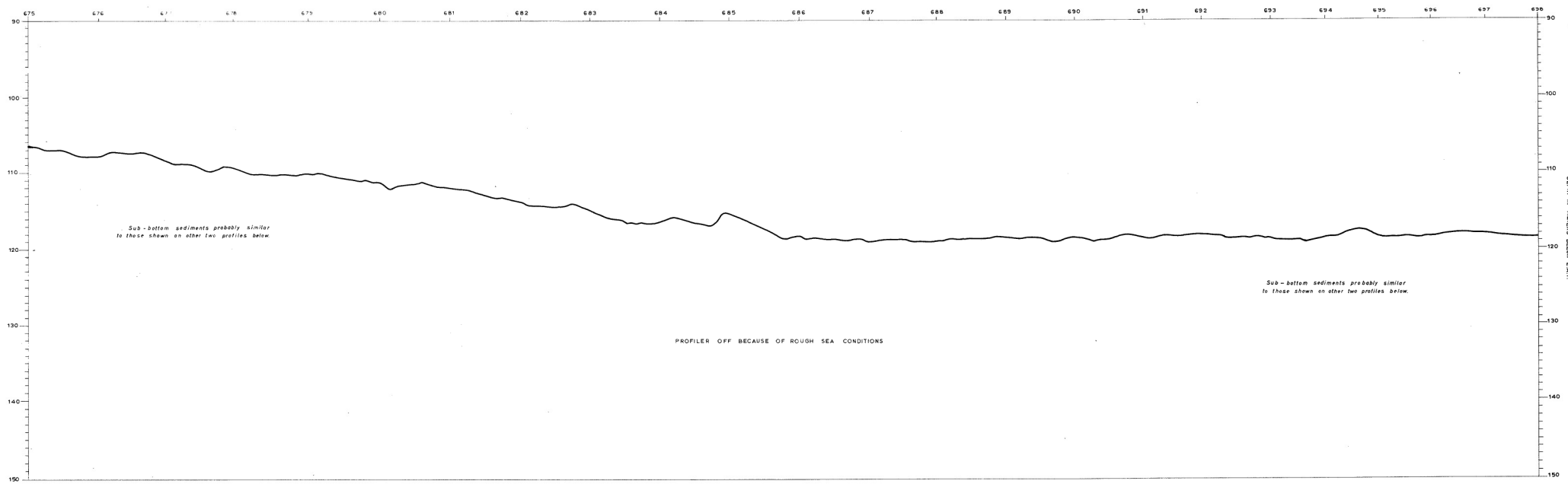
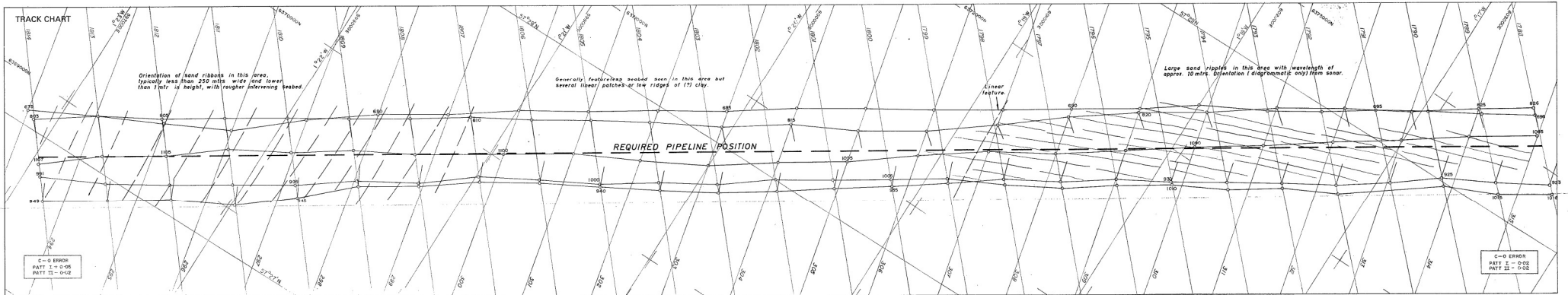
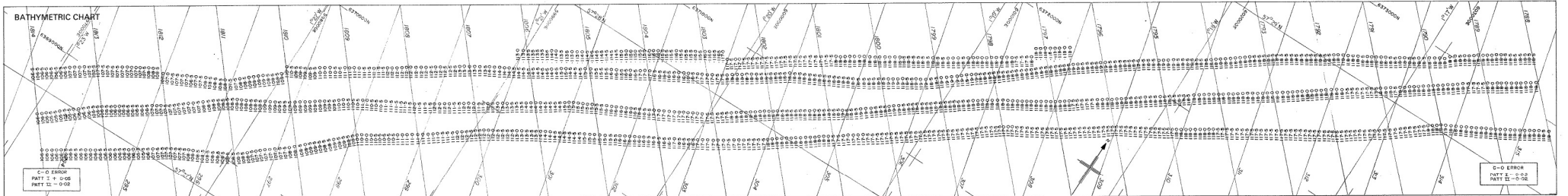
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CENTRAL MERIDIAN: 3°W
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PRIMARY SURVEY CONTROL: CROMARTY HFIX CHAIN

CROMARTY HFIX CHAIN APPLIED FIXED ERRORS - SEE BOXES.
DEPTHS IN METRES - REDUCED TO LAT FROM TIDAL
PREDICTIONS. SUPPLIED BY BRITISH PETROLEUM CO. LTD.
SPEED OF SOUND THROUGH WATER 1490 METRES/SECOND.

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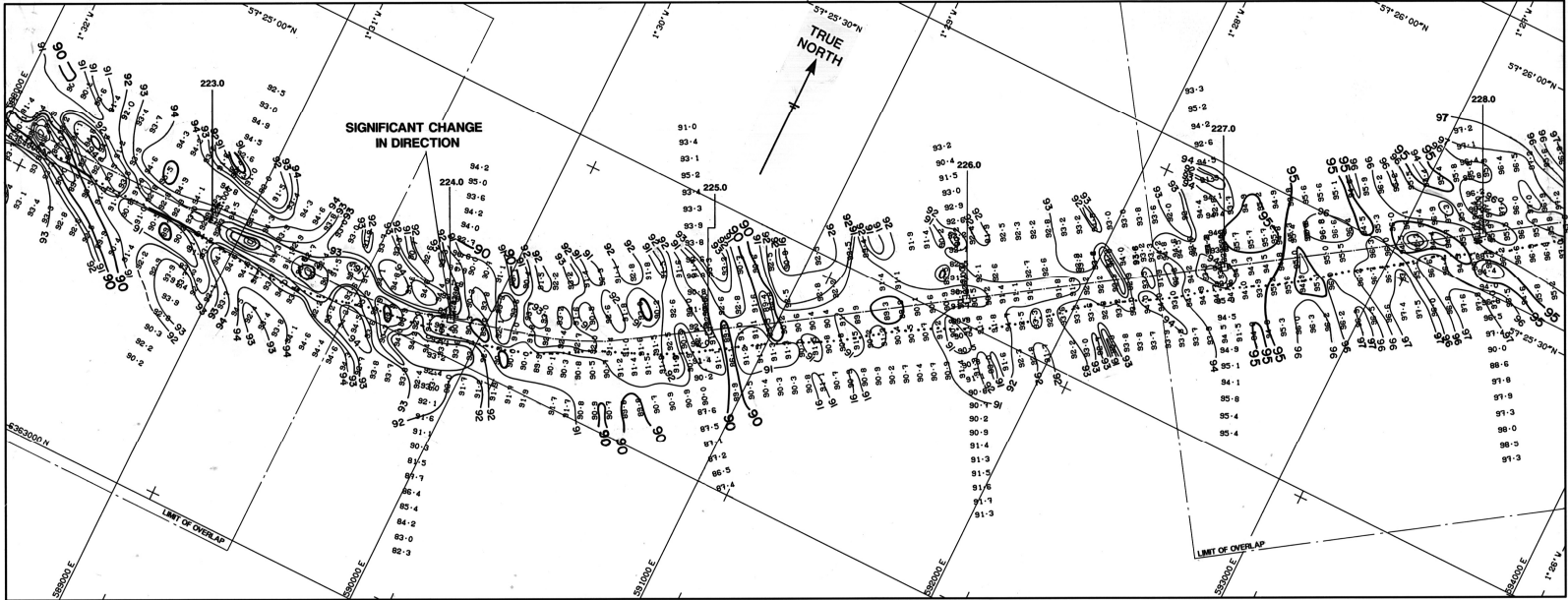
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AMENDMENTS BY BP MARINE SCIENCES GROUP	
11th May 1973 Required pipeline position and seabed data added	
20th June 1973 Profile data added	

SHEET NUMBER
5 OF 25

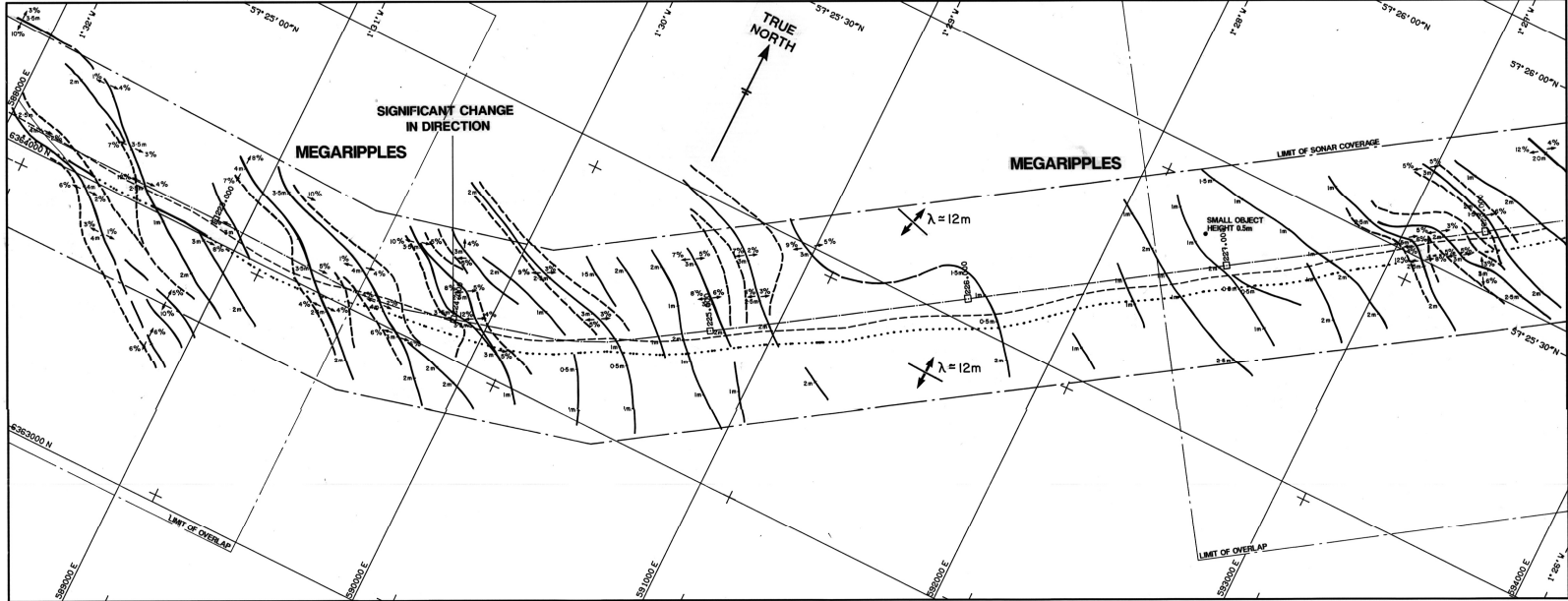


NOTE: For lithological subdivisions 'Ziptone' symbols have been used for clarity. These do not correspond exactly with conventional symbols used for core descriptions.

BATHYMETRY CHART



SEABED FEATURES CHART



INTERPRETED GEOLOGICAL PROFILE LINE 303

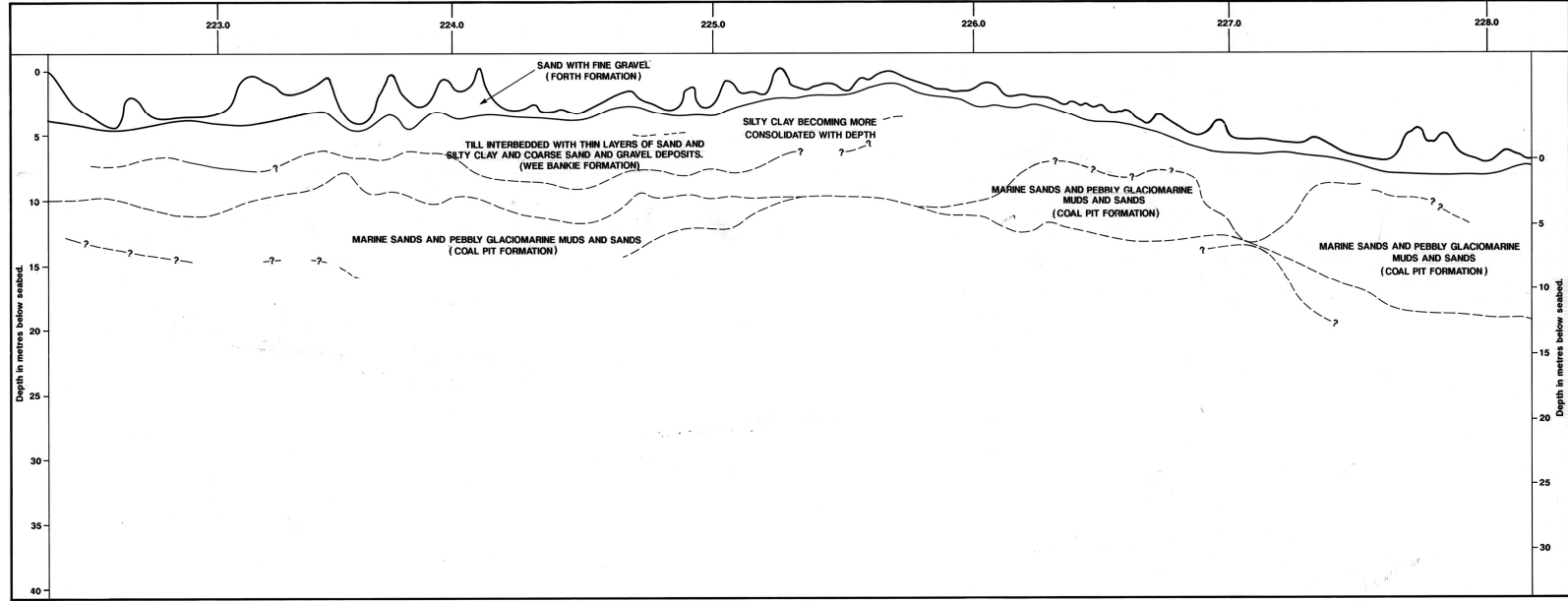


CHART LAYOUT

TRUE NORTH

CONVERGENCE
+01° 04' 02.12"
AT CHART
CENTRE
57° 25' 00" N
01° 29' 00" W

SCALE 1 : 10,000

PROJECTION : UNIVERSAL TRANSVERSE MERCATOR
ZONE 30. CENTRAL MERIDIAN 3° WEST
INTERNATIONAL SPHEROID. EUROPEAN DATUM 1950

POSITIONING BY WIMPOL CONSYL SYLEDIS

INSHORE STATIONS USED :
CAIRNULG
SHEKJILL
CRUDEN BAY
ASCO BASE
ABERDEEN

OFFSHORE STATIONS USED :
(CENTRAL NORTH SEA CHAIN)
FORTES BRAVO
MAUREEN ALPHA
BUCHAN ALPHA
TARTAN ALPHA
MONTROSE ALPHA
BRAE ALPHA

LEGEND

BATHYMETRY CHART

50 — Contour - Water depth in metres reduced to L.A.T.
50-5 — Representative spot depth in metres reduced to L.A.T.

SEABED FEATURES CHART

Width and trend of sandwave crest.
Height of sandwave crest above surrounding seabed with maximum slopes measured in the direction of the survey line.
General axial trend of megaripples with wavelength and assumed current directions.
Seabed object

ALL CHARTS

Change point with route survey centre line.
50m safety zone north of existing pipeline.
Exposed 32" MOL (As found position from sonar interpretation).
Buried 32" MOL (As found position from sonar interpretation).

INTERPRETED GEOLOGICAL PROFILE

Strong reflector.
Moderate reflector.
Weak reflector.

Horizontal scale Variable
Vertical scale 1 : 200

NOTES

BATHYMETRY CHART

1) Interpretation based upon Echo Sounder data.
2) Depths corrected to L.A.T. using predicted tides at Aberdeen.
Co-tidal factor : 0.20min
Co-range factor : 0.89

SEABED FEATURES CHART

1) Interpretation based upon Echo Sounder and Side Scan Sonar data.

INTERPRETED GEOLOGICAL PROFILE

1) Interpretation based upon Deep Tow Boomer data.
2) Assumed acoustic velocity - 1600m/s.

Client :
BP PETROLEUM DEVELOPMENT LIMITED

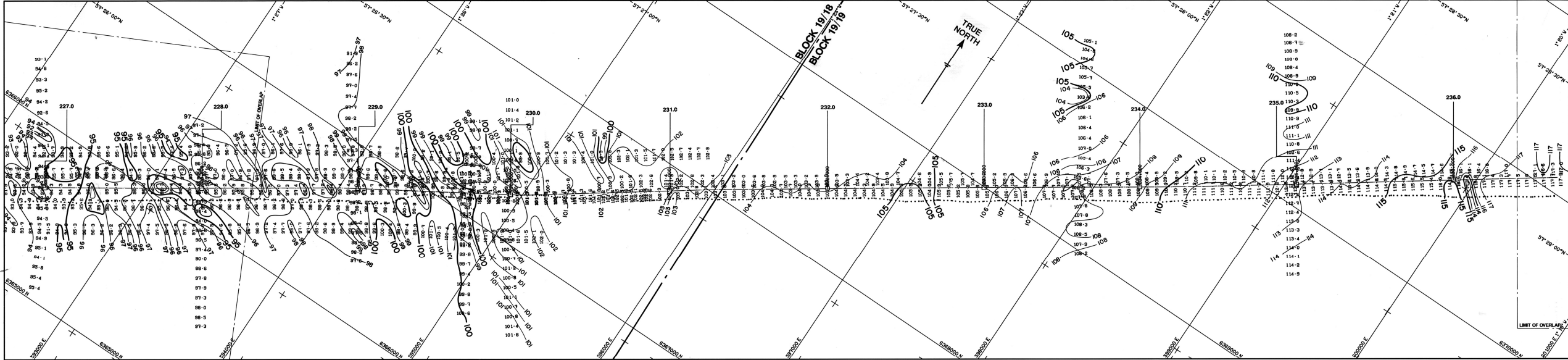
GEOTEAM U.K. LTD.
Regent House,
Regent Quay,
Aberdeen AB11 2JL,
Tel : (0224) 893366
Telex : 738888 OTUK G

FORTIES - CRUDEN BAY
EXPORT PIPELINE ROUTE SURVEY

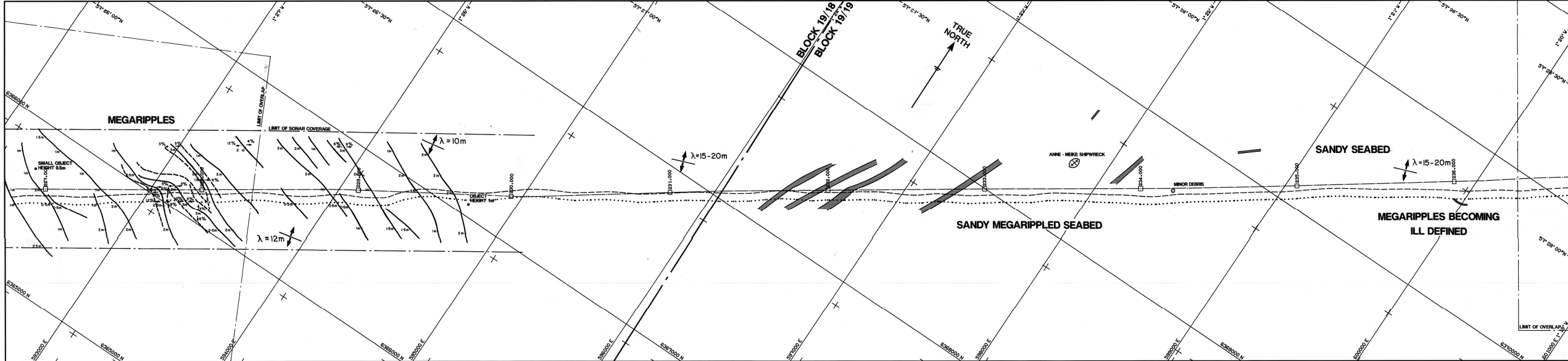
PIPELINE ALIGNMENT CHART
(CHART 4b)
CP 223.0 TO CP 228.0

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Field work by :	T.M. JULY 1989	BP drawing no: FEP - A - PO - PT - 3023 - No.04
Interpreted by :	P.B. JULY 1989	Geoteam project no. : 1077
Drawn by :	J.S.B. JULY 1989	Appendix no. : 4.4b
Checked by :	H.M.D. AUG. 1989	

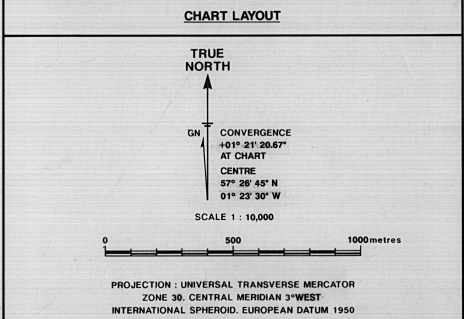
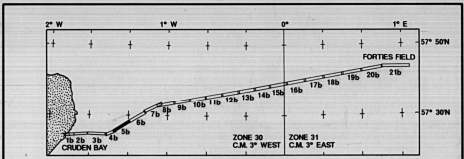
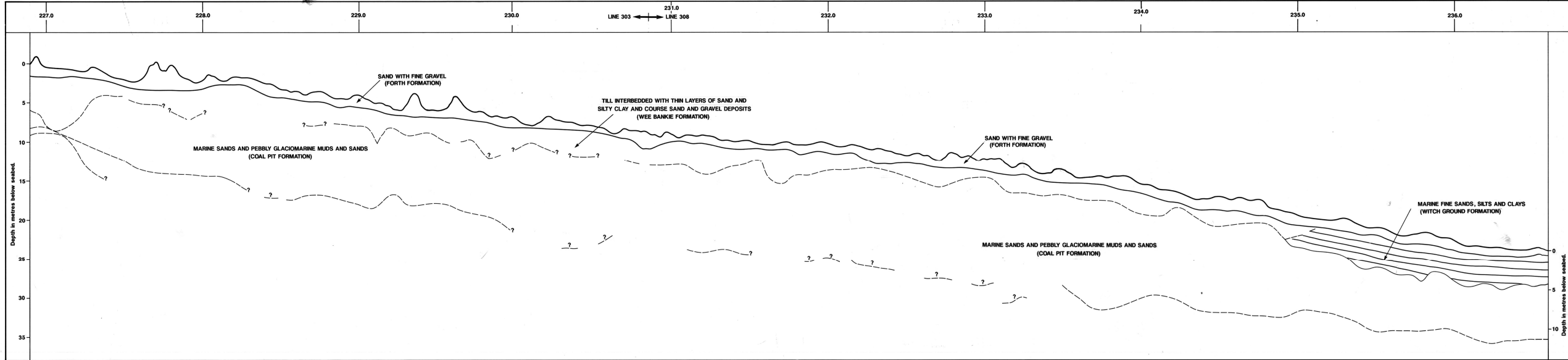
BATHYMETRY CHART



SEABED FEATURES CHART



INTERPRETED GEOLOGICAL PROFILE LINE 303/308



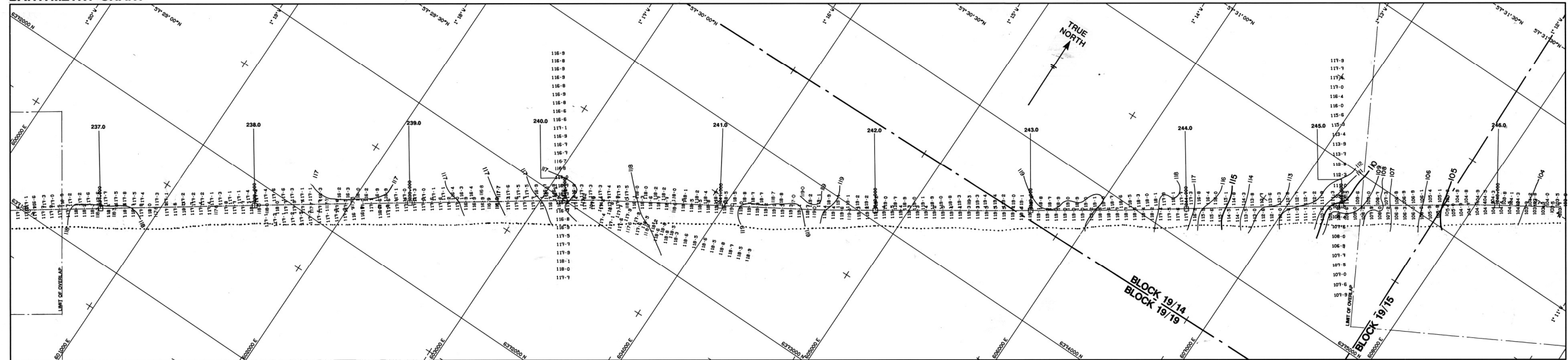
POSITIONING BY WIMPOL CONSL SYLEDIS	
INSHORE STATIONS USED:	OFFSHORE STATIONS USED:
CARNBULG	FORTIES BRAVO
SHERHILL	MAUREN ALPHA
CRUDEN BAY	BUCHAN ALPHA
	TARTAN ALPHA
	MONTROSE ALPHA
ASCO BASE	BRAE ALPHA
ABERDEEN	

LEGEND	
BATHYMETRY CHART	
50	Contour - Water depth in metres reduced to L.A.T.
50.5	Representative spot depth in metres reduced to L.A.T.
SEABED FEATURES CHART	
Width and trend of sandwave crest.	
Height of sandwave crest above surrounding seabed with maximum slopes measured in the direction of the survey line.	
General axial trend of megaripples with wavelength and assumed current directions.	
Seabed object.	
Area of gravel.	
Shipwreck of Anne - Mella.	
ALL CHARTS	
Change point with route survey centre line.	
50m safety zone north of existing pipeline.	
Exposed 32" MOL (As found position from Sonar interpretation).	
Buried 32" MOL (As found position from Sonar interpretation).	
INTERPRETED GEOLOGICAL PROFILE	
Strong reflector.	
Moderate reflector.	
Weak reflector.	
Horizontal scale Variable	
Vertical scale 1 : 200	

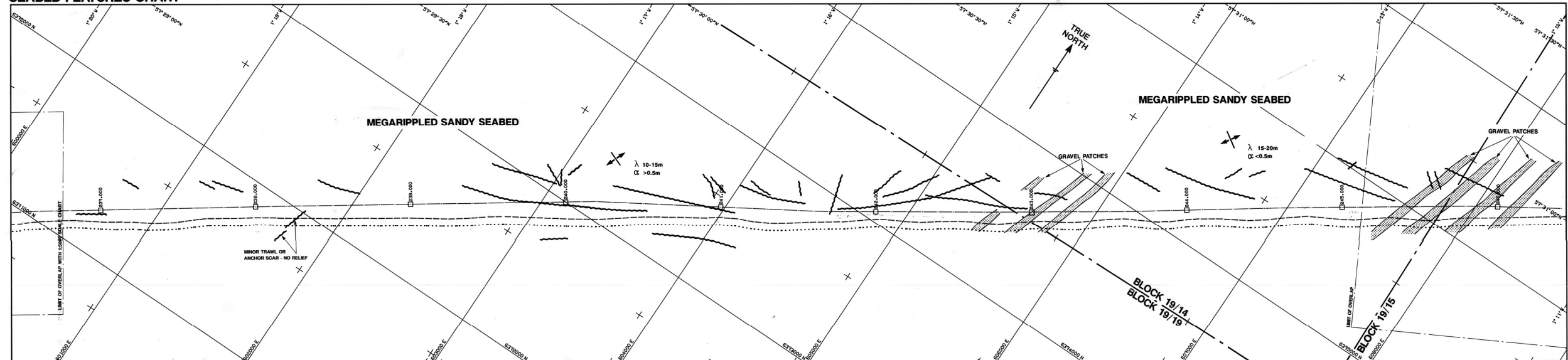
NOTES	
BATHYMETRY CHART	
1) Interpretation based upon Echo Sounder data.	
2) Depths corrected to L.A.T. using predicted tides at Aberdeen.	
Co-tidal factors : 0h 26min, 0h 24min	
Co-range factors : 0.89, 0.78	
SEABED FEATURES CHART	
1) Interpretation based upon Echo Sounder and Side Scan Sonar data.	
INTERPRETED GEOLOGICAL PROFILE	
1) Interpretation based upon Deep Tow Boomer data.	
2) Assumed acoustic velocity - 1600m/s.	

Client :	
BP PETROLEUM DEVELOPMENT LIMITED	
GEOTEAM U.K. LTD. Regent Quay, Aberdeen AB9 8AR. Tel : 0224 499385 Telex : 738888 GTRK G	
FORTIES - CRUDEN BAY EXPORT PIPELINE ROUTE SURVEY	
PIPELINE ALIGNMENT CHART (CHART 5b) CP 227.0 TO CP 236.0	
Vessel :	M/V GEO SURVEYOR
Field work by :	T.M. JULY 1989
Interpreted by :	P.B. JULY 1989
Drawn by :	J.S.B. JULY 1989
Checked by :	H.M.D. AUG. 1989
Survey date :	28/06 - 07/07/89
BP drawing no.:	FEP - A - PD - PT - 3023 - No.05
Geoteam project no.:	1077
Appendix no.:	4.5b

BATHYMETRY CHART



SEABED FEATURES CHART



INTERPRETED GEOLOGICAL PROFILE LINE 308

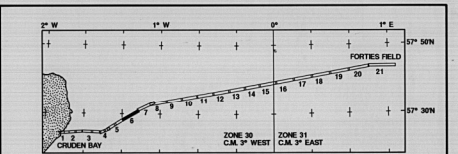
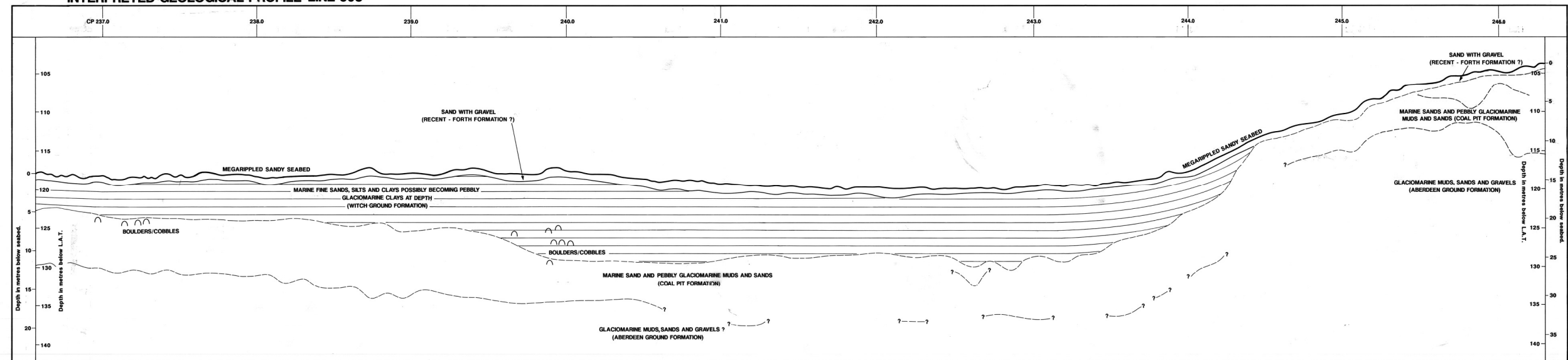


CHART LAYOUT

TRUE NORTH

GN

CONVERGENCE

AT CHART

CENTRE

57° 29' 45" N

01° 15' 30" W

SCALE 1 : 10,000

PROJECTION : UNIVERSAL TRANSVERSE MERCATOR
ZONE 30 CENTRAL MERIDIAN 3° WEST
INTERNATIONAL SPHEROID, EUROPEAN DATUM 1950

POSITIONING BY WIMPOL CONSYL SYLEDIS

INSHORE STATIONS USED : OFFSHORE STATIONS USED :
(CENTRAL NORTH SEA CHAIN)

CARNBULL FORTIES BRAVO
SHEKHL MAUREEN ALPHA
CRUDEN BAY BUCHAN ALPHA
TREASURE HUNTER TARTAN ALPHA
RATRAY HEAD MONTROSE ALPHA
ASCO BASE BRAE ALPHA
ABERDEEN

LEGEND

ALL CHARTS

- Change point (CP) every kilometre along route survey centre line.
- 50m safety zone north of existing pipeline (not on bathymetry chart).
- Exposed 2° M.O.L. (Position as found by sonar. Condition as found during 1989 annual sonar inspection).
- Buried 2° M.O.L.

BATHYMETRY CHART

- 50 Contour - Water depth in metres reduced to L.A.T.
- 50-5 Representative spot depth in metres reduced to L.A.T.

SEABED FEATURES CHART

- Position of vibrocore (VC) and percussion core (PC) samples recovered along 1972/73 proposed pipeline route survey.
- General acid trend of megaripples with wavelength (λ), amplitude (α) and assumed current direction.
- Trend of sandwave crest with height of crest above surrounding seabed and maximum slopes measured in the direction of the survey line.
- Area of megaripples with wavelength λ 5m, amplitude α 0.5m.
- Area of very thin surficial sand showing low amplitude (α 0.2m) ripples of wavelength 1-2m.
- Area containing both ripples of very thin rippled sand (wavelength 1-2m, amplitude α 0.2m) and megaripples (wavelength λ 5m, amplitude α 0.5m).
- Area of sand, gravel and cobbles.
- Area of sandy seabed with clay outcrops.
- Laydown drag scar unless labelled as anchor/trawl scar.
- Puckmark with diameter (D) and minimum depth (MD) in metres (calculated from sonar and echo sounder data).
- Sounded object with dimensions in metres, diameter (D), length (L), width (W), height (H), calculated from sonar and echo sounder data.
- Winchrope with length in metres and description.
- Pipe debris with length in metres.
- Gravel or rock dump along existing pipeline with length (L), width (W) and height (H), in metres (calculated from sonar and echo sounder data).

INTERPRETED GEOLOGICAL PROFILE

- Strong reflector.
- Moderate reflector.
- Weak reflector.
- Horizontal scale : Approximately the same as chart scale but variable due to vertical alignment of profile with bathymetry and seabed features charts.
- Vertical scale 1 : 200

NOTES

- 1) Interpretation based upon echo sounder, side scan sonar and sub bottom profiler data.
- 2) Depth corrected to L.A.T. using predicted tides at Aberdeen.
- 3) Co-sidal factor : 0.24m (includes \pm hour to G.M.T.)
- 4) Co-range factor : 0.78

SEABED FEATURES CHART

- 1) Sandwave field exists between CP 237.0 and CP 238.0 (charts 260 to 260.0).

INTERPRETED GEOLOGICAL PROFILE

- 1) Profile based upon route survey centre line.
- 2) Assumed acoustic velocity of 1,600m/s.

Client :
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FORTIES - CRUDEN BAY EXPORT PIPELINE ROUTE SURVEY

PIPELINE ALIGNMENT CHART (CHART 6b)

CP 237.0 TO CP 246.0

Vessel :	M/V GEO SURVEYOR	Survey date : 28/06 - 07/07/88
Field work by :	T.M. JULY 1988	BP drawing no: FEP - A - PO - PT - 3023 - No.06
Interpreted by :	P.B. JULY 1989	Geoteam project no. : 1077
Drawn by :	J.S.B. JULY 1989	Appendix no. : 4.6b
Checked by :	H.M.D. SEP. 1989	

Sheet 4 (1°30'W to 1°23'W)

Within this sheet water depths increase in an easterly direction from 91 m in the west to 106 m at the eastern edge. From the western sheet edge to 1°27'30"W the sea bed is rather irregular, and from 1°27'30"W to 1°25'30"W the route crosses a small sand wave field with wave heights along the centre line of 2 metres. These sand waves are oriented 110°/290°T, with their steeper slopes facing to the southwest.

From 1°25'30"W to the western edge of the sheet the sea bed is even and gradually falls from 100 m to reach 106 m.

The firm silty clay with stones already noted in the preceding sheet continues at the sea bed to 1°27'30"W. Here it gives way to material believed to consist of homogeneous soft to medium silty clay with an apparent absence of stones. Initially, from 1°27'30"W to 1°25'30"W, this soft clay is covered by the sand waves, but from 1°25'30"W to the sheet edge the soft silty clay outcrops on the sea bed. The underwater photographs indicate some very thin sand cover on this clay.

Bedrock lies at an average depth of 20 metres beneath the sea bed throughout the sheet falling from 110 m beneath datum level in the west to 120 m in the east.

Sheet 5 (1°23'W to 1°16'30"W)

In the area covered by this sheet the sea bed deepens gradually from a depth of 106 m at the western margin to 118 m in the east. West of 1°21'W sand ribbons trending 040°/220°T are seen on the sidescan sonar records. From 1°19'W to the eastern sheet edge large sand ripples with a wavelength ca. 10 m are seen. Between these two areas of sand the sea bed is featureless.

From the western sheet edge to 1°21'W to the sea bed is composed of soft silty clay with a thin cover of sand. East of this point the soft clay is covered by a gradually thickening sequence of very soft silty clay/sandy clayey silt, probably of Holocene age. This is the most characteristic layer seen on the profiler records, its multilayered appearance doubtless corresponding to variations in the sand/clay content. The surface layers are sandy and have been fashioned into the abovementioned ripples. The deposit increases in thickness gradually towards the east reaching 12 m at the sheet margin.

Sheet 6 (1°16'30"W to 1°10'W)

Over the greater part of the western half of this sheet the sea bed is fairly flat, varying from 117 m to 119 m in water depth. East of ca. 1°13'W however, the sea bed shallows to a minimum depth of ca. 103 m at about 1°11'30"W after which it continues eastwards at a fairly constant depth of 106 m - 107 m. The side-scan sonar records indicate a fairly featureless bottom except from 1°13'W to 1°10'W, where there is a zone of sand ribbons aligned ca. 030°/210°. An underwater photograph at ca. 1°15'15"W shows a faintly-rippled sandy bottom.

West of ca. 1°11'30" the sea floor is composed of soft multi-layered silts with an average thickness exceeding 10 m. On the western side of the bank this deposit rapidly thins, exposing the underlying material, which is believed to consist of silty clay. This is overlain even further to the east by a cover of silty sand, which varies in thickness from zero to 5 m. Within the centre of the bank a deeper sedimentary layer rises to within ca. 3 metres of the sea bed at fix 1071 on the central line. This material has not been sampled but is in all probability a glacial till consisting of stony clay.

APPENDIX B HYWIND STUDY AREA FIGURES