TotalEnergies E&P North Sea UK Ltd

Culzean - Floating Offshore Wind Turbine Pilot Project

Appendix J: Geophysical Survey Report

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Geophysical Survey Report

TotalEnergies PWT Site Survey

Geophysical, Geotechnical & Environmental Survey

Culzean Field, Central North Sea

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104728-TOT-OI-SUR-REP-SURVEYRE	Geophysical Survey Report	Ocean Infinity
104728-TOT-OI-SUR-REP-GEOTECRE	Factual Geotechnical Report	Ocean Infinity
104728-TOT-OI-SUR-REP-HABREP	Habitat Assessment Report	Ocean Infinity
104728-TOT-OI-SUR-REP-MMOPAMRE	MMO Report	Ocean Infinity
104728-TOT-OI-SUR-REP-ENVBASRE	Environmental Baseline Report	Ocean Infinity

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Abbreviations and Definitions

CAD...Computer Aided Design
CPT ....Cone Penetration Test
DGPS...Differential Global Positioning System
DPR...Daily Progress Report
DTM..Digital Terrain Model
DWG ....Drawing file extension
ED50 ....European Datum 1950
EPSG ....European Petroleum Survey Group
ENF ....Emergency Notification Flowchart
FRC ....Fast Rescue Crat
GAPS...Global Acoustic Positioning System
GIS ....Geographic information system
GPS ....Global Positioning System

HAZOP ....Hazard and Operability Study
HDD ....Hard Disk Drive
HSE ....Health, Safety and Environment
HSEQ ....Health, Safety, Environment and Quality
IMU ....Inertial Measurement Unit
INS ....Inertial Navigation System
ITRF ....International Terrestrial Reference Frame
JRCC..........Joint Rescue Coordination Centre
km ....kilometre
KP ....Kilometre Post, used to describe distance along a route (design)
LAT ....Lowest Astronomical Tide (vertical datum)
m ....metre
MAC..........Mobilisation and Calibration
MAG ....Magnetometer
MBES ....Multibeam Echo Sounder
OI..........Ocean Infinity AB
OI MS..........OI Management System
MNCR ....Marine Nature Conservation Review
MRU ....Motion Reference Unit
MS ....Management System
MRCC..........Maritime Rescue Coordination Centre
nT ....nanotesla
OM ....Offshore Manager
PCPT ....Piezo Cone Penetration Test
PDF ....Adobe Portable Document Format
PPS ....Pulse Per Second
QA ....Quality Assurance
QC..........Quality Control
QINSy..........Quality Integrated Navigation System
RC ....Report Coordinator
ROV ....Remotely Operated Vehicle
RPL ....Route Position List
SBP ....Sub-Bottom Profiler
SOW ....Scope of Work
SSS..........Side Scan Sonar
SV ....Sound Velocity
SVP ....Sound Velocity Profile
USBL ....Ultra Short Baseline System
UTC..........Coordinated Universal Time
UTM ....Universal Transverse Mercator
VC..........Vibrocorer

1. Introduction

1.1 Project Information and Survey Area

Ocean Infinity (OI) has been contracted by TotalEnergies E&P North Sea UK Ltd (TotalEnergies) to perform geophysical, environmental and shallow geotechnical investigations for a floating wind turbine in the Culzean Field.

The main survey area covers a 2.0 km by 2.0 km area and encompasses the proposed location of a wind turbine and its associated moorings. The centre of the main survey area is 2.1 km west of the Culzean ULQ platform and the approximate water depth over the survey area is 88 to 92 metres.

A 2.3 km long power cable will connect the floating wind turbine to the Culzean CPF platform.

The project details are summarized in Table 1.

Table 1 Project details.

Client	TotalEnergies
Project	TotalEnergies PWT Site survey
Ocean Infinity (OI) Project Number	104728
Survey Type	Geophysical/Geotechnical & Environmental
Area	Central North Sea
Survey period	March/April 2023
Survey Vessels	M/V Deep Helder
OI Project Manager	Edward Rich
Client Project Manager	Mark Grove Smith

1.2 Survey Area

An overview of the survey site is illustrated in Figure 1.

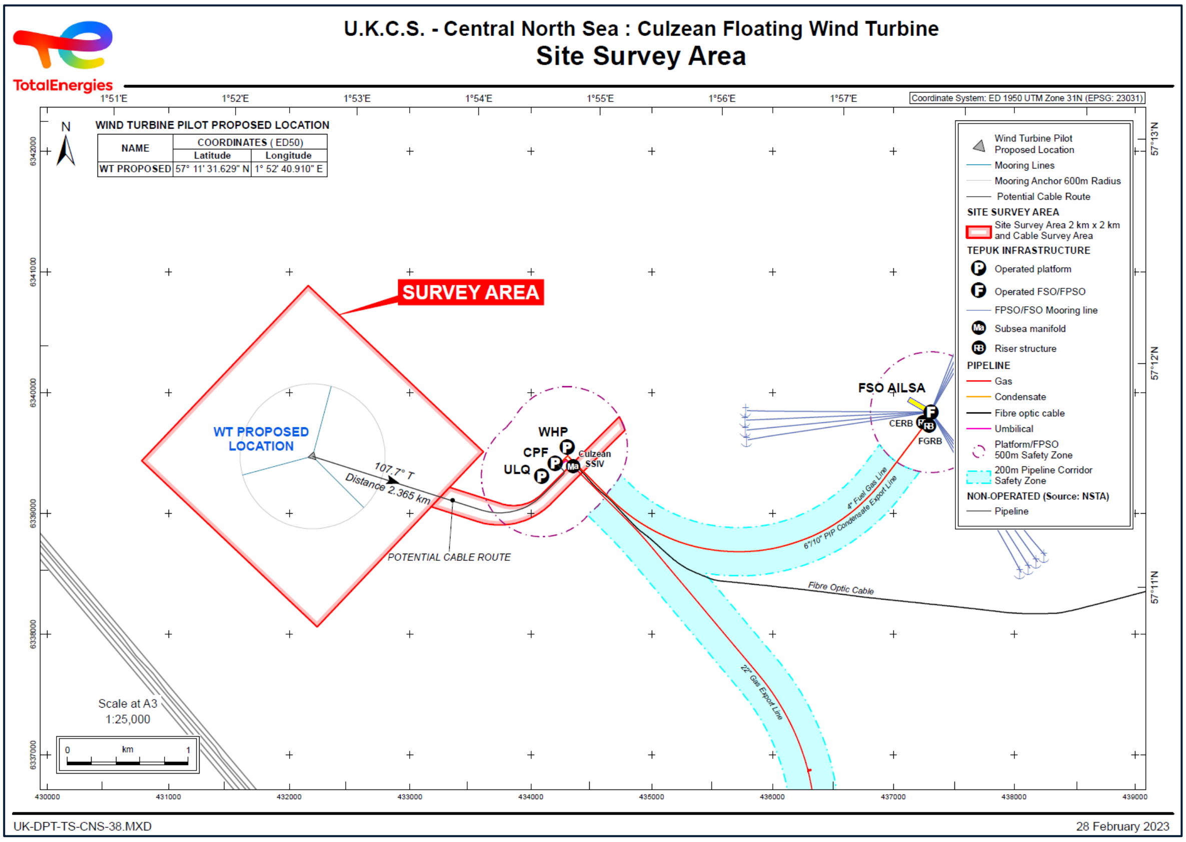


Figure 1 Survey Area.

1.3 Scope of Work

This scope of work covers the acquisition, processing, interpretation, and final reporting of a 2 km by 2 km site survey encompassing the location for a proposed floating wind turbine. In addition, data were acquired along a 2.3 km long infield power cable route to the Culzean CPF platform.

Acquisition will include a habitat assessment (HA) and sampling for an Environmental Baseline Survey (EBS). In addition, some geotechnical data is required at the anchor locations and along the cable route.

The objective of the survey is to identify and map potential seabed hazards at the proposed turbine, mooring locations and along the planned route of the infield power cable.

Acquisition of conventional shallow geophysical data for:

  - Seabed topography and bathymetry
  - Detection of shallow channelling to minimum 30 metres below seabed
  - Shallow layer identification
  - Debris identification

- Seabed habitat types shall be assessed using backscatter and side scan sonar together with seabed camera video and still photography.
- Seabed sediment grab samples shall be collected and analysed.
- Water samples to be collected and preserved for eDNA analysis.
- Vibrocore and CPT acquisition

1.4 Report Structure

This report presents the interpretation and results from the geophysical survey conducted on the proposed TotalEnergies PWT area and a 2.3 km long infield power cable route to the Culzean CPF platform. The interpretation is based upon geophysical data with the integration of geotechnical and environmental data.

An introduction to the TotalEnergies PWT project and the geophysical survey area is provided in Section 1 while Section 2 details the survey parameters used during the project. Section 3 outlines the interpretation methodology used for the different geophysical datasets. It describes how the interpretation has been performed and details the different classification schemes used for seabed gradients & sediments, shallow geology, and sonar contacts.

The results of the survey are presented in Section 4. The conditions within the TotalEnergies PWT survey area and along the cable corridor are described with regards to bathymetry, surficial sediments, seabed features and sub-surface geology. The results of the survey are also presented on a series of charts included in the appendices.

Reservations and recommendations are discussed in Section 5.

The results of the interpretation and detailed mapping are included in the report appendices. Appendix A contains the target listings for the MBES, SSS and MAG targets and the charts are included in Appendix B.

The interpretation results are shown on north up and alignment charts at a horizontal scale of 1:5,000 covering the TotalEnergies PWT area and the Export Route. The alignment charts include the following panels:

- 1. Contoured & Shaded Relief Bathymetry
- 2. Surficial Geology and Seabed Features
- 3. Isopachs of shallow geology
- 4. Longitudinal Profile and Shallow Geology (vertical scale of 1:100)

Profile charts at a horizontal scale of 1:5,000 and vertical scale of 1:100 show the shallow geology along the planned mooring lines and in the Wind Turbine area.

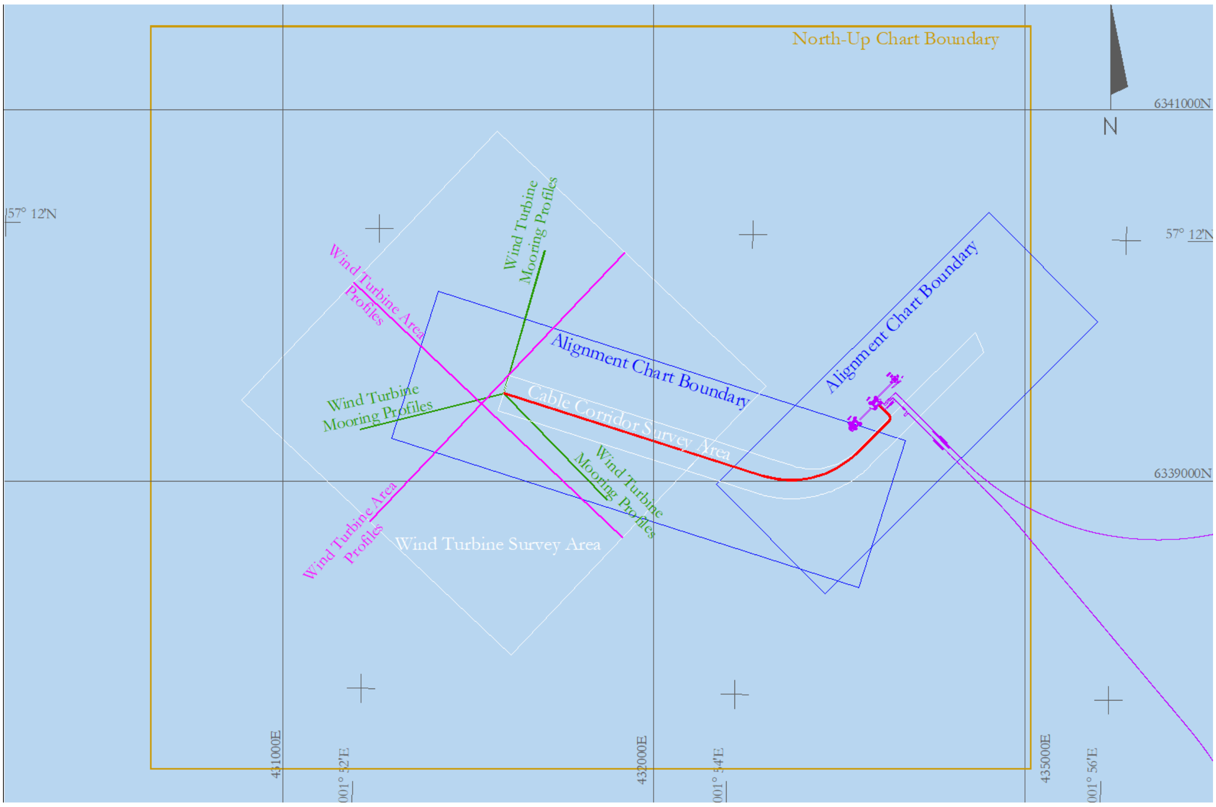


Figure 2 NU, AS Chart and Profile Charts Boundaries.

Survey Parameters

2.1 Geodetic Datum and Grid Coordinate System

2.1.1 Geodetic Datum

Acquisition

Details of the geodetic datum are presented in Table 2. The QINSy software will have the transformation parameters (Table 4) entered to transform the online positions from WGS84 to the survey datum ED50. The projection parameters will also be used in QINSy (Table 6).

Table 2 Geodetic parameters used during acquisition.

Horizontal Datum: WGS 84 (EPSG: 4326)	
Datum	World Geodetic System 1984 (6326)
Ellipsoid	World Geodetic System 1984 (7030)
Prime Meridian	Greenwich (8901)
Semi-major axis	6 378 137.000 m
Semi-minor axis	6 356 752.3142 m
Inverse Flattening (1/f)	298.257223563
Unit	International metre

Processing

The geodetic datum used during processing and reporting are presented in Table 3.

Table 3 Geodetic parameters used during processing.

Horizontal Datum: ED50	
Datum	ED50 (6230)
Ellipsoid	International 1924 (7022)
Prime Meridian	Greenwich (8901)
Semi-major axis	6 378 388.000 m
Semi-minor axis	6 356 911.946 m
Inverse Flattening (1/f)	297
Unit	International metre

2.1.2 Transformation Parameters

The transformation parameters used during the project are presented below. The transformation was used in the QINSy online software, although raw outputs from QINSy will be on the WGS84 datum.

Table 4 Transformation parameters.

Datum Shift Parameters: From WGS84 To ED50 (Reversed EPSG 1311)	
Shift dX (m)	+89.5 m
Shift dY (m)	+93.8 m
Shift dZ (m)	+123.1 m
Rotation rX (“)	0 sec
Rotation rY (“)	0 sec
Rotation rZ (“)	0.156 sec
Scale Factor (ppm)	-1.2 ppm

Table 5 Test coordinate for datum shift.

UTM Zone	Datum	Easting (M)	Northing (M)	Latitude	Longitude
31N	WGS 84			55° 43' 17.274” N	004° 48' 06.789” E
	ED50	613272.04	6176763.30	55° 43' 19.677” N	004° 48' 11.870” E

2.1.3 Projection Parameters

The projection parameters used during the survey are presented in Table 6.

Table 6 Projection parameters.

Projection Parameters	
Projection	UTM
Zone	31 N
Central Meridian	03° 00’ 00’’ E
Latitude origin	0
False Northing	0 m
False Easting	500 000 m
Central Scale Factor	0.9996
Units	metres

2.2 Vertical Datum

The vertical reference parameters used during the survey are presented in Table 14.

Table 14 Vertical reference parameters.

Vertical Reference Parameters	
Vertical reference	LAT
Height model	VORF

2.3 Time Datum

Coordinated universal time (UTC) was used on all survey systems on board the vessel. The synchronisation of the vessel's onboard system was governed by the pulse per second (PPS) issued by the primary positioning system. All displays, overlays and logs were annotated in UTC. The daily progress report (DPR) refers to UTC.

2.4 KP Protocol

For the export route, KP 0.00 is located at the proposed location of the Culzean turbine and increases towards the platform. KPs were calculated based upon the relevant UTM mapping projection zone and were at all times related to the selected route.

3. Interpretation Methodology

3.1 Seabed Gradient Classification

The seabed gradient is classified according to Table 7.

Table 7 Seabed gradient classification.

Classification	Gradient
Very Gentle	< 1°
Gentle	1° - 4.9 °
Moderate	5° - 9.9°
Steep	10° - 14.9°
Very Steep	> 15°

3.2 Interpretation of Seabed Geology and Features

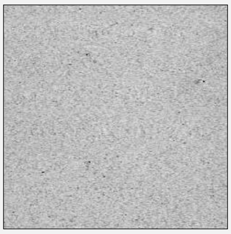
High frequency and low frequency sonar mosaics were created with a resolution of 0.2 m. Both HF & LF SSS mosaics were used to interpret and classify seabed geology and seabed features. High frequency data was primarily used to detect targets and measure contacts whilst low frequency data was mainly used for geo-boundary interpretation. The geo-boundaries were reviewed against backscatter, MBES and SBP data to produce integrated surficial interpretation.

3.3 Seabed Classification

The classification of the seabed sediments has been derived from the acoustic character of the SSS and correlated with the general seafloor morphology, MBES DTM, multibeam backscatter (MBBS) and sub-bottom profiler (SBP). During the review of the SSS survey data, higher intensity returns (darker grey to black colours) were interpreted as relatively coarser grained sediments, and lower intensity sonar returns (lighter grey colours) were interpreted as relatively finer grained sediments.

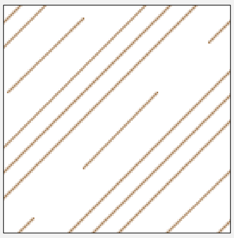
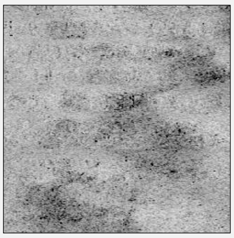
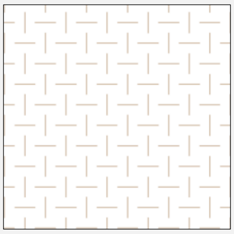
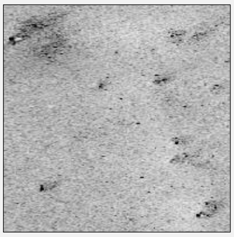
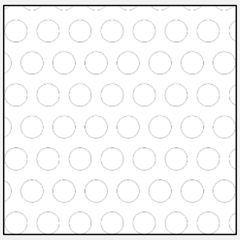
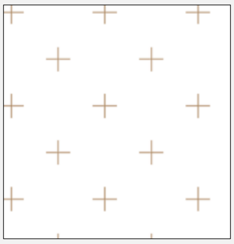
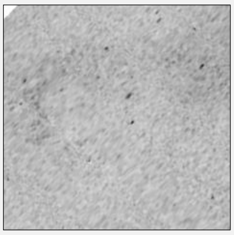
The ID column in Table 8 defines the color in the charts for the specific sediment type. All particle sizes refer to the soil classification in ISO 14688-1 (2002).

Table 8 Sediment classification.

ID	SSS Image	Acoustic Description	Lithological Interpretation
		Low to medium acoustic reflectivity, slightly grainy texture.	**Silty SAND** May contain clay and/or gravel.

The ID column in Table 9 defines the pattern in the charts for the specific feature type.

Table 9 Seabed features classification.

ID	SSS Image	Seabed Feature	Criteria
		Furrow Area	Longitudinal bedform in an NNE-SSW direction
		Area of small seabed depressions	Concentration of small seabed depressions Diameter < 15 m Depth 0.1-0.3 m
		Spudcan imprints	
		Seabed depression	Associated with the spudcan imprints Dimensions Length 11-22 m Width 5-9 m Depth 0.1-0.4 m

3.4 Classification of Sonar Contacts and Magnetic Anomalies

The interpretation of all SSS contacts was carried out in Sonarwiz from the high frequency (600 kHz). All contacts were digitised alongside MBES data to ensure that all contacts visible on the MBES data were also identified by the SSS. The shape of the SSS contacts was the main parameter used to distinguish between debris and boulders. Items of debris often show sharp edges and elongate/irregular shapes whilst boulders usually appear as more rounded SSS contacts.

After SSS targets had been finalised, correlation against magnetic anomalies was performed. Any SSS contacts that correlated with magnetic anomalies were marked as such in the contact list.

The SSS contacts were selected according to the following criteria:

- Boulders (> 0.5 m)
- Debris
- Other

Magnetic anomalies were interpreted from the residual magnetic field data. The anomaly was visually identified, a comparison was carried out between the different sensor information available (altitude, depth, motion, and signal quality) to determine if the anomaly was real or induced by low quality or rapid changes in MAG movement. The criterion used for magnetic anomalies was 10 nT (threshold). Clear anomalies below the threshold have also been picked.

All magnetic anomalies interpreted to be real were identified, positioned, and measured manually from the residual field. All MAG anomalies were compared to all SSS contacts. If a MAG anomaly was within 5 m of any contact detected in SSS, it was deemed a correlation, assigned the same ID and flagged in the comments of the SSS contact list.

3.5 SBP & UHRS Interpretation

The processed SBP Innomar and UHRS Sparker data was imported into the IHS Kingdom seismic interpretation software package and key interfaces associated with changes in the shallow geology were digitised. The interpretation was correlated with all the other available data, background data, along with multibeam shaded relief geotiffs for the morphology and SSS mosaics for sediment types and surface acoustic response.

Six horizons were interpreted from the Innomar and Sparker data, H10, H20, H30, H40, H50 and H60.

The Innomar data showed higher resolution in the upper 5-6 m. The shallow horizons H10 and H20 were mainly interpreted from the Innomar data but deeper sections of horizon H20 were interpreted from Sparker data, see data example in Figure 22. Horizons H30 and H40 were interpreted from the Sparker data as they appeared more continuous and better imaged than on the Innomar data. Horizons digitized in the Innomar data showed good correlation with the corresponding horizons seen in the Sparker data, see Figure 3. The relatively deep horizons H50 & H60 were interpreted from the Sparker data.

The SBP and UHRS data was interpretated in the time domain and then depth converted using an acoustic velocity of 1600 m/s. Horizons were gridded on client request with a gridding distance of 80% of the planned line spacing to eliminate gaps when survey line distance was greater than 100 m.

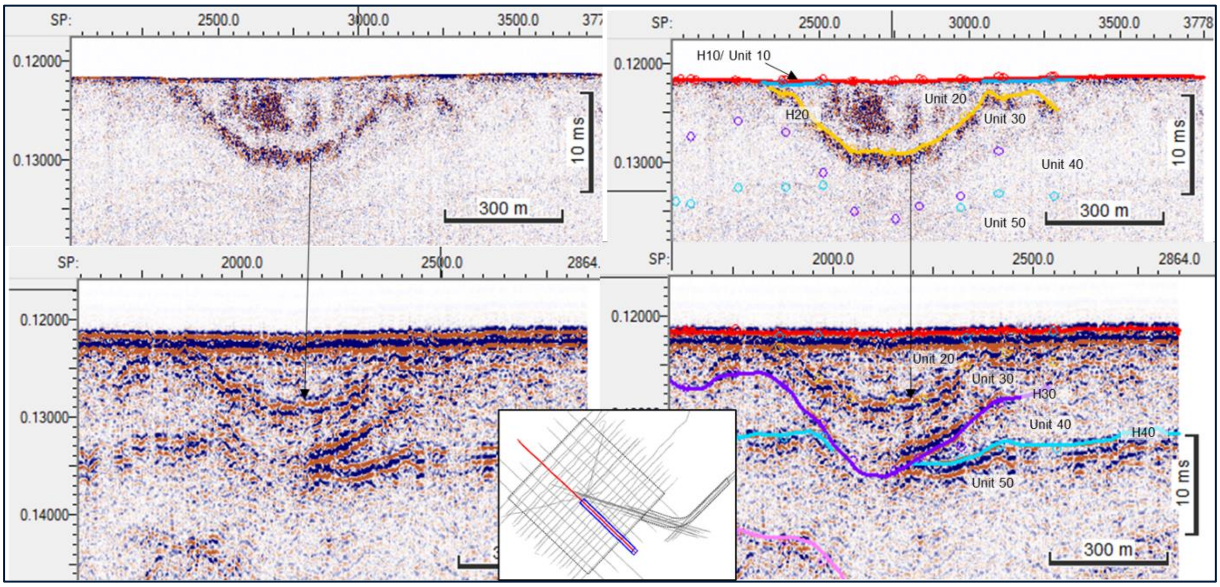


Figure 3 Comparison between SBP (top images) and UHRS (bottom images).

3.6 Shallow Geology Classification

The subsurface geology interpretation and description is based on the Sparker UHRS and Innomar SBP assessment.

The seismostratigraphic interpretation carried out for this project is based on six horizons that correspond to seismic reflectors with relevance to the understanding of the shallow structure. Seismic reflectors were chosen based on their geological significance, spatial continuity, and correlation between SBP and UHRS datasets. Seismic units were chosen based on their base geometries, seismic facies and internal reflections. All horizons were carefully chosen to best represent the sub-seabed in the survey area and route. Horizon H10 was digitized from Innomar data, H20 with a combination of Innomar and Sparker data and horizons H30, H40, H50 and H60 from Sparker data.

The shallow geology classifications shown in Table 10 are based on the integrated analysis of the acoustic characters of SBP and UHRS units in conjunction with information from BGS as well as MBES and SSS data to produce an integrated analysis of surface and subsurface geology. An attempt was made to correlate the interpreted seismic units with established lithostratigraphic formations.

Geological interpretation and unit description and lithology follow British Geological Survey (BGS) Forties Sheet 57°N-00° Quaternary Geology (1987) together with preliminary ground truthing results acquired during this campaign.

Table 10 Shallow geology units and expected lithology summary.

STRATIGRAPHY	UNIT	BGS UNIT	ASSOCIATED HORIZON	LITHOLOGY
Holocene	Unit 10	-	H10 (light blue) – base of surficial sediments, Holocene	Silty SAND
Holocene/ Pleistocene	Unit 20	Forth Formation	H20 (yellow) - base of upper Forth Formation channels	Silty CLAY to silty SAND (ground truthing) BGS: very soft to firm sandy muds with rare shell fragments and sand laminae. The upper-most sediments are frequently muddy sands with occasional clay laminae.
	Unit 30		H30 (purple) – base of lower Fourth Formation channels	
Pleistocene	Unit 40	Coal Pit Formation	H40 (cyan) – base of Coal Pit Formation channel	BGS: silty clay with occasional pebbles, some sand laminae
	Unit 50	Fisher Formation	H50 (green) – base of Fisher Formation	BGS: firm to very stiff overconsolidated silty and sandy clays with occasional shell fragments and dropstones
	Unit 60	Ling Bank Formation	H60 (orange) – base of Ling Bank channels	BGS: stiff to very stiff silty clays with abundant pebbles, occasionally it is sandy with shell fragments
	Unit 70	Aberdeen Ground Formation	No top or base horizon, sediment underlying either Fisher (H50) or Ling Bank Formation (H60)	BGS: very hard and normally consolidated to overconsolidated; sandy muds with occasional laminae of clay and silt or fine sand

4. Results

4.1 Bathymetry

The bathymetric data shows that the seabed topography within the survey area is relatively flat and featureless, with water depths ranging from 83.04 m to 92.35 m LAT (Figure 4). The shallowest depths are associated with the existing subsea infrastructure, most notably the SSIV and rockdumped pipeline (Figure 5). The greatest depths are located at an identified spudcan imprints (Figure 6). Excluding the existing infrastructure objects and the spudcan location, the survey site depths range between 87.87 m and 91.18 m.

A large number of small depressions are also observed, distributed across the survey area (Figure 7). A few of these depressions appear to potentially contain features (most likely small boulders), for example as shown in (Figure 8). Seabed slope values of less than 1° are observed across the majority of the site (Figure 9), with the highest values corresponding to the sides of the existing infrastructure and spudcan imprints.

The proposed route for the export cable passes close to some of the small depressions, which is reflected in the depths shown in the extracted longitudinal seabed profile (Figure 10).

The proposed anchor locations are situated within the main survey site area (Figure 11). The water depths at the proposed locations are listed in Table 11. No significant features are observed in the bathymetry within a 100 x 100 m box centered on each proposed anchor location.

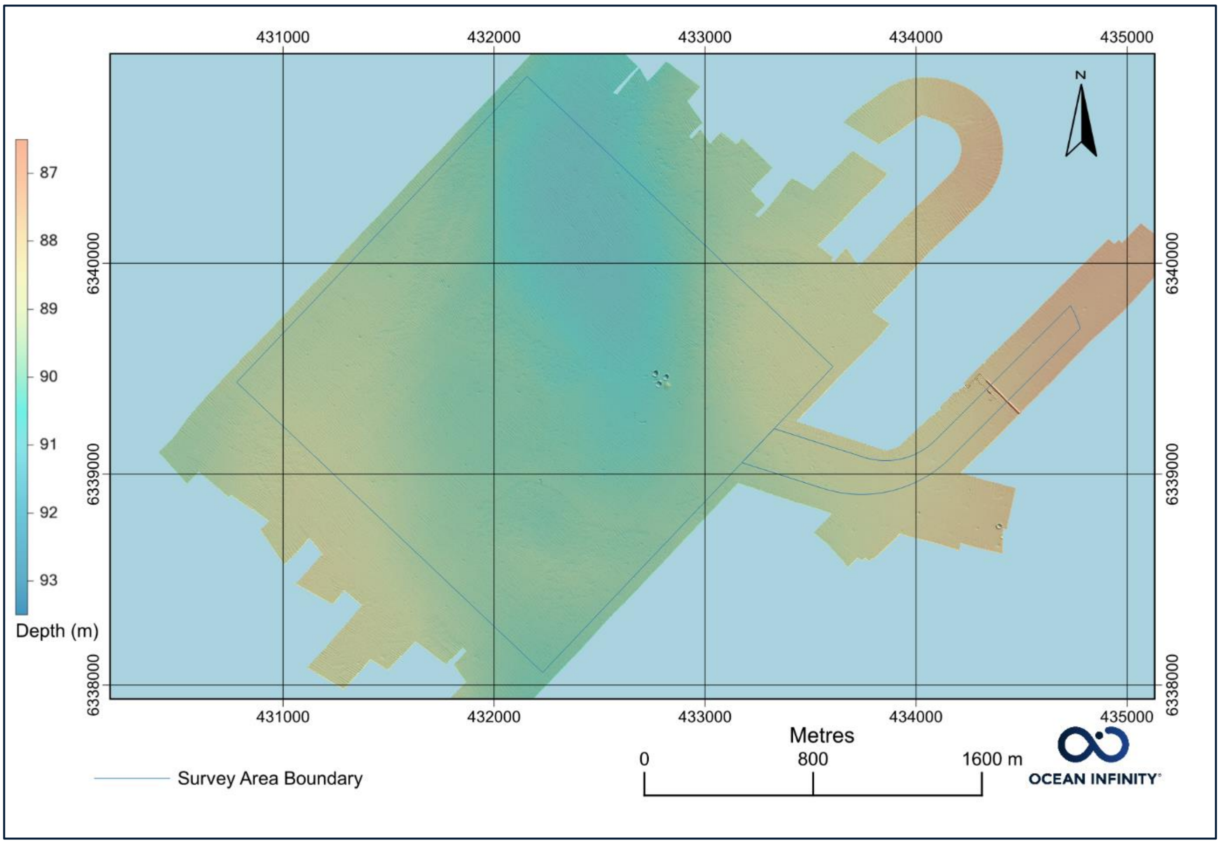


Figure 4 Bathymetry data survey area.

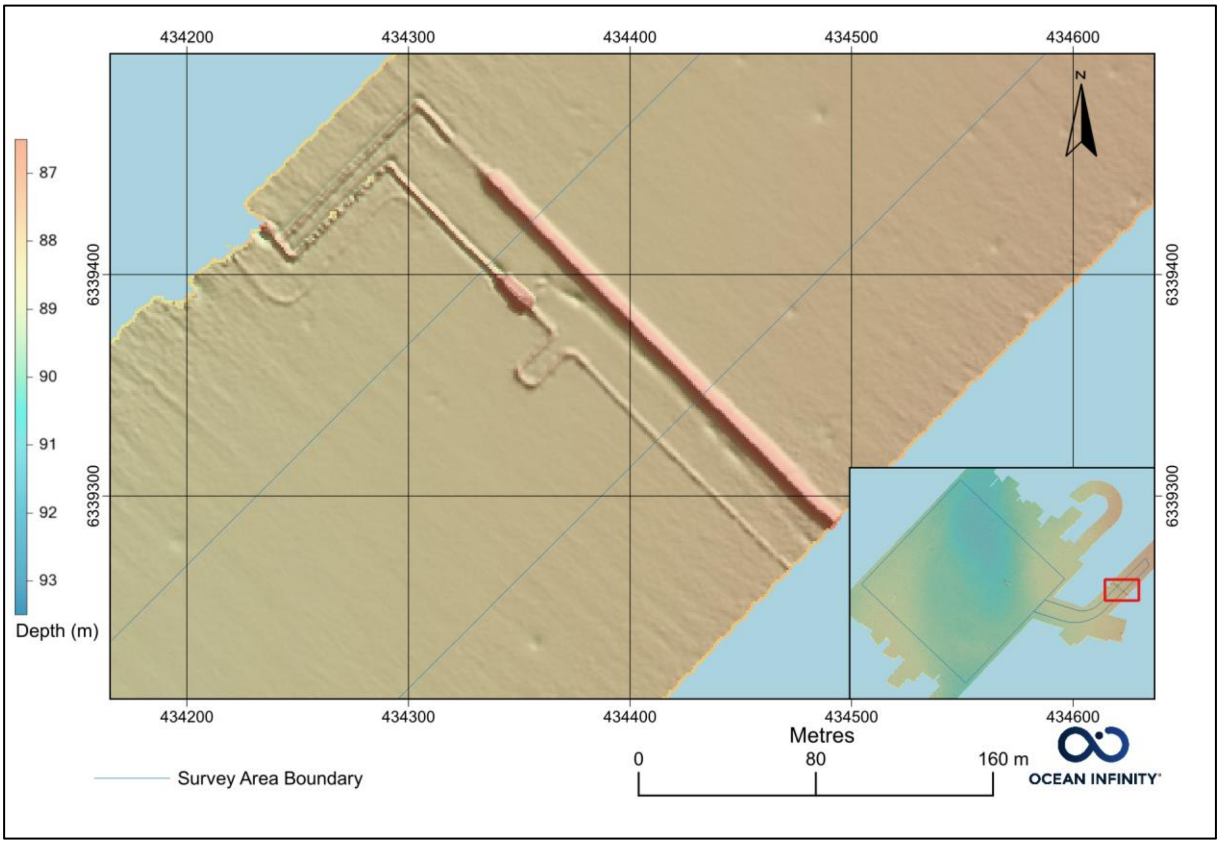


Figure 5 Bathymetry data survey area – SSIV and rockdumped pipeline.

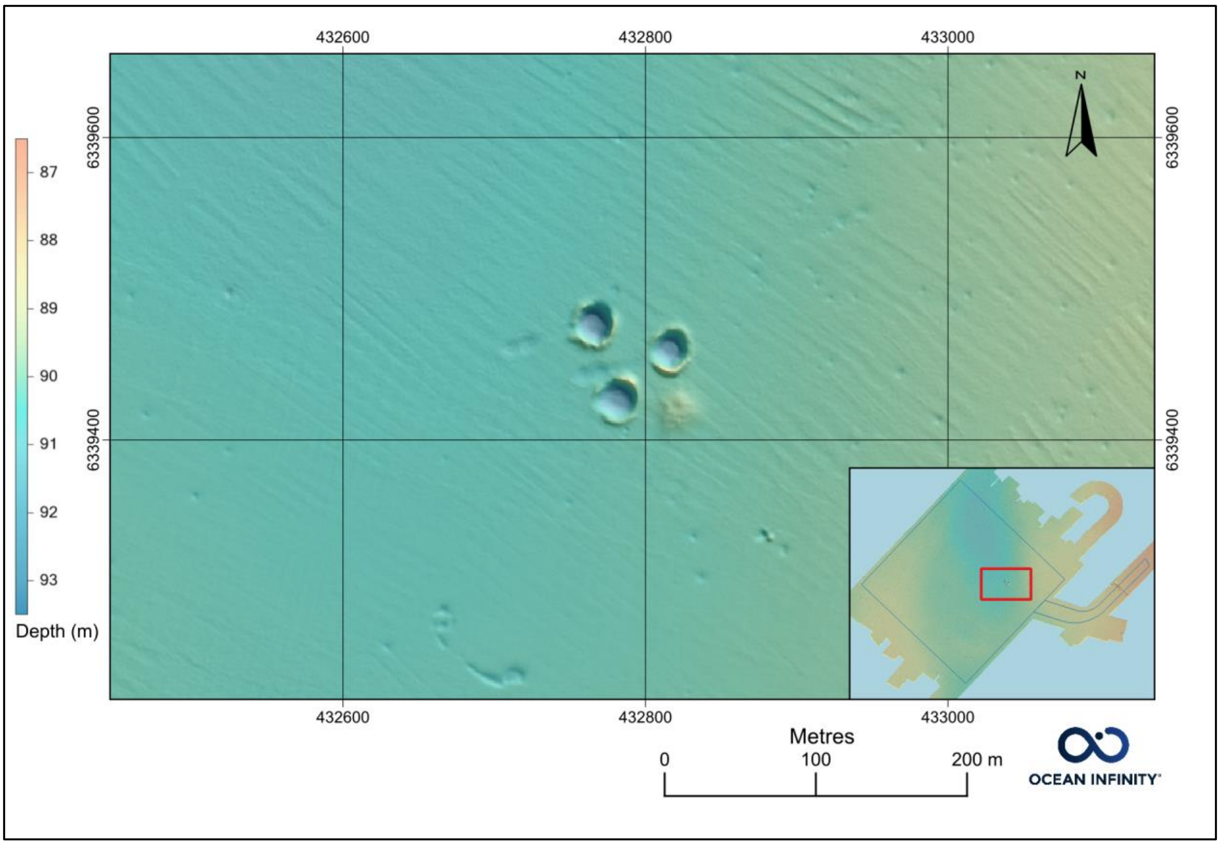


Figure 6 Bathymetry data survey area - spudcan imprints (Abandoned Well 22/25a-9/9Z)).

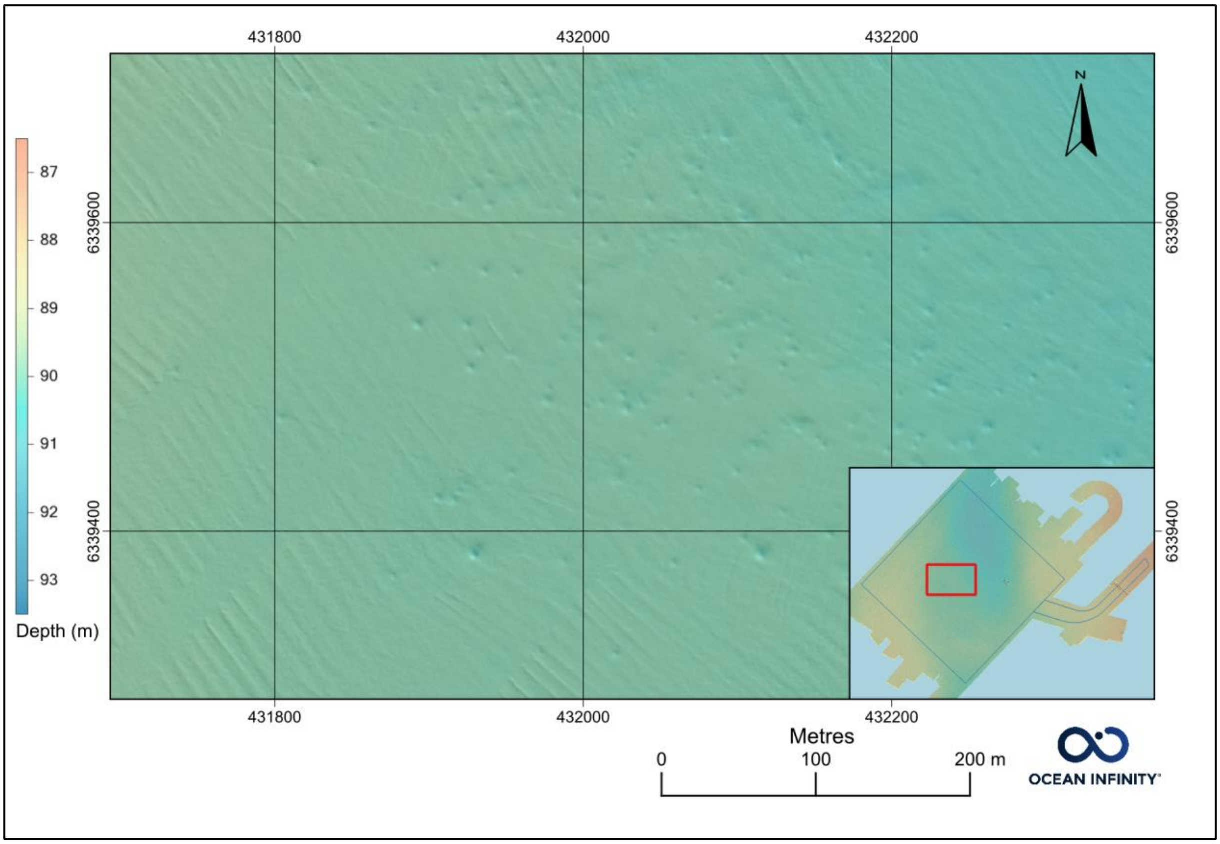


Figure 7 Bathymetry data survey area - small seabed depressions.

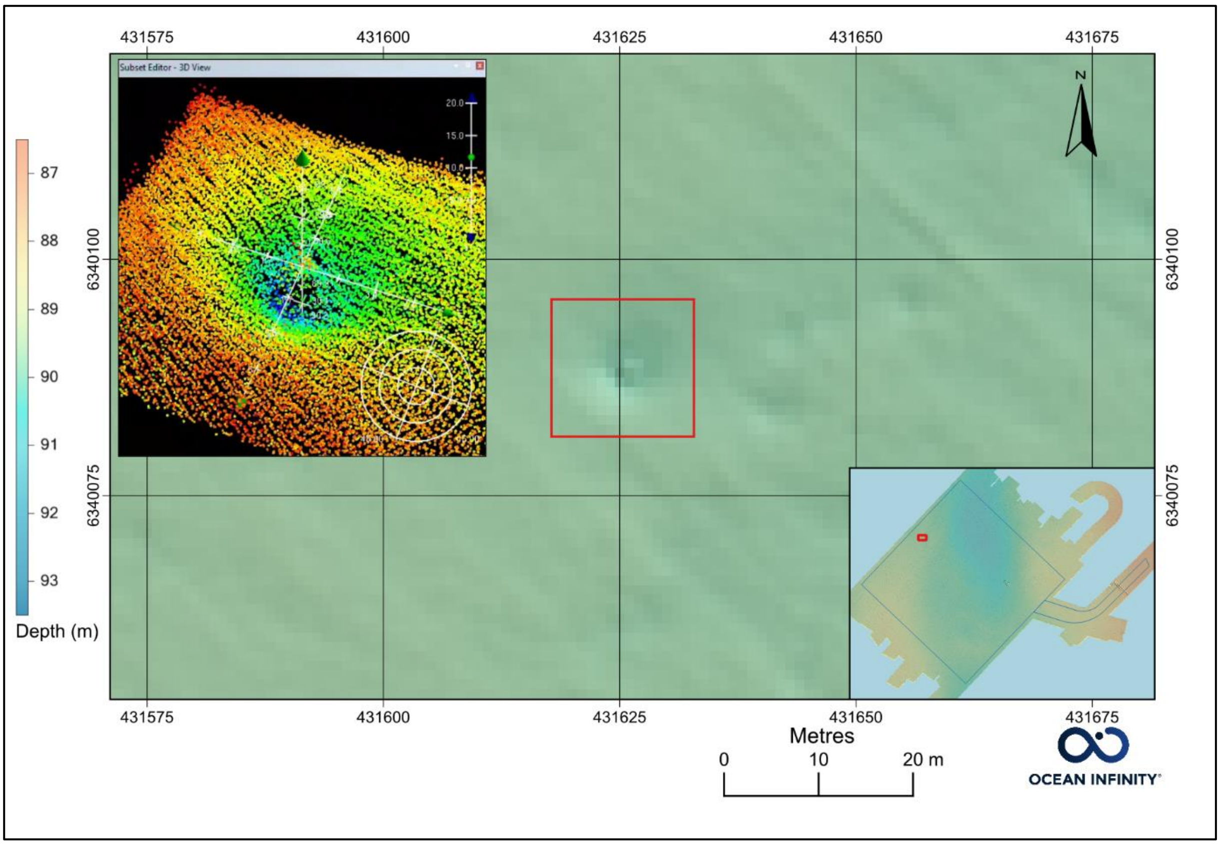


Figure 8 Bathymetry data survey area - possible feature within depression.

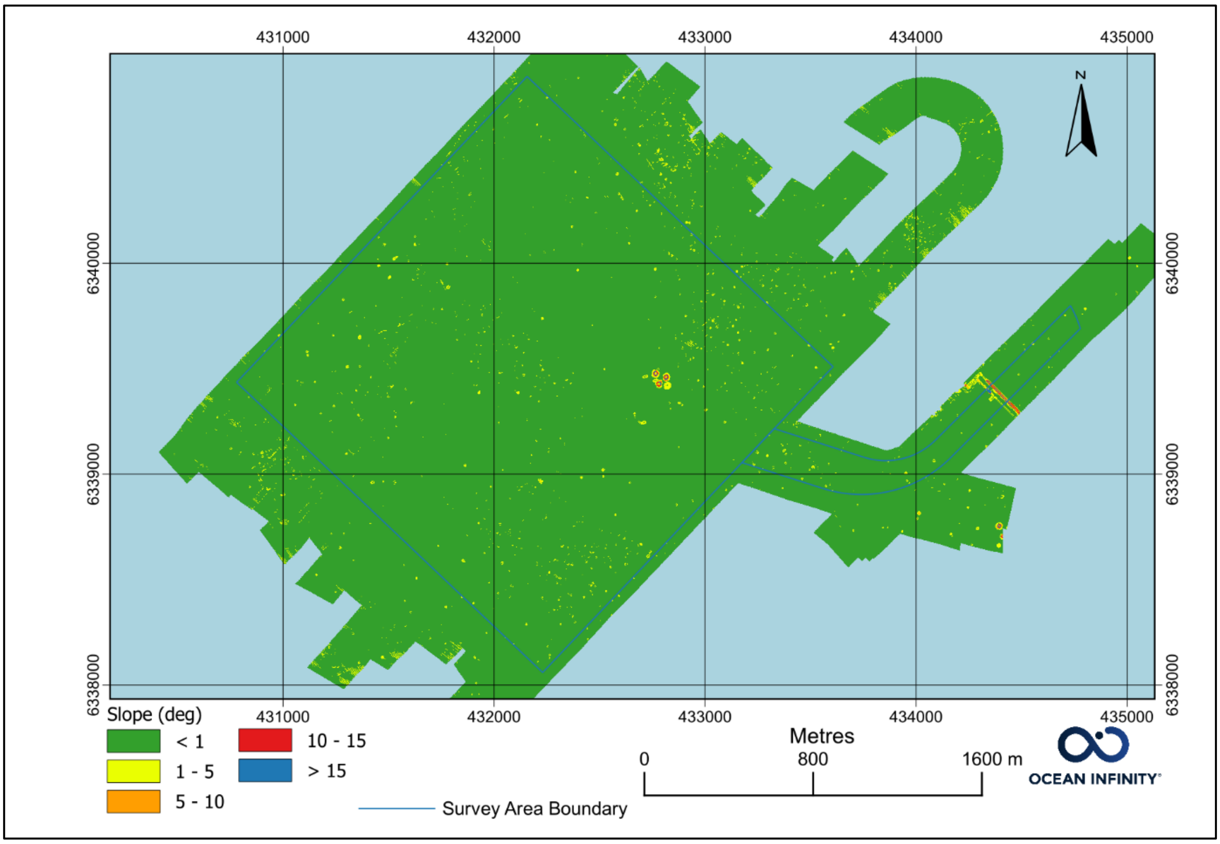


Figure 9 Bathymetry data survey area - slope angle plot.

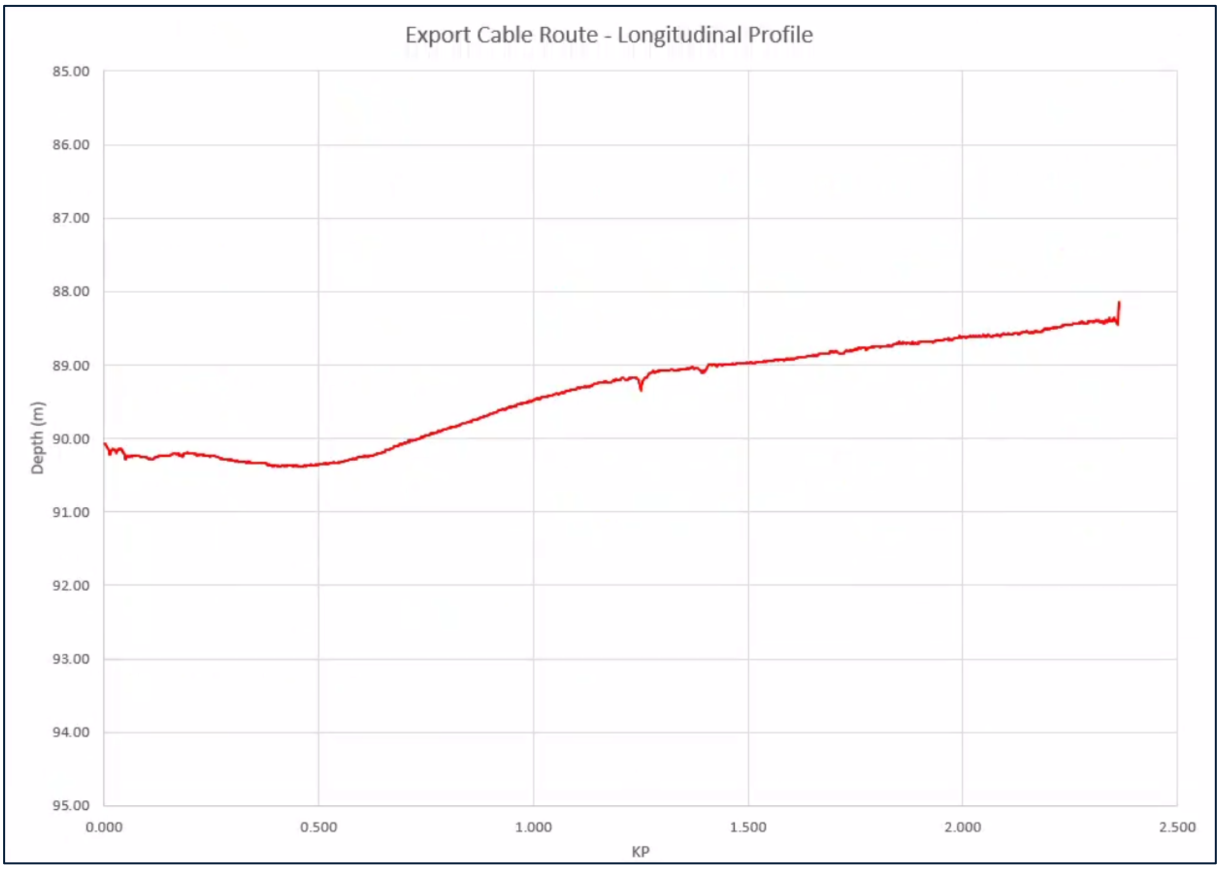


Figure 10 Export cable route – longitudinal profile.

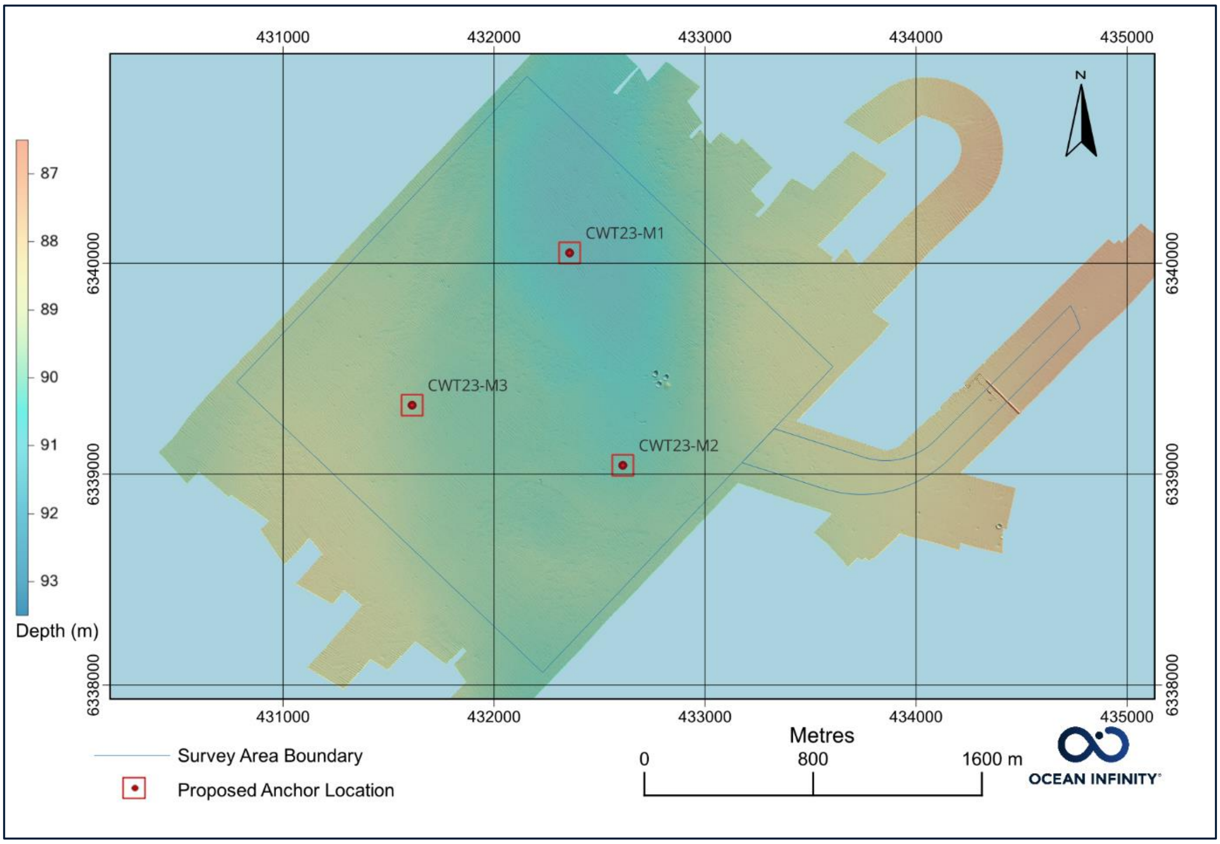


Figure 11 Bathymetry data survey area – proposed anchor locations.

Table 11 Proposed anchor locations.

Proposed Anchor	Easting (M)	Northing (M)	Depth (M) LAT
CWT23-M1	432357.6	6340049.2	90.80
CWT23-M2	432609.9	6339041.5	90.17
CWT23-M3	431611.0	6339326.8	89.63

4.2 Backscatter

The backscatter data shows a mainly homogenous seabed (Figure 12). The existing subsea infrastructure is clearly visible with marked changes in the return signal strength. Slight differences are evident over localised regions which broadly correspond to areas of textural difference noted within the bathymetry data. These are likely to indicate a sediment property change.

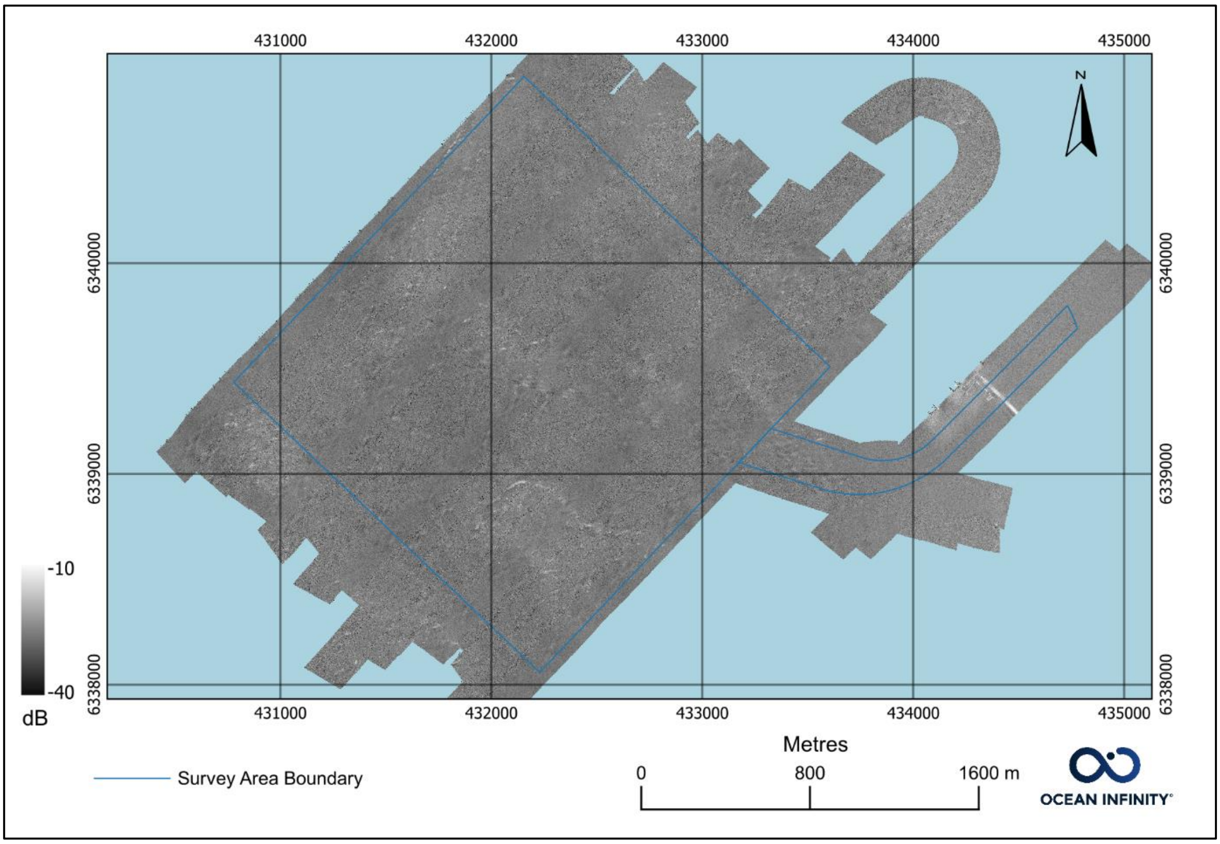


Figure 12 Backscatter data survey area.

4.3 Surficial Geology and Seabed Features

An overview of the surficial geology and seabed features across the TotalEnergies PWT survey area and cable route is shown in Figure 13. The seabed sediment is mostly homogeneous with a low to medium reflectivity, interpreted to comprise silty SAND, which is supported by the geotechnical sampling results. In the northwestern part of the area a furrow is seen in the data, orientated in an NNE-SSW direction. The furrow is a shallow feature (only 10 cm deep); it shows some rippling which could indicate bottom currents and may be related to changes in the underlying geology (Figure 14). The closest proposed anchor location to the furrow area is CWT23-M3 which is approximately 400m to the SSE.

A large number of small depressions are identified within the survey area (Figure 15). Where there is a high concentration, they are outlined and presented as areas of small seabed depressions. These small depressions range between 0.1-0.3 m in depth and are generally less than 10 m in diameter (Figure 7). Some of these depressions contain features, most likely small boulders or cobbles (Figure 8).

In the center of the area spudcan imprints from previous drilling activity (abandoned well 22/25a-9/9Z) are preserved on the seabed (Figure 6).

The Culzean seabed infrastructure crosses the extension of the proposed cable route and is shown on Figure 16. The as-found positions of the subsea infrastructure correspond well to the database positions provided by TotalEnergies.

At proposed anchor locations, within the 100 x 100 m box centered on each coordinate, CWT23-M1 and CWT23-M2 (Figure 15) show no significant features, while at location CWT23-M3 small depressions (Figure 15) are observed.

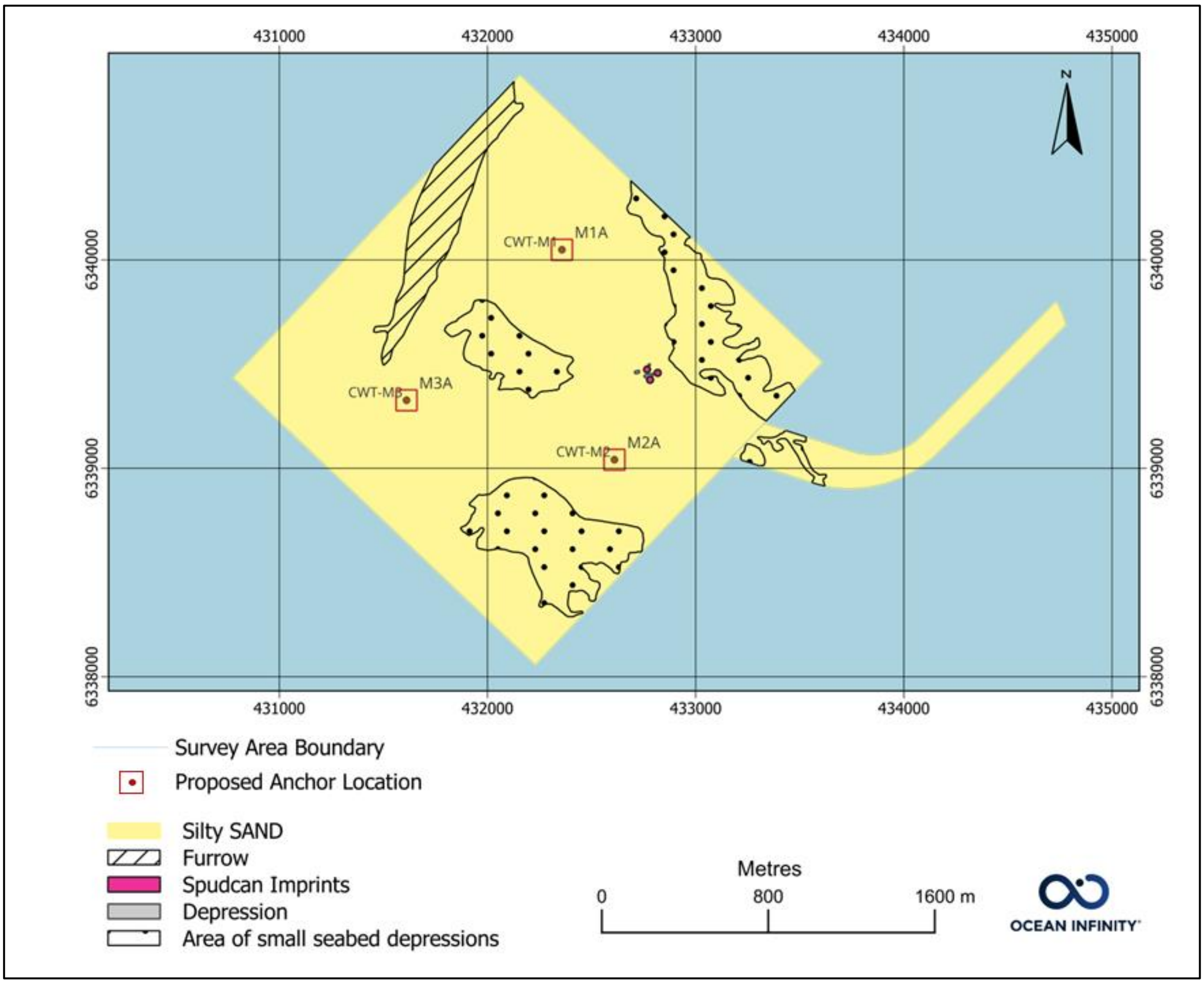


Figure 13 Overview image showing surficial sediment distribution and seabed features.

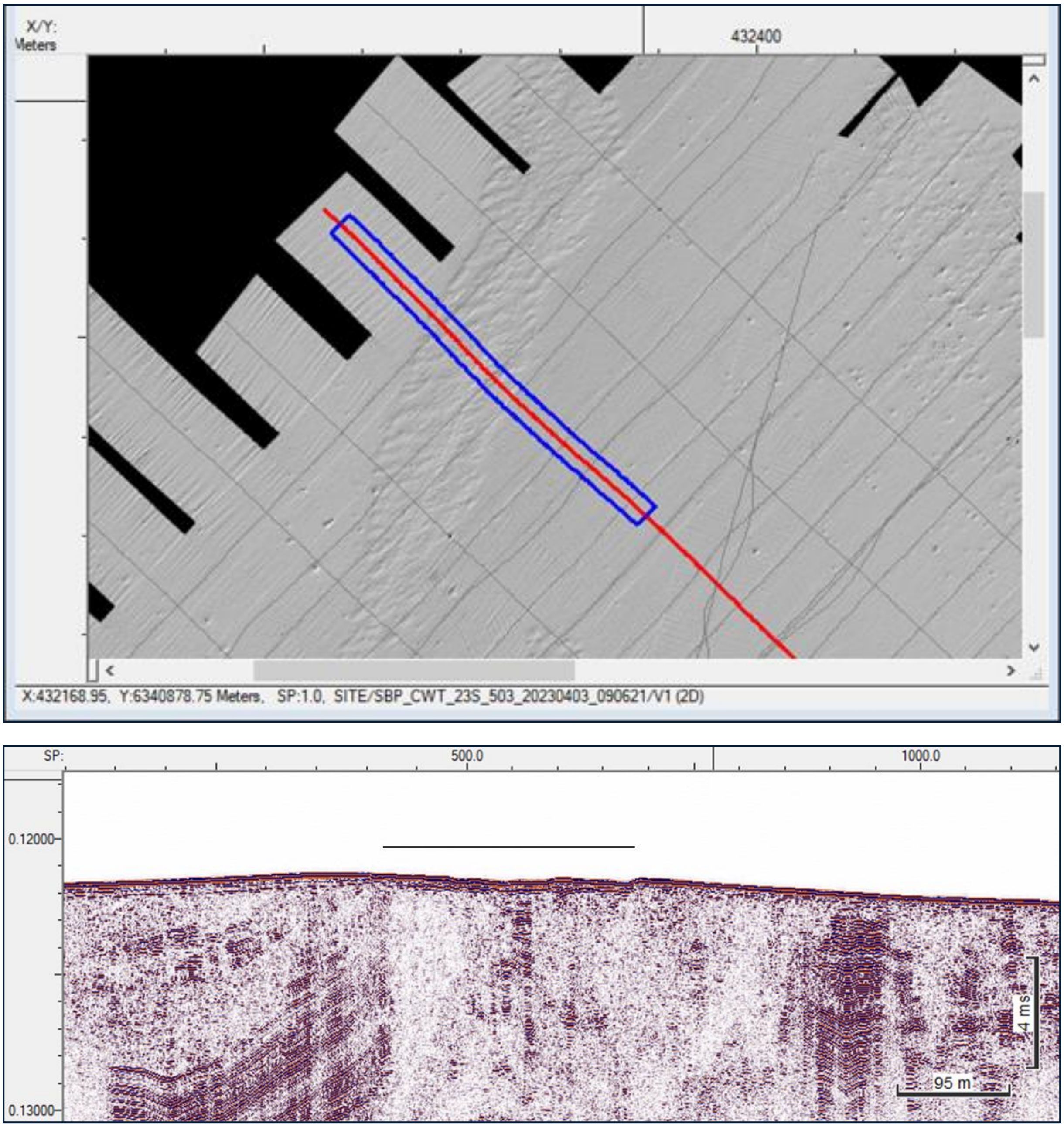


Figure 14 MBES shaded relief image and SBP data example of area interpreted as a furrow.

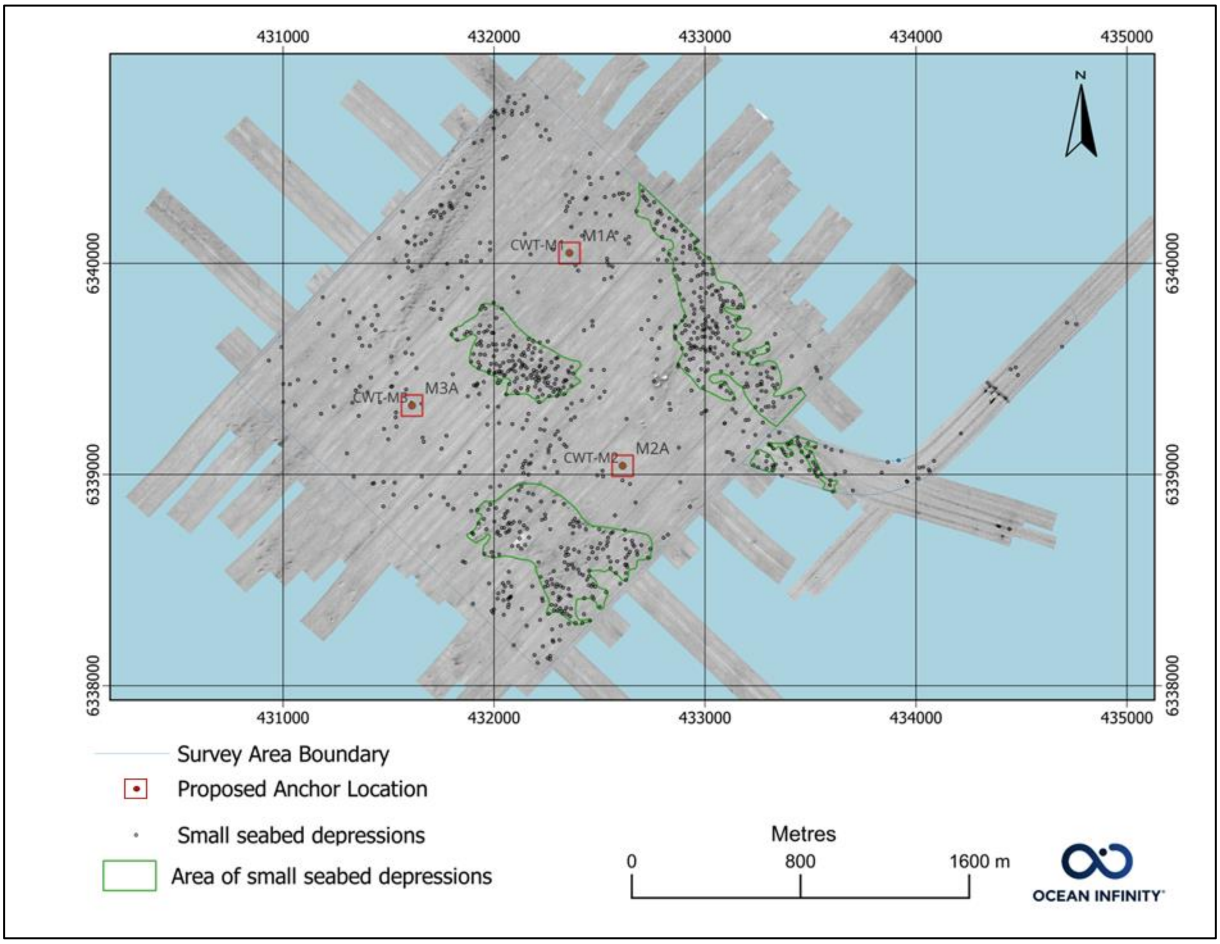


Figure 15 Overview image showing SSS mosaic and distribution of small seabed depressions.

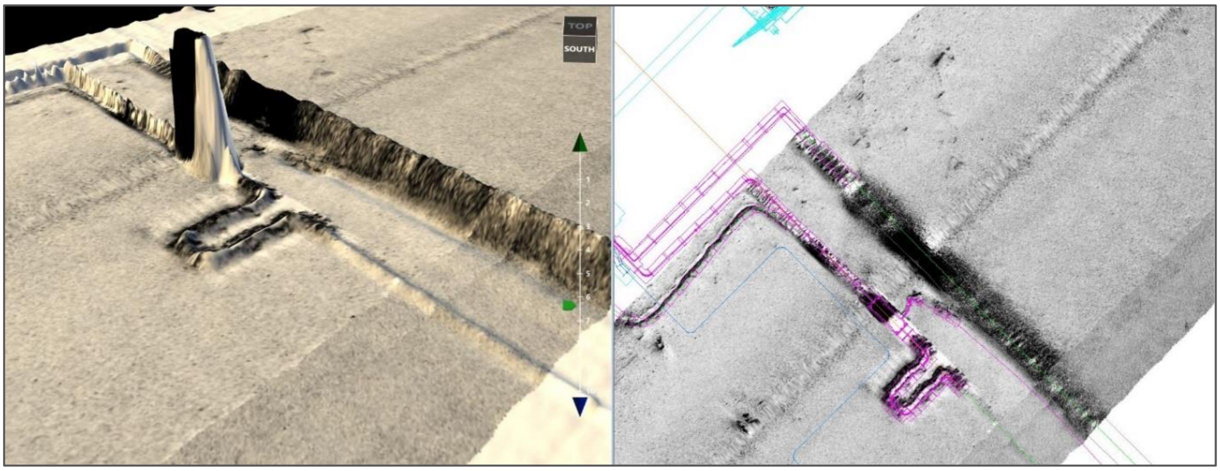


Figure 16 SSS mosaic draped on bathymetry (left) and with subsea infrastructure database (right).

4.4 SSS Contacts and MAG Anomalies

In total, 95 individual SSS contacts and 24 magnetic anomalies were detected within the survey area and along the cable route. All SSS contacts were classified as debris or possible boulders. The magnetic anomalies were individual single anomalies, except where associated with seabed infrastructure at Culzean. Seven of the SSS contacts and one MAG anomaly are located in the area where the cable route corridor overlaps the WT survey area. No wrecks were interpreted.

A summary of SSS contacts is presented in Table 12 and an overview of the distribution of SSS contacts and MAG anomalies is shown in Figure 17.

Complete listings of the SSS contacts and MAG Anomalies are presented in Appendix A.

Table 12 Summary of SSS contacts.

Classification	No. Survey Area	No. Export Cable Route
Possible Boulder	40	17 (includes 4 in overlap area)
Debris	24	21 (includes 3 in overlap area)
Total	64	38 (includes 7 in overlap area)

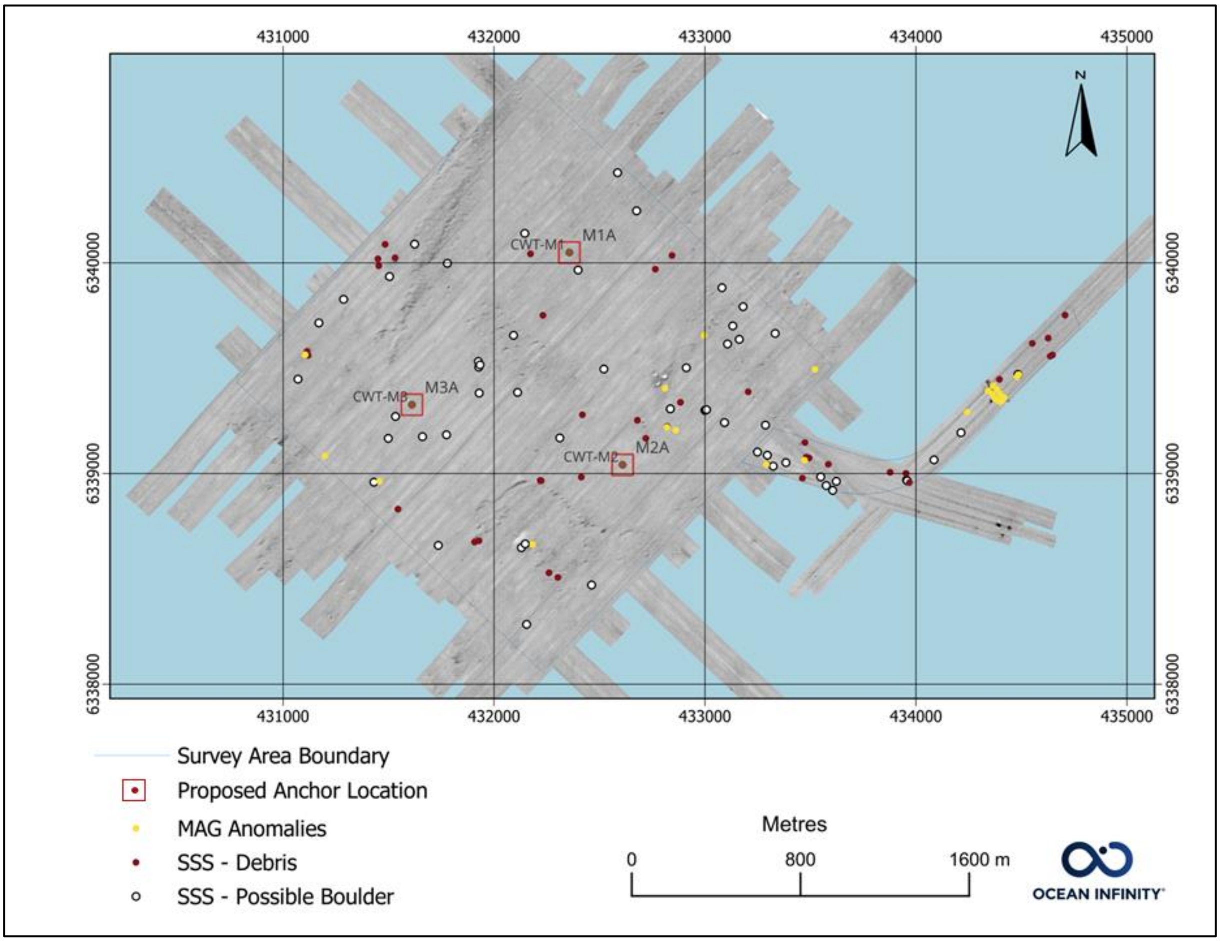


Figure 17 Overview image showing the distribution of potential debris, possible boulders, and magnetic anomalies.

4.5 Shallow Sub-Seabed Geology

Six significant geologic reflectors were mapped in the shallow subsurface in the survey area; H10, H20, H30, H40, H50 and H60, as well as two internal reflectors, H25 (very limited extent within Unit 30) and H45 (within Unit 50). Interpreted reflectors and associated geological units are shown along the proposed cable route in Figure 18.

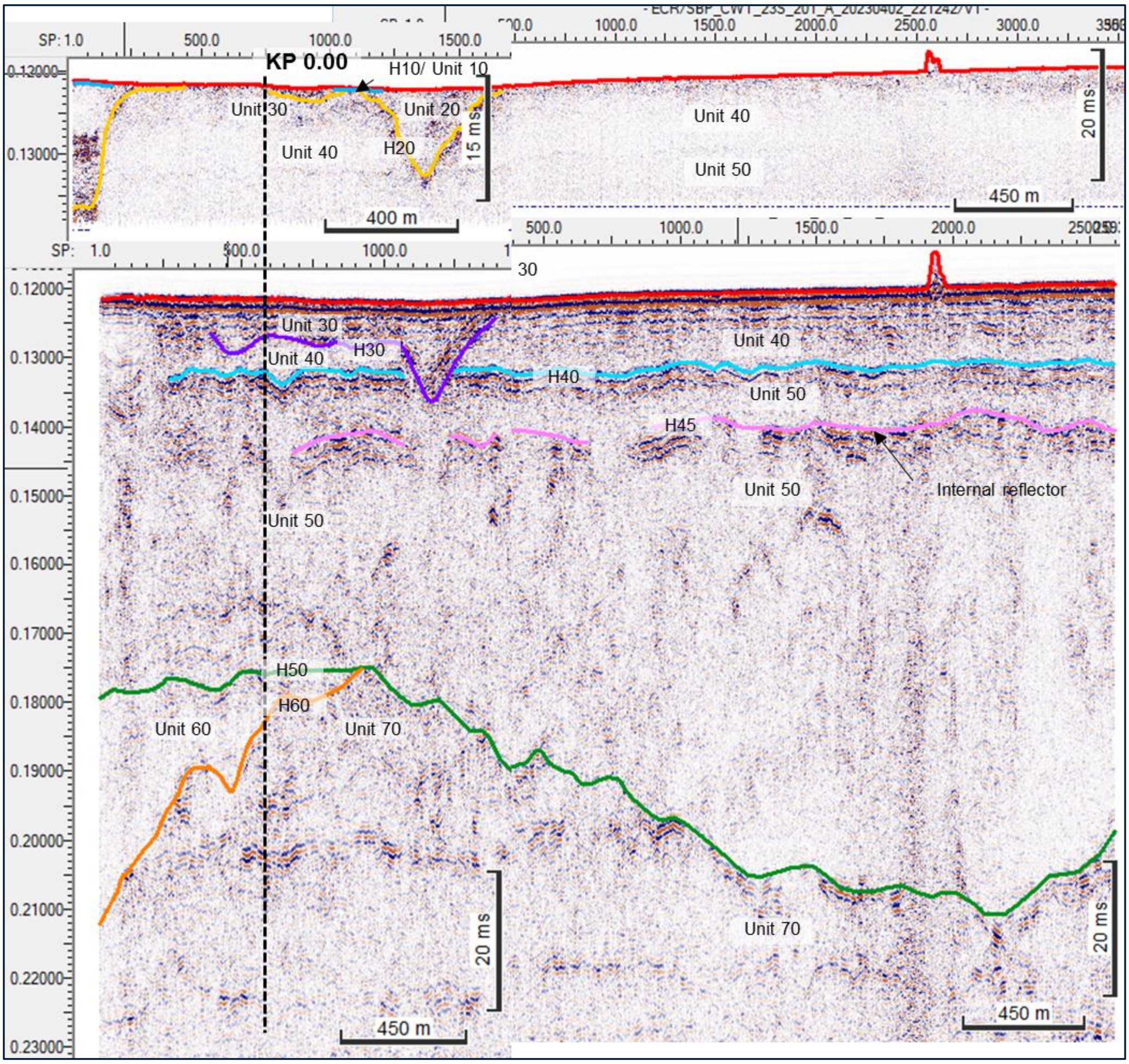


Figure 18 Shallow geology along the proposed cable route. SBP/Innomar data (top) and UHRS/Sparker data (bottom).

Figure 19 shows the geological profiles at the three mooring locations.

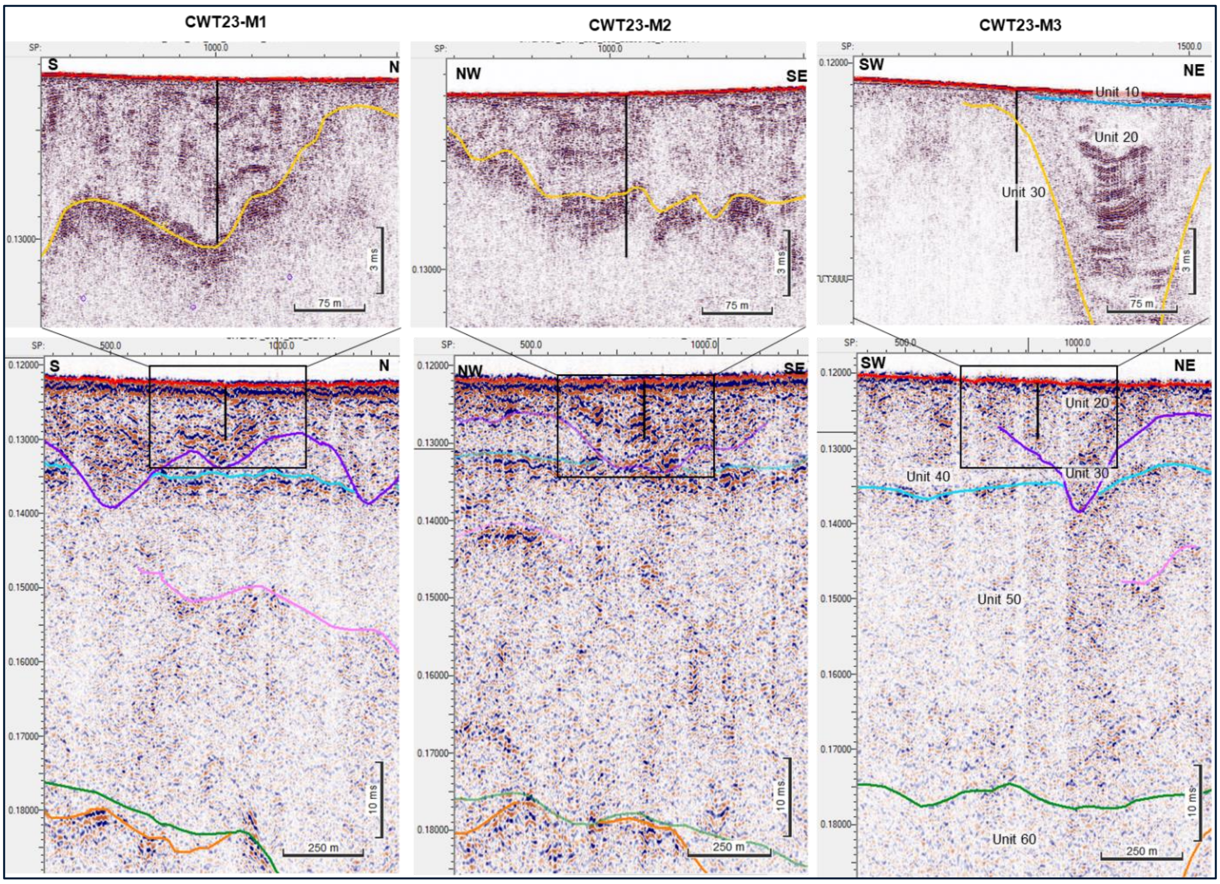


Figure 19 Shallow geological profiles at mooring locations. SBP/Innomar data (top) and UHRS/Sparker data (bottom). Mooring locations indicated by black vertical line (6 m).

4.5.1 Unit 10 – Holocene

Seismic Unit 10 is the youngest unit found in the survey area. Horizon H10 marks the base of Unit U10 and was mapped based on Innomar SBP data.

Where H10 has been interpreted, it is characterized by a distinct and intermittent reflector cutting the layering seen in the underlying channel sediments of Unit 20 (Figure 21). This suggests it represents an erosional surface and it is mainly seen where deep, layered Unit 20 channel infill sediments are close to the seabed. The detection of horizon H10 is limited by the resolution of the data and it is not possible to trace this reflector on the Innomar data over the whole survey area. The uniform surficial sediment distribution seen in the SSS data and the results from the shallow geotechnical investigation suggests that it might be present as a thin veneer throughout the site.

Unit 10 deposits are interpreted as reworked unconsolidated deposits of Holocene age deposited after the Last Glacial Maximum. The expected composition consists of silty SAND based on the ground truthing results.

Survey Area

The depth of Unit 10 below seabed (BSB) varies from 0.0 m (where absent) to ~0.7 m (Figure 20).

Horizon H10 was not identified from the SBP data at any of the mooring locations (Figure 19). However, the shallow geotechnical results indicate that thin Unit 10 sediments can be expected at these locations. Unit 10 sediments are expected to be thin or absent at the proposed mooring location.

Cable Route

Along the route Unit 10 is only intermittently present between KP 0.000 and KP 0.334 to a depth of up to 0.4 m BSB.

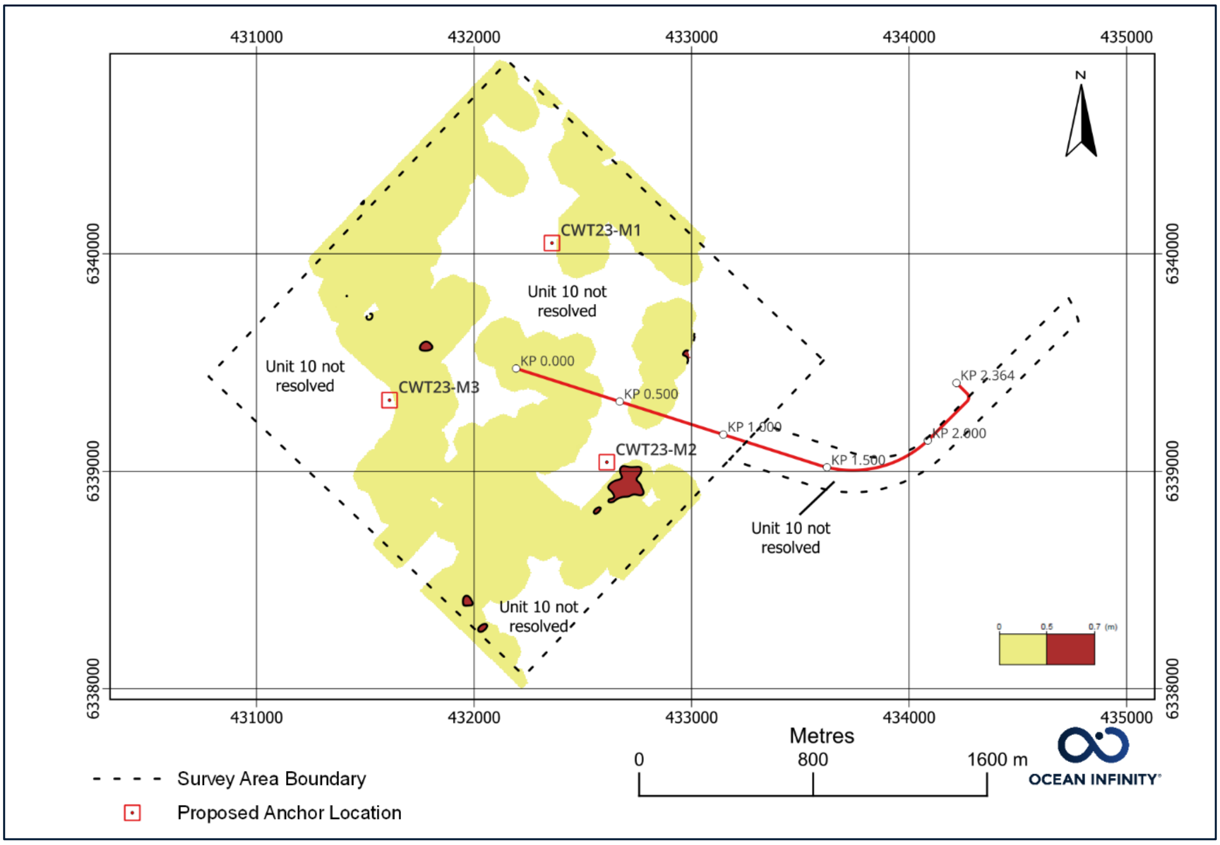


Figure 20 Base of Unit 10 in metres below seabed.

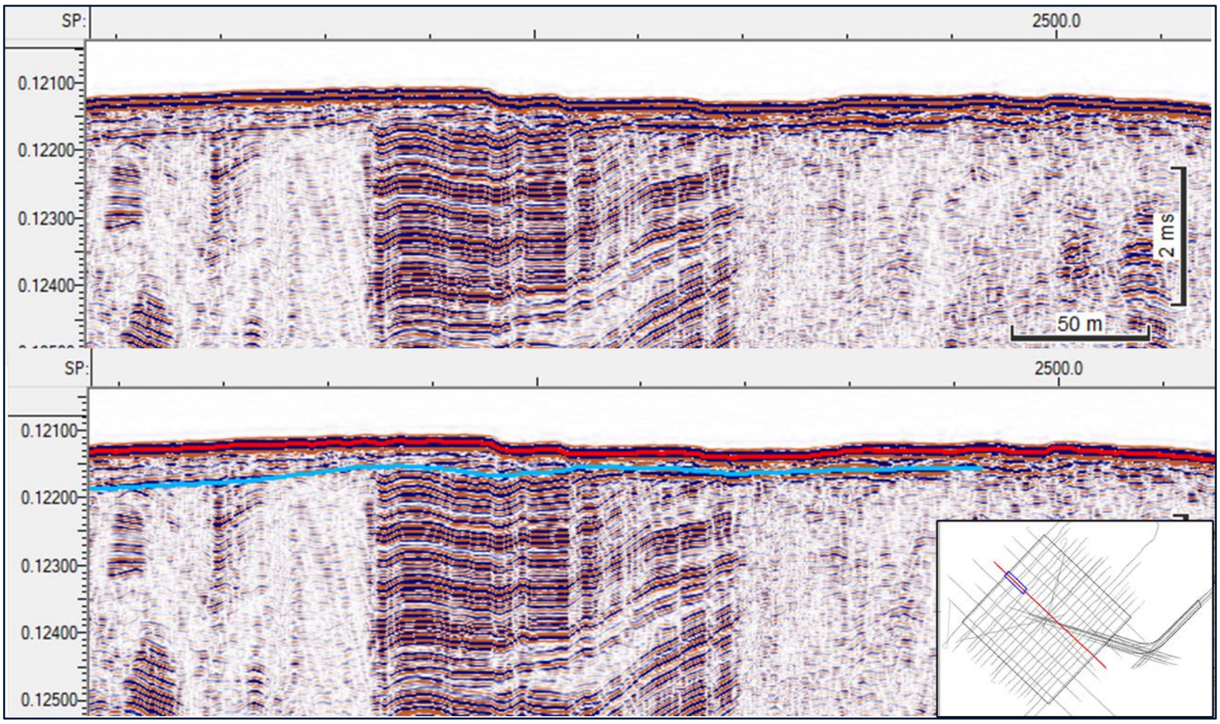


Figure 21 Innomar SBP example showing horizon H10. Survey line: CWT_23S_504.

4.5.2 Unit 20 – Upper Forth Formation

Horizon H20 marks the base of Unit 20 and was mapped mainly from the Innomar SBP data.

Unit 20 deposits are interpreted as channel infill sediments of the Forth Formation of Holocene to Pleistocene age. More than one generation of channels are likely to be present with several stages of sedimentation and erosion. Sediments can appear layered, homogenous or chaotic. The expected composition of Unit 20 is silty CLAY to silty SAND based on the ground truthing results.

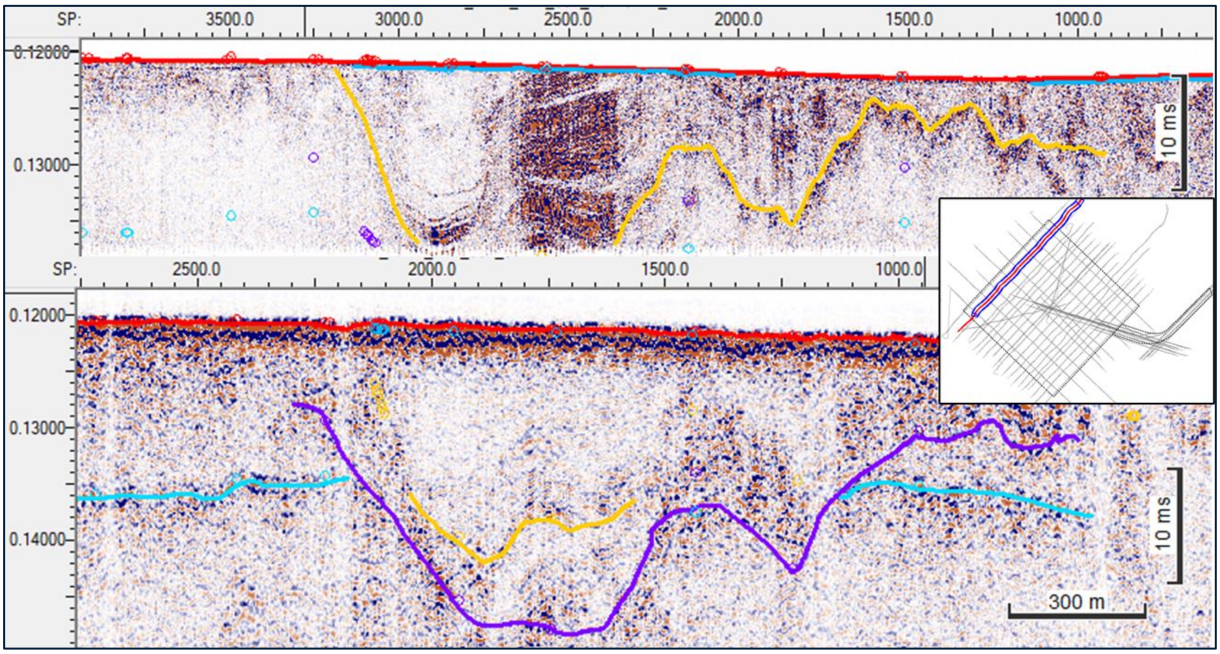


Figure 22 H20 interpretation (yellow line) combined horizons from Innomar (top) and Sparker (bottom). Survey line: CWT_23S_002.

Survey Area

Unit 20 is present from 0.0 to ~16.2 m BSB and it can be overlain by Unit 10 or be at or close to seabed.

In the north and northwest part of the survey area, where a deep channel is present, the Sparker data was used to guide the interpretation of horizon H20 (Figure 22). Grids were calculated on the combination of both data sets (Figure 23). Unit 20 is absent in the eastern and western corners of the survey area, as well as in small areas in the centre and south of the site (Figure 23).

The base of Unit 20 is present at mooring location CWT23-M1 at 6.1 m BSB, at CWT23-M2 at 3.6 m BSB and at CWT23-M3 at 1.2 m BSB (Figure 19).

Cable Route

Unit 20 is present along the section of the proposed cable route from KP 0.000 to KP 0.692 and reaches a maximum depth below seabed of ~ 8.3 m BSB. The unit is thin or absent from KP 0.692 along the remainder of the route.

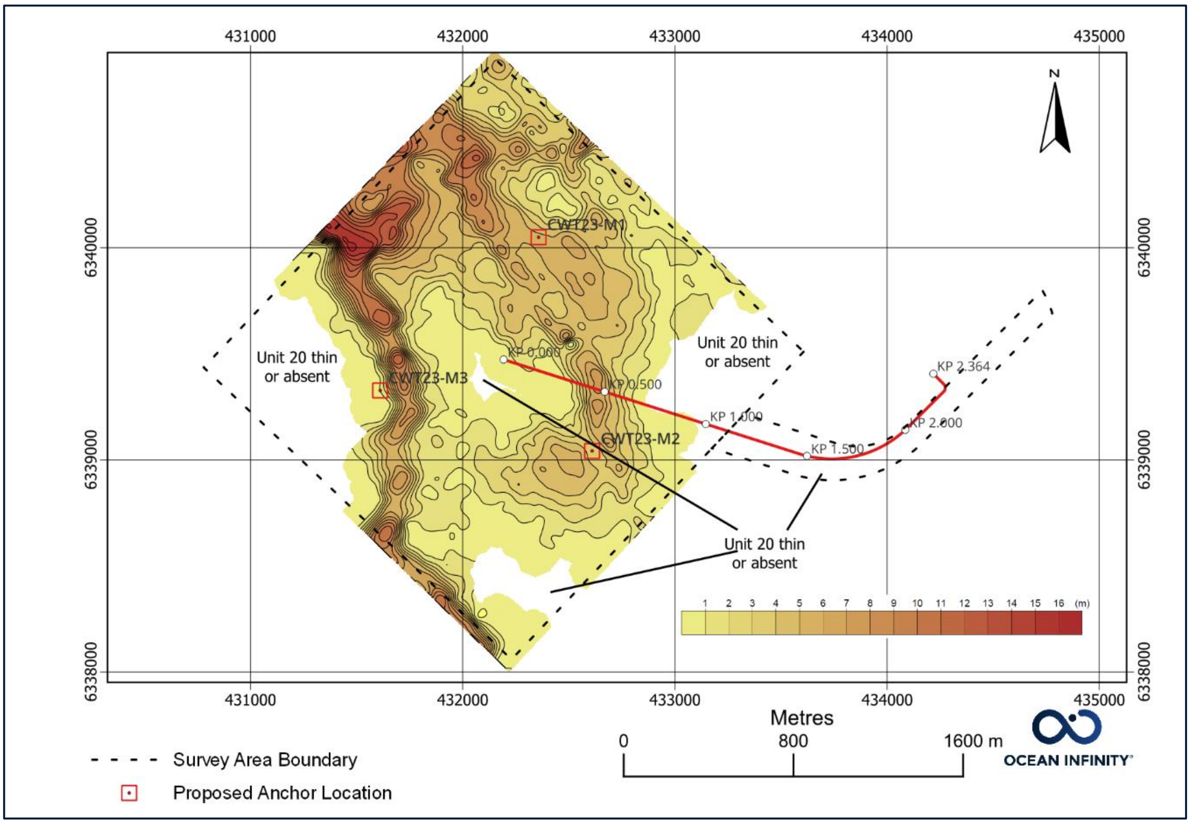


Figure 23 Base of Unit 20 in metres below seabed.

4.5.3 Unit 30 – Lower Forth Formation

Horizon H30 marks the base of Unit 30 and was mapped from the Sparker data.

Horizon H30 was mapped as the base of the oldest channel infills of the Forth Formation. Figure 24 illustrates the two generations of Forth Formation that have been interpreted, the upper, younger H20 (yellow line - base of Unit 20) and the deeper, older H30 (purple line). The base of Unit 30 is an erosional surface, cutting mainly into the Coal Pit Formation (Unit 40) and occasionally into the Fisher Formation (Unit 50). As with Unit 20 the expected composition is silty CLAY to silty SAND based on the preliminary ground truthing results. The sediments are expected to be of higher strength or denser than Unit 20.

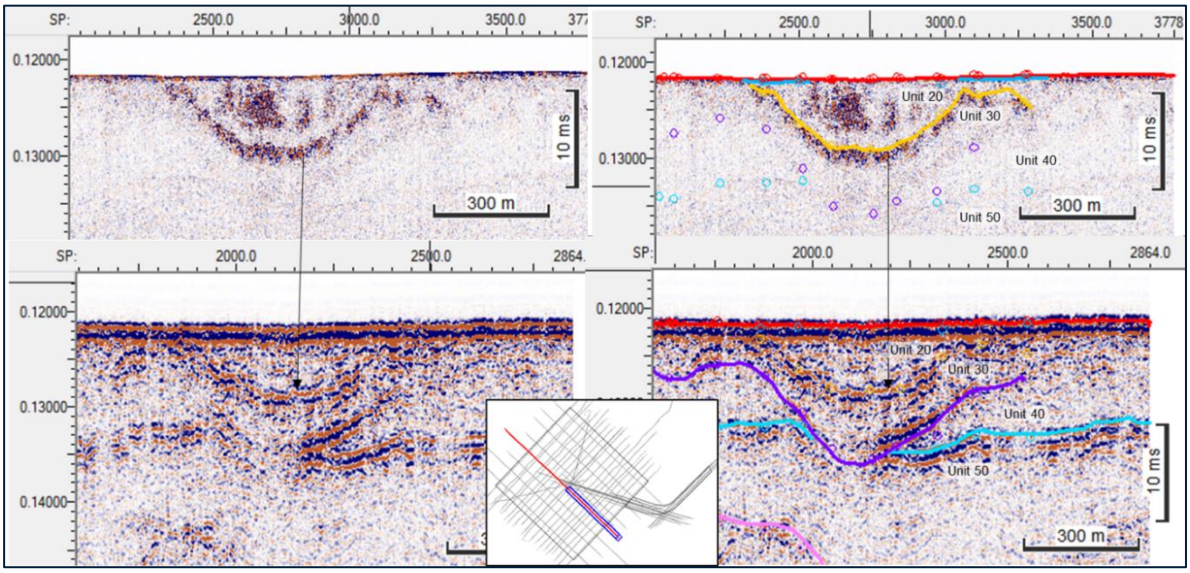


Figure 24 SBP example images of at least two generations of channels, Unit 20 and Unit 30 (Forth Fm). Innomar images (top), Sparker (bottom). Survey line: CWT_23S_002.

Survey Area

The base of Unit 30 occurs from 2.1 m to 20.1 m BSB and covers a similar extent as the overlying Unit 20 (Figure 25). Horizon H30 becomes indistinct towards the eastern and western parts of the survey area (Figure 25).

The base of Unit 30 is present at mooring location CWT23-M1 at 8.9 m BSB, at CWT23-M2 at 8.8 m BSB and at CWT23-M3 at 7.8 m BSB (Figure 19).

Cable Route

Unit 30 is present along the section of the proposed cable route from KP 0.000 to KP 0.774 and reaches a maximum depth below seabed of 11.5 m. Along the remainder of the route horizon 30 is indistinct and Unit 30 is expected to be thin or absent.

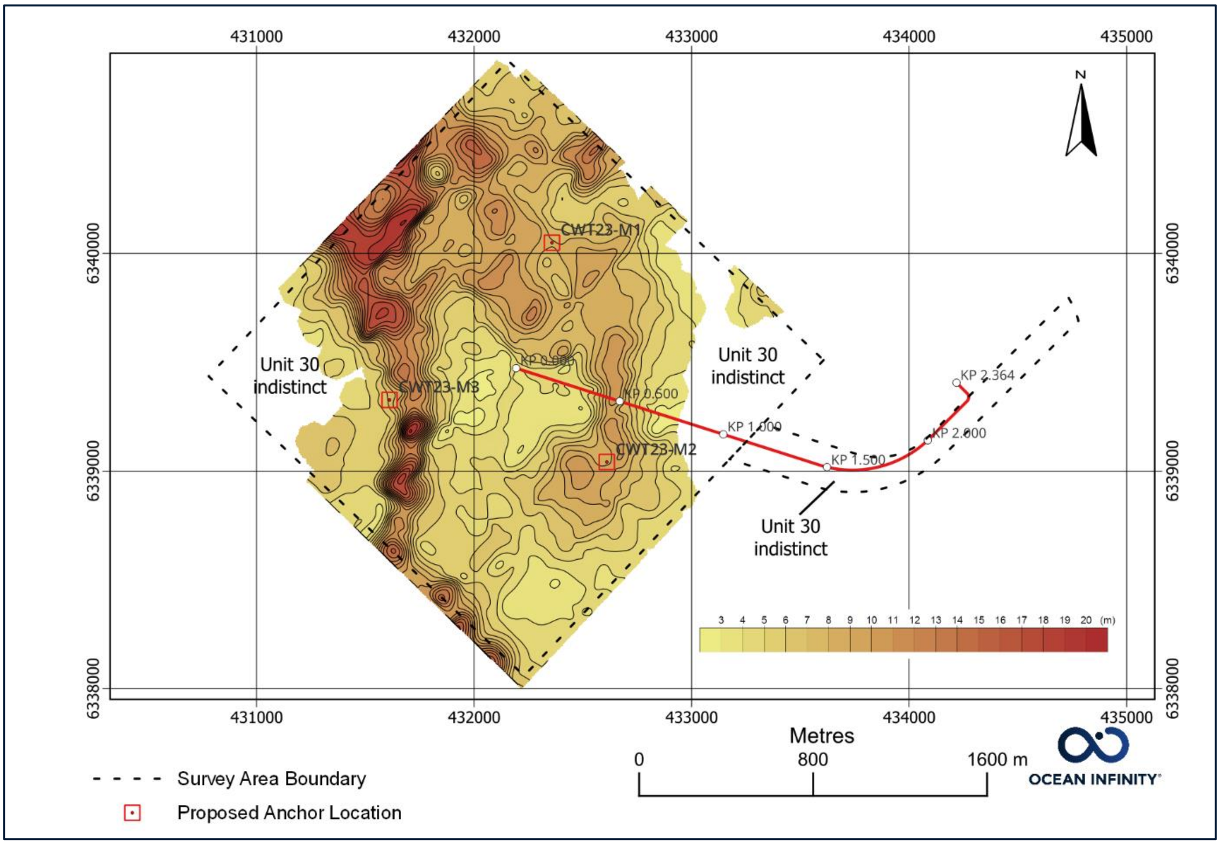


Figure 25 Base of Unit 30 in metres below seabed.

4.5.4 Unit 40 – Coal Pit Formation

Horizon H40 marks the base of Unit 40 and was mapped from the Sparker data.

Unit 40 is interpreted to present the Coal Pit Formation overlaying and filling in the eroded surface of the Fisher Formation (Unit 50). According to BGS it consists of silty CLAY with occasional pebbles and some sand laminae.

Survey Area

The base of Unit 40 is present from 6.9 to 12.5 m BSB (Figure 27).

Unit 40 is present throughout the survey but is absent where eroded by channels of Unit 30 (Figure 26). In the eastern and western parts of the survey area were horizon H30 is indistinct, a thin layer of Forth Formation sediments (Units 20 & 30) may be present, potentially overlain by a veneer of surficial sediment.

The base of Unit 40 is present at mooring location CWT23-M1 at 9.5 m BSB and at CWT23-M3 at 10.9 m BSB (Figure 19). The unit was not interpreted to be present at CWT23-M2.

Cable Route

Unit 40 is interpreted to be present along the whole route apart from a small section between KP 0.370 and KP 0.570 where it has been eroded by a Forth Formation channel (Figure 18). From approximately KP 0.820 Unit 40 is interpreted to be present at or close to seabed, potentially overlain by a veneer of surficial sediment. In general, the base of Unit 40 is sub-horizontal and occurs at a depth of 8-10m BSB

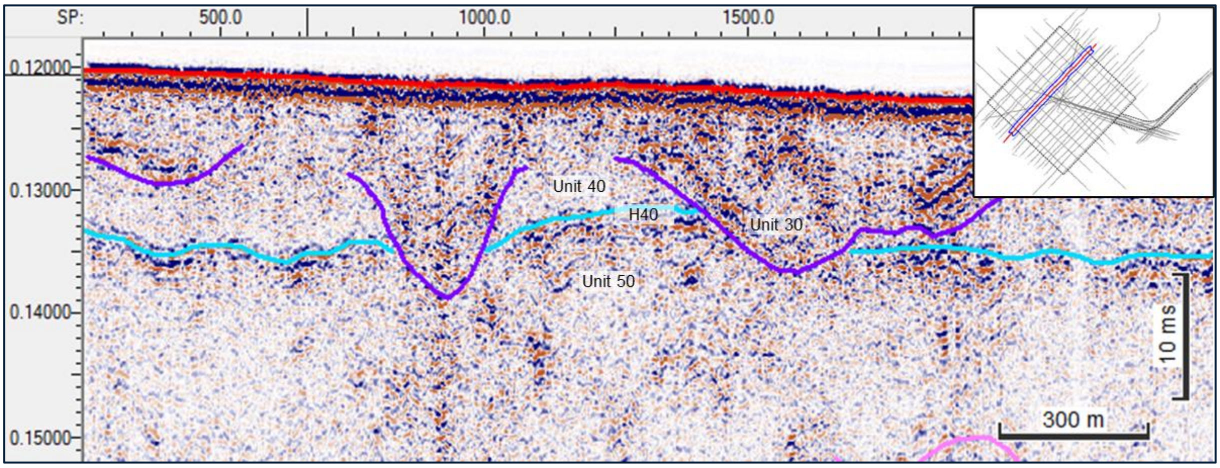


Figure 26 Sparker example image showing Horizon H40 (base of Coal Pit Formation) cut by channel of Unit 30 (Forth Formation). Survey line: CWT_23S_008.

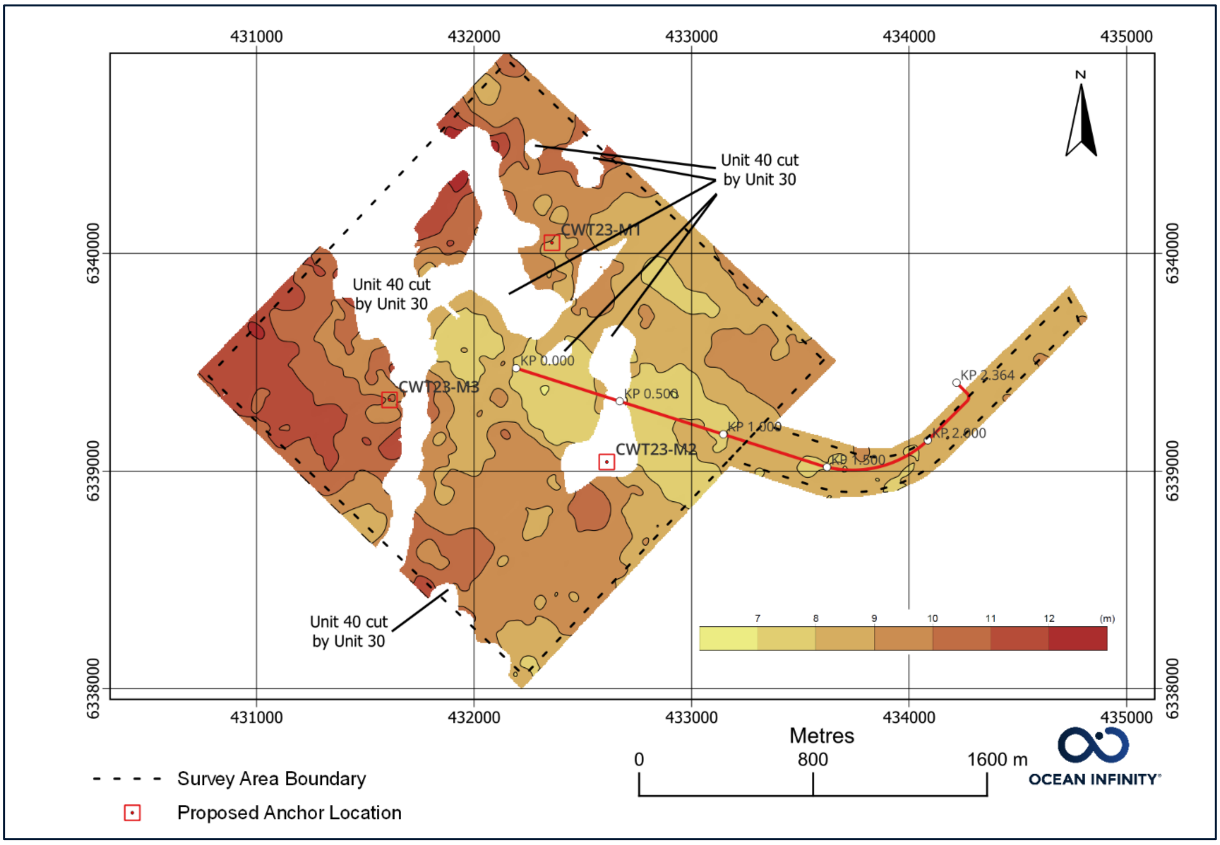


Figure 27 Base of Unit 40 in metres below seabed.

4.5.5 Unit 50 – Fisher Formation

Horizon H50 marks the base of Unit 50 and was mapped from the Sparker data.

Unit 50 is interpreted to represent the Fisher Formation, its upper surface forming an erosional surface with channels subsequently infilled by the Coal Pit (Unit 40) and Forth Formations (Unit 30). The base of Unit 50 forms a relatively smooth surface on the Ling Bank (unit 60) and Aberdeen Ground Formations (Unit 70) (Figure 29). Unit 50 contains several discontinuous subhorizontal reflectors and intraformational erosion surfaces. A strong internal reflector (H45) can be seen in the north and north-eastern part of the area, as well as on the route, see Figure 18. According to BGS the Fisher Formation sediments consist of firm to very stiff overconsolidated silty and sandy clays with occasional shell fragments and dropstones.

Survey Area

The base of Unit 50 is present approximately 39.0 m to 70.4 m BSB and can be traced throughout the whole survey area (Figure 28).

The base of Unit 50 is present at mooring location CWT23-M1 at 48.0 m BSB, at CWT23-M2 at 44.5 m BSB and at CWT23-M3 at 44.3 m BSB (Figure 19).

Cable Route

The top of Unit 50 is interpreted to be present at a depth of 8-10m BSB along most of the planned cable route. The depth of the base of Unit 50 increases from 40.0 m to 70.0 m BSB along the route (Figure 18). A strong internal reflector (H45) is present along the route at about 15-18 m BSB, sub-horizontal to the upper boundary of the unit (H40).

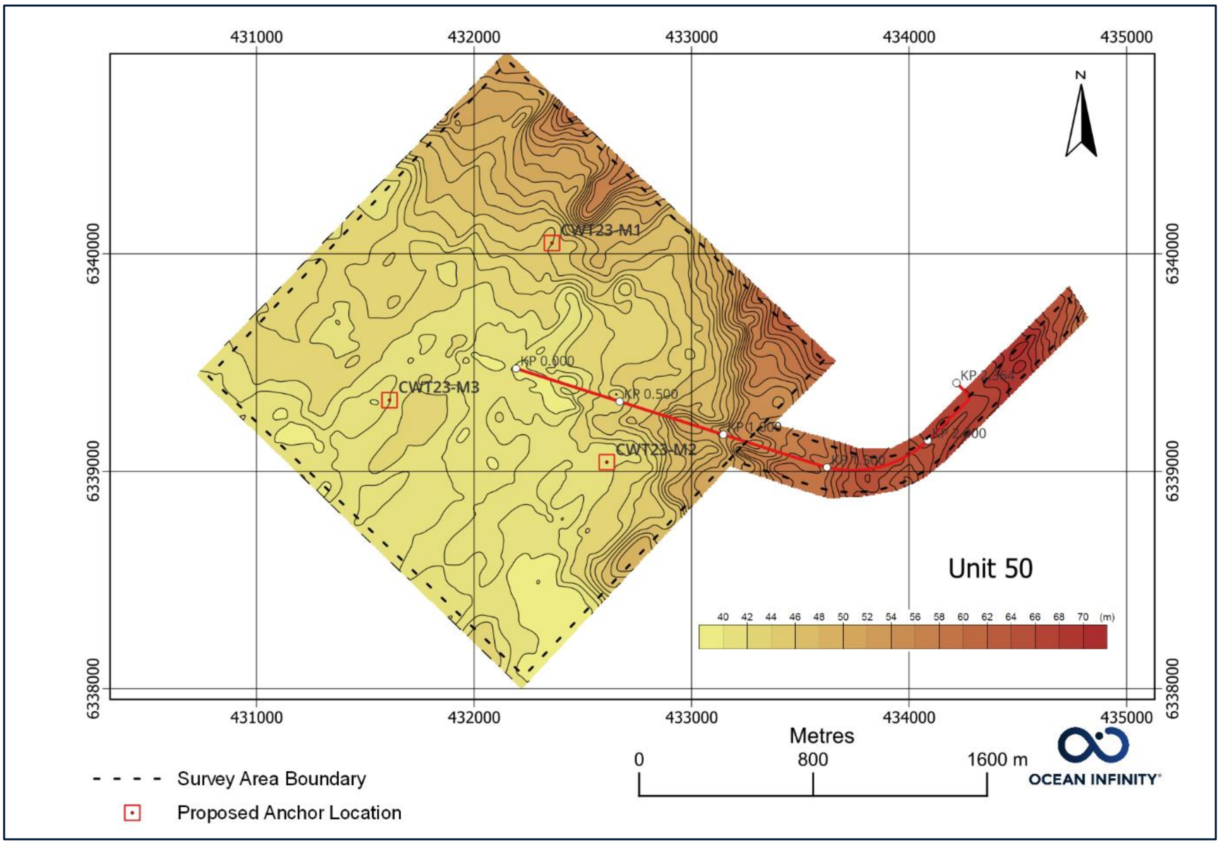


Figure 28 Base of Unit 50 in metres below seabed.

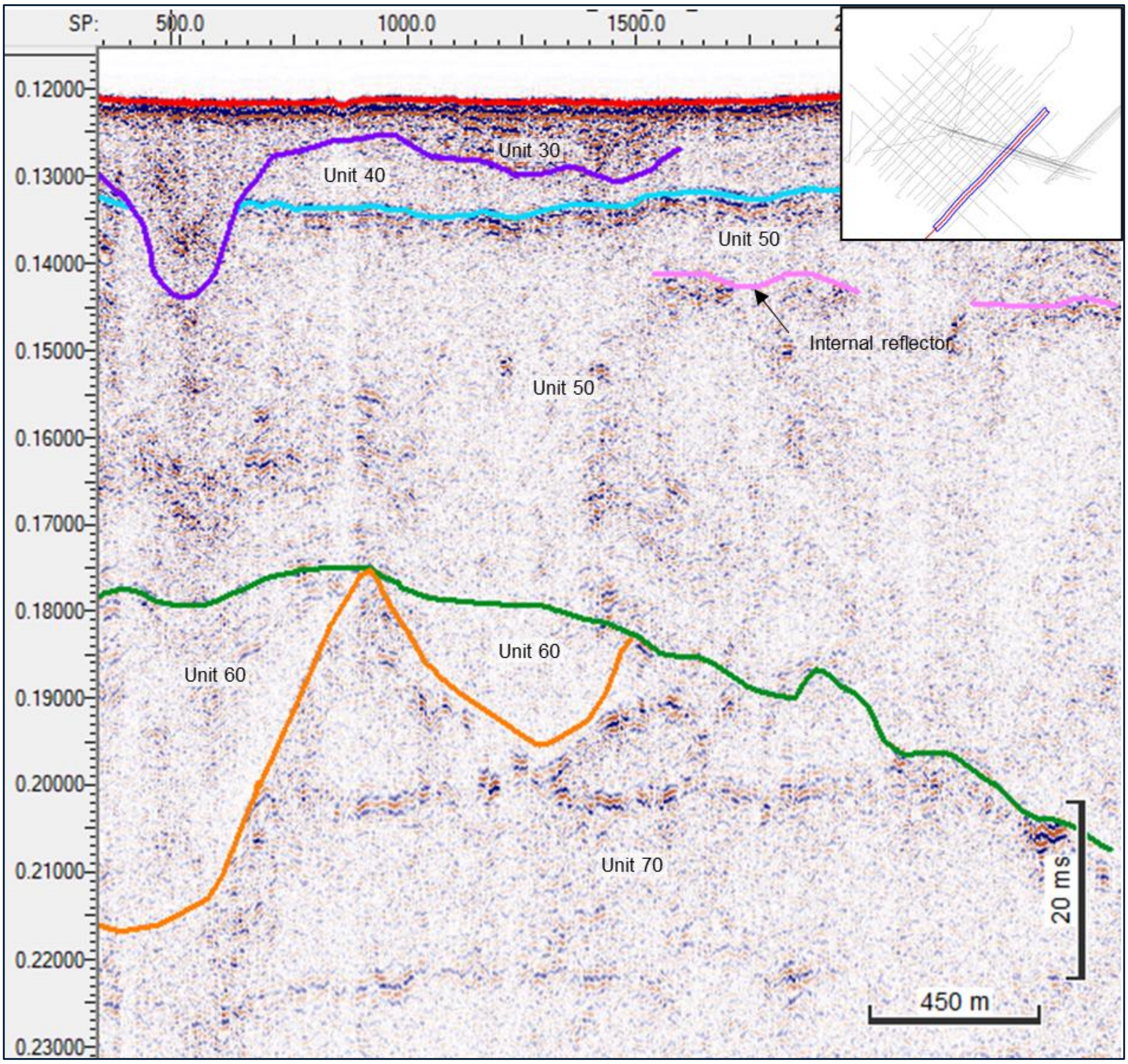


Figure 29 Sparker example image showing Unit 50 (Fisher Formation), Unit 60 (Ling Bank Formation) and Unit 70 (Aberdeen Ground Formation). Survey line: CWT_23S_019.

4.5.6 Unit 60 – Ling Bank Formation

Horizon H60 marks the base of Unit 60 and was mapped from the Sparker data.

Unit 60 is interpreted to represent Ling Bank Formation Pleistocene channels infilled by stiff to very stiff silty CLAY with abundant pebbles, occasionally it is sandy with shell fragments (according to BGS). Unit 60 is located beneath the Fisher Formation (Unit 50) and occupies erosional features cut into the Aberdeen Ground Formation (Unit 70), see Figure 29. Unit 60 appears seismically transparent to layered.

Survey Area

Unit 60 is mainly found in the western and middle part of the survey area (Figure 30). Where present, the base of Unit 60 is found at approximately 39.2 to 89.5 m BSB. In the western corner of the survey area the base of Unit 60 was beyond the penetration of the Sparker data.

The base of Unit 60 is present at mooring location CWT23-M1 at 49.2 m BSB, CWT23-M2 at 42.1 m and CWT23-M3 at 87.7 m BSB (Figure 19).

Cable Route

Where present, Unit 60 is >40m BSB, so beyond the depth of interest for cable installation (Figure 18).

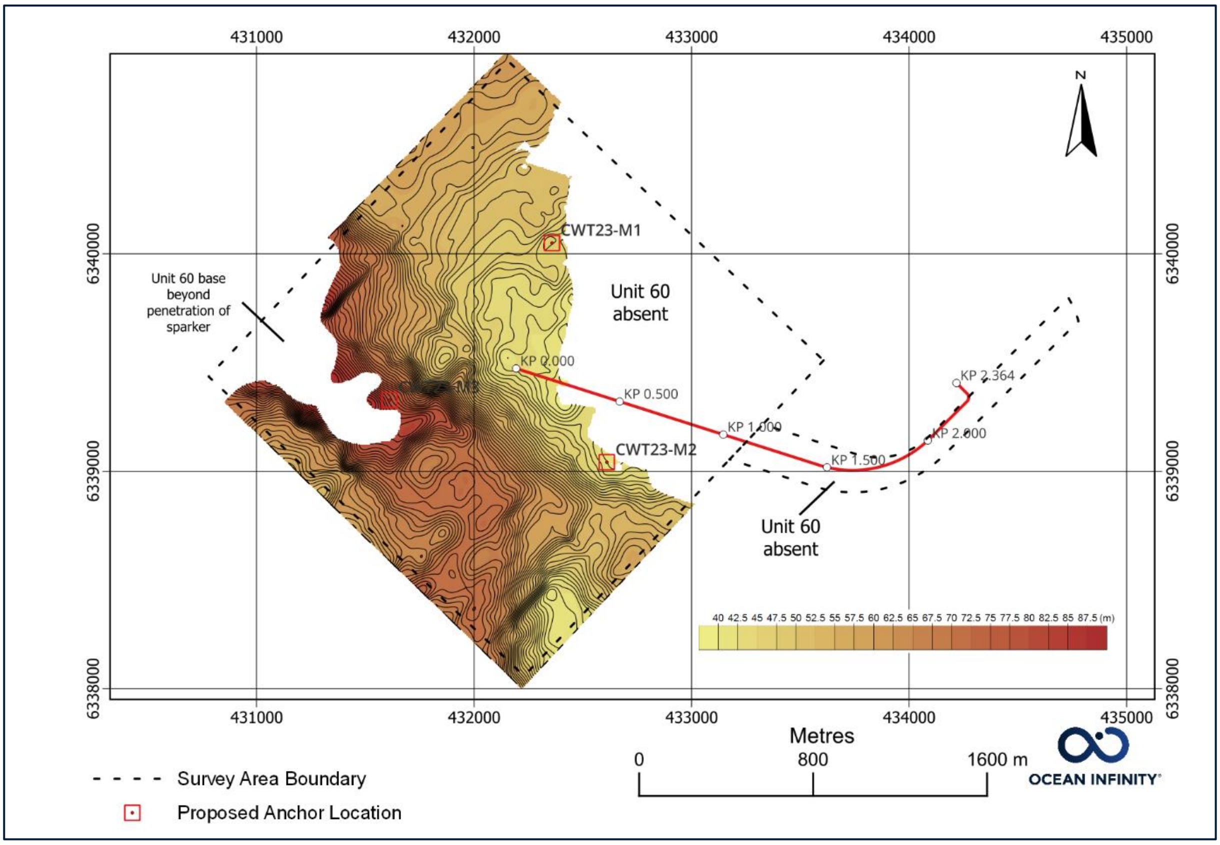


Figure 30 Base of Unit 60 in metres below seabed.

4.5.7 Unit 70 – Aberdeen Ground Formation

Unit 70 is interpreted to represent the Aberdeen Ground Formation. It is taken to be the oldest Quaternary deposit in the central North Sea and is locally dissected by later erosive episodes and overlain by Fisher (Unit 50) and Ling Bank Formations (Unit 60). The unit contains several internal strong and laterally persistent sub-parallel reflectors. According to BGS the Aberdeen Ground Formation consist of generally very hard and normally consolidated to overconsolidated sandy muds with occasional laminae of clay and silt or fine sand.

Survey Area

Unit 70 is present throughout the whole survey area at a depth of at least 39.0 m BSB.

Unit 70 is present at all planned mooring locations. At mooring location CWT23-M1 below 49.2 m BSB, at CWT23-M2 below 44.5 m BSB and at CWT23-M3 at 87.7 m BSB (Figure 19).

Cable Route

‘Where present, Unit 70 is >40m BSB, so beyond the depth of interest for cable installation (Figure 18).

4.6 Seabed and Sub-Seabed Hazards

Table 13 summarizes the hazards identified from MBES, SBP, SSS and UHRS interpretation within the survey area and route.

Table 13 Summary of geohazards and man-made hazards within the survey area and route.

HAZARD	PRESENT	DESCRIPTION
Seabed Gradients	No	No steep seabed gradients were detected in the survey area
Mobile sediments and bedforms	Yes	The only indication of mobile sediments in the area is an isolated furrow, orientated in an NNE-SSW direction. The furrow is shallow, only 10 cm deep and shows rippling, indicating bottom currents.
Cable and pipelines	No	The planned cable route doesn't cross any Culzean seabed infrastructure but is close to the SSIV umbilical where it approaches the platform.
Boulders	Yes	Possible boulders are detected in the survey area. Boulders are often associated with small seabed depressions.
Sub-surface boulders	No	No sub-surface boulders were detected in the survey area.
Glaciotectonics in Quaternary deposits	Yes	Disturbance in Unit 50, Fisher Formation
Erosive Channels	Yes	Base of channels and channel-like features were interpreted, Unit 20, 30 and 60. Several stages of sedimentation and erosion can be seen in Units 20 and 30.
Acoustic blanking and gas seepage features	Yes	No gas-charged sediments deposits were interpreted from SBP and UHRS data. However, numerous small depressions are present in the surficial sediments, possibly indicating fluid escape.

5. Reservations and Recommendations

The results in this report, both geological descriptions and contact selection, are based on interpretations of geophysical data obtained during the survey. It should be considered that there is a natural limitation in the accuracy of interpretation. Results from geotechnical sampling have been used for verification of the geological interpretations and is considered as ground truthing at those locations where collected. Where considered applicable, the sampling results have been extrapolated to guide the interpretation within the survey area.

Appendix A Seabed Targets

Appendix A.1 SSS Targets and MAG Anomalies - Cable Route

Appendix A.2 SSS Targets and MAG Anomalies – Site Survey Area

Appendix B Charts

Table 14 Chart index.

Appendix	Chart Name	Type	Description	Scale	Plot Size
B.1	104728-TOT-OI-SUR-DWG-ALECR001.pdf	AS Chart	Alignment Sheet Chart from KP 0 to KP 2.919	1:5000	A0
B.2	104728-TOT-OI-SUR-DWG-NUBAT001.pdf	NU Chart	Bathymetry Chart	1:5000	A0
B.2	104728-TOT-OI-SUR-DWG-NUGEO001.pdf	NU Chart	Seabed Features Chart	1:5000	A0
B.2	104728-TOT-OI-SUR-DWG-NUSSS001.pdf	NU Chart	Mosaic Chart	1:5000	A0
B.2	104728-TOT-OI-SUR-DWG-NUH10001.pdf	NU Chart	Unit 10 – Holocene Chart	1:5000	A0
B.2	104728-TOT-OI-SUR-DWG-NUH10002.pdf	NU Chart	Unit 20 – Upper Forth Formation Chart	1:5000	A0
B.2	104728-TOT-OI-SUR-DWG-NUH10003.pdf	NU Chart	Unit 30 – Lower Forth Formation Chart	1:5000	A0
B.2	104728-TOT-OI-SUR-DWG-NUH10004.pdf	NU Chart	Unit 40 – Coal Pit Formation Chart	1:5000	A0
B.2	104728-TOT-OI-SUR-DWG-NUH10005.pdf	NU Chart	Unit 50 – Fisher Formation Chart	1:5000	A0
B.2	104728-TOT-OI-SUR-DWG-NUH10006.pdf	NU Chart	Unit 60 – Ling Bank Formation Chart	1:5000	A0
B.2	104728-TOT-OI-SUR-DWG-NUTMB001.pdf	NU Chart	MBES Track Lines Chart	1:5000	A0
B.2	104728-TOT-OI-SUR-DWG-NUTSB001.pdf	NU Chart	SBP Track Lines Chart	1:5000	A0
B.2	104728-TOT-OI-SUR-DWG-NUTSS001.pdf	NU Chart	SSS Track Lines Chart	1:5000	A0
B.3	104728-TOT-OI-SUR-DWG-PRO001.pdf	Profile Chart	Shallow Geological Profile Charts	1:5000	A0