Danish Offshore Wind 2030 Cable Route Survey

Title	**Kattegat - Cable Route Integrated Report**
Project document code	BE5950H-711-RR-01
Client document code	SN2023_027-IR-KT
Revision	2.0

2.0	19/11/2024	For Client Review	RDM	ELM	PMI
Revision	Date	Description of Revision	Author	Checked	Approved

SERVICES WARRANTY

1 The Report and its associated works and services have been prepared in accordance with an agreed contract 23/08626-1 (**the "Contract**") between the Contractor and the Client as named at the front of this report. The Report is expressly intended to be used and match requirements and specifications as set forth in the Contract.

2 The Contractor has exercised due care and diligence in the preparation of the Report, applying the level of skill and expertise reasonably expected of a reputable Contractor experienced in the specific types of work conducted under the Contract.

3 Any findings, conclusions, and opinions presented in the Report are based on an interpretation of the available data. It is acknowledged that professionals may differ in their interpretations and opinions. Unless explicitly stated otherwise, the Report does not constitute a recommendation for any specific course of action.

4 In the event of any changes in the circumstances under which the Report was prepared and/or is to be used, including but not limited to alterations in site conditions, modifications to the client's final objectives, or changes to relevant legislation after the Report's production, some or all of the results contained herein may become invalid. The Contractor disclaims any liability arising from the usage of the Report under such changed circumstances.

5 The Contractor assumes no responsibility or liability to any other party in respect of or arising out of the Report and/or its contents. Any reliance placed upon the Report and/or its contents by any third party is done so entirely at their own risk.

6 By accepting the Report, the Client acknowledges and agrees to the terms and conditions outlined herein.

REVISION HISTORY

The screen version of this document is always the CONTROLLED COPY. When printed it is considered a FOR INFORMATION ONLY copy, and it is the holder's responsibility that they hold the latest valid version.

The table on this page should be used to explain the reason for the revision and what has changed since the previous revision.

Rev.	Date	Reason for revision	Changes from previous version
0.0	24/06/2024	First draft	N/A
0.1	09/08/2024	Internal revision	Minor corrections
1.0	27/08/2024	For Client review	
2.0	28/11/2024	For Client Review	Ref. "Deliverable_Register_DOW2030_Kattegat_ECR2_rev1.xlsx"

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

DEFINITIONS AND ABBREVIATIONS

Throughout this document the following terminology is used:

Energinet	*Energinet (Client)*
GEOxyz	*GEOxyz Offshore (Consultant)*
GeoDK	*GEO DK (Sub-contractor)*
Peak	*Peak Processing (Sub-contractor)*
Field	*Field Geospatial AS (Sub-contractor)*
BSL	*Benthic Solutions Limited (Sub-contractor)*
Fielax	*Fielax GmbH (Sub-contractor)*
OSC	*Ocean Science Consulting Ltd (Sub-contractor)*

The abbreviations and units listed in the table below are used within this report. Where abbreviations used in this document are not included in this table, it may be assumed that they are either equipment brand names or company names.

Table 1: Abbreviations used in this document

Acronym	Description	Acronym	Description
BS	Backscatter	MCA	Maritime and Coastguard Agency
BSF	Below seafloor	MCR	Mobilisation & Calibration Report
CMP	Common Mid-Point	MMO	Marine Mammal Observer/Man-Made Object
CPT	Cone Penetration Test	MRU	Motion Reference Unit
CPTU	Cone Penetration Test with Pore Pressure	mbsb	Metres below seabed
CTV	Crew Transfer Vessel	MSL	Mean Sea Level
DGPS	Differential Global Positioning System	PAM	Passive Acoustic Monitoring
DP	Dynamic Positioning	PG	Post Glacial
DTM	Digital Terrain Model	QA	Quality Assurance
DTS	Desktop Study	QC	Quality Control
ECR	Export Cable Route	QINSy	Quality Integrated Navigation System
EEZ	Exclusive Economic Zone	QPS	Quality Positioning Services B.V.
EGN	Empirical Gain Normalisation	RPL	Route Position List
EPSG	European Petroleum Survey Group	RTK	Real Time Kinematic
ETRS	European Terrestrial Reference System	SBP	Sub Bottom Profiler
GIS	Geographical Information System	SOW	Scope Of Work
GL	Glacial	SSS	Side Scan Sonar
GNSS	Global Navigational Satellite System	SVP	Sound Velocity Profile
GOIV	Geo Ocean IV	SVS	Sound Velocity Sensor
GSV	Geo Surveyor V	SWL	Safe Working Limit
GS	Grab Sampling	TD	Target Depth
GSXVII	Geo Surveyor XVII	THU	Total Horizontal Uncertainty

Acronym	Description	Acronym	Description
H	Height	TRT	Thermal Response Testing
HF	High Frequency	TVG	Time Variable Gain
IMU	Inertial Measurement Unit	TVU	Total Vertical Uncertainty
INS	Inertial Navigation System	USBL	Ultra Short Base Line
KG	Kattegat	UTC	Universal Time Coordinated
KP	Kilometric Point	UTM	Universal Transverse Mercator
L	Length	UXO	Unexploded Ordnance
LF	Low Frequency	VC	Vibrocore
LG	Late Glacial	W	Width
MAG	Magnetometer	WD	Water Depth
MBES	Multi Beam Echo Sounder		

1 EXECUTIVE SUMMARY

Kattegat Cable Route			
Survey dates	Geophysical survey	Start	11/09/2023
		End	01/06/2024
	Geotechnical survey	Start	20/03/2024
		End	21/03/2024
Sensors	Multibeam Echo Sounder (MBES), Side Scan Sonar (SSS), Magnetometer (MAG), Sub-Bottom Profiler (SBP), Grab Sampling (GS), Backscatter (BS), Vibrocore (VC), Cone Penetration Test (CPT), Thermal Response Testing (TRT), Lidar		
Coordinate system	Datum	European Terrestrial Reference System (ETRS89)	
	Projection	UTM zone 32N (EPSG: 25832)	
Bathymetry and topography			
Elevation	16.35 m MSL (Topographic) – -21.33 m MSL (Bathymetric)		
Site characteristics	The elevation levels across the Kattegat ECR 2 site range from 16.35 metres above Mean Sea Level (MSL) in the western landfall area to -21.33 metres below MSL towards the southeastern boundary. Analysing the seabed gradient from KP 14.980 eastward reveals an almost negligible slope up to KP 8.000, where the seabed remains nearly flat. Beyond this point, the gradient gently inclines at approximately 0.14° over 7.12 kilometres, resulting in a total elevation change of 17.5 metres. Starting at KP zero and moving westward from zero MSL into the topographic region of the survey area, the gradient initially rises steeply at 63° over half a metre, gaining 0.5 metres in elevation, then decreases to a moderate 6° over 21 metres as the route proceeds inland over foliage. Further inland, the area features gently undulating topography and relatively flat land, interspersed with foliage, hedgerows, and farming fields, peaking at 16.35 metres above MSL. Overall, the slope characteristics of the Kattegat ECR 2 area are predominantly gentle, with slopes less than 1° being the most common. Slopes ranging from 1° to 5° become noticeable from KP 4.600 westward, where the seabed begins to rise as the landfall approaches. The highest slope values, defined as very steep slopes greater than 15°, are associated with seabed features such as boulders. High-density boulder fields create slopes exceeding 15° over an otherwise flat seabed.		
Seabed surface: Geology			
The surface geology of the Kattegat ECR 2 area exhibits a relatively complex diversity of seabed surface geology, characterized primarily by extensive and irregular deposits of till/diamicton and sand that dominate much of the site. The western part of the area is chiefly composed of till/diamicton, interspersed with pockets of mud and sandy mud, alongside sections of gravel and coarse sand. In the mid-eastern portion of the area, a distinct strip of gravel and coarse sand is present, bordered by regions of sand. Just east of this strip lies a small patch of muddy sand, the only occurrence of this specific classification within the area			

Kattegat Cable Route	
Seabed surface: Morphology	
The initial kilometre of the survey area shows no detectable seabed features. As the landfall sector emerges around zero MSL, high-density and intermediate-density boulder fields dominate the next 4.5 kilometres. Occasional patches with featureless seabed and a small area of ripples are present. At KP 4.500, a 100-metre-wide strip of ripples runs perpendicular to the route. Eastward, a narrow section with featureless seabed is detected. From KP 4.500 to KP 6.500, a 1.5-kilometre stretch shows flat seabed interpreted as sand. From KP 6.500 to KP 9.000, intermediate boulder fields dominate, with occasional high-density boulder patches. Between KP 9.000 and KP 13.000, there is a mix of high and medium-density boulder fields, patches with scour pattern (defined as 'other'), and areas with featureless seabed, with trawl marks evident over sandy seabed areas. Between KP 13.000 and KP 14.500, two patches of 'unknown' features cover approximately 1.8 km², surrounded by trawl-marked regions. The final stretch towards the eastern boundary is characterized by intermediate boulder fields, with interspersed high-density boulders and areas with featureless seabed. The seabed morphology along the Kattegat ECR 2 route mainly consists of boulder fields of varying densities, flat sandy areas, ripples, and trawl-marked zones, presenting a complex but manageable landscape for the corridor.	
Seabed surface: Man-made features and site-specific hazards	
Wrecks	No wrecks were identified within the Kattegat ECR 2 site.
Metallic objects	Two metallic linear contacts were found within a 5 m radius of a magnetic anomaly. 1,196 sonar contacts found within a 5 m radius of a magnetic anomaly.
Anchors	Two anchors were found within the site.
Other contacts	439 contacts are identified to be debris
Rope	102 contacts related to possible soft rope item were discovered within the Kattegat ECR 2 site.
Cables	No infrastructure or communication cables were identified within the Kattegat ECR 2 site.
Pipelines	No Pipelines were identified within or crossing the Kattegat ECR 2 site.
Boulders	12,275 Boulders were identified within the site
Sub-seabed soil units	
Unit I	Post Glacial - Fine to medium SAND
Unit II	Late Glacial - Variable, includes intervals of laminated CLAY, SAND-prone packages
Unit III	Glacial - Variable, CLAY-prone, locally over-consolidated
Geology	
In general, the area has a glacial to post-glacial sequence. The post glacial sequence is of relatively recent sediments. Only the upper post glacial, late glacial and glacial deposits are discussed along the ECR.	
Geohazards	

Kattegat Cable Route
Unit I sediments are very weak and soft, with negligible bearing capacity, potentially causing retrieval difficulties related to the settlement of seabed frames. Unit II contains numerous cobbles and boulders. Unit III may exhibit variable levels of over-consolidation and contains numerous cobbles and boulders. Some small areas of organic matter which have similar acoustic properties to gas have been identified in the cable corridor, concentrated to the north of the RPL. These present a possible geohazard relating to heat dissipation, as well as trenching considerations.

2 PROJECT INTRODUCTION AND BACKGROUND

2.1 PROJECT OVERVIEW

Following a decision in the Danish Parliament in 2022, Denmark is on the path to establish offshore energy infrastructure in the Danish inner sea (Kattegat) to connect further offshore wind energy to the Danish mainland. The Kattegat project location is depicted in Figure 1.

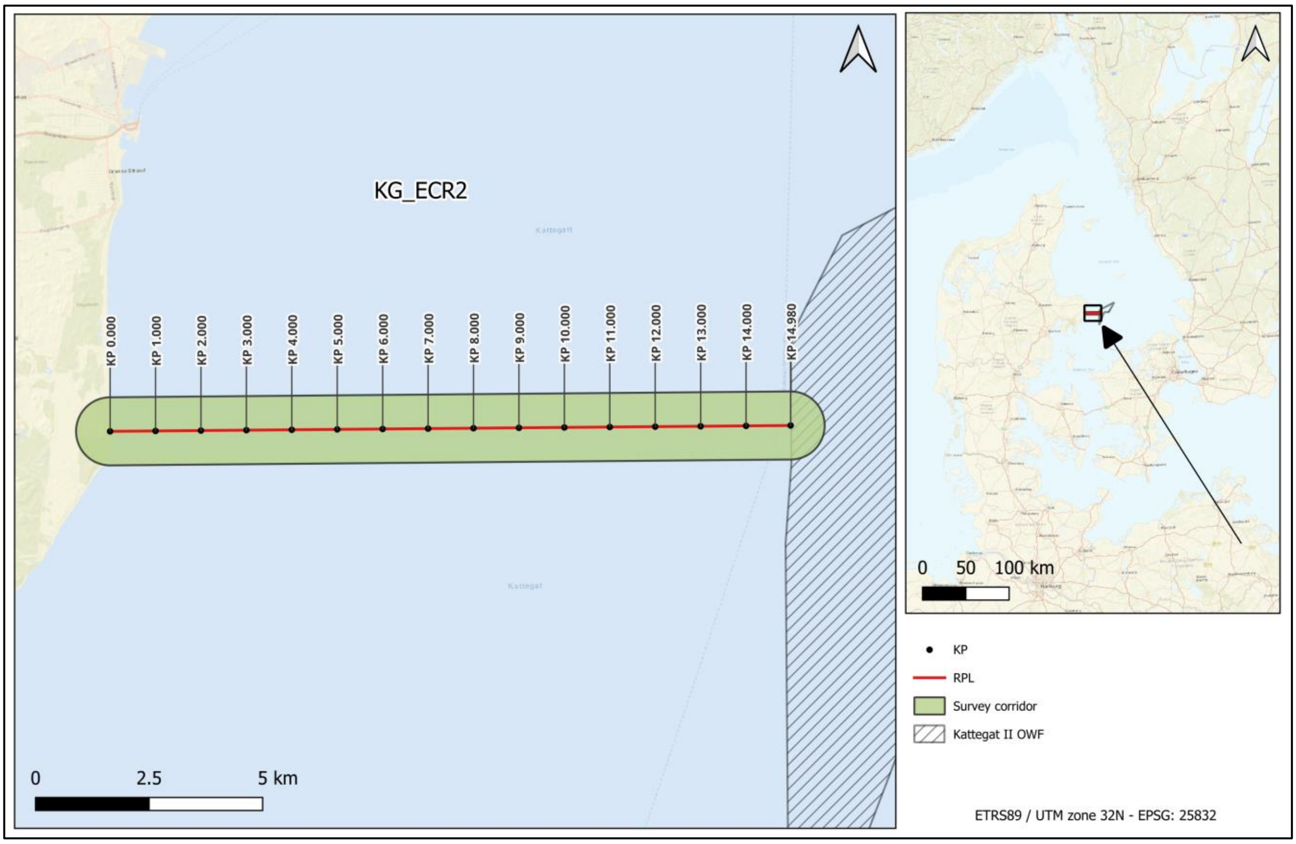


Figure 1: Project overview map - Kattegat

The Client has awarded GEOxyz a contract to provide surveys of the marine cable routes connecting the wind farm sites with land (Export Cable Routes, ECR). The work includes geophysical survey and shallow geotechnical investigations. The area of investigation is summarized in Table 2 below.

Table 2: Area of investigation for the cable route surveys

Export Cable Route	Route length	Route width	Water depth
Kattegat ECR 2	15 km	1500 m	0-22 m

2.2 CABLE ROUTE

The Kattegat ECR 2 cable survey corridor spreads from Grenaa beach towards the planned Kattegat II offshore wind farm in the Kattegat Sea. A summary of coordinates is displayed in Figure 2 and Table 3 below.

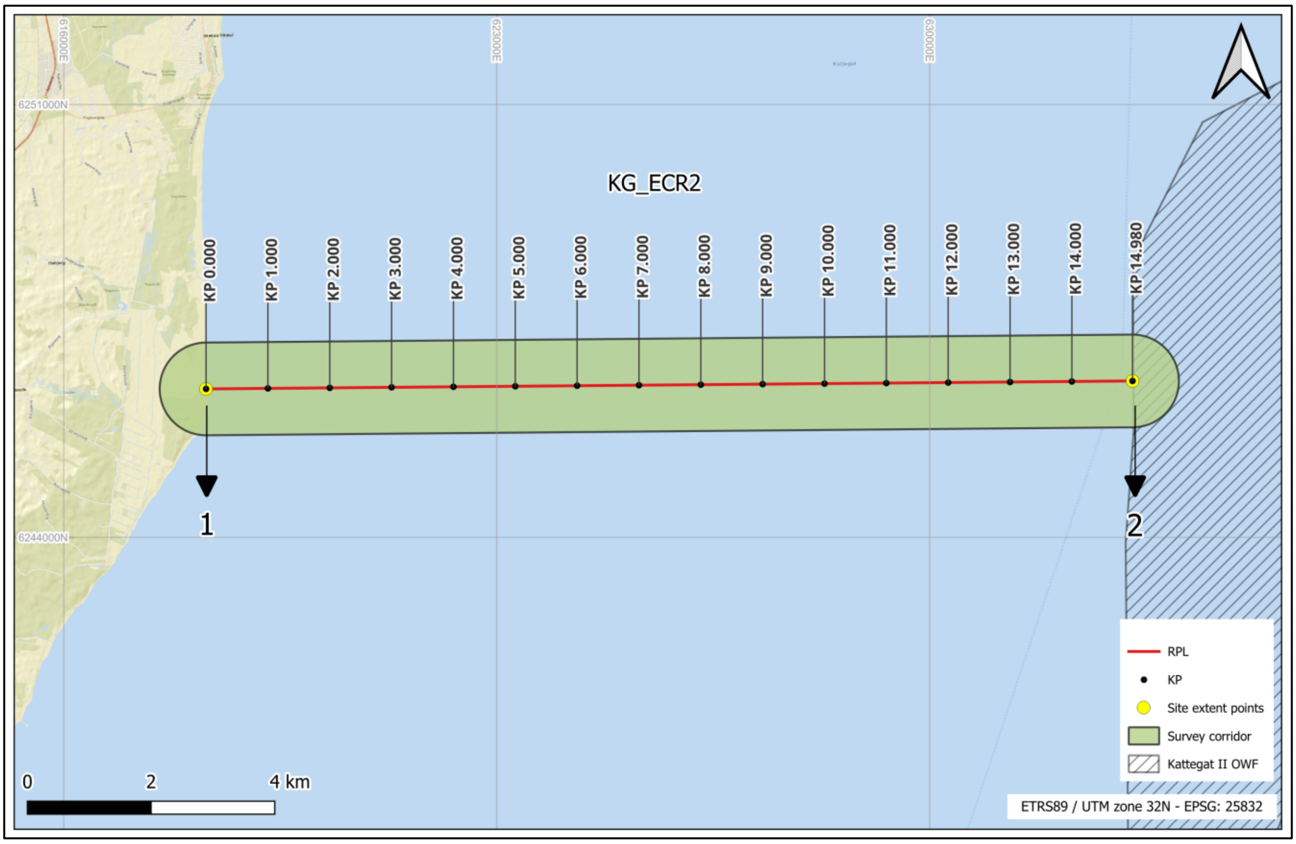


Figure 2: Overview of the Kattegat ECR 2 cable extent

Table 3: Coordinates of the Kattegat ECR 2 cable

Point ID	Point KP	Easting	Northing	Longitude	Latitude
1	0.000	618300.38	6246401.23	010° 54’50.99”	56° 20’50.98”
2	14.980	633280.39	6246530.23	011° 09’23.15”	56° 20’40.83”

The Kattegat ECR 2 survey area's landfall site is situated on the beach at Grenaa, Denmark as presented in Figure 3 below.

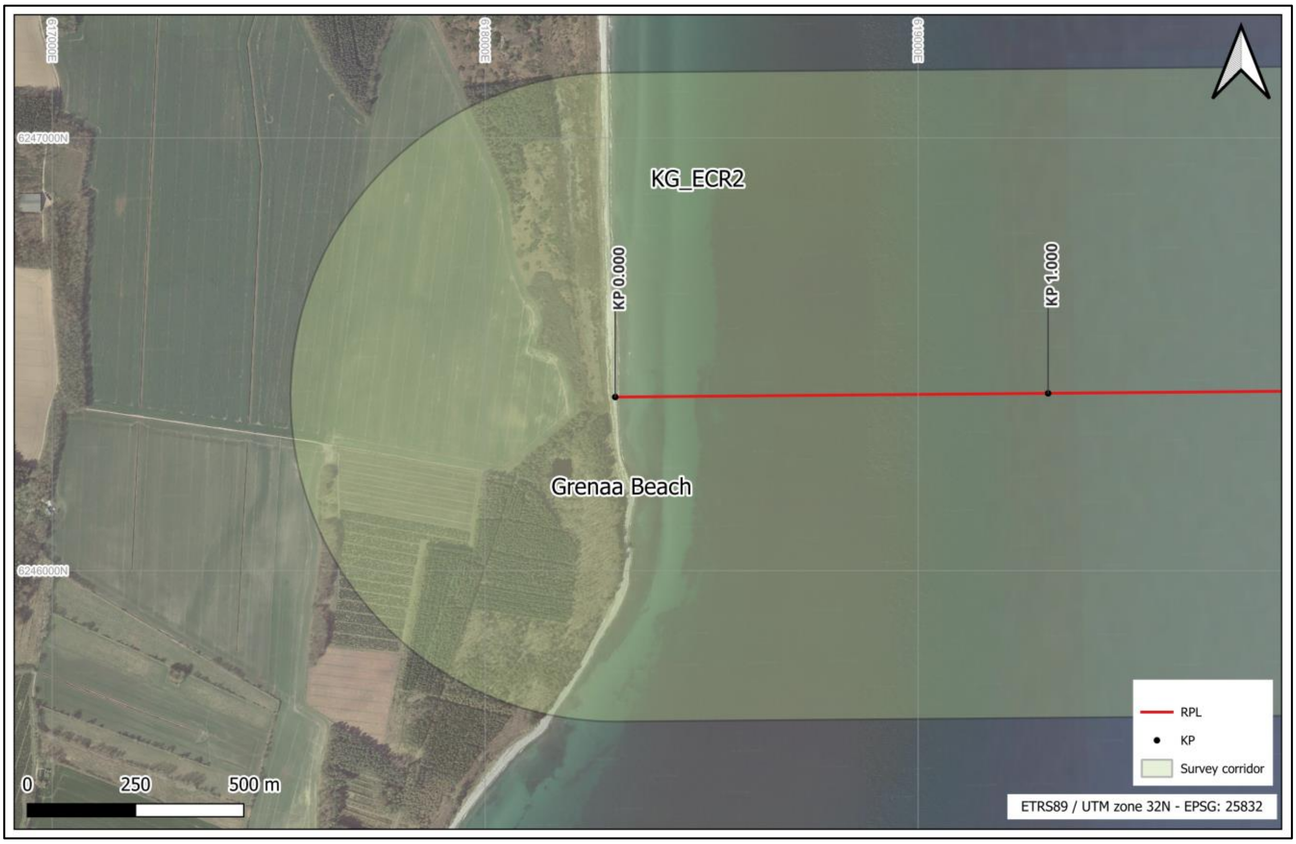


Figure 3: Landfall location overview

2.3 EXISTING INFRASTRUCTURE

No existing infrastructure was identified during the planning of the survey and no infrastructure was identified during the survey and reporting of the Kattegat ECR 2 site.

2.4 PARTIES INVOLVED

The parties involved in the project are represented by the organogram given in Figure 4.

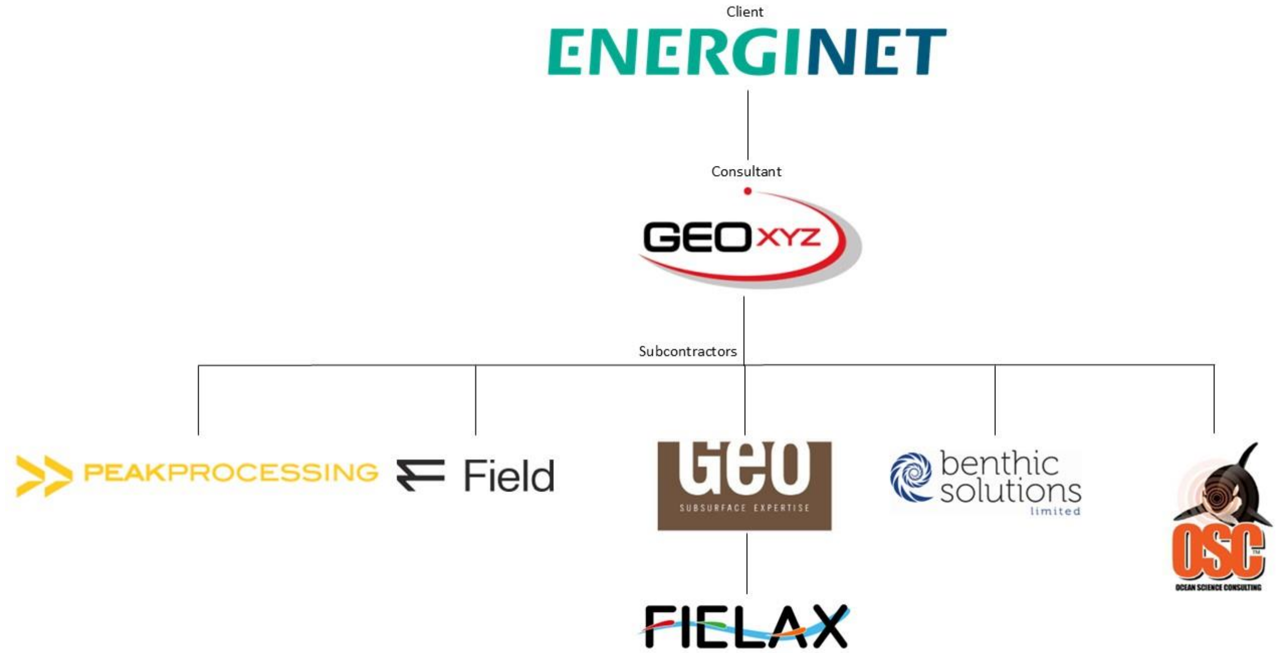


Figure 4: Parties involved in the project

A summary of the involvement of the subcontractors used by GEOxyz to facilitate the project is:

- Peak Processing – to process and interpret the SBP data
- Field – To acquire the Lidar data in the landfall areas of the site
- GeoDK and Fielax – To process and interpret the geotechnical data, with Fielax to support with TRT data analysis
- Benthic Solutions – To process and interpret the grab sample data, as well as provide visual surveys and subsequent interpretation for Marine Mammal Reporting and Analysis
- OSC – To provide visual surveys and subsequent interpretation for Marine Mammal Reporting and Analysis

2.5 SCOPE OF WORK

The offshore and nearshore elements of the project comprise the export cable between the offshore wind farm and the Danish mainland.

2.5.1 Geophysical survey

A comprehensive geophysical offshore, nearshore, and landfall site survey was conducted, encompassing MBES (Multibeam Echo Sounding) including backscatter, SSS (Side Scan Sonar), magnetometer, and SBP (Sub-Bottom Profiler) to map the bathymetry, static and dynamic elements of the seabed surface, and the subsurface geological soil layers to a depth of at least 10 m below the seabed. Grab sampling was also performed to support the interpretation of the seabed surface geology.

In the terms of the water depths, nearshore and landfall surveys referred to the land and underwater areas with depths up to a 10 metres MSL, whilst offshore survey refers to the underwater areas deeper than 10 m MSL.

The functional requirements of the work included the following acquisitions:

- A Multibeam Echo Sounding survey with full bathymetric coverage, where the data quality allowed for the preparation of digital elevation models (DTMs) of the bathymetry with a 25 cm spatial resolution (minimum 4 pings per 25 cm²).
- A dual-frequency side scan sonar with over 200 % coverage to ensure overlap with the nadir of adjacent survey lines, capable of detecting all objects greater than 0.5 m.
- A single magnetometer towed behind the vessel along all survey lines.
- Sub-bottom profiling using a high-resolution and relatively high-frequency single-channel system to a depth of 10 m along all survey lines.
- Horizontal positioning uncertainty of less than 0.5 m for vessels.
- Horizontal positioning uncertainty of less than 2.0 m for towed equipment.
- Vertical positioning uncertainty meeting IHO S-44 Special Order standards of less than 0.2 m.
- Grab sampling at an approximate rate of one sample per route kilometre.

2.5.2 Line planning

For the offshore survey, the survey lines comprised of main lines spaced at 30 m and cross lines, for MBES and SBP only, spaced every 2000 m. The nearshore and landfall survey comprised of 10 m spaced survey lines. Both offshore and nearshore areas have a minimum overlap of 250 m. Figure 5 shows an example schematic diagram of the line plans for offshore and nearshore work.

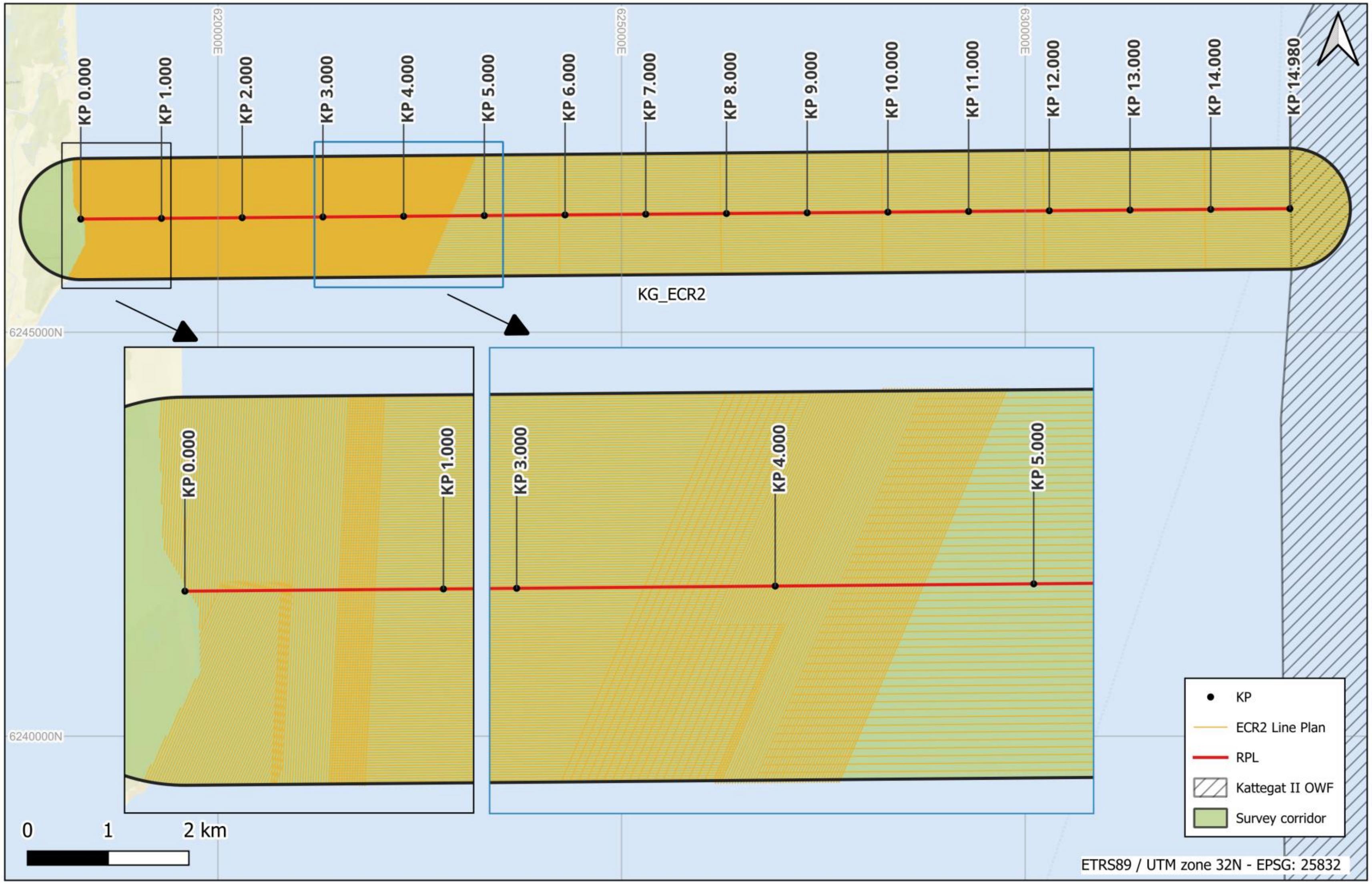


Figure 5: Kattegat ECR2 offshore and nearshore geophysical line plan

2.5.3 Geotechnical survey

The geotechnical survey of Kattegat ECR 2 was performed from the 20th to the 21st of March 2024. Geotechnical investigations were carried out in water depths greater that 10 metres due to vessel limitations and limited gain of additional samples within the nearshore section.

Investigation consisted of the following field work:

1) Cone Penetration Test with pore pressure (CPTU) with a target depth of 3 and 6 mbsb

2) Vibrocore (VC) sampling with target depth of 3 and 6 m*

3) In-situ Thermal Response Testing (TRT)

4) Offshore field descriptions of VC section ends and undrained shear strength testing.

5) Onshore laboratory testing of VCs including core splitting, photography and geological description of entire core

6) Various geotechnical tests at selected sub-samples

7) Reporting

The number of tests carried out for each investigation is summarized in Table 4, and overview of geotechnical locations is presented in Figure 6. Detailed overview of geotechnical locations is presented in APPENDIX B.

Table 4: Geotechnical works summary

Type of test	Planned tests	Performed tests
CPT	16	22
VC	16	20
In-situ TRT	4	4

** Maximum penetration depth is 5.7 m when In-Situ TRT equipment is mounted on VC*

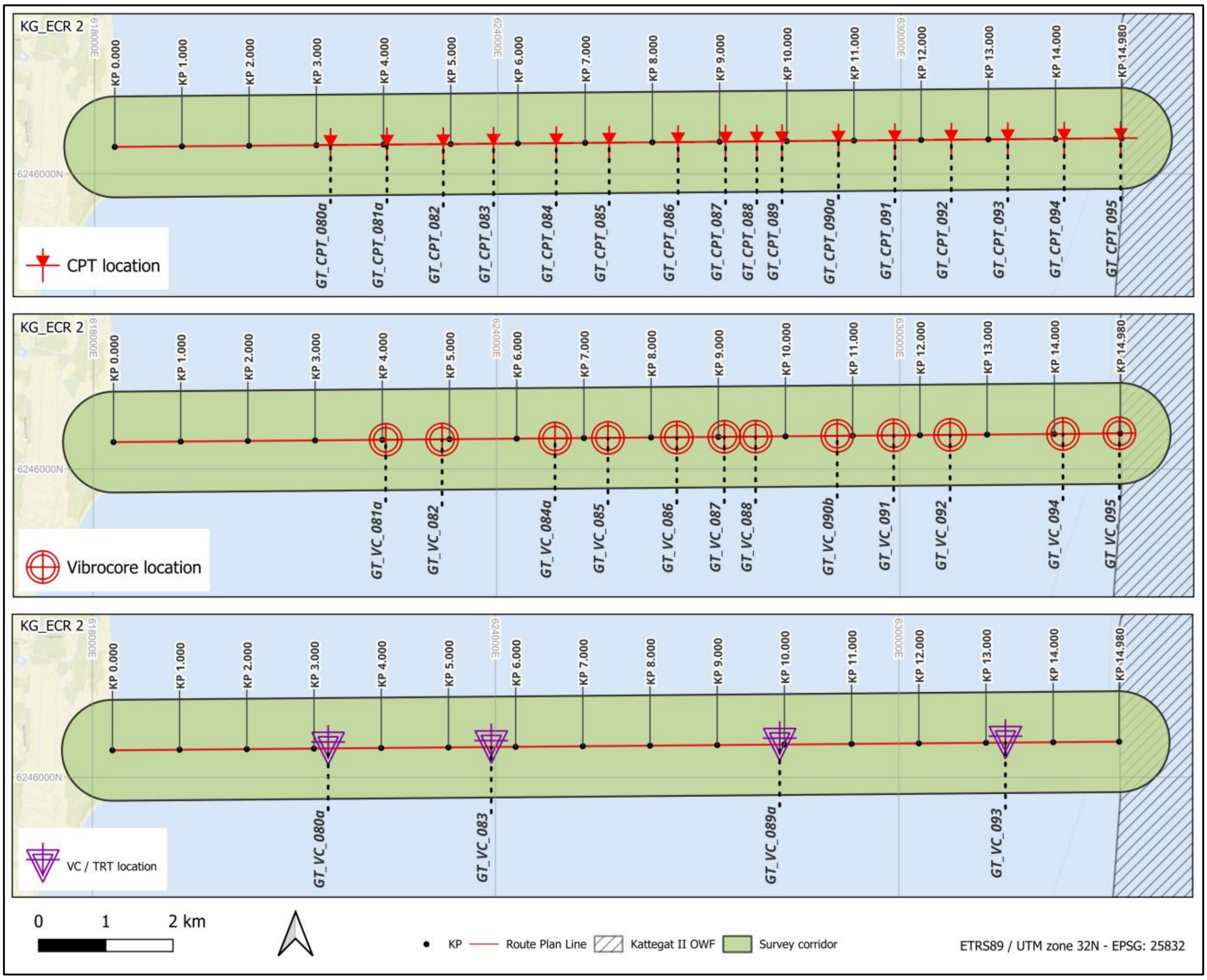


Figure 6: Geotechnical locations overview

2.5.4 General survey objectives

The scope of work of the project consisted of geophysical surveys, grab sampling, and geotechnical site investigations of the export cable route. The results of the survey can be used for:

- Verification of the feasibility of the investigated cable route
- Marine archaeological assessment
- Planning of environmental investigations and assessment of environmental conditions
- Design of subsea cable burial
- Assessment of conditions for installation and maintenance
- Providing site information to be enclosed in the tender for offshore cable and installation

2.6 REFERENCE DOCUMENTATION

Key project and corporate documentation are listed below.

Client reference documentation

Documentation provided by the Client for the project is listed in Table 5 below.

Table 5: Client reference documentation

Document Code	Title
23/00573-5	Scope of Services – Lot 1
22/00573-6	Scope of Services – Enclosure 1 – Technical Requirements
22/00573-7	Scope of Services – Enclosure 2 – Standards of Deliverables
16/19566-2	Scope of Services – Enclosure 3 – Standards of Deliverables Annex 1
23/00573-8	Scope of Services – Enclosure 4 – HSE Requirements
23/00573-9	Scope of Services – Enclosure 5 – Quality Management Requirements

Company and project documents

Key project and corporate documentation are listed in Table 6 below.

Table 6: Company and project documentation

Title
Project Execution Plan
Data Deliverables List
MBES Data Processing
SSS Data Processing
SBP Data Processing
Backscatter Data Processing
Processing Flow – Energinet Geophysical survey

Other references

Other references relevant to the project are listed below.

Table 7: Other references

Title	Type
SN2023_027_KG_ECR2_Export_cable_route_v1.shp	RPL shapefile
BE5950H-771-MP-02-2.0_Kattegat Geo Ocean IV Noise Monitoring logs	Noise Monitoring Logs
EMODnet	Online database
GEOxyz (2024), Geophysical Surveys for Danish Offshore Wind 2030, Kattegat II, BE5376H-711-02-RR, Rev.3.0	GEOxyz report
HELAS	Online database
Jensen, J. B., Petersen, K. S., Konradi, P., Kuijpers, A., Bennike, O., Lemke, W. & Endler, R. 2002: Neotectonics, sea-level changes and biological evolution in the Fennoscandian Border Zone of the southern Kattegat Sea. Boreas, Vol. 31, pp. 133–150. Oslo.	Academic paper
Larsen G., et. al. (1995) A guide to engineering geological soil description. DGF-Bulletin 1. Danish Geotechnical Society	Book
National drilling database (Jupiter database), GEUS. Borings DGU 550711.12, DGU 550711.18, DGU 560722.3 https://data.geus.dk/Jupiter-WWW/index.jsp	Online database

Project reports

Table 8 lists all the reports delivered as part of this survey, with this report highlighted in bold.

Table 8: Project reports

Title	Type of Report
Mobilisation and Calibration Report - Geo-X	Mobilisation and Calibration Report
Mobilisation and Calibration Report - GSXVII	Mobilisation and Calibration Report
Mobilisation and Calibration Report – GSV	Mobilisation and Calibration Report
Mobilisation and Calibration Report - GOIV	Mobilisation and Calibration Report
DOW2030 KG_ECR2_OPS_Report_Offshore_Survey_Geophysical-rev1.2	Operational Report
DOW2030 KT_ECR2_OPS_report_Nearshore_survey_Geophysical-rev1.2	Operational Report
Danish Offshore Wind 2030 - WPC, Kattegat, Operational Report, Rev. 00, 2024-04-17	Geotechnical Operational Report
DOW 2030 - WPC, Kattegat, Factual Report, Rev. 01, 2024-10-28 REPORT	Geotechnical report
MMO-PAM Report Kattegat Geo Ocean IV	Offshore MMO/PAM Report
OSC_2023_Geophysical_Vesselbased_v2.2, OSC_2024_Geophysical_Landbased_v2.7, OSC_2023_Geophysical_GEOXVII_v1.5	Nearshore MMO/PAM Report
BE5950_LiDAR_Production_Report	Topographic Report
Kattegat – Cable Route Integrated Report	**Results report**

3 GEODETIC PARAMETERS AND TRANSFORMATIONS

3.1 HORIZONTAL DATUM

The datum parameters for the survey are described in Table 9 and the projection parameters are given in Table 10.

Table 9: Datum parameters

Parameter	Details
Name	European Terrestrial Reference System 1989 (ETRS89)
EPSG Datum Code	6258
EPSG Coordinate Reference System	4258
Spheroid	GRS80
EPSG Ellipsoid Code	7019
Semi-Major Axis	6378137.000
Semi-Minor Axis	6356752.314140
Flattening	1/298.2572221010
Eccentricity Squared	0.00669428002290

Table 10: Projection parameters

Parameter	Details
Area of Use	North Sea Kattegat II
EPSG Coordinate Reference Code	25832
EPSG Map Projection Code	16032
Projection	UTM
UTM Zone	32N
Central Meridian	9° East
Latitude of Origin	0°
False Easting	500000.00 m
False Northing	0.00 m
Scale Factor at Central Meridian	0.9996
Units	Metres

3.2 VERTICAL REFERENCE

The vertical datum for the project is Mean Sea Level (MSL) as defined by the Technical University of Denmark geoid model DTU21MSL. Height data were acquired relative to the ellipsoid and reduced to the project vertical datum.

The onshore Datum for the project is defined as DVR90. However, the reporting for all onshore works was referenced as per the offshore datum.

3.3 SURVEY UNITS

The following survey units were used during the project:

- Linear units are expressed in international metres (m)
- Angular units are expressed in degrees (°)

3.4 TIME REFERENCE

Local time was used for record keeping during the project (including the Daily Progress Reports unless stated otherwise). The vessel(s) also maintained local time for operations.

Data time-tagging and synchronization used UTC (Universal Time Coordinated). All data recorded in the online navigation software was time stamped where appropriate using the time string and the pulse-per-second (PPS) from the GNSS.

4 SURVEY RESOURCES

4.1 SURVEY VESSELS

4.1.1 Offshore geophysical survey

For the geophysical surveys, the survey vessel Geo Ocean IV (GOIV) was utilised to complete the work across the offshore cable route survey area. The specifications of the GOIV are summarised in Table 11.

Table 11: Survey vessel specifications

Geo Ocean IV	Specifications	
	Owner:	GEOxyz
	Length:	41.9 m
	Width:	9.1 m
	Maximum draught:	5.53 m
	Cruising speed:	5 knots
	Propulsion:	High screw CP-propeller
	Endurance:	24 h day operations (20 days)
	Accommodation:	23

4.1.2 Nearshore geophysical survey

Survey operations for nearshore area were carried out using the Geo X, Geo Surveyor XVII (GSXVII), and Geo Surveyor V (GSV). Specifications of the utilized vessels are presented in Table 12, Table 13, and Table 14.

Table 12: Survey vessel specifications

Geo Surveyor XVII	Specifications	
	Owner:	GEOxyz
	Length:	17.8 m
	Width:	7.4 m
	Maximum draught:	2.54 m
	Cruising speed:	5 knots
	Propulsion:	Fixed pitch propellors
	Endurance:	12 h day operations
	Accommodation:	15

Table 13: GSV survey vessel specification

Geo Surveyor V	Specifications	
	Owner:	GEOxyz
	Length:	7.2 m
	Width:	2.45 m
	Maximum draught:	0.75 m
	Cruising Speed:	5 knots
	Propulsion:	2x outboard motorblock
	Endurance:	< 12-hour operations, day vessel
	Accommodation:	6

Table 14: Survey vessel specifications

Geo X	Specifications	
	Owner:	GeoGroup
	Length:	16.5 m
	Width:	4.8 m
	Maximum draught:	1.5 m
	Cruising speed:	14 knots
	Propulsion:	Main diesel engines MAN 2 x 325 kW; Aux Engine 28 kVA
	Endurance:	24 hr (2x 12 hr shift pattern)
	Accommodation:	4

4.1.3 Landfall topographic survey

Lidar data on the landfall was acquired by the sub-contractor Field. More details on the acquisition of the topographic data can be found in the Topographic Operations Report (Ref. “BE5950_LiDAR_Production_Report.pdf”).

4.1.4 Geotechnical survey

The geotechnical activities were carried out from the Dynamic Positioning (DP II) vessel Connector, supplied by Geo DK, presented in Table 15.

.

Table 15: DP II Connector vessel specifications

Connector	Specifications	
	Owner	GeoDK
	Length	90.2 m
	Width	7.0 m
	Maximum draught	5.53 m
	Cruising speed	16 knots
	Propulsion	Fixed Pitch Propellors
	Endurance	24 h day operations (20 days)
	Accommodation	60

4.2 SURVEY SYSTEMS

The survey equipment used onboard the vessel GOIV are listed in Table 16.

Table 16: GOIV geophysical survey equipment specifications

System	Manufacturer – Model	Equipment Specifications
GNSS	2 x Trimble BX992 (1 x XP2 and 1 x G4 corrections)	RTK: < 0.05 m; DGNSS: <0.10 m
INS (motion, heading)	IXBlue Phins II / Octans IV	H: 0.05°; R&P: 0.01°; Heave: 0.05 cm
SVP	Valeport – Swift	0.02 m/s
MBES	Kongsberg 2040, dual head, dual swath system	Freq: 200 - 400 kHz Focus: 0.4° x 0.7° at 400 kHz
USBL	Kongsberg HiPAP 351p	0.02 m range detection accuracy or < 0.3% of slant range
Magnetometer	Geometrics G882	Accuracy: < 2nT throughout range. Freq: up to 40Hz
SSS	Edgetech 4200MP 300/600/900kHz	Horizontal beamwidth: 0.5°@300 kHz, 0.26°@600 kHz, 0.3°@900 kHz Resolution Across Track: 3 cm@300 kHz, 1.5 cm@600 kHz, 1 cm@900 kHz
SBP	Innomar SES-2000 Medium	3.5-15 kHz 1-5 cm resolution
Grab	Day grab/Dual Van Veen grab	1 x 0.1 m^2 Sample size

The Geo Surveyor XVII vessel was mobilized with the equipment listed in Table 17.

Table 17: Geo Surveyor XVII geophysical survey equipment

System	Manufacturer – Model
GNSS	Stema 982 POE
INS (motion, heading)	SBG Apogee
SVP	Valeport Swift
MBES	R2Sonic 2024

System	Manufacturer – Model
USBL	Sonardyne Mini Ranger 2
Magnetometer	Geometrics G882
SSS	Edgetech 4200 series (300/600 kHz)
SBP	Innomar SES-2000 Standard

The Geo Surveyor V vessel was mobilized with the equipment listed in Table 18.

Table 18: GSV survey equipment

System	Manufacturer – Model	Equipment specifications
Primary GNSS	Trimble BD992-INS	Horizontal: RTK: 0.008m; DGNSS: 0.25m Vertical: RTK: 0.015m; DGNSS: 0.50m
INS (motion, heading)	iXblue Phins II	Hdg: 0.01°; roll & pitch: 0.01°; heave: 2.5 cm
SVP	Valeport Swift	0.02 m/s
MBES	Edgetech 6205 s2	Freq: 520 kHz
Magnetometers	Geometrics G-882 magnetometer	Accuracy: < 2 nT throughout the range. Sampling rate: up to 20 Hz
SSS	Edgetech 6205 s2 (520/850 kHz)	Horizontal beamwidth: 0.36° @ 520kHz, 0.29° @ 850 kHz Resolution Across Track: 1cm @ 520 kHz, 0.9cm @ 850 kHz
SBP	Innomar SES-2000 Medium	2-22kHz - 1-5cm resolution

The GEO X vessel was mobilized with the equipment listed in Table 19.

Table 19: Geo X survey equipment

System	Manufacturer – Model
GNSS	Septentrio AstRx-m2a RTK-
MRU	iXBlue Hydrins
Gyrocompass	iXBlue Hydrins
SVS	N/A
SVP	Valeport – Swift
MBES	T50-R IDH
SSS	Edgetech 4200 300/900kHZ
SBP	Innomar SES Quattro
Mag	G882 magnetometer
USBL	Sonardyne Mini Ranger II
Grab	Van Veen Grab

The equipment onboard the Connector vessel is listed in Table 20.

Table 20: Connector survey equipment

System
POSMV Ocean master INS navigation system, with GNSS aided gyro
POSMV IMU (type 320)
Trimble BX992 navigation system, with GNSS heading
TSS IMU on CPT platform
CPTU/VC rig, GeoCeptor

An overview of the equipment used to acquire the topographic lidar data is presented Table 21 below.

Table 21: Topographic survey equipment

System	Manufacturer – Model
Vessel	Cessna 208B Grand Caravan LN-TER
LiDAR sensor	Teledyne Optech CZMIL SuperNova
GNSS	Trimble Applanix POS AV 610 med PPRTX
Digital camera	Phase One iXM-RS 150F

4.3 SOFTWARE

The primary software installed on the Geo X, Geo Ocean IV, Geo Surveyor V, and Geo Surveyor XVII used to acquire and process the data is listed in Table 22.

Table 22: Primary software list

Type	Software	Related equipment
Acquisition	QPS QINSy	Navigation, MBES, GNSS, SSS, MAG
	Beamworx NavAQ	Navigation, MBES, GNSS, MAG
	Edgetech Discover	SSS Edgetech
	Innomar SESwin	SBP
Processing	Beamworx Autoclean	MBES
	QPS Qimera	MBES
	QPS FMGT	Backscatter
	Sonarwiz	SSS
	Oasis Montaj	MAG
	Silas	SBP
	QGIS	GIS
	TerraPos, vendor, Terrasolid	Lidar

4.4 TOWED PASSIVE ACOUSTIC MONITORING SYSTEM

The PAM System is a stand-alone marine mammal acoustic system for the accurate detection and monitoring of marine mammal vocalisations. The system is towed and utilizes high bandwidth hydrophones to identify and track whale, dolphin and porpoise species.

Towed passive acoustic monitoring system was used in all area's when visibility was reduced and during hours of darkness to establish the presence of marine mammals prior to the commencement of acoustic geophysical operations.

4.5 MARINE MAMMAL REPORTING AND ANALYSIS

GEOxyz provided a full survey report of the findings from the visual surveys and subsequent interpretation (Ref. "MMO-PAM Report Kattegat Geo Ocean IV") for the offshore scope, and for the nearshore scope: "OSC 2023 Geophysical GEOXVII", "OSC 2023 Geophysical Landbased", "OSC 2023 Geophysical Vesselbased", "OSC 2023 MarineMammalFormsGeoX", "OSC 2023 MarineMammalFormsGSV", "OSC 2023 Marine Mammal Recording Form Geo17", "OSC 2023 Noise Monitoring Geo17", "OSC 2023 Noise Monitoring GeoX", "OSC 2023 Noise Monitoring GSV").

4.6 GENERAL SURVEY TIMELINE

A summary of the survey operations is listed in Table 23 below. More details on the mobilization and survey operations can be found in the Mobilisation and Calibration Reports and Operations Reports, respectively.

Table 23: General survey timeline

Section	Vessel	Dates	Activity
Offshore	Geo Ocean IV	02/10/2023 – 08/10/2023	Mobilisation and calibrations
		01/11/2023 – 11/11/2023	Geophysical operations
		25/11/2023 – 27/11/2023	
		16/12/2023 – 17/12/2023	
		17/12/2023	Demobilisation
Nearshore	Geo Surveyor XVII	18/09/2023 – 22/09/2023	Mobilisation and calibrations
		28/09/2023 – 08/10/2023	Geophysical operations
		09/10/2023	Demobilisation
	Geo X	08/08/2023 – 21/08/2023	Mobilisation and calibrations
		11/09/2023 – 18/09/2023	Geophysical operations
		20/09/2023	Demobilisation
	Geo Surveyor V	04/08/2023 – 06/08/2023	Mobilisation and calibrations
		30/08/2023	
		31/08/2023 – 06/09/2023	Geophysical operations
		06/09/2023	Demobilisation
Geotechnical	Connector	04/03/2024 – 08/03/2024	Mobilisation and calibrations
		20/03/2024 – 21/03/2024	Geotechnical operations
		22/04/2023	Demobilisation
Topographic	Cessna 208B Grand Caravan	01/06/2024	Geophysical operations

5 DATA PROCESSING AND WORKFLOW

5.1 LIDAR

5.1.1 Data acquisition

Lidar data were acquired using the Cessna 208B Grand Caravan LN-TER with a Phase One iXM-RS 150F camera. More details can be found in the topographic operations report (Ref. "LiDAR Production Report.pdf").

5.1.2 Processing

Processing of navigation data was performed with the TerraPos software. Observations from inertia sensor (IMU) and GNSS were combined in a Kalman filter by so-called "tightly coupled" processing. Together with a subsequent backward filter recursion ("RTS-smoother"), it provided a statistically optimal parameter estimation.

Using the vendor's software, a point cloud was generated. The resulting LAS-files was first outputted in WGS84 deliverables and later transformed to the project's projection.

To make the final deliverables, the laser data were processed by classifying the point cloud to isolate hits on seabed and ground. The lidar data were classified as follows:

1) Unclassified
2) Ground
7) Noise
40) Seabed
41) Water surface
45) Unclassified bathymetric points (seaweed, objects, etc.)

Terrasolid OY software was used for point cloud classification and deliverables generation, while QGIS software was used to handle shapefile attributes. Finally, orthophoto mosaics were produced.

5.1.3 Data quality assessment

Not all 0.25 cm grid cells had lidar points which resulted in many nodata cells in the gridded output. Nodata values were set to -9999 in the GEOTIFF delivery.

5.2 MULTIBEAM ECHOSOUNDER

5.2.1 Data acquisition

Bathymetric data was acquired following the Special Order, as defined in the IHO standard S-44, with the additional specifications listed in Table 24 below.

Table 24: MBES specifications

Item	Client specification
Data density	16 hits/m^2
MBES mode	Equi-distant
Gridded	0.25 m cell size
Hit count survey	4 hits per 0.25 m^2 after processing (97.5 % of site)
THU/TVU	Follow IHO special order
Coverage	100 %
Target size detecting	1 m (height, width and length)

The MBES acquisition setting onboard are outlined in Table 25, Table 26, Table 27, and Table 28, split per vessel.

Table 25: GOIV MBES acquisition settings

General parameters		
System type	Kongsberg 2040, TX, dual RX, dual swath	
Survey speed	4.2 knots	
Frequency	400 kHz	
Bottom sampling	High density dual swath (1024 beams)	
Coverage swath	50 m	
Power	Maximum	
Pulse length	Auto	
Calibration parameters	**Head 1 Rx port**	**Head 2 Rx stbd**
Pitch	0.577°	0.322°
Roll 1	-39.464°	41.014°
Roll 2	-39.564°	41.172°
Heading	-2.118°	-0.768°
Sector width	70°	70°
Ping rate	13 Hz (WD 40 m), dependent on range	

Table 26: Geo X MBES acquisition settings

General parameters	
System type	Teledyne Reson Seabat T50-R
Survey speed	Average 4.5 knots
Frequency	400 kHz
Bottom sampling	Equi-distant (1024 beams)
Range	Variable
Power	193 db
Pulse length	50 µs

General parameters	
Patch test roll	-2.30°
Patch test pitch	-1.66°
Patch test heading	0.99°
Sector width	100-120° depending on WD
Ping rate	25 Hz, fixed

Table 27: GSV MBES acquisition settings

General parameters	
System type	Edgetech 6205 s2
Survey speed	Average 4.5 knots
Opening angle	55-60 degrees
Power	Maximum
Pulse length	Auto
Beam spacing	Equidistant
Number of beams	2 x 400
Trigger	External trigger (slave) from SBP to avoid interference

Table 28: GSXVII MBES acquisition settings

General parameters	
System type	R2Sonic 2024
Survey speed	Average 4.5 knots
Frequency	400 kHz
Bottom sampling	High Density
Range	25 m
Power	200 dB
Pulse length	Auto
Sector width	90° – 120° depending on water depth
Ping rate	Pending on water depth – 15-25 Hz

5.2.2 MBES processing

All MBES data were processed following the below steps outlined in Table 29 to Table 32. Figure 7 displays the general MBES processing workflow. A processing checklist was populated while processing.

Table 29: Data import into Qimera and initial QC

Step 1	Data import Qimera and QC
1.1 Set Up Project	Load in RAW multibeam files (*.db) as recorded by QINSy in a new project, grid cell size 0.25 x 0.25 m

Step 1	Data import Qimera and QC
1.2 QC of coverage	Check completeness of data by cross-referencing the imported files with the Survey Log.
1.3 QC of Raw data	Check the update rate and accuracy of Gyro/MRU data. Check for systematic noise (i.e. interference). Check for any positioning jumps/inconsistencies.

Table 30: Positioning QC

Step 2	Positioning QC
2.1 SVP correction	Applying the most recent SVP into the data set. Consider using the 'Nearest in time' or 'Nearest in distance' sound velocity strategy in Qimera.
2.2 Comparison with old data set	Compare the positioning with previous data set of the area. Check if there is any mismatch in the overlap parts with the adjacent blocks.
2.3 Create full block surface	Generate a dynamic surface at 1 x 1 m cell size.
2.4 Overall statistics	Run Standard Deviation statistics. The standard deviation must be < 0.25 m, unless exceeded due to the significant changes in the seabed morphology.
2.5 Create positioning QC surfaces	Generate THU and TVU surfaces from the 1 x 1 m grid.
2.6 Verify horizontal positioning and THU	Apply the correct colour map and review the data to make sure the horizontal positioning quality is within the client specifications. The surface needs to be updated and a new export can be done.
2.7 Verify vertical positioning and TVU	Apply the correct colour map and review the data to make sure the vertical positioning quality is within the client specifications. The surface needs to be updated and a new export can be done.

Table 31: Data de-spiking

Step 3	Data de-spiking
3.1 Manual De-spiking	Manually remove remaining substantial spikes using the 2D / 3D views and the slice editor. Correct where necessary.
3.2 Filter De-spiking	Run any filter profiles to provide an optimal surface, ensuring the features and the data density are not affected by filter (filter profiles to be adjusted and optimised by processor).
3.3 SVP refraction correction	Apply any required SVP refraction corrections.

Table 32: Data QC

Step 4	QC
4.1 Coverage Gaps	Ensure there are no gaps caused by excessive manual or filtered de-spiking.
4.2 Shallowest/Deepest Areas	Special attention is needed for these areas to verify all spikes are removed.
4.3 Check for steps in data	Change plan view to the mean depth colour data to verify no steps are present in the data.
4.4 Statistics Control	Run Standard Deviation, Density, Total Horizontal Uncertainty (THU) and Total Vertical Uncertainty (TVU) statistics. The standard deviation must be < 0.25 m and density ≥ 16 hits per 1 m^2. Ensure the THU and TVU requirements are met (depth dependant).

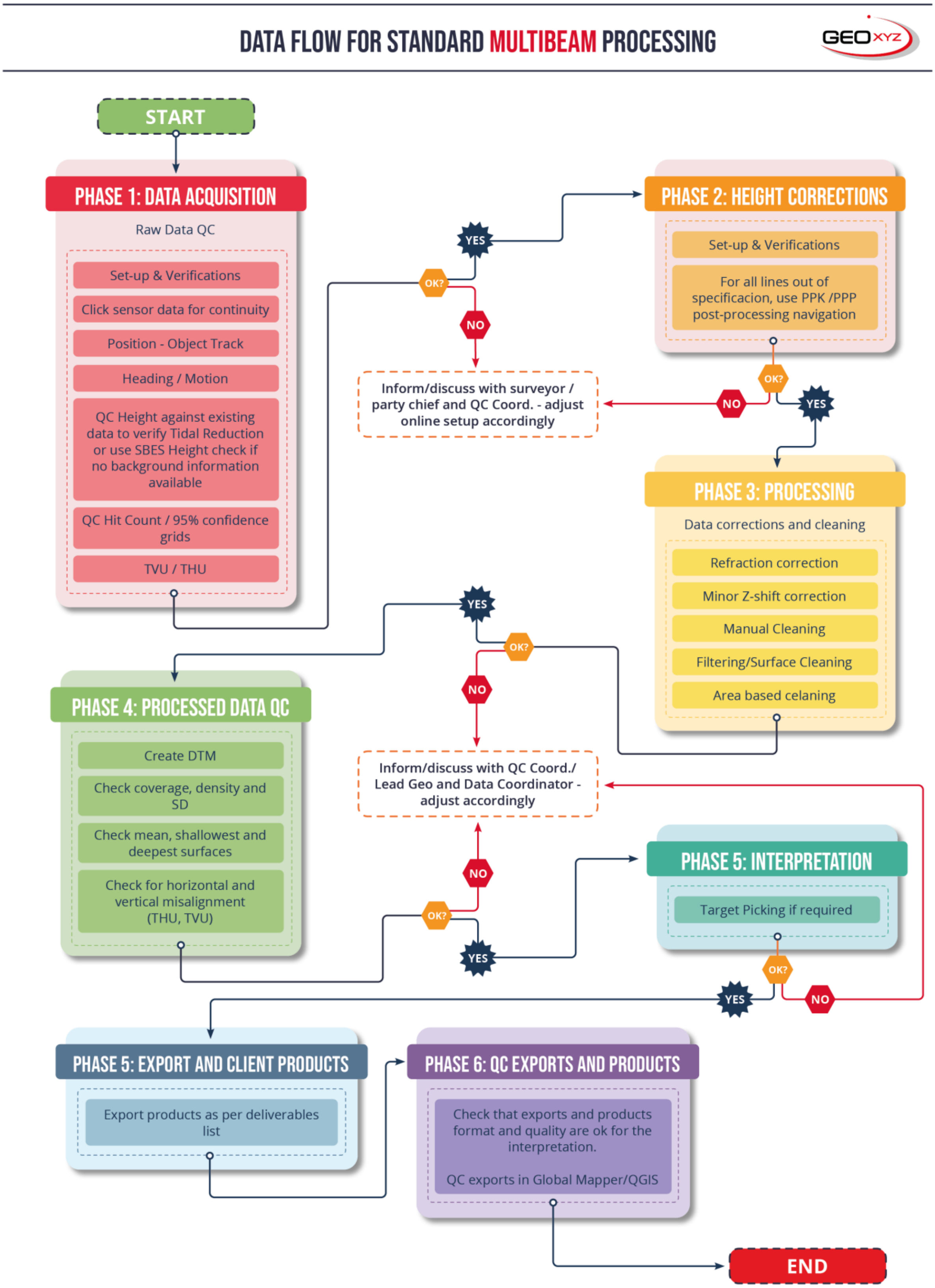


Figure 7: MBES processing workflow

Backscatter data were recorded on all lines and the data were processed and delivered with all other digital deliverables. The backscatter data were processed and exported, using QPS Fledermaus GeoCoder Toolbox (FMGT) software.

Backscatter processing was carried out on the fully cleaned and processed MBES data files, from previous steps in the Qimera software. Combined GSF (both heads exported in the same file) were exported and then imported in FMGT along with a MBES reference surface.

The gain was modified to normalize the intensity over the survey area. It was also optimized to enhance changes in seabed sediment composition and morphological features on the seafloor.

5.2.3 MBES target picking

MBES target picking was carried out after processing, using the automatic tool in BeamworX AutoClean software. Only targets larger than 1 metre were flagged, and vessel names were added to the target IDs. The automatic picking was used to help define areas of boulder fields identifying boulders larger than 0.5m and then the automatic tool was used again to identify targets larger than 2m within the boulder fields.

Targets were detected based on a reference grid, which automatically measures the targets in Length x Width x Height. The detection process was fully automated and based on input parameters. These parameters could change per area depending on data quality, target numbers, size, and seabed complexity, but always in accordance with the specification of the project relative to minimum size and their interpretation as per TSG requirement. Detection and accuracy are greatly dependent on data quality. Artefacts such as thermocline, vertical alignment and complex morphology could impact the detectability of potential targets.

After running the detection process, a manual QC was conducted and any amendment were applied if needed e.g. false positives are removed, false negatives are added, and target dimensions were adjusted manually if required. The automated routine combined with a manual QC gave this output a reliable result.

Finally, a target correlation was done with the SSS and MAG contacts, and a final QC was done to ensure consistency on the target classification across the sites. SSS and MBES targets were correlated if within 2 m of each other (as per the positional accuracy specification of the project). MBES and MAG targets were correlated if within 5 m of each other.

5.2.4 MBES and backscatter data quality assessment

In general, the data quality for all the vessels and areas was good and within the project specifications. However, some issues were faced to achieve the final stage of the project deliverables. The following is a brief description of the quality of the data for each area and each vessel, as well as some examples of the problems encountered.

Geo X data

Good data quality was observed in both, MBES and backscatter. Slight differences in values scale compared against GOIV and GSXVII data, but within expectations as they are different vessels. These differences can be observed, before merging the backscatter data in Figure 8 (a) and after merging and normalizing the data in AutoClean in Figure 8 (b), both corresponding to KG_ECR2 block.

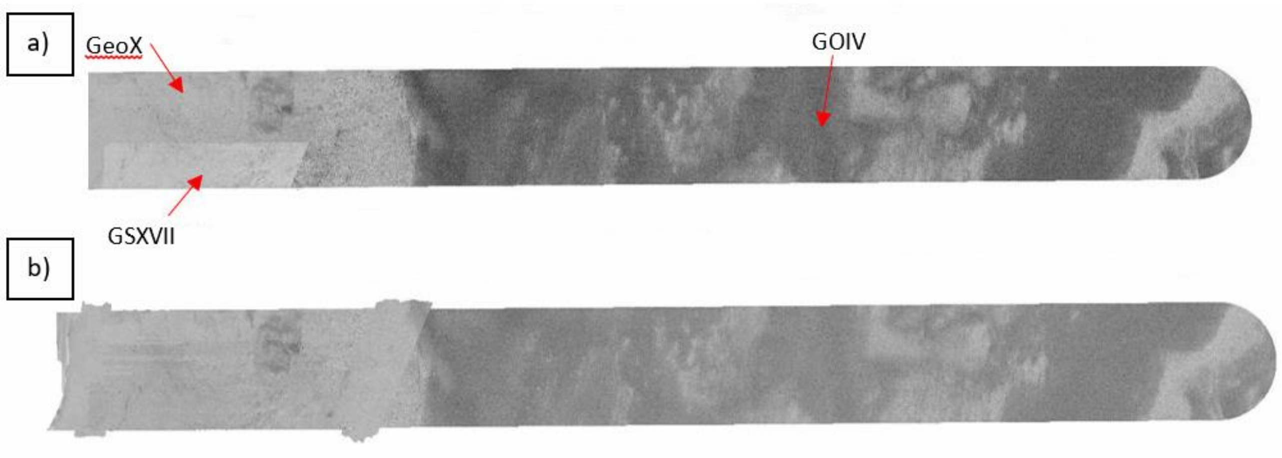


Figure 8: Differences in Backscatter before and after merging multi vessel data

Geo Surveyor XVII data

Good data quality was observed in both, MBES and backscatter. There were some areas where the vertical reference was changed from SBG (RTK) to Trimble (Marinestar), due to RTK lost, resulting in a worsening of THU and TVU values. In these areas, the TVU and THU were improved by processing the navigation in Qimera, changing the vertical referencing back from Trimble to SBG. Bathymetry data showed no problems and could be processed normally.

Geo Ocean IV data

Good data quality was observed in both MBES and backscatter.

Geo Surveyor V data

Overall, the data is of good quality. The data was noisier compared to the data obtained from deeper areas, yet this is to be expected given the characteristics of the ship and the shallow depth of the nearshore part. Given the characteristics of the coupled system (MBES-SSS), the backscatter data came from SSS raw files, resulting in a different values scale compared to backscatter from MBES of the rest of vessels.

The THU and TVU coverage maps of the survey area are displayed in Figure 9 and Figure 10, respectively.

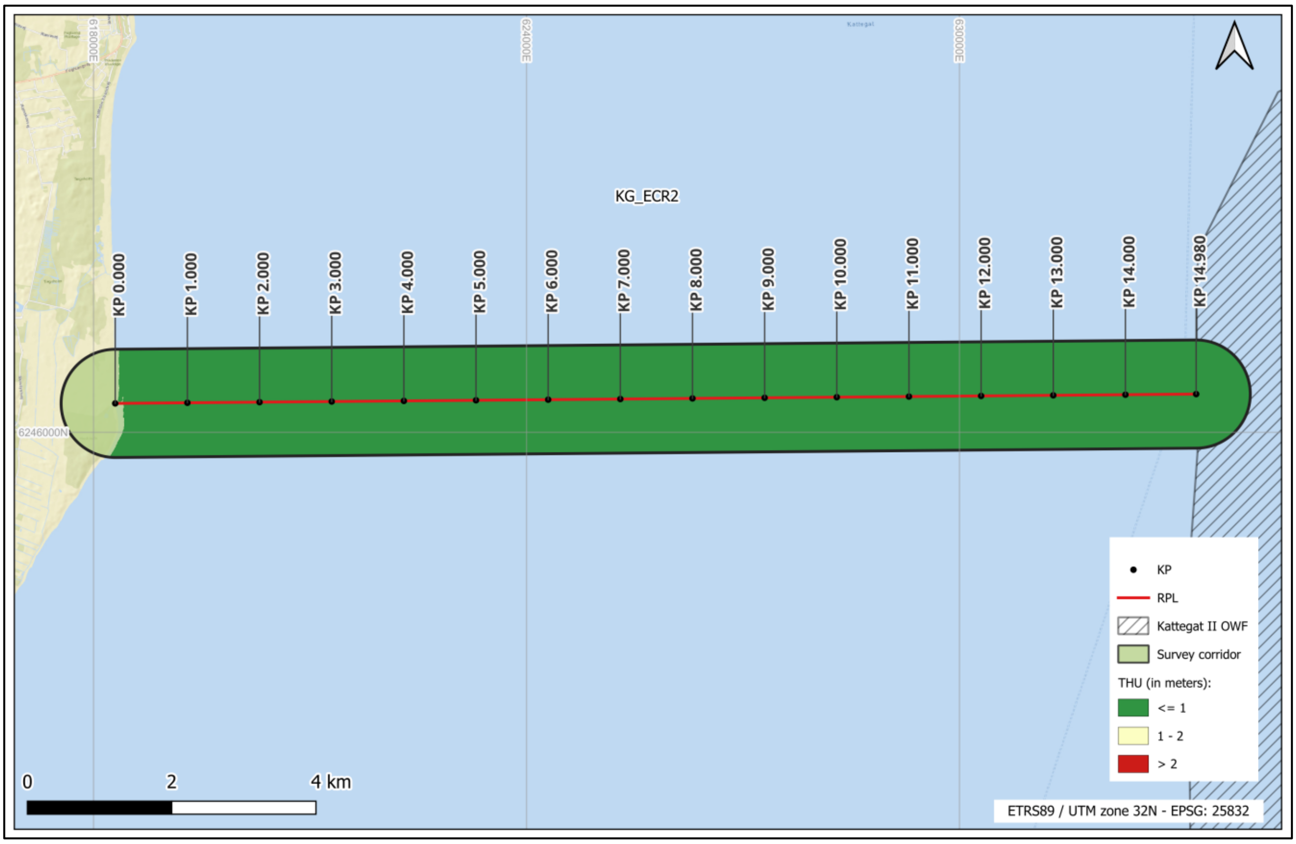


Figure 9 : THU coverage map of the survey area

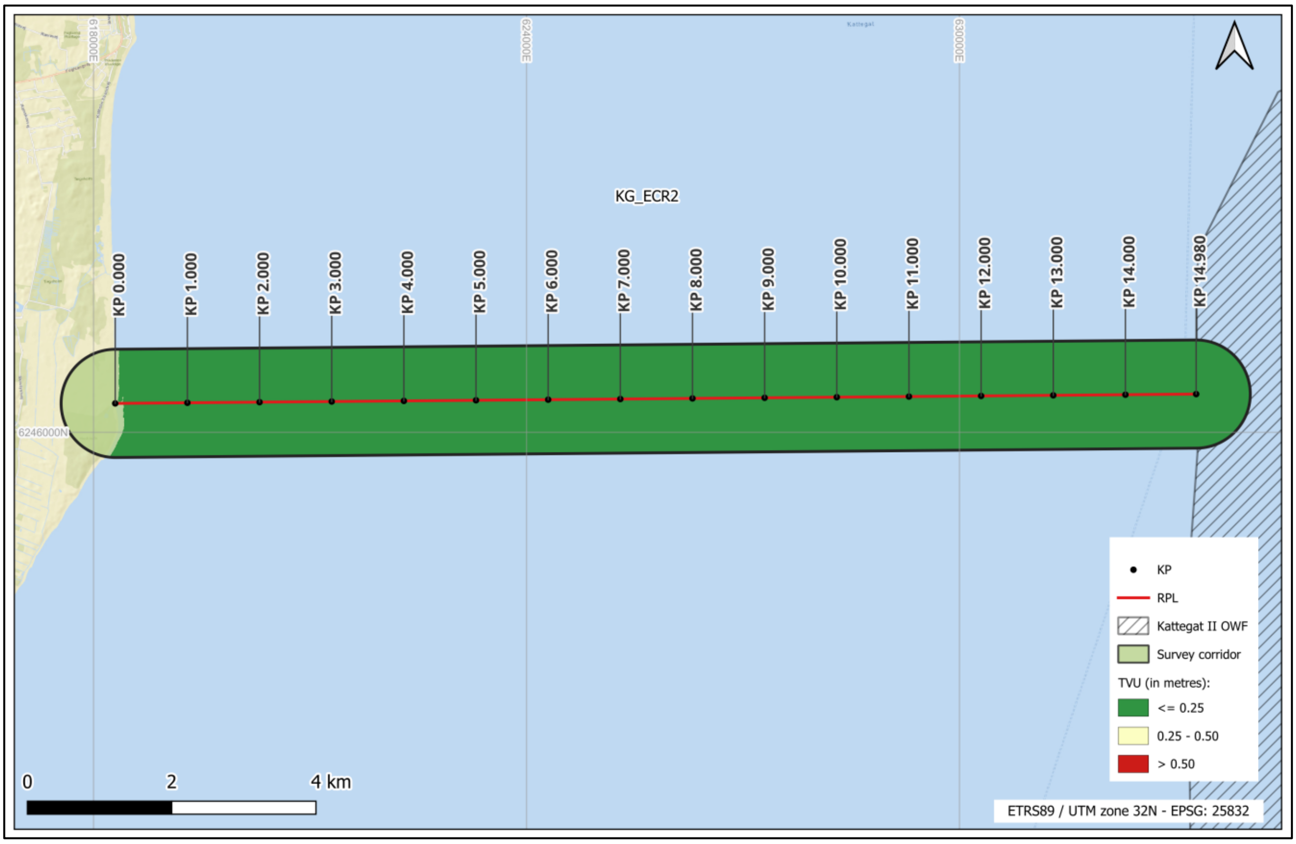


Figure 10: TVU coverage map of the survey area

5.3 SIDE SCAN SONAR

5.3.1 Data acquisition

Side Scan Sonar (SSS) data was acquired following specifications listed in Table 33 below.

Table 33: SSS specifications

Item	Client Specification
Low frequency	1 m
High frequency	0.1 m
Coverage	200 %
Target picking	1 m (height, width and length)
Position accuracy	±2 m (using vessel course-over-ground and USBL) between SSS lines and compared to MBES
SSS range	70 m
Frequency SSS use	Dual frequency 300/600 kHz

The primary SSS system settings used for the project are outlined in Table 34, Table 35, Table 36, and Table 37, split per vessel.

Table 34: SSS acquisition settings – GOIV

Item	Settings
System type	Edgetech 4205MP 300/900kHz
Survey speed	Average 4.5 knots
Positioning	HiPAP 351 USBL
Mean fish altitude	8-12 % of sonar range
Trigger	High frequency = master
TVG/Gain	Recording RAW (*.jsf)
Range	75 m/55 m
Mode	High Definition mode

Table 35: SSS acquisition settings – GSXVII

Item	Settings
System type	Edgetech 4200 series (300/600 kHz)
Survey speed	Average 4.5 knots
Positioning	Sonardyne Mini Ranger 2
Mean fish altitude	10 % of range – 3.5 m
Trigger	High Frequency = Master
TVG/Gain	Recording RAW (*.jsf)
Range	HF = 35 m / LF = 35 m
Mode	High Definition Mode

Table 36: SSS acquisition settings – GSV

Item	Settings
System type	Edgetech 6205 s2 (520/850 kHz)
Survey speed	Average 4.5 knots
Positioning	GNSS
SSS altitude	Pole mounted
Trigger	External trigger (slave) from SBP to avoid interference
TVG / gain	Recording RAW (*.jsf)
Range	35 m

Table 37: Geo X SSS acquisition settings

Item	Settings
System type	Edgetech 4200 300/900kHz
Survey speed	Average 4.5 knots
Positioning	Sonardyne Miniranger II
Mean fish altitude	Between 3 -4 m
Trigger	High Frequency = Master
TVG / Gain	Recording RAW (*.jsf)
Range	HF = 35 m / LF = 35 m
Mode	High Definition Mode

5.3.2 SSS processing

SSS data were processed and interpreted using Chesapeake SonarWiz software. The SSS processing steps are outlined in Table 38 to Table 44.

Figure 11 outlines the SSS processing workflow used for the project.

Table 38: Importing SSS data into SonarWiz

Step 1	Importing data: overview of the acquired lines
Set up project	The raw sonar files (*.jsf) had corrected navigation applied, using the SonarWiz NavInjectorPro utility, before being imported into Chesapeake SonarWiz software. The navigation data was de-spiked and exported from QINSy validator, to provide a smoothed position, with a bearing to towpoint heading solution. The processed sonar files (*.jsf) were imported into the SonarWiz project with the appropriate file type specific settings, as those were determined during the mobilization and calibration tests. A smoothing filter of 100 pings was applied during import. Once the parameters were agreed and checked with the Employer's Offshore Supervisor, they were used for the remainder of the dataset.
Bottom track	Using the automatic bottom tracking feature, SSS data were bottom tracked, line by line, and then, if needed, bottom track was manually adjusted.

Table 39: Navigation correction in SonarWiz

Step 2	Navigation correction
Check position	The SSS data were checked for positional accuracy against the MBES data, by locating clearly distinguishable features and contacts in both datasets and comparing their positions. If needed, the navigation data were re-processed and re-exported from QINSy as new navigation files (x, y, heading) and injected into the SSS data, using the SonarWiz NavInjectorPro utility. After that, positional accuracy was checked again.
Navigation	The towfish heading source was set to the fish heading to tow point. Using the SonarWiz ZEdit utility, navigation spikes were corrected and the positional accuracy was checked. The towfish heading was QC'd for small data jumps or artifact "vortex" effects.

Table 40: SSS signal processing

Step 3	Signal processing
EGN (Empirical Gain Normalization)	An EGN (Empirical Gain Normalization) table was calculated and applied to the data, creating a normalised gain, both along track and across track.
TVG (Time Variable Gain)	If the EGN table applied to the data did not have the desired effect, an Auto TVG was used.

Table 41: SSS infill assessment

Step 4	SSS infill assessment
Manual check for gaps	Manual check for data gaps, overlap and data loss during QC/QA.
Check for pycnocline interference	Quality control check for pycnocline interference towards swath edges. Affected areas were marked for infill and re-run if required.
SonarWiz coverage	Checked for 200 % coverage (100 % nadir coverage for pycnocline-thermocline affected data), using SonarWiz Coverage report.

Table 42: SSS contact picking

Step 5	SSS target picking
Target picking	Must include: H-L-W measurements Description of the target Confidence level The interpretation of contacts was performed in SonarWiz digitizing mode, in accordance with the specifications. Contacts were digitized alongside MBES data and confidence level was updated accordingly. Wrecks and cables were correlated to relevant databases.
Criteria of object detection	Minimum of 1 m (height, width or length) Object is identified as deviation from natural seabed forms The object is verified in wing line side scan image Position is verified with MBES data Man-made objects or very clear objects (even if only detected on one line only) Contact classification criteria defined with the Reporting Coordinator and sent to the Data Coordinator onshore.
Image picture	Colour grey inverted
Confidence level (Low, Medium, High)	Every contact has a confidence level attributed to it based on its detection in: • 1 SSS line -> Low,

Step 5	SSS target picking
	• 2 or more SSS lines -> Medium • 1 or more SSS lines and MBES data -> High
Boulder fields	Within 50 m x 50 m area, the boulder zone defining criteria are: • 0 – 10 boulders: Not a boulder zone. Targets > 1 m in any direction picked. • 10 – 20 boulders: Intermediate boulder density. Targets > 2 m in any direction picked. • > 20 boulders: High boulder density. Targets > 2 m in any direction picked.

Table 43: SSS mosaic creation

Step 6	SSS mosaic creation (HF and LF)
Adjust SSS line drawing order	SSS lines drawing order was adjusted to optimize the exported seabed image
Line grouping	Lines were grouped in: Approved, Rejected, Trials or Other
EGN and gain check	Final QC of EGN and gains was performed. If required, new EGNs and gains were recalculated and reapplied.
Inter file gap check	Data was checked for small inter-file gaps. SonarWiz inter-file gap tool was used when required.
Range check	Range was adjusted for optimized quality without compromising the 200 % data coverage.
Mosaic export	SSS mosaics were exported using the standardised project tile size and arrangement.

Table 44: SSS seabed classification

Step 7	Seabed classification
Seabed features	Seabed features have been created and QC'd using the exported SSS LF mosaics. SSS HF mosaics and the MBES exports were also taken into account.
Seabed geology	The SSS LF and HF mosaics, as well as the MBES data and the SBP contours were used in order to outline the sediment differences, as those are represented by the reflectivity changes mainly on the SSS mosaics. Grab samples were the most useful for interpretation and confirming the outlined sediment boundaries

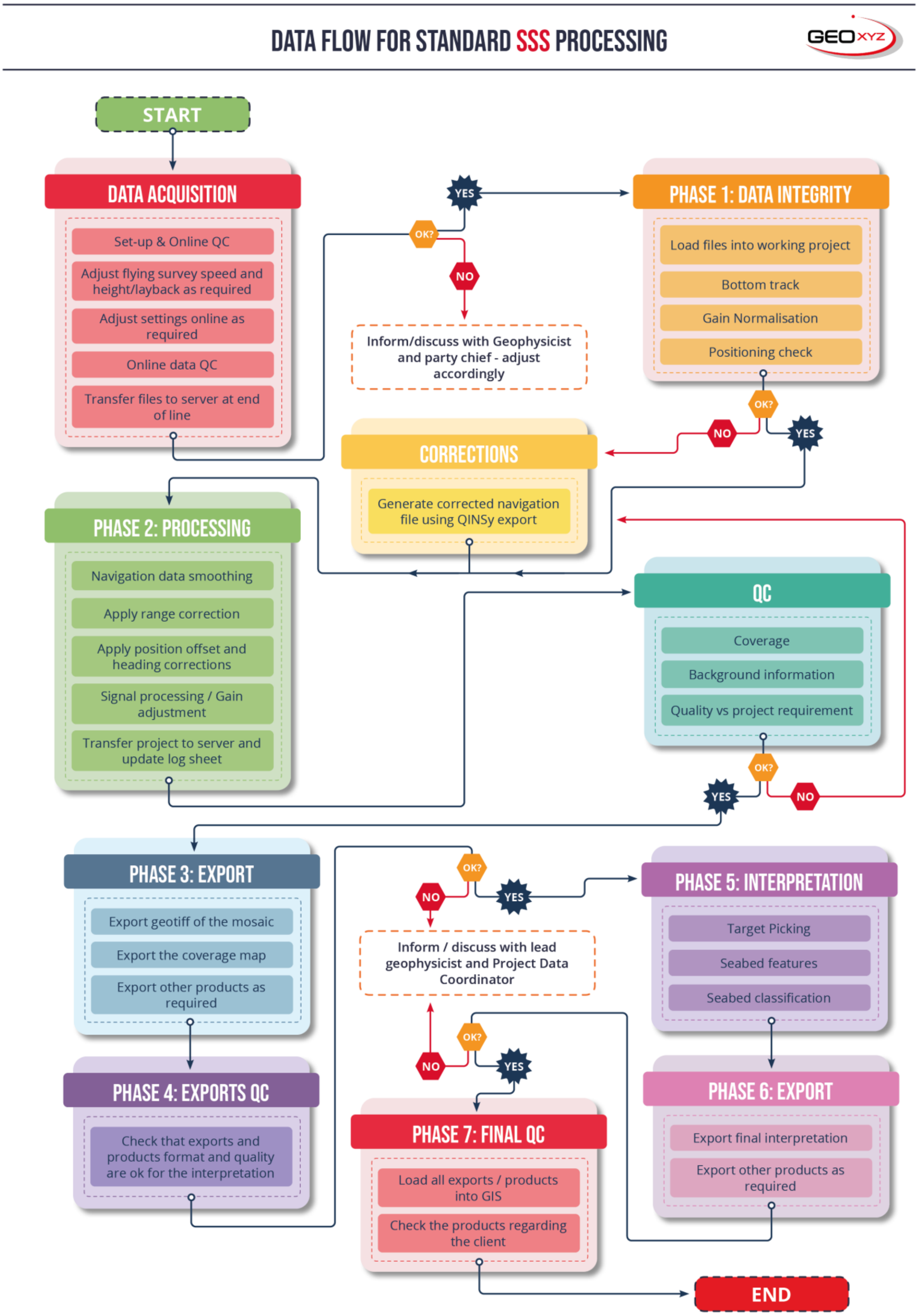


Figure 11: SSS data processing workflow

5.3.3 SSS target picking

As defined in TQ-012-Boulder Picking clarification:

- Boulders zones were mapped with the automatic tool for boulders > 0.5 m (height/length/width).
- Individual boulders/blocks within boulder zones were mapped with the automatic tool for boulders > 2 m (height/length/width).
- Rocks/blocks outside boulder zones were mapped by manual method on boulders > 1 m (height/length/width).
- Quality of automatic boulder picking tool was demonstrated with a comparison between automatic versus manually mapped boulders (Comparison is done in boulder field area 100 x 100 m).

Within 50 m x 50 m area, boulder zones were defined using the following criteria:

- 0 – 10 boulders = not a boulder zone. Targets > 1 m in any direction picked
- 10 – 20 boulders = intermediate boulder density. Targets > 2 m in any direction within the zone picked
- > 20 boulders = High boulder density. Targets > 2 m in any direction within the zone picked

The primary sensor for target identification was the MBES (in terms of positioning), as it has greater positional accuracy. Therefore, targets seen on MBES were classed as 'High' in confidence. SSS targets were classed 'Medium' when the targets were identified on multiple SSS lines and 'Low' confidence levels were assigned to targets which were only resolved within one SSS line.

SSS target measurements were determined in Sonar Wiz. The lengths and width are manually measured and the heights were automatically calculated within SonarWiz. The software takes into account the manually measured target shadow length, towfish altitude and range to auto- calculate the height. Due to limitations in the software, is possible that some target heights may exceed what is listed. Due to occasional stretching of the data in the far ranges, this sometimes results in elongated representation of contacts. Contact picking was verified over multiple lines and data where possible to report accurate measurements, however some elongated contacts may still be visiable within the mosaic.

The steps of target identification are presented in Table 45.

Table 45: Target identification workflow

Step	Procedure
1.	Once the MBES data was clean and ready, the AutoClean boulder picking algorithm was executed.
2.	The shapefile from AutoClean was extracted and imported into QGIS.
3.	In QGIS, a density function was applied to determine boulder field classification areas using Kernel Density estimation, resulting in a new raster hit map.
4.	The density hit map in QGIS was vectorised.
5.	Individual boulders larger than 2 metres within boulder areas and larger than 1 metre outside the boulder field polygons were filtered. The SSS automatic boulder picking script from Hidrocibalae was run.
6.	The results were imported into the SW project.
7.	Individual boulders larger than 2 metres within boulder areas and larger than 1 metre outside the boulder polygons were filtered. Individual boulders were plotted in QGIS.
8.	2-metre buffers around MBES-identified individual boulders were created, and SSS boulders that fall within these buffers were identified.

Step	Procedure
9.	Correlation between the MBES and SSS boulders in QGIS via a model was done.
10.	The same method was applied to MAG anomalies using the same technique with the residual grid.

The detection process, as presented in Figure 12, was performed on each individual SSS line, and for each target the automated detection yielded a polygon that outlines the reflection and a line that outlines the shadow. When requested to identify the same target from several SSS lines, a specifically developed tool compared target position and dimension on different lines and created average values for one representative target. This task was especially challenging inside high-density boulder fields where target reflection varied between the lines and shadows overlaps between contacts.

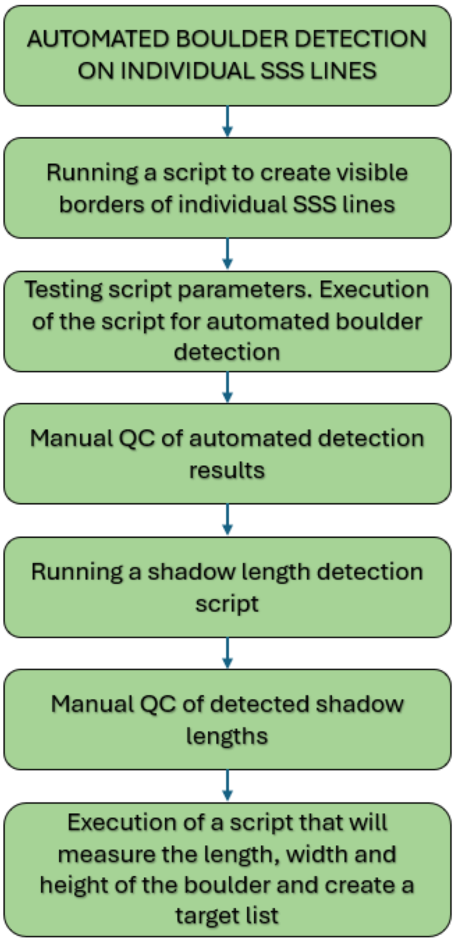


Figure 12: Automated boulder detection progress

A QC process was manually performed by a processor to check whether the detection results correspond to the real target by size and location, making adjustments if necessary to avoid false positive target detections. Manual quality control enabled the processor to ensure accurate and reliable detection results, adjust the results where needed, and improve the overall quality of the detection process.

Once the algorithm was run and the QC was finished, a SSS boulder shapefile was exported and correlated with the MBES and MAG contacts. SSS and MBES targets were correlated if within 2 m of each other. SSS and

MAG targets were correlated if within 5 m of each other. A final QC by the Lead Geo was done to assure the correct definition of contact.

5.3.4 SSS data quality assessment

Overall, the SSS data quality was monitored throughout the survey and was of high quality, achieving Client specifications. The data acquired by the Geo Surveyor V, Geo X, and Geo Surveyor XVII was of high quality and no significant presence of the pycnocline was observed. However, the presence of a pycnocline within the data obtained by the Geo Ocean IV resulted in marginal or reduced data quality in the outer range for few sections of SSS lines. The affected sections were removed during processing and good quality data was used for mosaic exports and target picking.

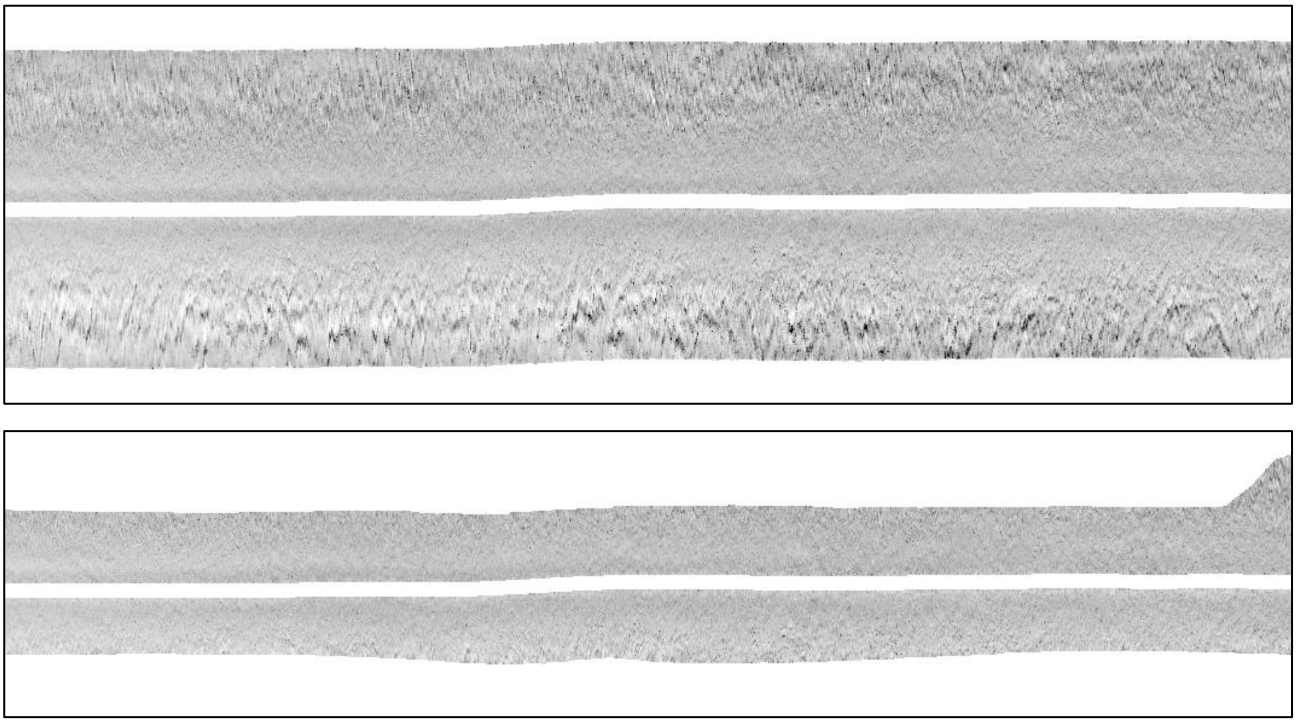


Figure 13: Pycnocline artefact before (above image) and after (below image) removal in the SSS dataset

Figure 14 below shows the achieved SSS data coverage within Kattegat ECR2.

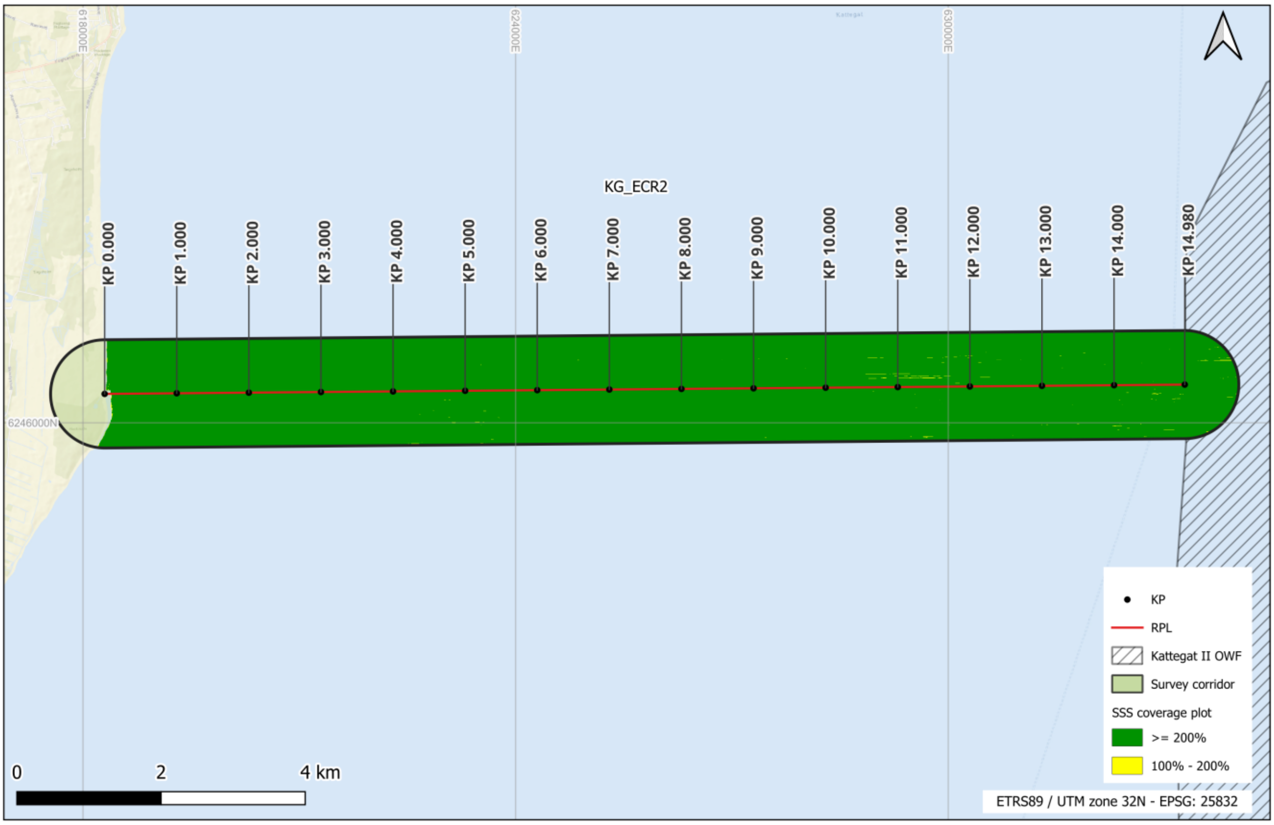


Figure 14: SSS coverage plot

5.4 MAGNETOMETER

5.4.1 Data acquisition

Magnetometer data was acquired following specifications listed in Table 46 below.

Table 46: MAG specifications

Item	Client Specification
Measurement sensitivity	0.01 nT
Seabed altitude(max)	≤ 5.0 m
Seabed altitude (min)	2 m
Coverage	100 % by line
Minimum nT target detecting	10 nT on analytical signal grid
MAG frequency	1-20 Hz (selectable)
Position accuracy	2.5 m in two lines in opposite direction (GEOxyz specs)
Noise level	≤ 2 nT
Blanking distance	5 m

The primary settings that were used onboard the GOIV, GSV, GSXVII and Geo X are presented in Table 47, Table 48, Table 49, and Table 50, respectively.

Table 47: MAG acquisition settings – GOIV

Geometrics G882	
Survey speed	4.2 knots
Positioning	HiPAP 351 USBL
Magnetometer altitude	Below 5 m
Frequency	10 Hz

Table 48: MAG acquisition settings – GSV

Geometrics G882	
Survey speed	Average 4.5 knots
Positioning	Layback
Magnetometer altitude	ca. 3 m
Frequency	10 Hz

Table 49: MAG acquisition settings - GSXVII

Geometrics G882	
Survey speed	Average 4.5 knots
Positioning	Sonardyne Mini Ranger II USBL system
Magnetometer altitude	Variable – similar or higher than SSS altitude, <5 m
Frequency	10 Hz

Table 50: Geo X MAG acquisition settings

Geometrics G882	
Survey speed	Average 4.5 knots
Positioning	Sonardyne Mini-ranger II USBL system
Mean fish altitude	Variable – similar or lower than SSS altitude
Frequency	10 Hz

5.4.2 MAG processing

The magnetometer data were processed using GeoSoft Oasis Montaj following the below processing steps:

- QC Raw Navigation
- Process Navigation
- Process Altitude
- Process Total Field / Calculate Residual
- Generate Final XY

Processing scripts with associated database views to easily QC the results were developed to streamline the magnetometer processing. Navigation and altimeter data were first de-spiked and smoothed. A residual was derived by subtracting a background field, derived using a set of non-linear and smoothing filters, from the Total field. Total field and residual grids were created using a cell size of 50 cm. From the residual grid an analytical signal grid was derived and was primarily used for target picking.

The processing steps used for the project are outlined from Table 51 to Table 56, while the general workflow is outlined in Figure 15.

Table 51: Magnetometer navigation processing

Step 1	Magnetometer navigation processing
Backup of "Easting" and "Northing"	The raw easting and northing were copied; all subsequent navigation processing were performed upon these copies.
De-spiking	Data windowed for survey site Non-linear filter applied, with a fiducial width of 5 (and tolerance of 1.5 m). The filter was used to remove small spikes present in the data.
Back up of smoothed navigation	The smoothed/interpolated/de-spiked data were backed up.
Projection	Project projection is set.
Distance	Calculates the total distance along the track for each fiducial.
Distance separation	The distance between each fiducial is calculated. This was done by applying a convolution filter to the distance. The settings were -1, 1, 0. The results were written to the *Dist_QC* channel. This helped to monitor the frequency (10 Hz) of the magnetometer, it helped to spot any "freezes" in the data acquisition. It was compared to the magnetometer signal. Any large jumps in distance separation could have caused a spurious anomaly or missed data.
Comparison	The raw navigation, de-spiked navigation, smoothed navigation, the distance separation and magnetometer signal had their profile plotted together within Oasis Montaj. This allowed the quality control (QC) of the navigation and its processing. The database view plots these profiles against each other.

Table 52: Magnetometer altitude processing

Step 2	Magnetometer altitude processing
De-spiking	The raw altitude was de-spiked. The filter stripped out any data spike that is above 5 m. This was done within Oasis Montaj using channel tools and channel mathematics.
Interpolation	The interpolation restored the gaps created by removing the altitude spikes. This was done using a linear interpolation, for gaps over ten fiducials (approximately 2 m).
Smoothing filters	A set of filters (low pass and B-spline) was applied to the de-spiked/interpolated altitudes to produce a smooth, more realistic values for altitude.
Alt cut-off	Clipped any data above 5 m and below 2 m.
Clip X and Y with Alt masked	Clipped the position according to the altitude cut-off.
Comparison	The raw altitudes, de-spiked, smoothed altitudes, averaged altitudes and smoothed average altitudes, the distance separation and magnetometer signal had their profile plotted together within Oasis Montaj. This allowed QC of the altitude and the processing.

Table 53: Magnetometer data QC

Step 3	Magnetometer data QC
De-spiking	A de-spiking filter was applied to the total magnetic TMF values.
Non-linear filtering	A non-linear filter was applied to attenuate any noise present in the data.

Step 3	Magnetometer data QC
B-spline smoothing	A "B Spline" filter was applied to the non-linear filter. This helped to make the signal to appear more realistic (smooth).
Copy mask of interpolated TMF values and poor magnetic signal to Easting and Northings	The stripped magnetic data is used to mask the eastings and northings. The data gaps that are present in the interpolated TMI (total magnetic interpolated) values were reintroduced by using these TMI values to mask the eastings and northings. This is done because original gaps may have been reduced due by the previous smoothing filters.
Comparison	All the processing steps for the TMI are plotted along with the magnetometer signal for QC.

Table 54: Magnetometer background calculation

Step 4	Magnetometer background calculation
Background	To obtain the background magnetometer signal, a series of non-linear filters were applied. These were as per GEOxyz's procedures. An additional geological filter was produced by using a variation of filter parameters to attenuate magnetic anomalies.
B-Spline	A "B Spline" filter was applied to the final non-linear filters to smooth the result.
Compare	The final data were compared with the raw data to identify over or under filtering of the data.

Table 55: Magnetometer residual field calculation

Step 5	Magnetometer residual field calculation
Residual (Anomalies)	Filtered magnetometer data minus the background signal (anomaly and geology).
Gridding	Data were gridded using Minimum Curvature with a cell size of 0.5 m and a blanking distance of 5 m.

Table 56: Magnetometer target picking

Step 7	Magnetometer target picking
Analytic signal	AS grids were produced using a 0.5 m cell size, blanking distance set at 5 m.
Target picking	Anomalies greater than 10 nT from the analytical signal were picked. MAG anomalies less than 10nT were kept only if they have a corresponding SSS target within 5 m. Residual field was checked against total field to help determine anomalies.
De-duplication of targets	Compare targets with Altitude and Residual and TMI profiles. Targets were de-duplicated as required.
Target list	Magnetometer target list was compiled, as per client requirements

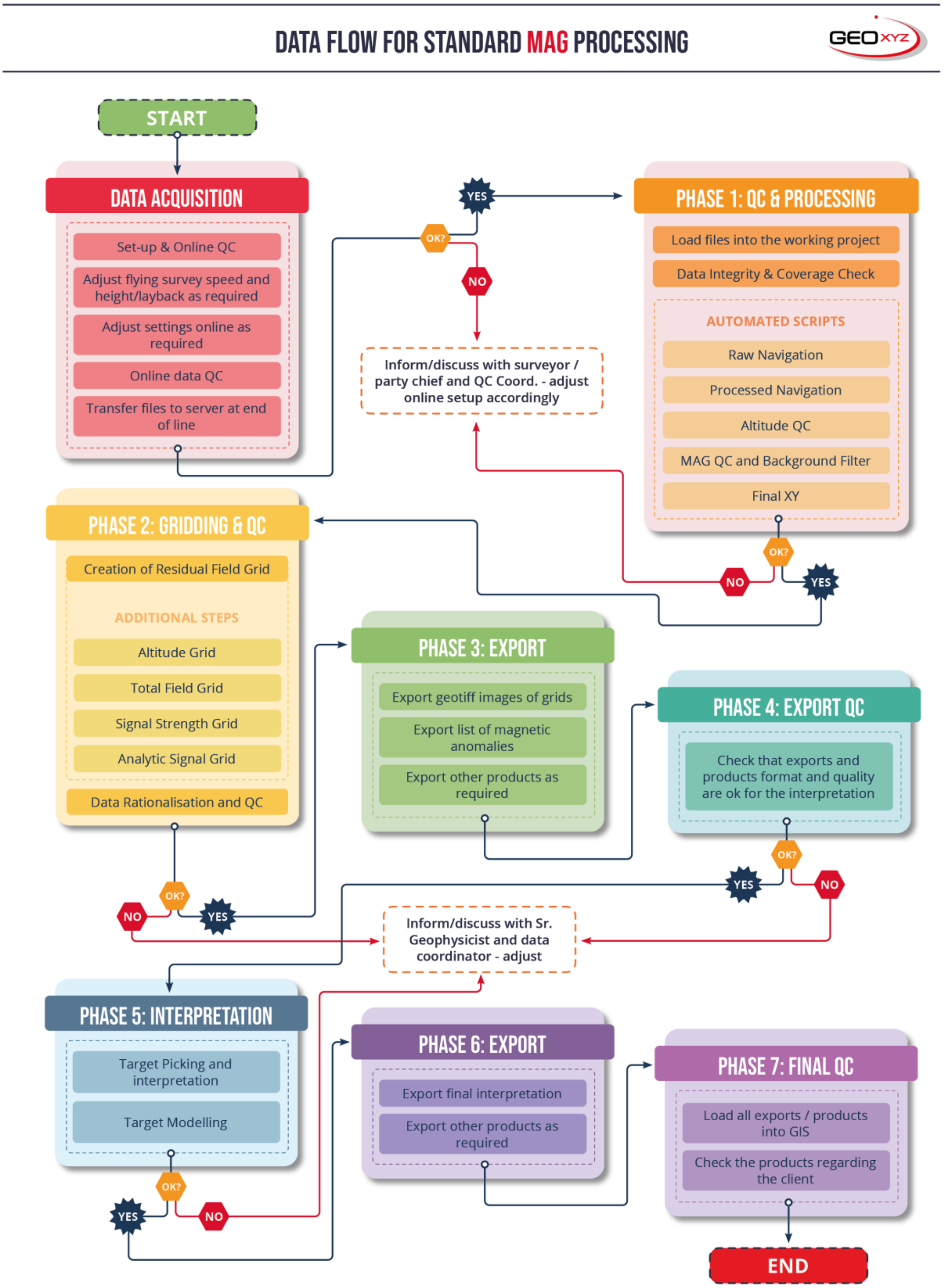


Figure 15: Magnetometer data processing workflow

5.4.3 MAG target picking

Magnetometer was used for screening larger ferrous objects, crossing cables, and pipelines. MAG list includes magnetic linear anomalies indicative of ferrous masses greater than 50 kg, including wrecks, potential UXO, fishing gear, man-made objects. Contact list was completed at the GEOxyz office and involves checking for all targets and seabed features mentioned above.

5.4.4 MAG data quality assessment

The data acquisition and processing Kattegat was successfully completed, with interim deliverables and backups produced on schedule. However, significant attention was required for post-processing and final deliverables on the nearshore data due to the presence of high geological noise across various zones. Despite applying the standard GEOxyz non-lineal filters and testing alternative magnetic background noise outputs, improvements were minimal. Consequently, an additional non-linear filter that follows the total field values closer, was applied.

The offshore data in Kattegat maintained high quality with no deviations from the normal processing workflow.

5.5 SUB-BOTTOM PROFILER

5.5.1 Data acquisition

SBP data was acquired following specifications listed in Table 57 below.

Table 57: SBP specifications

Item	Client Specification
Penetration	10 m
Vertical resolution	0.3 m

The primary settings that were used onboard the GOIV, GSV, GSXVII and Geo X are presented inTable 58, Table 59, Table 60, and Table 61, respectively.

Table 58: SBP acquisition settings - GOIV

General parameters GOIV	
System type	Innomar SES-2000 Medium 100
Survey speed	4.2 knots
Source frequency	8 kHz
Power setting	100 %
LF gain	4 dB
LF pulse	1

Table 59: SBP acquisition settings - GSV

General parameters GSV	
System type	Innomar SES-2000 Standard

General parameters GSV	
Survey speed	Average 4.5 knots
Source Frequency	10 kHz
Power Setting	100%
LF Gain	-6
LF Pulse	1

Table 60: SBP acquisition settings - GSXVII

General parameters GSXVII	
System type	Innomar SES-2000 Standard
Survey speed	Average 4.5 knots
Source Frequency	8 kHz
Power Setting	100%
LF Gain	6-16 depending on water depth
LF Pulse	1

Table 61: SBP acquisition settings – Geo X

General parameters Geo X	
System type	Innomar SES Quatro
Survey speed	Average 4.5 knots
Source Frequency	8 kHz
Power Setting	100%
LF Gain	6
LF Pulse	1

Sub-Bottom Profiler (SBP) data was recorded using as '.ses3' files then processed with Silas processing software. Incoming data was monitored for quality during recording before secondary QC of both SBP and navigation data. An acquisition log was kept of all settings and observations.

Position was sent via QINSy to SESWIN24, and raw files were tide corrected. Heave was corrected when converting the .ses3 files in SEG-Y using 'SES Convert' software. SEG-Y files were imported to Silas software. Sound velocity was set and processed MBES data (tide corrected) was compared to ensure correct seabed arrival time. Since the raw SEG-Y recorded time was rounded to 1 ms, the trigger delay was corrected up to 2 decimal precisions to ensure the seabed matched the bathymetry. The bottom was tracked over the centre beams using Silas Auto Tracing. Processed SEG-Y in 32-bit padded format was then exported.

5.5.2 SBP processing

The main SBP processing steps used for the QC are outlined in Table 62 and Table 63. SBP processing workflow diagram is presented in Figure 16.

Table 62: SBP data import and data QC

Steps	SBP data import and QC
Import of SEG-Ys	Import SEG-Y Tide file applied
Data Quality	Lines checked for: No empty pings Correct bottom detection No motion influence No noise in the data No artefacts in data Good reflector visibility Good penetration (5 m)
Position check	Lines checked for: Data coverage Verification of the absolute height by importing the MBES grid (no manual offset is accepted, after tide/heave correction applied online)

Table 63: SBP acquisition and processing methodology

High frequency shallow sub-bottom profiler (SBP)	
Objective	• To characterise and map the sediment architecture and structure down to 10 metres beneath the seabed, in order to obtain a detailed understanding of the uppermost soil/geological conditions of the survey area • To identify geological or manmade hazards down to 5 metres beneath the seabed, such as lithological heterogeneities, organic-rich soils/peat shallow gas, buried objects, etc
Equipment	• System: Innomar SES-2000 Standard • Acquisition software: SESWIN recording software • SBP processing software: ISE, SES Convert and Stema Silas • SBP interpretation software: IHS Kingdom seismic interpretation software

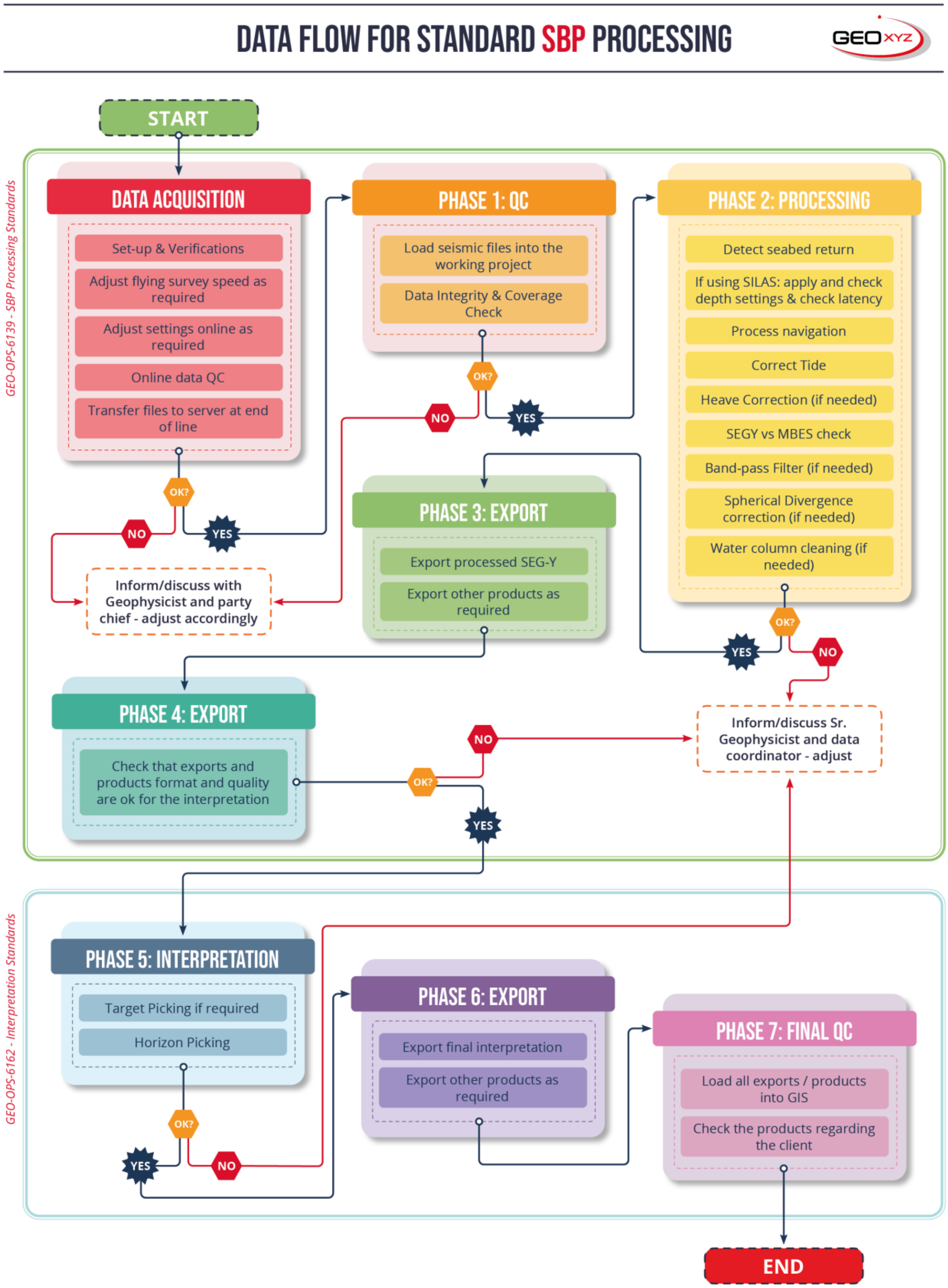


Figure 16: SBP processing workflow

5.5.3 Geology interpretation

Once processed, the SBP data were loaded into an IHS Kingdom project for interpretation. The data are of good quality and uniform across the different vessels used in acquisition. The vertical resolution allows separation of surfaces ~0.15 m apart.

The picked horizons were gridded to 5 m lateral resolution using the IHS Kingdom Flex Gridding algorithm default settings. The final project datum depth grids were created from thickness horizons, which were then added to the MBES bathymetry. This was to remove the effect of any static misties and to provide the best gridded surface possible.

Sub-bottom data and interpretations were depth converted using a velocity of 1650 m/s. A velocity of 1650 m/s was chosen as not only does it follow on from the velocity selected for the windfarm sites, but it was assumed that the shallow geology would mainly be Sandy CLAY. Therefore, this velocity is in between the velocities of these two sediment types. CLAY being 1600 m/s and SAND being 1700m/s.

5.5.4 SBP data quality assessment

Data quality on all lines is generally very good, with mapping undertaken of all intended horizons on all lines. Penetration is limited more due to the geology in certain areas, particularly where the glacial till is close to seabed rather than the SBP system not achieving desired depth.

Data examples for each vessel are presented below.

Data acquired by GOIV is presented in Figure 17, which shows minimal ambient noise or interference in the dataset. Data resolution is shown to be excellent, where fine laminations are visible. Data penetration is good through finer sediments but appears to be limited by geology in places where interpreted till is close to the surface. Occasional lines show increased burst noise likely due to adverse sea conditions, but data remains fit for interpretation.

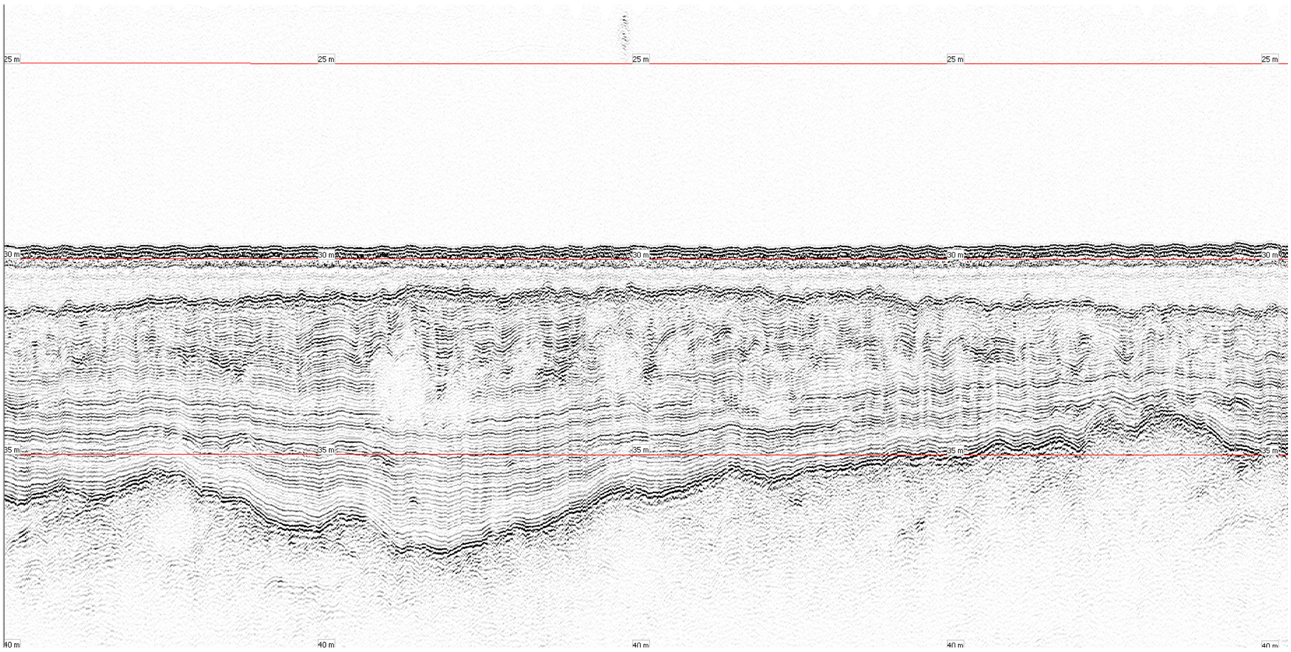


Figure 17 SBP data example from GOIV

Data acquired by GSV is presented in Figure 18, which shows some bursts of noise in the dataset, caused by the vessel having to increase engine power to maintain line heading. These bursts do not limit the interpretability of the dataset, and reflectors are still clearly delineated beneath the additional noise. Data resolution is shown to be excellent, where fine laminations are visible (left side of data example). Data penetration is good through finer sediments but appears to be limited by geology in places where interpreted till is close to the surface, as shown towards the right as the prominent reflector shoals.

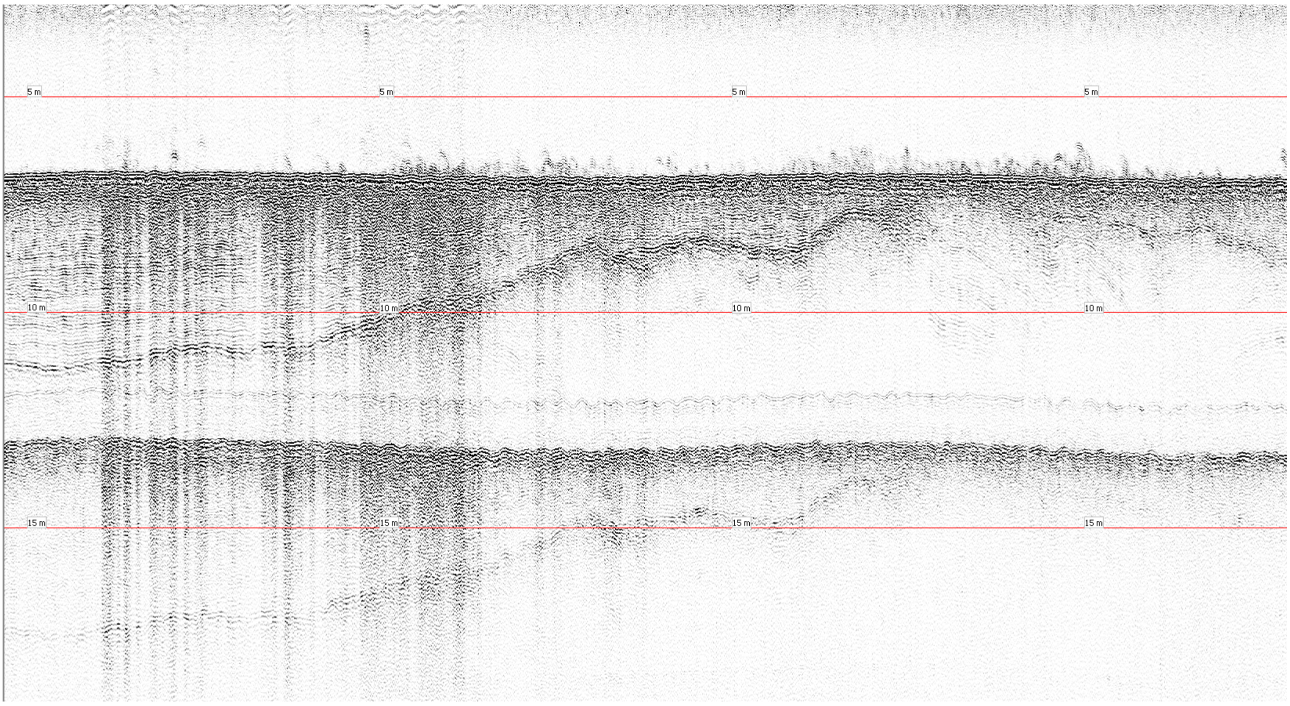


Figure 18 SBP data example from GSV

Data acquired by GSXVII is presented in Figure 19, which shows minor ambient noise, and a sea surface reflection approximately 2m below the acoustic seabed. The sea surface reflection is clearly identifiable and does not adversely affect the interpretability of the dataset. These bursts do not limit the interpretability of the dataset, and reflectors are still clearly delineated beneath the additional noise. Data resolution is shown to be excellent, where fine laminations are visible within the channel feature shown in the figure. Data penetration is good through finer sediments but appears to be limited by geology in places where coarser sediments are likely to be closer to the surface, as shown either side of the channel. Occasional lines show increased burst noise likely due to adverse sea conditions, but data remains fit for interpretation.

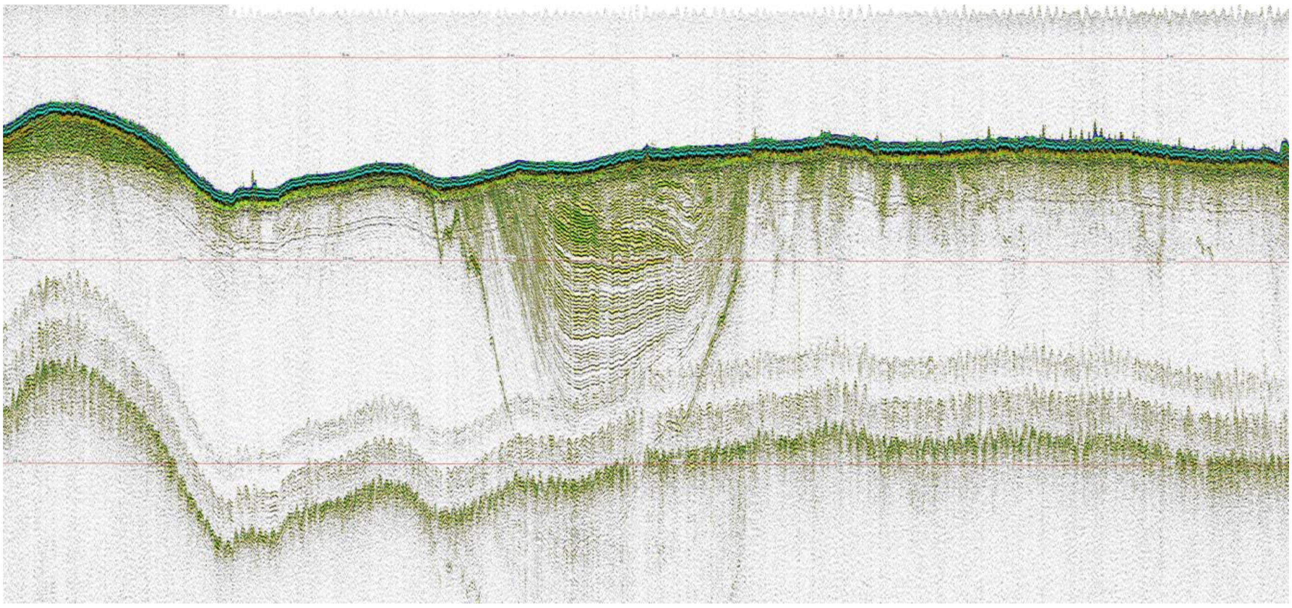


Figure 19 SBP data example from GSXVII

Data acquired by Geo X is presented in Figure 20, which shows some bursts of noise in the dataset, caused by the vessel and sea conditions. These bursts do not limit the interpretability of the dataset, and reflectors are still clearly delineated beneath the additional noise. Data resolution is shown to be excellent, where fine laminations are visible within channels in the figure. Data penetration is good through finer sediments but appears to be limited by geology in places where interpreted till is close to the surface, as shown towards the right as the prominent reflector shoals.

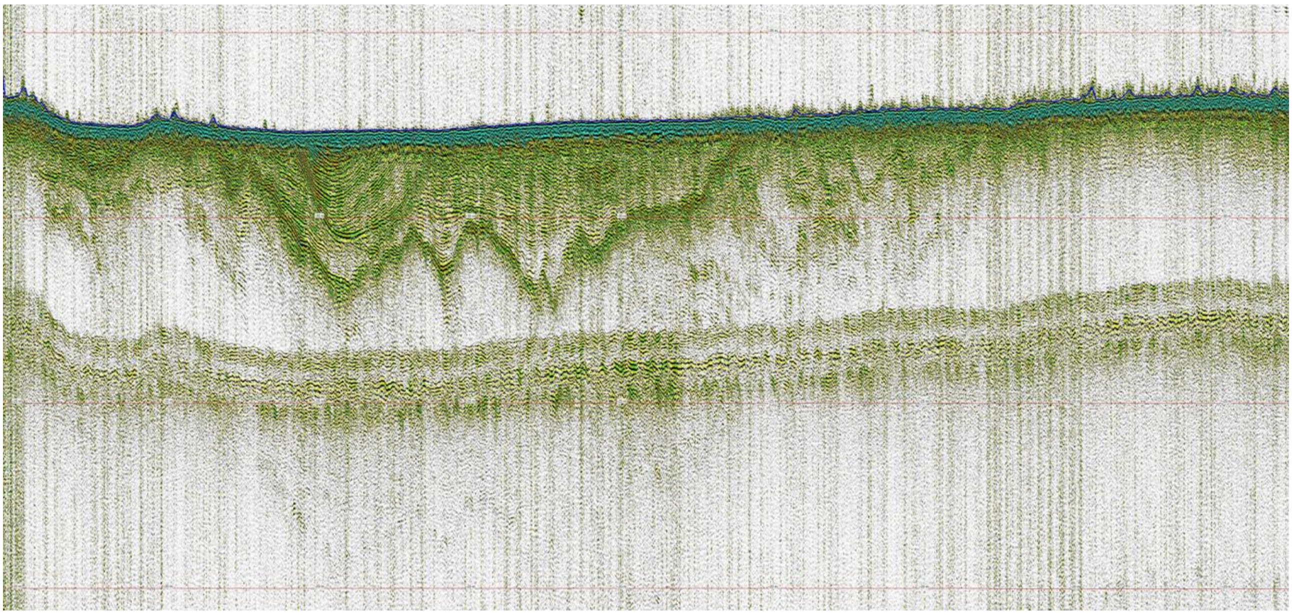


Figure 20 SBP data example from Geo X

5.4.4 Depth SBP data

The SBP depth data are based on the final time SEG-Y files. The water column and recorder delay are depth converted at the water velocity. This velocity interval extends from the top of the record to a point just above the picked water bottom. This small offset ensures that the seabed return signal is not distorted by the transition from one interval velocity to another. Due to the large range of water velocities observed across the site and between vessels, an average water velocity of 1490m/s was used for time/depth conversion of the water column.

The remainder of the record is converted at an assumed velocity of 1650 m/s. This is because these shallow penetrating data only image normally consolidated, uncompacted, sediments and there are no associated processing velocities to consider.

This sub-seabed interval velocity was also applied to the thickness conversion of the interpretation of the upper two units: the depth SBP data match the supplied thickness/depth grids for units I and II.

The depth SEG-Y lines are in the Kingdom projects as multiversions of the parent timelines. All interpretation is of the time data. These time interpretations have been thickness and depth converted and can be displayed on the depth lines as grids. The depth data/interpretation show some very minor artefacts (<0.3 m) related to busts between adjacent lines. These artefacts are primarily caused by the high density of survey lines and slight variations in horizon picking between these lines.

5.6 GRAB SAMPLING

Grab sampling was carried out to support the interpretation of the seabed surface geology.

Only grab samples comprising a minimum of 40 % grab capacity or minimum 5 kg of material with no evidence of wash-out was accepted.

All sampling operations were logged during operations both on deck and independently in the laboratory. This allows quality control and cross-checking of operations on completion of the project.

After a preliminary visual geological description of the soil, the samples were stored on the vessel for potential later transportation to an onshore laboratory for further testing.

All grab samples were subject to a geological characterization according to Larsen et al. (1995).

All grab samples were described regarding:

- Lithology
- Depositional environment
- Geological age

Grab samples were subject to the following geotechnical classification tests:

- Particle size, sieve analysis
- Particle size, hydrometer analysis
- Organic content, loss on ignition

All field observations were made in accordance with Dansk Geologisk Forening (DGF) detailed in Larsen et al. (1995). However, laboratory analysis was conducted in accordance to BS EN ISO 17892-4 which uses the

Wentworth scale for particle size analysis. An overview of the sampling locations is presented in Figure 21 below. A more detailed overview of grab samples and results is presented in APPENDIX A.

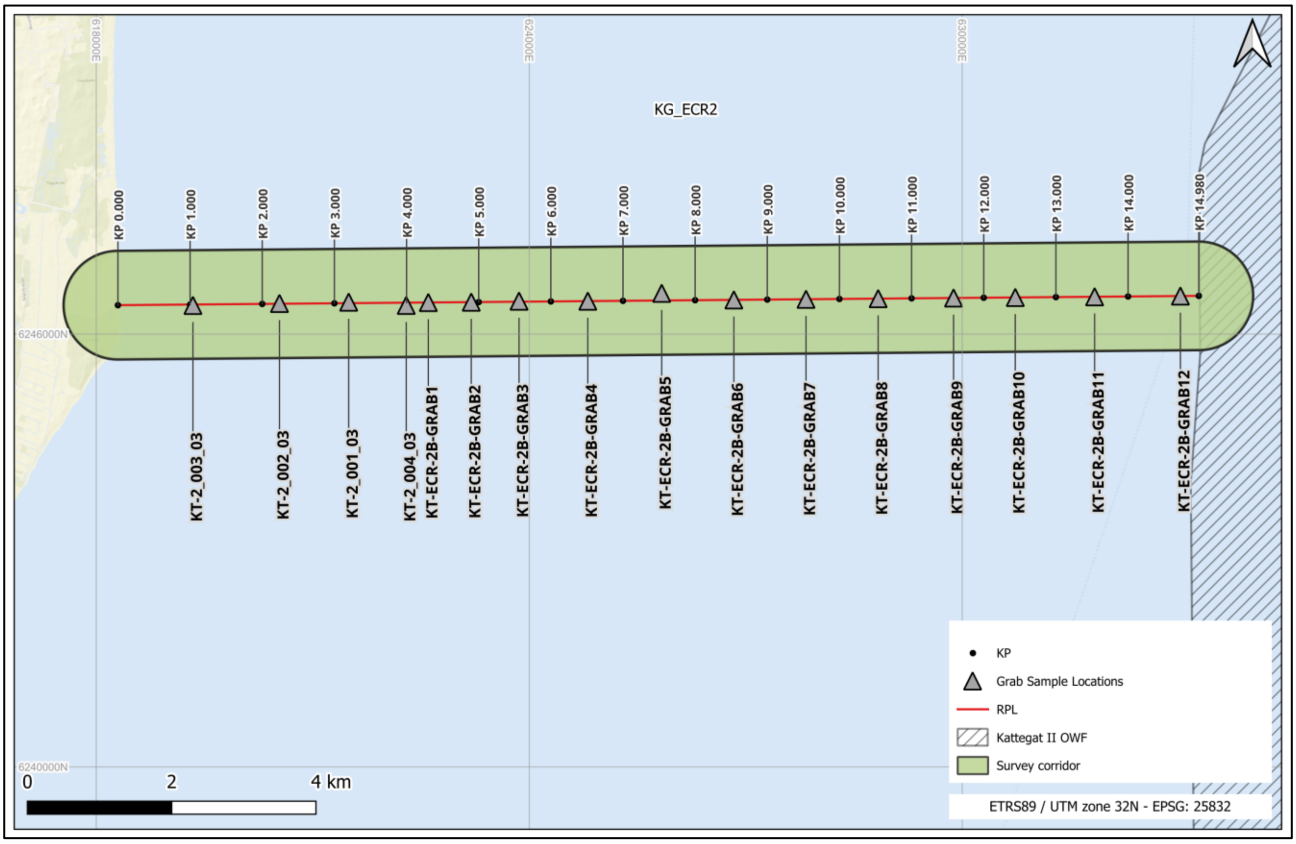


Figure 21: Grab sample locations overview

5.7 GEOTECHNICAL SAMPLING AND TESTING

The offshore geotechnical survey was conducted from the DP II vessel Connector and included 16 locations for CPTU, VC, and in-situ TRT. The survey was executed using Geo DK's combined seabed rig GeoCeptor, capable of performing CPTU, VC, and in-situ TRT in a single deployment (Figure 22). The CPTU and VC units on the rig were positioned 80 cm apart.

Sampling locations were carefully selected through an evaluation of survey data, including SBP, MAG, SSS, and MBES data. The selections were finalized during a workshop between GEOxyz and Energinet.

Figure 22: GeoCeptor - Combined Vibrocore and CPTU rig

5.7.1 CPT testing

A total of 22 seabed CPTUs were performed across 16 locations, with target depths of 3 m and 6 m. Penetration depths ranged from a minimum of 0.04 mbsb to maximum 6.2 mbsb, with an average penetration of 4.6 mbsb for tests targeting 6 m and 3.0 mbsb for tests targeting 3 m. Six re-runs were conducted due to unsatisfactory results or failure to reach target depth on the initial attempt. Re-runs were identified by appending "a" or "b" to the original location ID.

5.7.2 Vibrocore sampling

A total of 20 VCs were performed across the 16 geotechnical locations, including four re-runs, achieving penetration depths between 1.2 mbsb and 5.9 mbsb. As for CPTs, re-runs were identified by appending "a" or "b" to the original location ID. The average recovery was 4.0 m, with individual recoveries ranging from 0.8 m to 5.9 m. VC samples were transported to Geo DK’s laboratory in Lyngby, Denmark, for further analysis.

5.7.3 In-Situ TRT

TRT was planned and successfully conducted at four of the CPTU/VC locations. Geo DK’s subcontractor, Fielax, performed the testing using their Vibroheat equipment, providing thermal property data of the seabed materials.

5.7.4 Laboratory testing

Following the fieldwork, laboratory tests were conducted to evaluate soil conditions and determine key geotechnical characteristics. Table 64 provides types and amounts of laboratory testing performed on recovered sample.

Table 64: Overview of classification test on VC samples

Test type	Quantity	Sediment type	Standard
Geological Description and Classification	n/a	All	A guide to engineering geological soil description. G. Larsen et. al. DGF-Bulletin 1
Tor Vane	21	Cohesive	ASTM D8121/D8121M_9
Pocket Penetrometer	20	Cohesive	ISO 19901-8:2014(F)
Geotester	1	Cohesive	ISO 19901-8:2014(F)
Moisture Content	76	All	ISO 17892-1:2014
Bulk / Dry Density	75	All	EN ISO 17892-2:2014
Particle Size Distribution	44	All	DS/EN ISO 17892-4:2016
Atterberg Limits	14	Cohesive	DS/EN ISO 17892-12:2018 |
Max. and Min. dry density	7	All	DGF Bulletin 15
Thermal Conductivity	15	All	ASTM D5334-14
Loss on Ignition	13	Organic	ASTM D2974-20
Particle density	44	All	DS/EN ISO 17892-4:2016
C14 dating	2	Organic	In-house procedure by Beta Analytical Inc.

Particle Size Distribution (PSD):

The characterization of soil types along the route was achieved by integrating visual descriptions of split VC samples with PSD analyses (Figure 47 and Figure 48). A total of 44 sieve analyses and 23 hydrometer analyses were conducted, with visual VC sample descriptions updated based on PSA results. Sieve analyses included all material components, with gravel content potentially incorporating shells, fragments, and organic debris. Hydrometer tests were performed when fines exceeded 10 %. Combined results provided detailed data on D10, D30, D50, D60, D90, Cu, and the percentages of clay, silt, sand, and gravel, as documented in the geotechnical report.

Thermal conductivity:

Thermal conductivity tests have been carried out on both intact VC samples and reconstituted specimens. Ten tests were measured directly in the VC samples just after opening of the core, and the corresponding classification parameters were determined in proximity to the conductivity test. The samples were kept at room temperature before the measurements. All tests were conducted using the MP-2 controller from Thermtest and the needle TLS100. Six tests have been carried out on granular samples as reconstituted tests. The specimens are reconstituted to a target density based on the relative density obtained from the CPTU and maximum and minimum dry density tests. For some specimens the relative density derived from the CPTUs was lower than 35 %. The low relative density led to a lower target density, which made the reconstitution process of the specimen difficult to achieve during specimen preparation. Consequently, these samples were tested assuming a relative density of 35 %. For other specimens there were no value of relative density detected at the CPTUs. These specimens were tested based on a relative density of 35 % or more.

Tor Vane

Tor Vane has been carried out both onshore and offshore on cohesive material for determination of undrained shear strength. Notably, the maximum value that can be measured by the tor vane is 250 kPa.

Geotester / Pocket Penetrometer

Pocket Pen has been carried out both onshore and offshore on cohesive material for determination of undrained shear strength. It should be noted that the maximum value that can be measured by the pocket penetrometer is 1000 kPa.

Moisture Content

Moisture content is an accredited test and has been determined if Bulk and Dry Density test was not possible. The values range from lowest 9.5 % to highest 33.8 % in CLAY sediment type.

Bulk and Dry Density

Bulk and dry density measurements have been conducted onshore across all soil types. The highest values were recorded in sand TILL, where the bulk density reached 2.41 g/cm³ and the dry density measured 2.19 g/cm³ at the depth of 3.90 metres below seabed.

Atterberg Limits

The liquid and plastic limits were determined on 14 specimens. The plasticity index for all 14 of the specimens varies between 5 and 35 %.

Organic Content

Tests has been conducted on all types of material indicating a content of organic matter. The organic content in these samples varies between 0.5 – 2.9 %. The results of the organic content determination tests are considered reliable, and representative of the material encountered across the site.

C14 Dating

C14 dating were performed at Beta Analytical Inc. according to an in-house standard. The "Conventional Radiocarbon Age" was calculated using the Libby half-life (5568 years) and was corrected for total isotopic fraction and was used for calendar calibration where applicable. The Age is rounded to the nearest 10 years and is reported as radiocarbon years before present (BP), “present" = AD 1950. Results greater than the modern reference are reported as percent modern carbon (pMC). The modern reference standard was 95 % of the 14C signature of NIST SRM-4990C (oxalic acid). Dating has been conducted on all types of material indicating a content of organic matter.

Details about geotechnical methods and sampling/testing results are provided in APPENDIX B and APPENDIX C.

5.8 GROUND TRUTHING FOR ACOUSTIC DATA INTERPRETATION

Geotechnical parameters reported in Table 65 have been correlated with the acoustic dataset to support ground truthing:

- Seabed nature: Determined based on the description of the upper sections of the VC samples and CPT results.

- Sub-seabed units: Interpreted using data from VC, CPT, and laboratory test results.

The results of the integration between geotechnical data and geophysical interpretation are discussed in Section 6.6.

Table 65: Analysis on vibrocores and CPTs integrated in our results

Analysis	Description
Bulk density	Dry weight of soil per unit volume of soil.
Moisture Content (%)	Mass of water which can be removed from the soil, usually by drying, expressed as a percentage of the dry mass.
D50 percentile value	Median diameter of particle size distribution, value of the particle diameter at a 50 % in the cumulative distribution.
D90 percentile value	Grain size of the 10 % “coarse" fraction of the sample
Cone resistance (Qc)	Cone resistance presented in MPa
Friction resistance (Fc)	Sleeve friction resistance in MPa

5.9 ARCHAEOLOGICAL SUB-SAMPLING

Sub-sampling for archaeological C14 dating has been conducted on organic layers. When possible, the following guidelines were followed during the subsampling:

1) A minimum sample size 0.5-1.0 L of preferably undisturbed sample. 10-15 cm of sample from relevant intervals.
2) If possible, a cylinder shape is preferred.

However, some of the organic layers were either thin (less than 10 cm) or consisted of loose sand material not possible to sub-sample as cylinder shaped. A selected number of the sub-sampled specimens were used for archaeological purposes.

5.10 CLASSIFICATION CRITERIA

5.10.1 Seabed gradient classification criteria

Seabed gradient has been classified as per Table 66 below.

Table 66: Slope classification

Classification	Slope
Very Gentle	< 1°
Gentle	1° - 5°
Moderate	5° - 10°
Steep	10° - 15°
Very Steep	> 15°

5.10.2 Confidence interval classification for targets

Confidence interval classification for targets has been classified as per Table 67.

Table 67: Confidence interval classification for targets

Confidence interval	Criteria
Low	Visible on a single SSS line
Medium	Seen on more than one SSS line
High	Seen on one or more SSS lines and correlated with MBES

5.10.3 Boulder field classification

Boulders zones were mapped with the automatic tool for boulders > 0.5 m (height/length/width). Individual boulders/blocks within boulder zones were mapped with the automatic tool for boulders > 2 m (height/length/width). Any rocks/blocks outside boulder zones were mapped by manual method on boulders > 1 m (height/length/width).

Boulder fields were classified as per Table 68 below.

Table 68: Boulder field classification criteria

Number of targets within 50 x 50 m area	Boulder dimension	Class
0 – 10	>1 m in any direction	Not a boulder field
10 – 20	>2 m in any direction	Intermediate
> 20	>2 m in any direction	High density

5.10.4 Mobile bedform classification

Nomenclature for mobile bedform classification is presented in Table 69 below.

Table 69: Bedform classification criteria

Bedform classification	Height (m)	Wavelength (m)
Ripples	< 0.1	< 5
Large ripples	0.1 – 1.0	5 – 15
Megaripples	1.0 – 3.0	15 – 50
Sand waves	3.0 – 5.0	50 – 200

5.10.5 Sediment classification

The sediments across the survey areas have been described using a combination of the DGF, GEUS and Wentworth classifications.

For the grab sample analysis, the definition of the particle sizes followed the Wentworth scale. The sediment classifications in the seabed geology polygon shapefile deliverable were then made by correlating the observations seen in the MBES and SSS data with the grab and geotechnical results and were described according to the DGF classification and GEUS Sediment Classes for Danish surface seabed sediments.

Details of the Wentworth scale for classifying sediments are presented in Figure 23, with the GEUS seabed sediment classification for Danish waters in Table 70.

.

Major Grade	Phi (Φ) limits		Wentworth size class
	Lower	Upper	
gravel	<-8	-8	boulder
	-8	-6	cobble
	-6	-2	pebble
	-2	-1	granule
sand	-1	0	very coarse sand
	0	1	coarse sand
	1	2	medium sand
	2	3	fine sand
	3	4	very fine sand
mud	4	5	coarse silt
	5	6	medium silt
	6	7	fine silt
	7	8	very fine silt
	8	>8	clay

Scale by Wentworth (1922) classifying sediment particles according to the diameter expressed in units of N (phi, the negative log 2 of the diameter in millimeters).

Figure 23: Wentworth Scale – classifying sediment particles

Table 70: GEUS Seabed Sediment Classification for Danish Waters

GEUS Sediment Class	GEUS Sediment Description for Danish Waters
Quaternary clay	Marine, meltwater or lake deposits of clay. Often laminated with sand/silt and/or peat layers, in some cases covered by few cm of lag sediments (sand, gravel or pebbles). The deposit is often related to the Yoldia Clay (Kattegat), The Baltic Icelake (The Baltic Sea) or Holocene clay (The North Sea).
Mud	Soft and fine-grained sediment with more than 10 % fine organic matter and less than a few percent coarser material. Very high water content. Often with shells and plant remains. Related to accumulation and basin areas in the inner Danish waters.
Sandy Mud / Muddy Sand	A mixed sediment type composed of variable content of sand and mud. Deposited at the rim of basins or as a thin cover layer in erosion areas.
Sand	Homogeneous layer of loose, well-sorted sand. Often combined with ripples and/or sand waves due to current or wave action.
Sand, Gravel and Pebbles	Mixed sediments of more than 0.50 m thickness. Lag sediments covering till, meltwater deposits or fossil coastal deposits.
Till	Mixed sediment type of glacial origin. Often covered by a thin layer of sand, gravel, boulder and/or sandy mud washed out of the till.
Sedimentary bedrock	Not observed in this survey area.

6 KATTEGAT ECR 2 ROUTE OVERVIEW

6.1 RESULTS

This report section provides a detailed analysis of the findings from topographic data, bathymetric data, side scan sonar data, sub-bottom profiling, and magnetometer surveys conducted within the survey area.

Datasets were reduced to MSL, which involved applying the DTU21MSL geoid separation model during post-processing.

Listings for all sonar, magnetometer and sub-bottom contacts and linear targets across the site are presented within each relevant section of the text. A confidence level is assigned to sonar contacts as presented previously in Section 5.10.

6.2 BATHYMETRY & TOPOGRAPHY

The elevation levels across the Kattegat ECR 2 site exhibit a range of elevations, from a highest point of 16.35 metres above mean sea level (MSL) in the western landfall area near coordinates 618164 mE, 6246557 mN, to a deepest point of -21.33 metres below MSL near 628541 mE, 6245867 mN, towards the southeastern boundary of the survey area. Figure 24 presents a comprehensive overview of the Kattegat ECR 2 survey area, merging both topographic and bathymetric data to illustrate the general morphology.

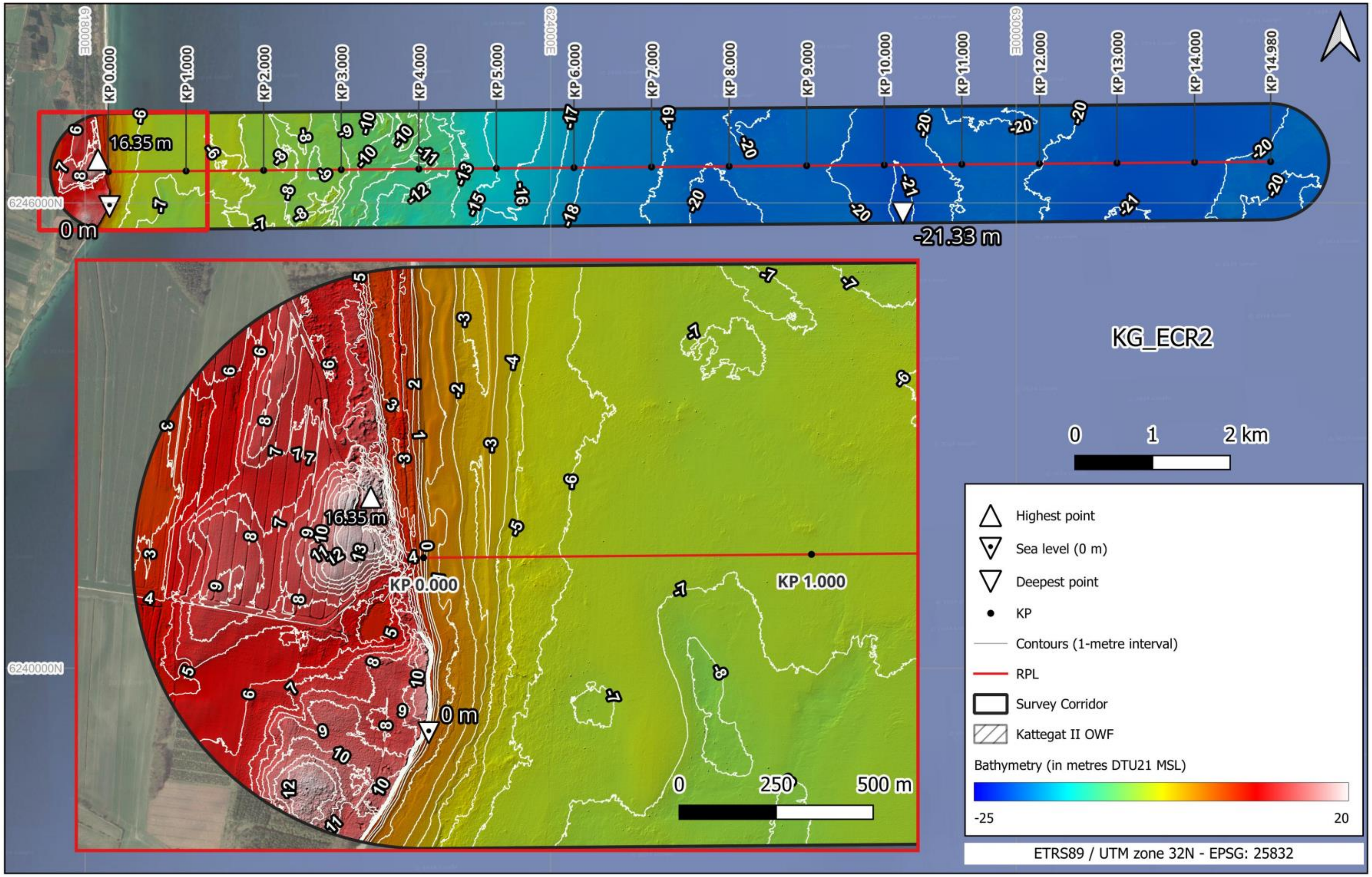


Figure 24: Bathymetry and topographic combined overview

6.2.1 Landfall & topography

The highest point in this topographic part of the survey corridor measures 16.35 MSL and is located 207 metres north west from the landfall. Further inland, the survey area is characterized by gently undulating topography and relatively flat land, interspersed with foliage, hedgerows, and farming fields. The complete topographic overview of the survey corridor in the landfall area is presented in Figure 25.

Figure 26 represents the detailed overview of the landfall area and the cross section of the topographic data and RPL, from KP 0.000 to KP 0.008. This 8 m intersection is characterised by landfall elevation of 1.21 m MSL at the KP 0.000 which gradually decreases towards 0.03 m MSL at the KP 0.008. These two values represent highest and shallowest points in this part of the RPL. The highest slope value is 20.5 degrees and average slope for all measured points in this area is 8.3 degrees.

Both, north and south areas from the RPL, exhibit varying characteristics. North of the landfall RPL, the terrain is generally more gentle, despite dunes and the highest point within this area. In contrast, south of the landfall RPL the terrain features a steep and abrupt ridge dividing coastline form the inland area. The detailed overview of these two areas are presented in Figure 27 and Figure 28.

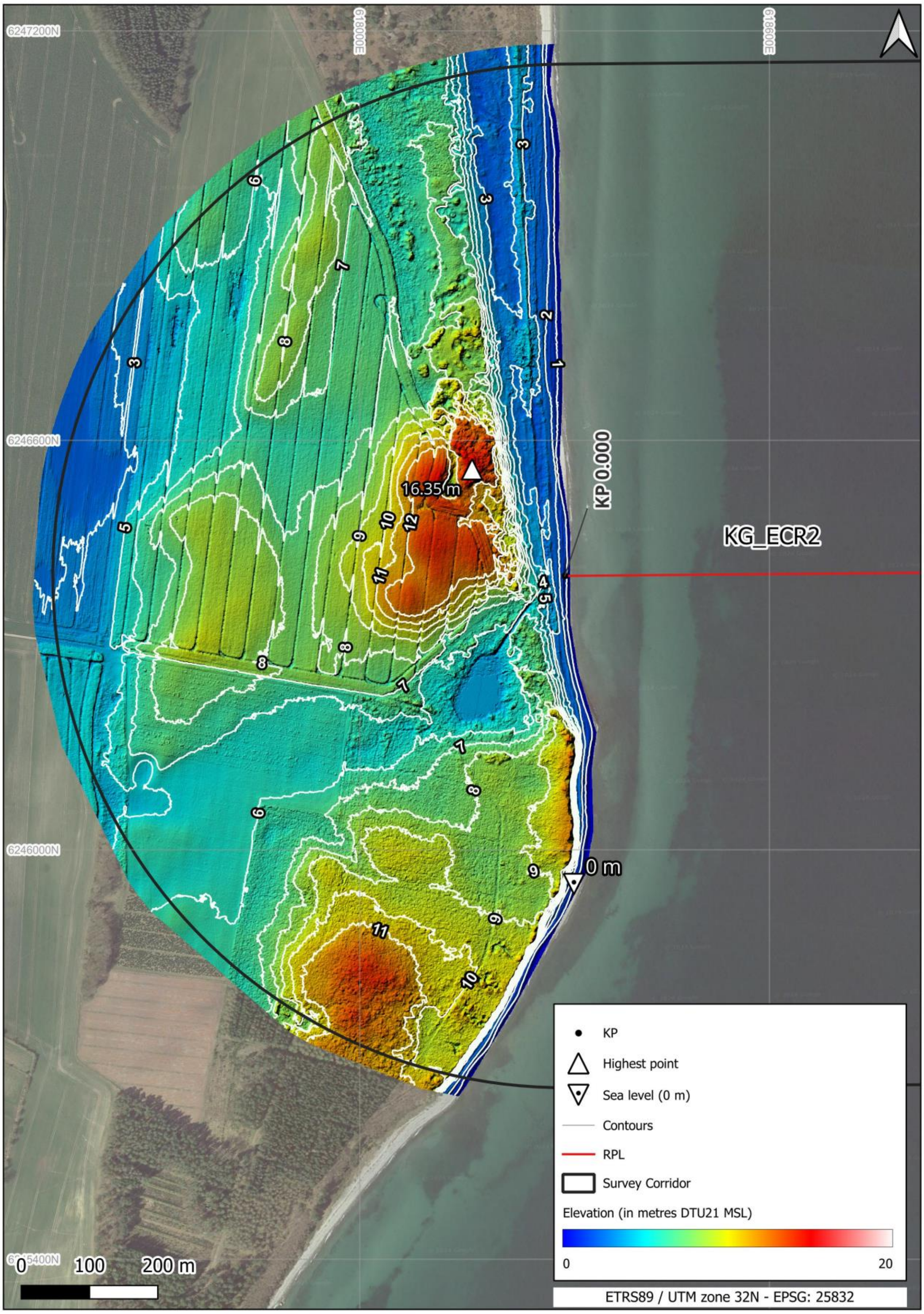


Figure 25: Topographic overview

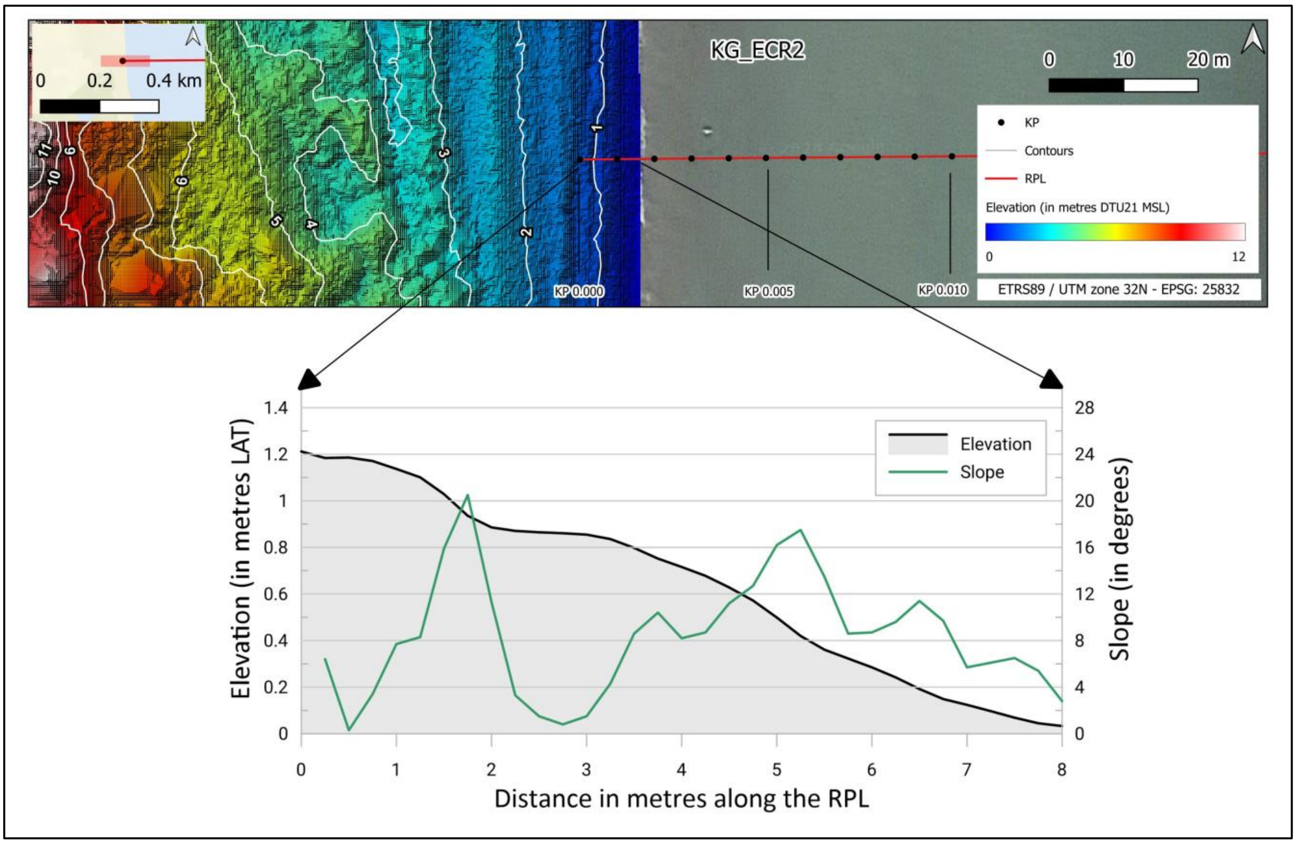


Figure 26: Detailed topographic overview and topographic cross section along the RPL

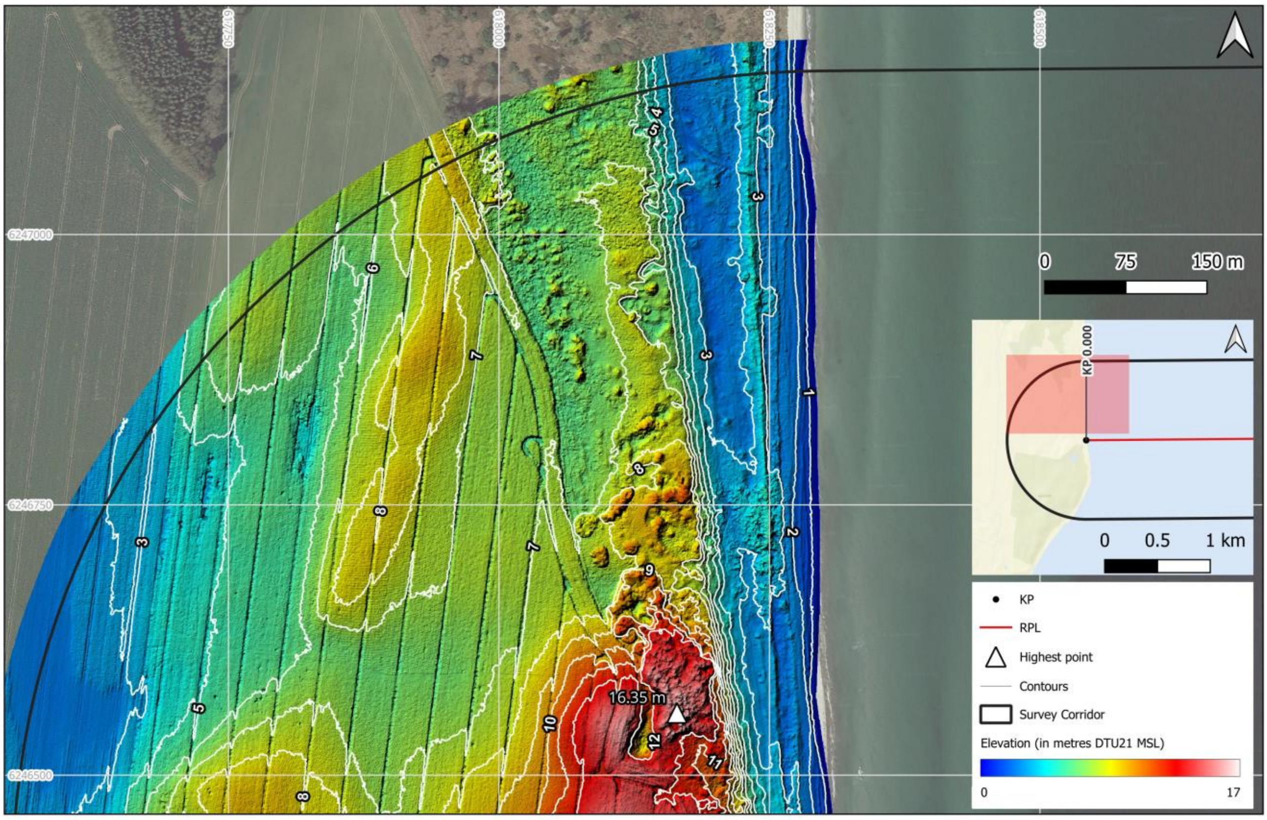


Figure 27: Detailed topographic overview - north of the landfall

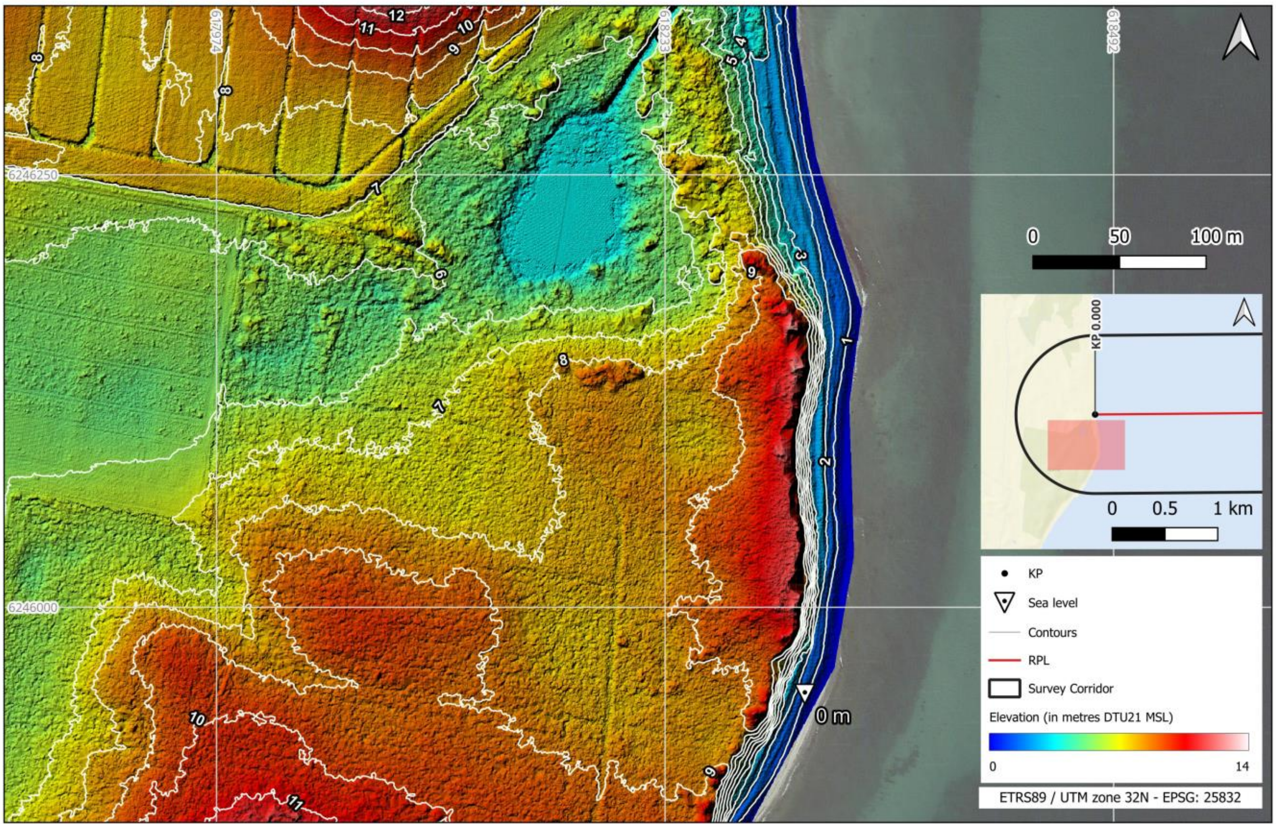


Figure 28: Detailed topographic overview - south of the landfall

6.2.2 Bathymetry Differences

As a result of different sensors, vessels and acquisition times of Bathymetry data there is notable differences in seabed level within the dataset. Therefore, an integrated MBES and LIDAR bathymetry grid was created and presented as the final bathymetry results which are displayed in the charts. The integrated grid used the most recent bathymetry data from both MBES and LIDAR.

However, there are notable differences between the LIDAR and MBES data. The MBES data was acquired in August 2023, the LIDAR acquired in July 2023. The differences between the datasets are particularly noticeable when looking at the sandbank at KP 0.1. Between the LIDAR data taken in July and the MBES data taken in August, the Sandbank had moved vertically 0.2 to 1.2 m in places and laterally the Sandbank had moved to the West a varying distance of 53 m to 80 m.

This sandbank at KP 0.1 has also introduced inconsistencies within the SBP data at this point. The Sub bottom Profile data interpretation was referenced to the MBES dataset which the SBP was acquired with. The SBP data was made into below seabed horizons using the acoustic seabed which at the time, included a sandbank. However, when the horizons were exported into LAT horizons this was created by adding the latest bathymetry to the BSB horizons and then gridded. Therefore, the LAT horizons and grids are relative to the integrated bathymetry grid which has introduced an inconsistency highlighted in Figure 29 below, as the sandbank is no longer present in the integrated bathymetry. Within Figure 29 below the orange line represents the seabed at the time of SBP acquisition. The red and green lines represent horizon 1 and horizon 2. The Purple line represents the integrated bathymetry grid which the depths of H01 and H02 are relative too. H01 depicts the firmer layer of sediments which were present underneath the sand bank. Now that the sandbank has moved, H01 at this location is now the seabed according to the integrated bathymetry. The interpretation of H01 roughly matches current bathymetry so it could be inferred that H01 was an accurate interpretation of the firmer sediments situated underneath the sand bank. Within our results, it is an error that H01 and H02 at this location only are calculated as deep as they are. This error is only present until KP 0.183. After this point, the differences between the MBES and integrated bathymetry are negligible and the SBP horizon mapping is accurate.

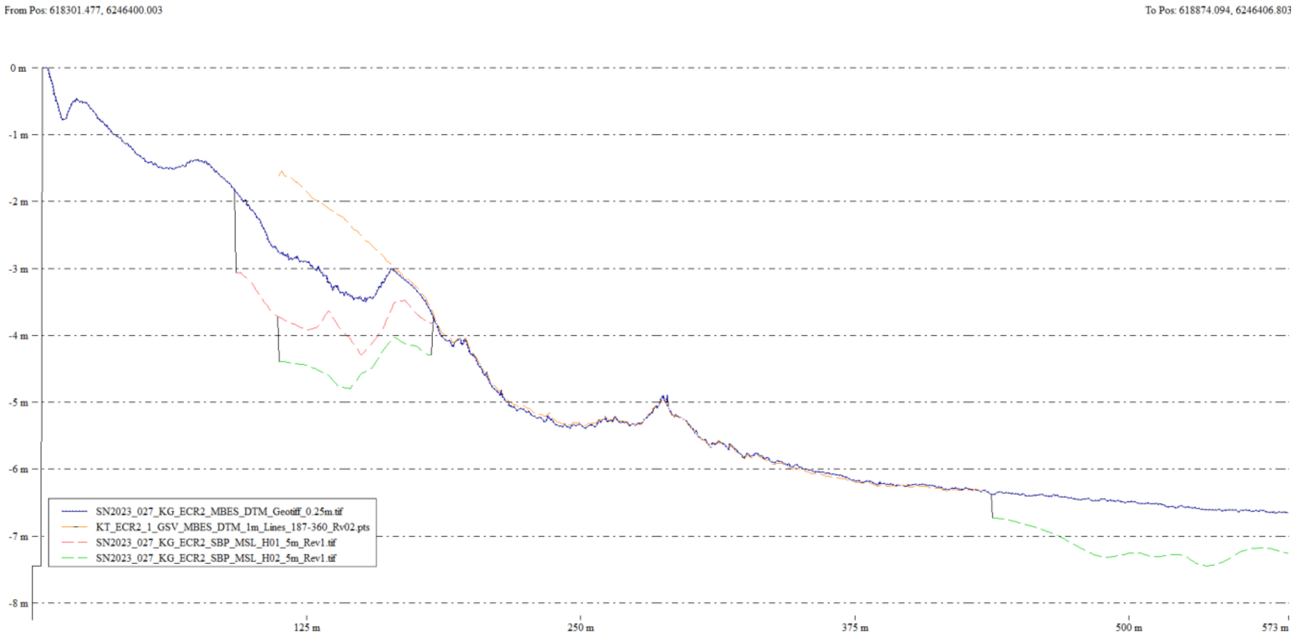


Figure 29: SBP Horizons and bathymetry differences

6.2.3 Bathymetry overview

A comprehensive overview of the bathymetry within the Kattegat ECR 2 survey area is illustrated in Figure 30, while a detailed bathymetry cross section along the Route Position List (RPL) is depicted in Figure 31.

Analysing the seabed gradient from east to west, starting from KP 14.980, reveals that the slope is almost negligible up to approximately KP 8.000, where the seabed remains nearly flat. Beyond this point, as the survey area approaches the western landfall, the gradient begins to increase slightly. The slope, while still very gentle, maintains a relatively constant incline of approximately 0.14° over a distance of 7.12 kilometres. The total elevation change over this distance is 17.5 metres, as presented in Figure 31.

This gradual increase in gradient as the RPL moves from the deeper part of the survey area towards the shore indicates a slow rise in the seabed elevation, reflecting the topographical characteristics of the region.

Overall, the slope characteristics of the Kattegat ECR 2 area are predominantly gentle, with slopes less than 1° being the most common. Slopes ranging from 1° to 5° become noticeable from KP 4.600 westward, where the seabed begins to rise as the landfall approaches (Figure 33).

The highest slope values, defined as very steep slopes greater than 15°, are associated with seabed features such as outcrops, boulder areas and possible bedforms, as visible in Figure 33. Figure 34 illustrates a typical section where elevation variation due to the outcrop creates slopes exceeding 15°, along with the boulder field resting on top. This is further depicted in Figure 35, with charts A, B, and C highlighting several areas with the highest density of boulders and their corresponding steep slopes.

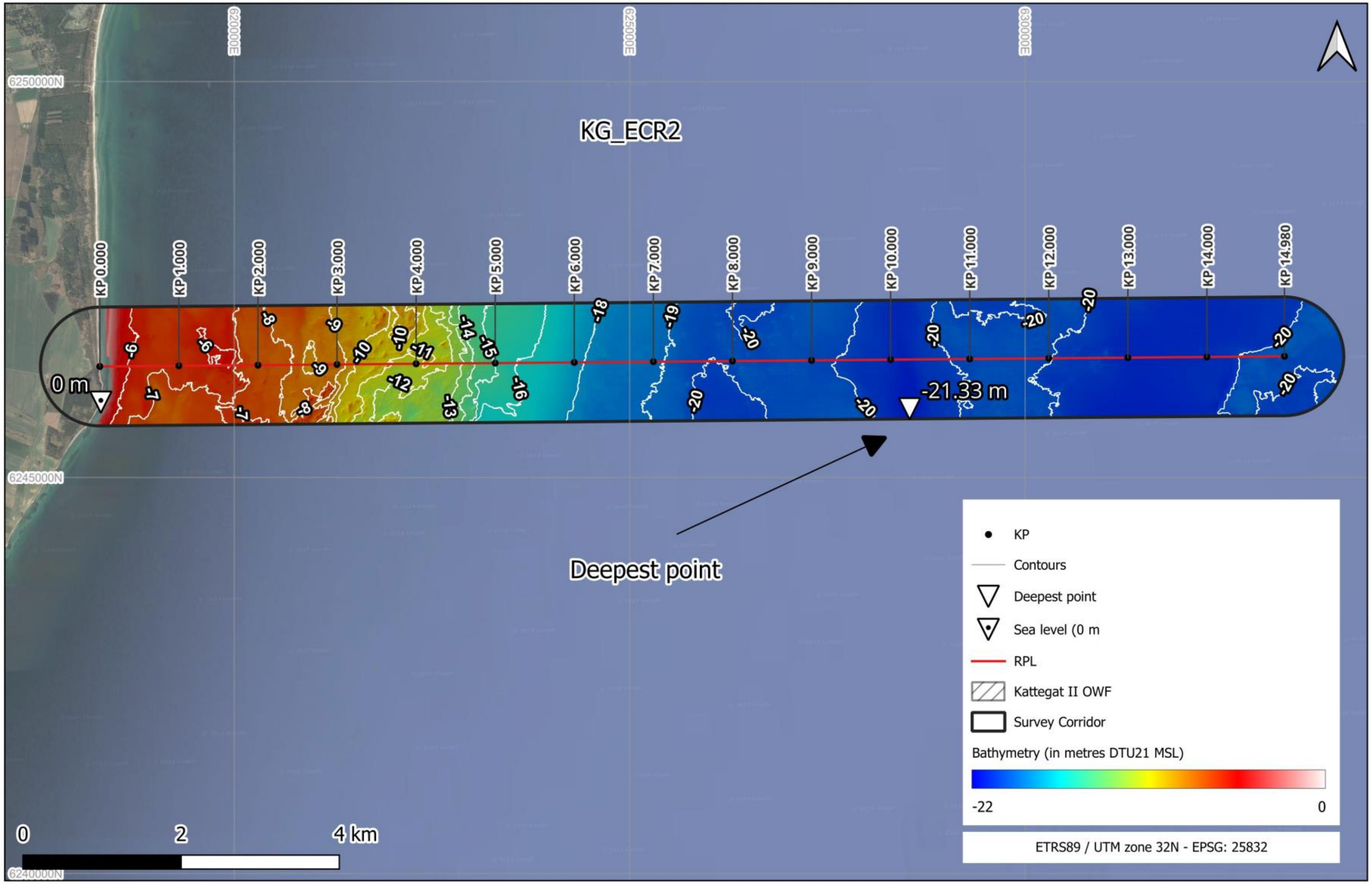


Figure 30: Bathymetry overview up the landfall site to zero mean sea level (MSL)

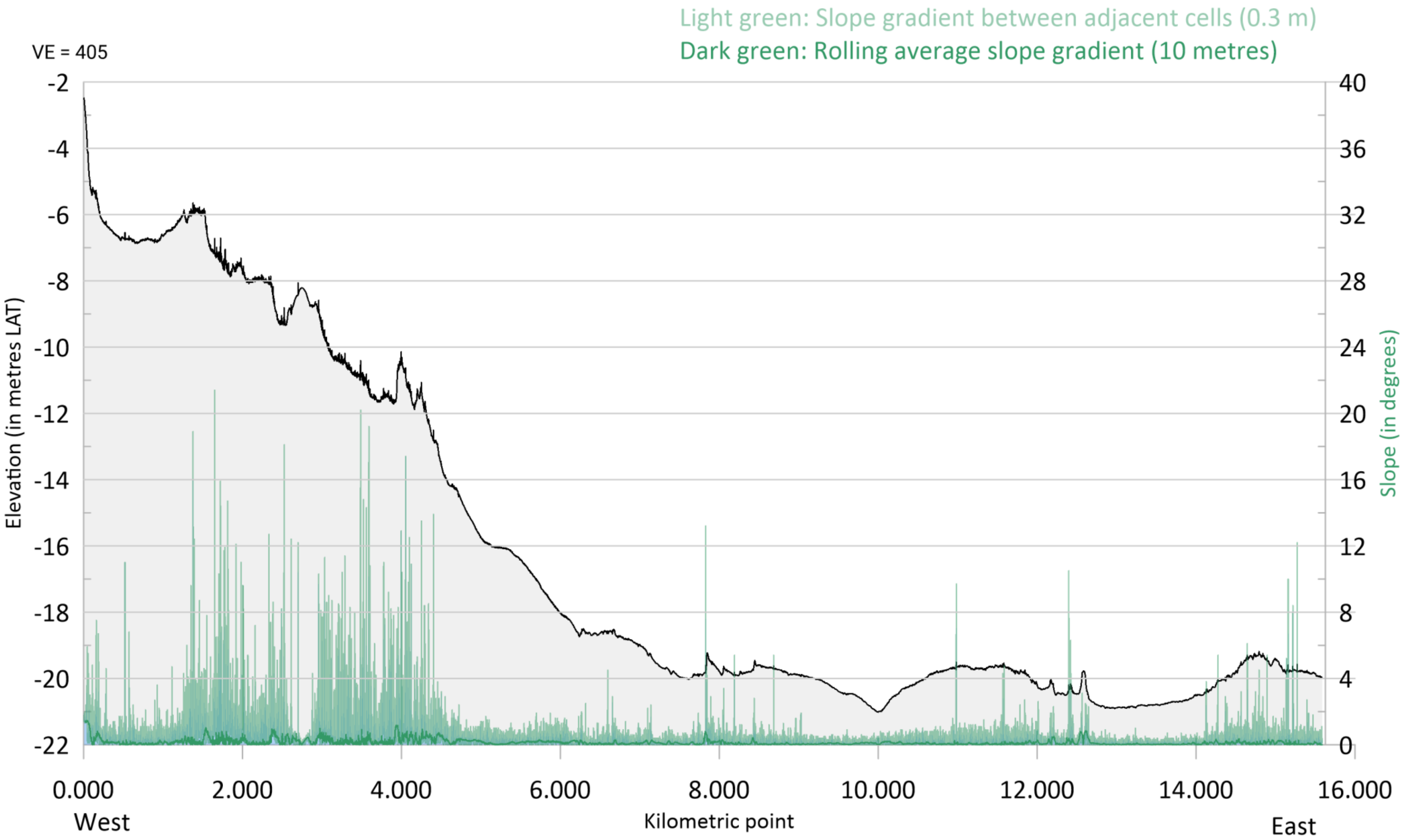


Figure 31: Depth and slope profile along the ECR 2 route RPL up to zero Mean Sea Level (MSL)

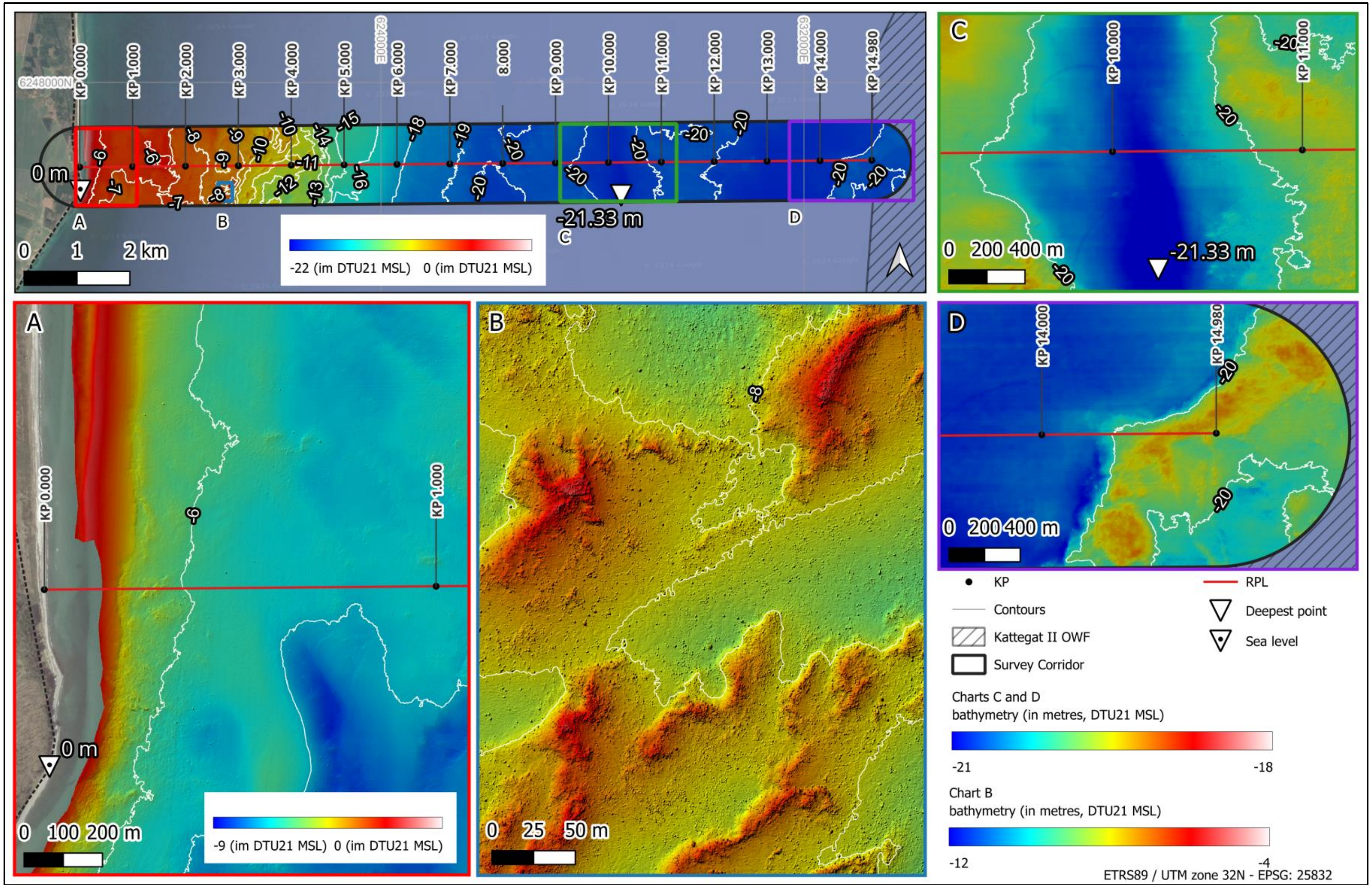


Figure 32: Bathymetry overview with detailed zooms

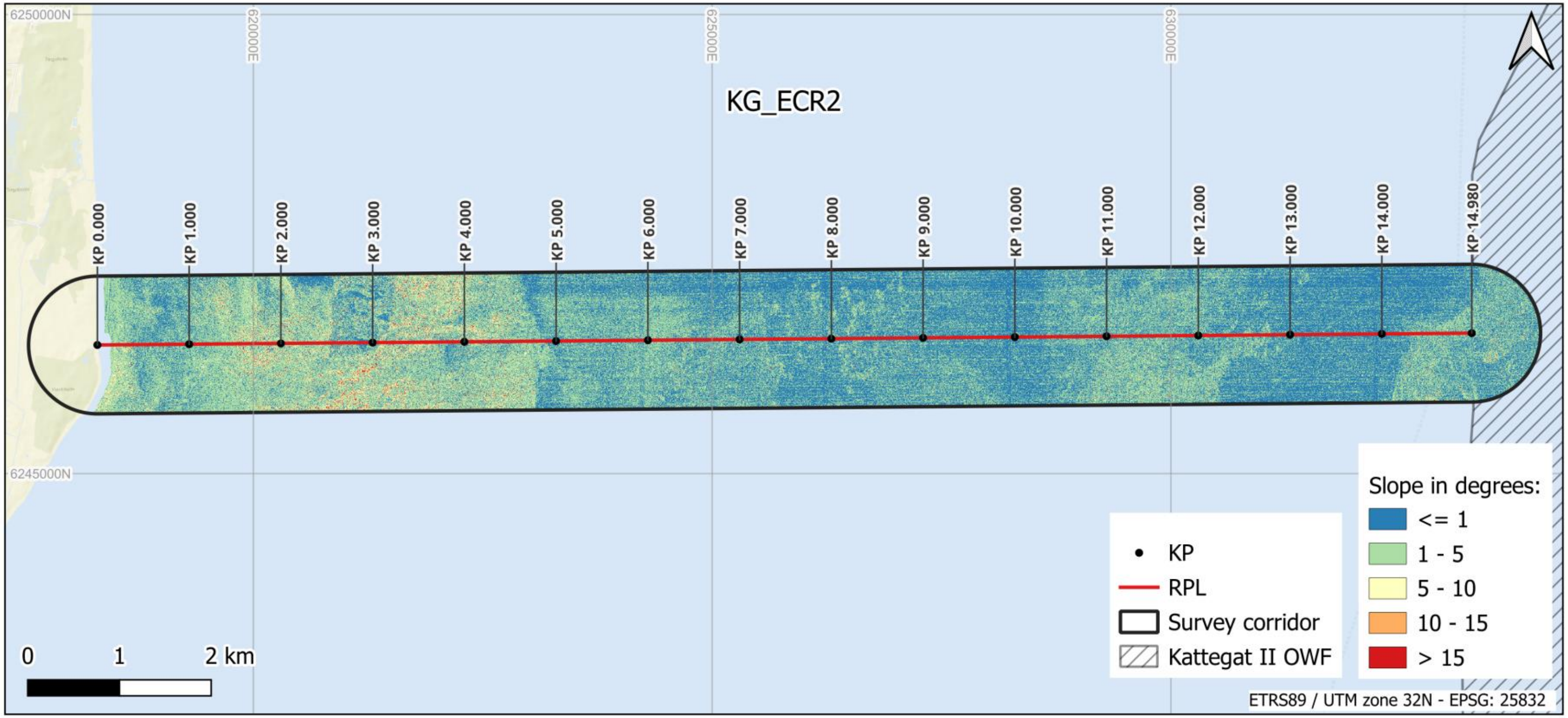


Figure 33: Slope overview of the ECR 2 route up to zero MSL

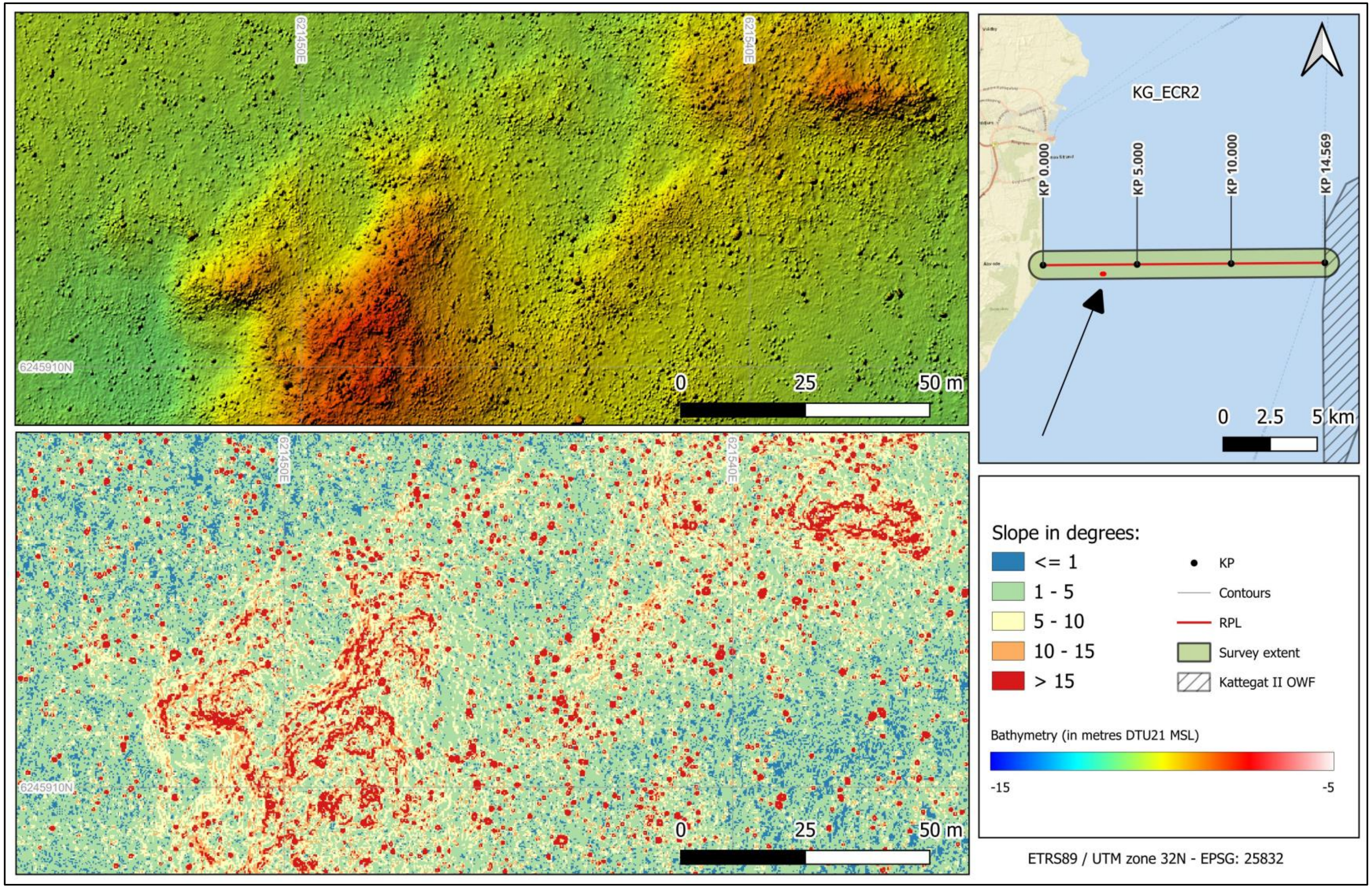


Figure 34: Area with the highest slope values within the survey area. The top panel showing bathymetry and the lower panel showing the corresponding slope values

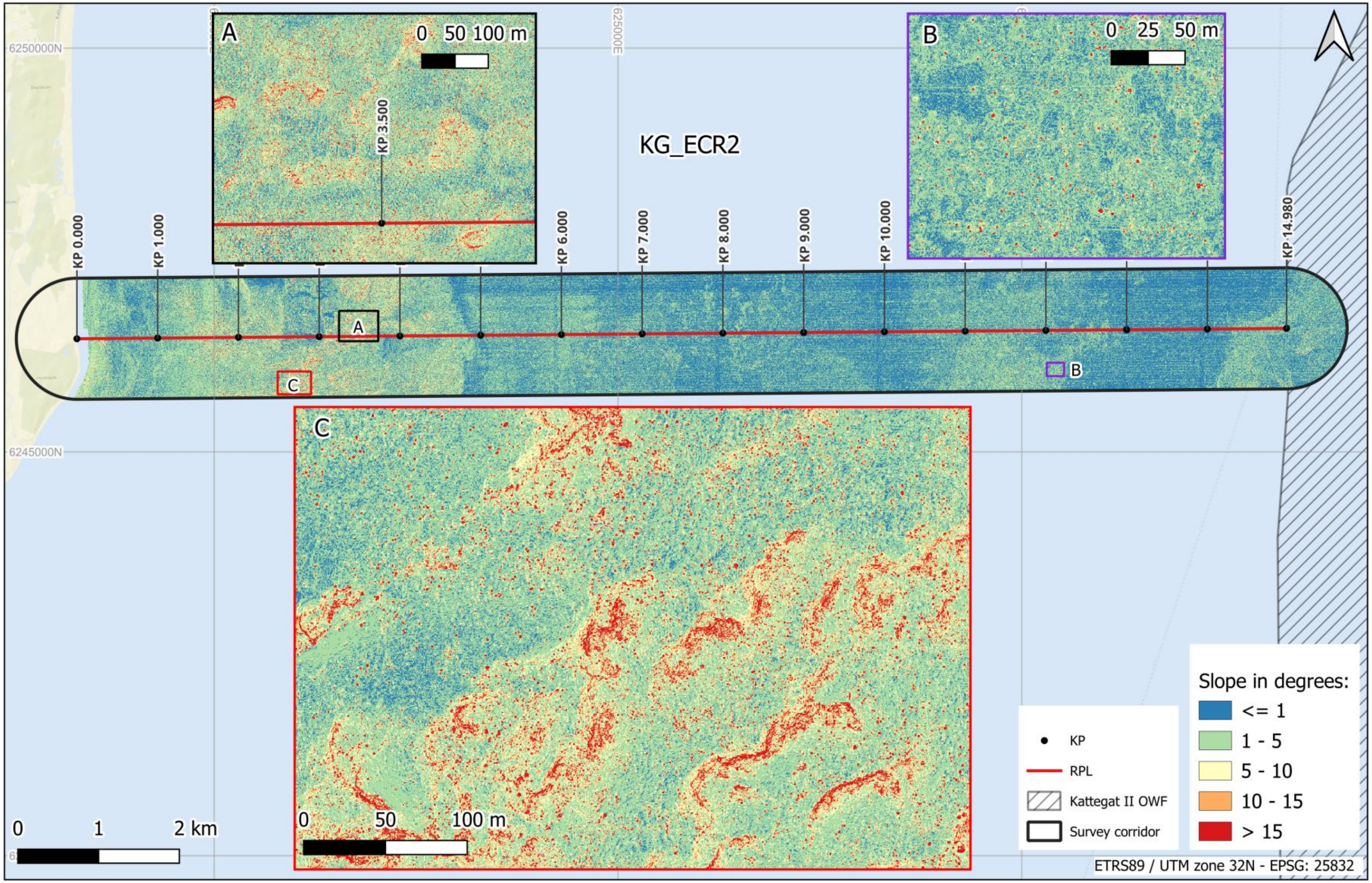


Figure 35: Slope overview highlighting areas of interest

6.3 SEABED SURFACE GEOLOGY

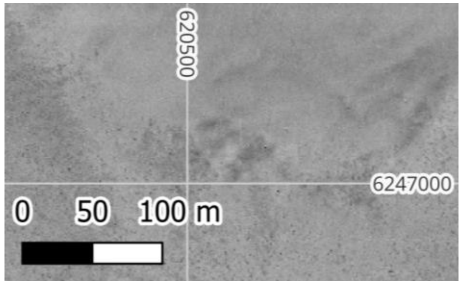
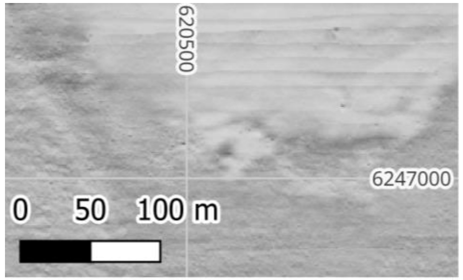
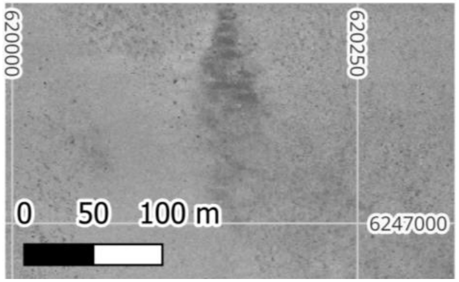
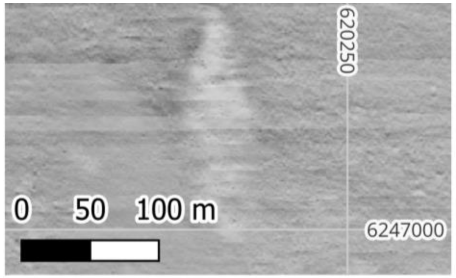
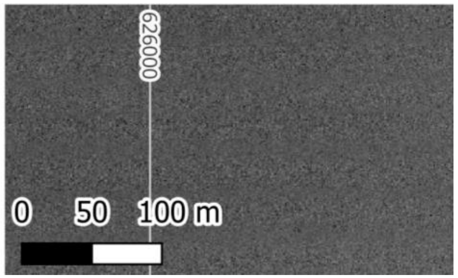
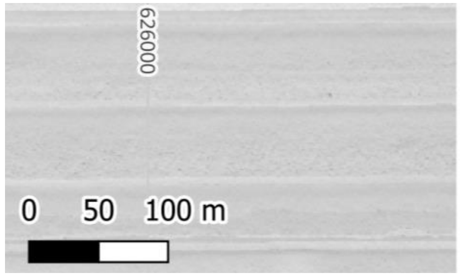
The seabed geology for Kattegat ECR 2 site was evaluated from the interpretation of the low and high frequency SSS data, the backscatter imagery and the MBES dataset. Data analysis and classification was performed using the seabed acoustic characteristics, such as reflectivity and backscatter strength, as well as the seafloor relief and the overall pattern. During the interpretation of the SSS data, higher reflectivity areas – higher intensity sonar returns (darker grey to black colours) have been related to relatively coarse-grained sediments and lower reflectivity areas – lower intensity sonar returns have been related to relatively fine-grained sediments (Table 71). As detailed in section 5.10.5, GEUS terminology was used to define the identified seafloor sediment in the survey area. Bathymetric data aided the interpretation mainly in outlining of possible outcrops and the boulder field delineation.

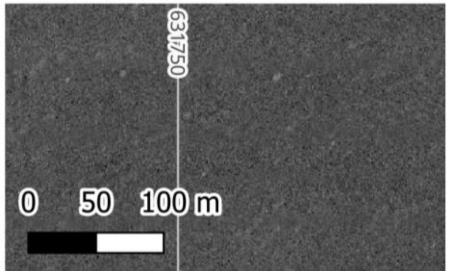
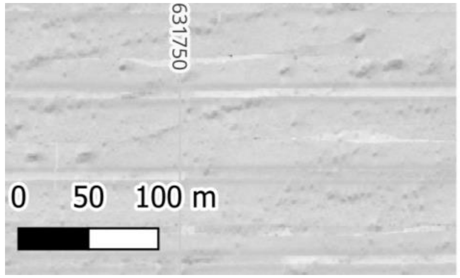
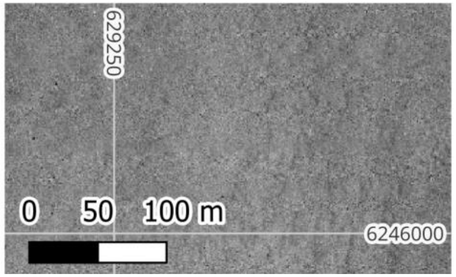
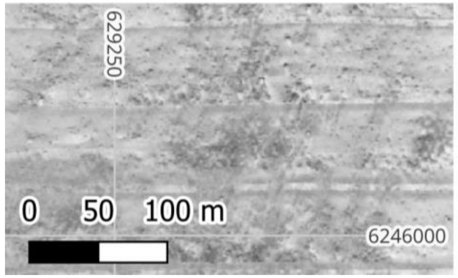
The resultant seabed surface geology has been correlated to the soil description of the surficial grab samples and the onshore laboratory results. Field descriptions of the grab results were in accordance to DGF however the laboratory analysis, the definition of the particle sizes followed the Wentworth scale (Figure 23) in accordance to BS EN ISO 17892-4. Seabed geology was also correlated to Vibrocore Top Geology (seabed) results.

It should be noted that not only the grab samples (that might not be representative of the entire area outlined), but also SSS reflectivity, MBES relief, backscatter data, sub-surficial geology and the EMODnet classification have been considered for the Geology polygons.

Finally, seafloor sediment classification has been integrated to the sub-seabed geology data.

Table 71: Acoustic characteristics of the sediment types within the Kattegat ECR 2 site

Geological interpretation	Colour and code	Sediment interpretation	Acoustic description	Backscatter image	LF SSS image
Mud and sandy mud	21	Predominately mud with minor to significant fractions of sand. May contain minor fractions of gravel	Low reflectivity		
Muddy sand	13	Predominately sand with significant fractions of mud and muddy sand. May contain minor fractions of gravel	Low to medium reflectivity		
Sand	12	Predominately sand. May contain minor fractions of mud and/or gravel	Medium reflectivity		

Geological interpretation	Colour and code	Sediment interpretation	Acoustic description	Backscatter image	LF SSS image
Gravel and coarse sand	11	Mixed sediment. Predominately gravel and sand. May contain mud	Medium to high reflectivity. Patches of high reflectivity interspersed in areas of low to medium reflectivity		
Till/diamicton	41	Mixed sediment. Constituents range between mud and boulders	Low to high reflectivity. Patches of high reflectivity interspersed in areas of low to medium reflectivity. Usually, positive relief in MBES data		

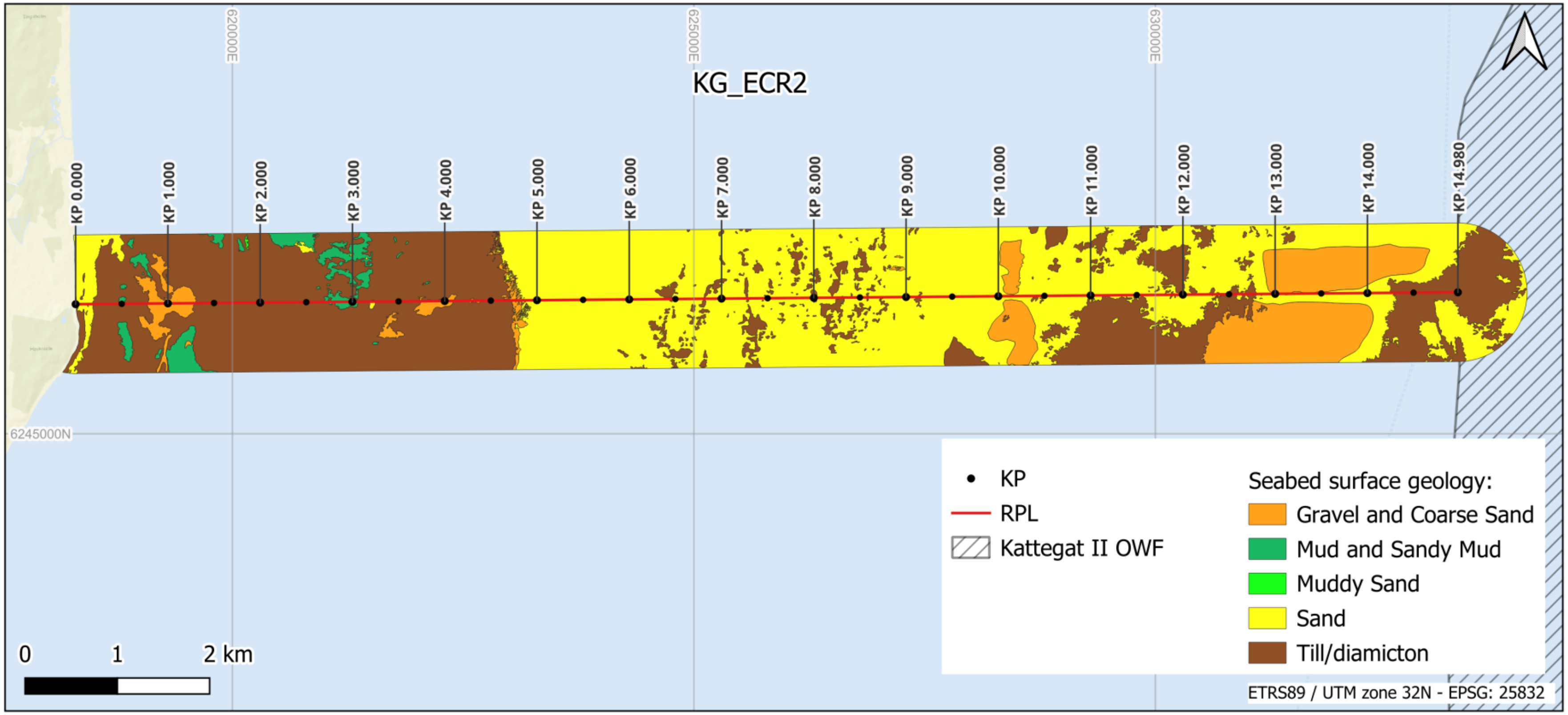


Figure 36: Seabed surface geology classification

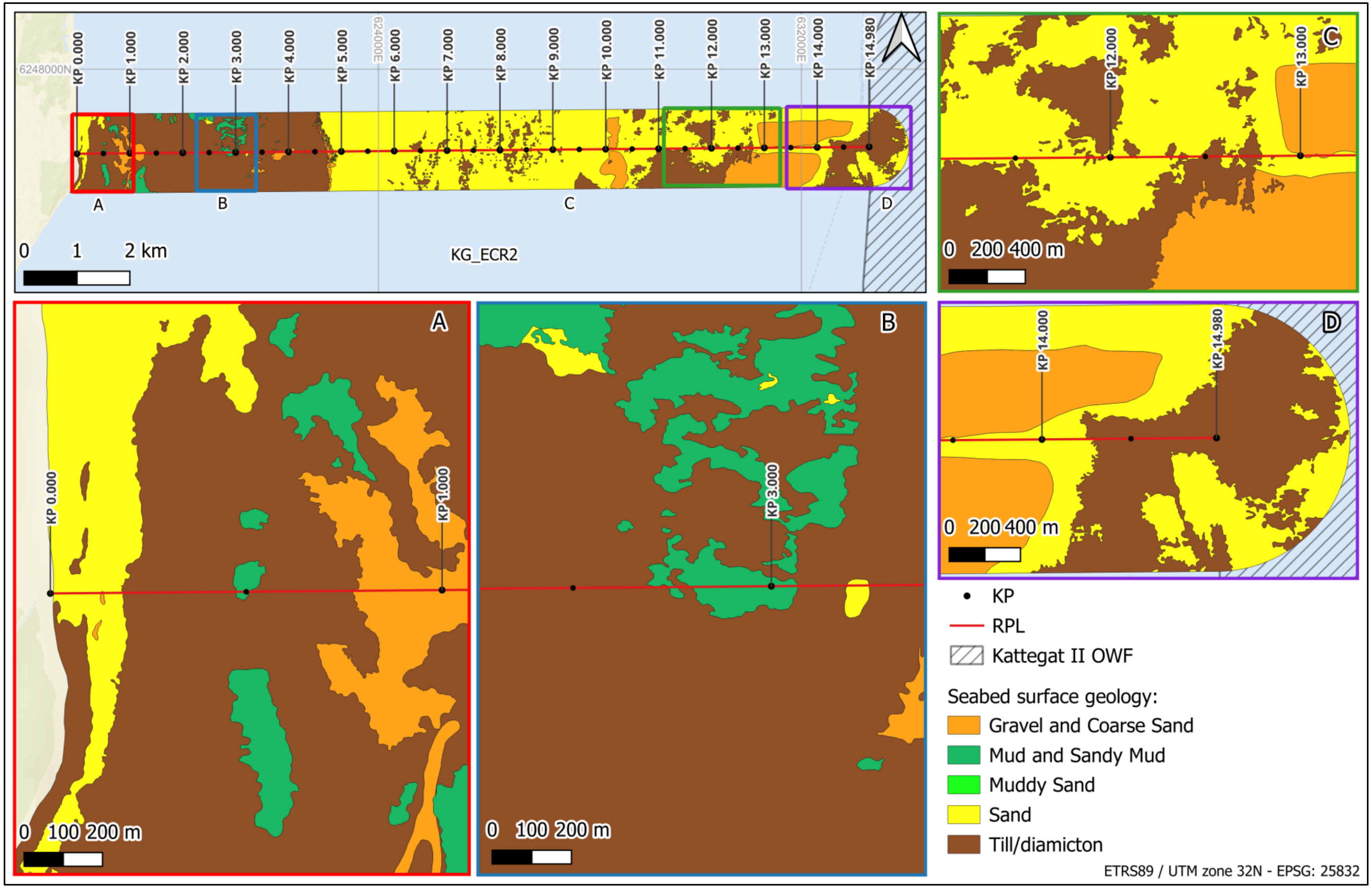


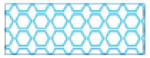
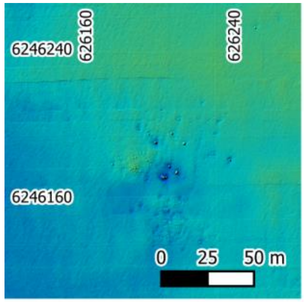
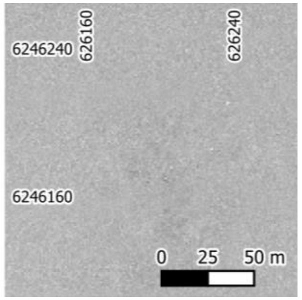
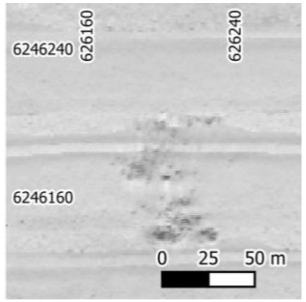
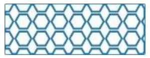
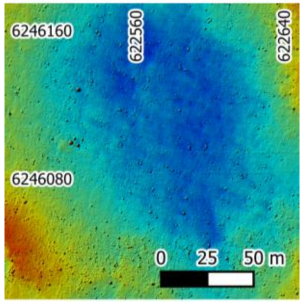
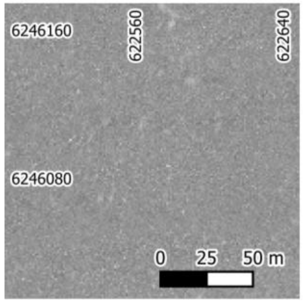
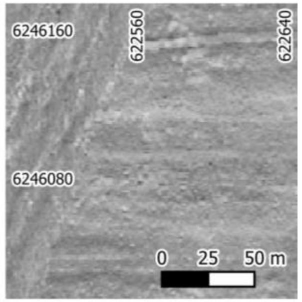
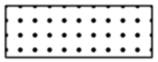
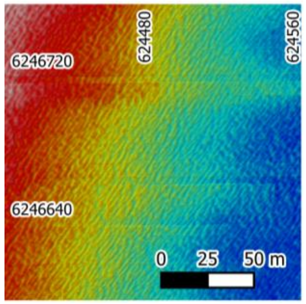
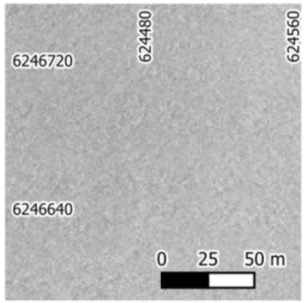
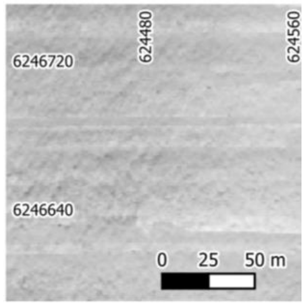
Figure 37: Seabed surface geology classifications with detailed zooms

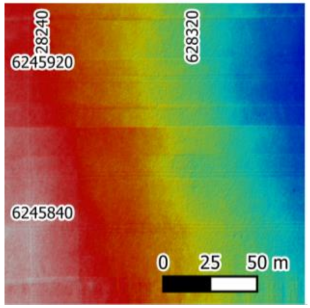
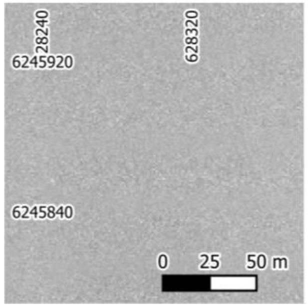
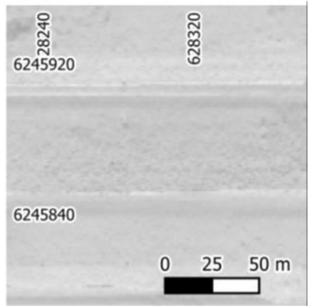
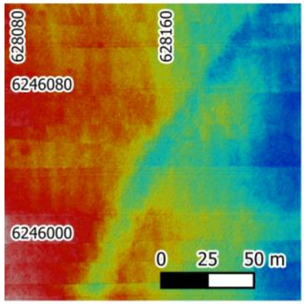
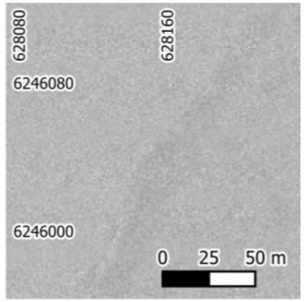
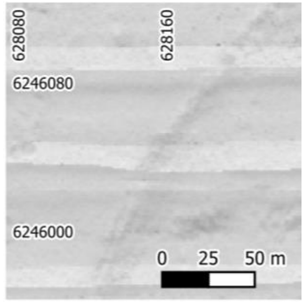
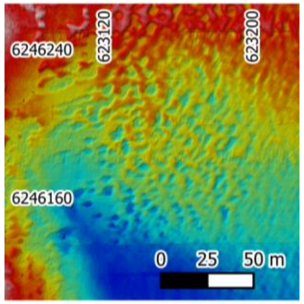
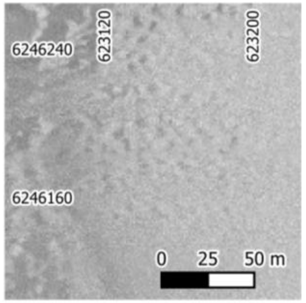
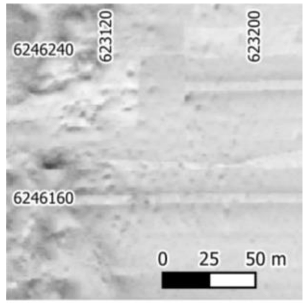
The seabed substrate across the Kattegat ECR 2 area consists predominantly of sand (Figure 36). The surface geology of the Kattegat ECR 2 area exhibits a relatively complex diversity of seabed surface geology, characterized primarily by extensive and irregular deposits of till/diamicton and sand that dominate much of the site (Figure 36). The western part of the area is chiefly composed of till/diamicton, interspersed with pockets of mud and sandy mud, alongside sections of gravel and coarse sand. In the mid-eastern portion of the area, a distinct strip of gravel and coarse sand is present, bordered by regions of sand. Just east of this strip lies a small patch of muddy sand, the only occurrence of this specific classification within the area (Figure 37, chart C).

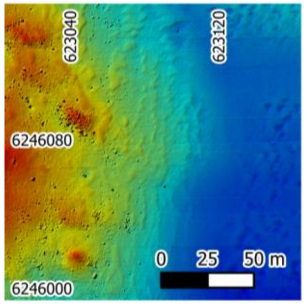
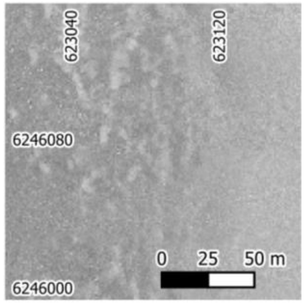
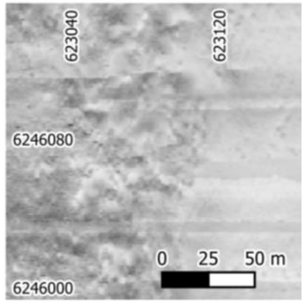
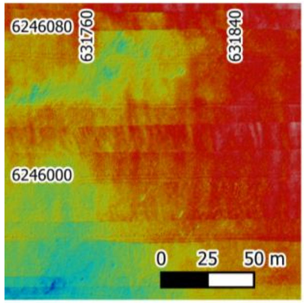
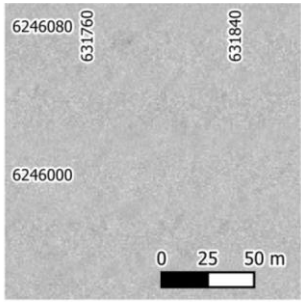
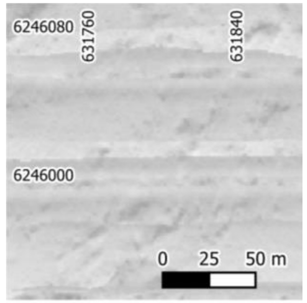
6.4 SEABED SURFACE MORPHOLOGY

The seafloor morphology and seabed features were analysed using SSS (Side Scan Sonar), BS (Backscatter), and MBES (Multibeam Echo Sounder) datasets, with additional insights derived from SBP (Sub-Bottom Profiler) data. The acoustic characteristics of the interpreted seabed features at the Kattegat ECR 2 site are depicted in Table 72. A variety of morphological seabed features of differing dimensions were identified. These features reflect a diverse geological environment influenced by both historical and current hydrodynamic conditions associated with sea level fluctuations (e.g., areas of boulders, ripples). Ripples were classified based on their wavelengths and heights. Ripples were classified based on whichever of the two, height or wavelength, fall into the larger category, e.g. for example, if wavelength of the ripple was 3 m but height was 0.3 m then it was classified as a large ripple. Additionally, some features have anthropogenic origins, such as trawl marks.

Table 72: Morphological interpretation

<table>
<tr><th>Seabed Feature</th><th>Symbology</th><th>Description</th><th>MBES image</th><th>Backscatter image</th><th>LF SSS image</th></tr>
<tr><td>Boulder Field – intermediate density (Class 1)</td><td></td><td>High reflectivity contacts of intermediate density (10 to 20 boulders in a 50 x 50 m box), visible in MBES</td><td>
</td><td>
</td><td>
</td></tr>
<tr><td>Boulder Field – high density (Class 2)</td><td></td><td>High reflectivity contacts of high density (more than 20 boulders in a 50 x 50 m box), visible in MBES</td><td>
</td><td>
</td><td>
</td></tr>
<tr><td>Other – Scour pattern</td><td></td><td>Low to medium reflectivity linear scars forming a pattern, visible in MBES</td><td>
</td><td>
</td><td>
</td></tr>
</table>

Seabed Feature	Symbology	Description	MBES image	Backscatter image	LF SSS image
Other - Featureless seabed		Areas of no significant seabed features (exception of boulders)			
Trawl marks		Low to medium reflectivity linear features, visible in MBES			
Ripples		Low to high reflectivity alternating areas. Clear in MBES. Wavelength (<5 m) and height <0.01 m - 0.1 m) are the primary classifiers			

Seabed Feature	Symbology	Description	MBES image	Backscatter image	LF SSS image
Large Ripples		Low to high reflectivity alternating areas. Visible in MBES. Wavelength, 5-15 m, height 0.1 m – 1 m.			
Unknown – Patches of low reflectivity		Low reflectivity irregular patches, distinguishable only in SSS.			

The resulting seabed surface morphology interpretation is presented in Figure 38, with a more detailed overview of the distribution of morphological features in the western, central and eastern areas presented in Figure 39.

The Kattegat ECR 2 route does not exhibit any significant seabed features of concern, aside from the presence of extensive boulder fields. The morphology and distribution of these features are detailed below.

The initial stretch of the survey area, spanning approximately one kilometre, shows no detectable seabed features. As the landfall sector emerges around zero MSL, high-density and intermediate-density boulder fields become prominent (Figure 39, chart A). These boulder fields, with concentrations exceeding 20 boulders per 50 m², dominate the seabed for the next 4.5 kilometres. There are occasional small patches with featureless seabed and an area of ripples measuring approximately 0.057 km² at KP 3.500.

At approximately KP 4.500, a strip of ripples and large ripples runs perpendicular to the route, with a width of roughly 100 metres (Figure 39, chart B). This feature is visible in both backscatter and MBES data, showing alternating areas of low to high reflectivity in SSS images. Eastward of this strip is a narrow section with featureless seabed detected. Continuing towards KP 6.500, a 1.5-kilometre stretch is classified as 'other,' showing flat seabed with low to medium reflectivity, interpreted as sand.

From KP 6.500 to KP 9.000, intermediate boulder fields dominate the seabed, with occasional patches of high-density boulders interspersed. The segment from KP 9.000 to KP 13.000 displays a mix of high and medium-density boulder fields, patches with scour pattern (defined as 'other'), and areas with featureless seabed detected. Anthropogenic influences, particularly trawl marks, are evident over sandy seabed areas.

Between KP 13.000 and KP 14.500, two patches of 'unknown' features are observed, covering approximately 1.8 km² in the central and southern sectors of the corridor. These areas show trending NE-SW streaks of coarser sediment possibly related to trawl marks. Surrounded these unknown patches are areas interpreted as trawl-marked regions. The final stretch towards the eastern boundary is predominantly characterized by intermediate boulder fields, especially in the central region (Figure 39, chart B). Interspersed patches of high-density boulders and areas with featureless seabed are also present.

The seabed morphology along the Kattegat ECR 2 route primarily consists of boulder fields of varying densities, interspersed with flat sandy areas, ripples, and trawl-marked zones.

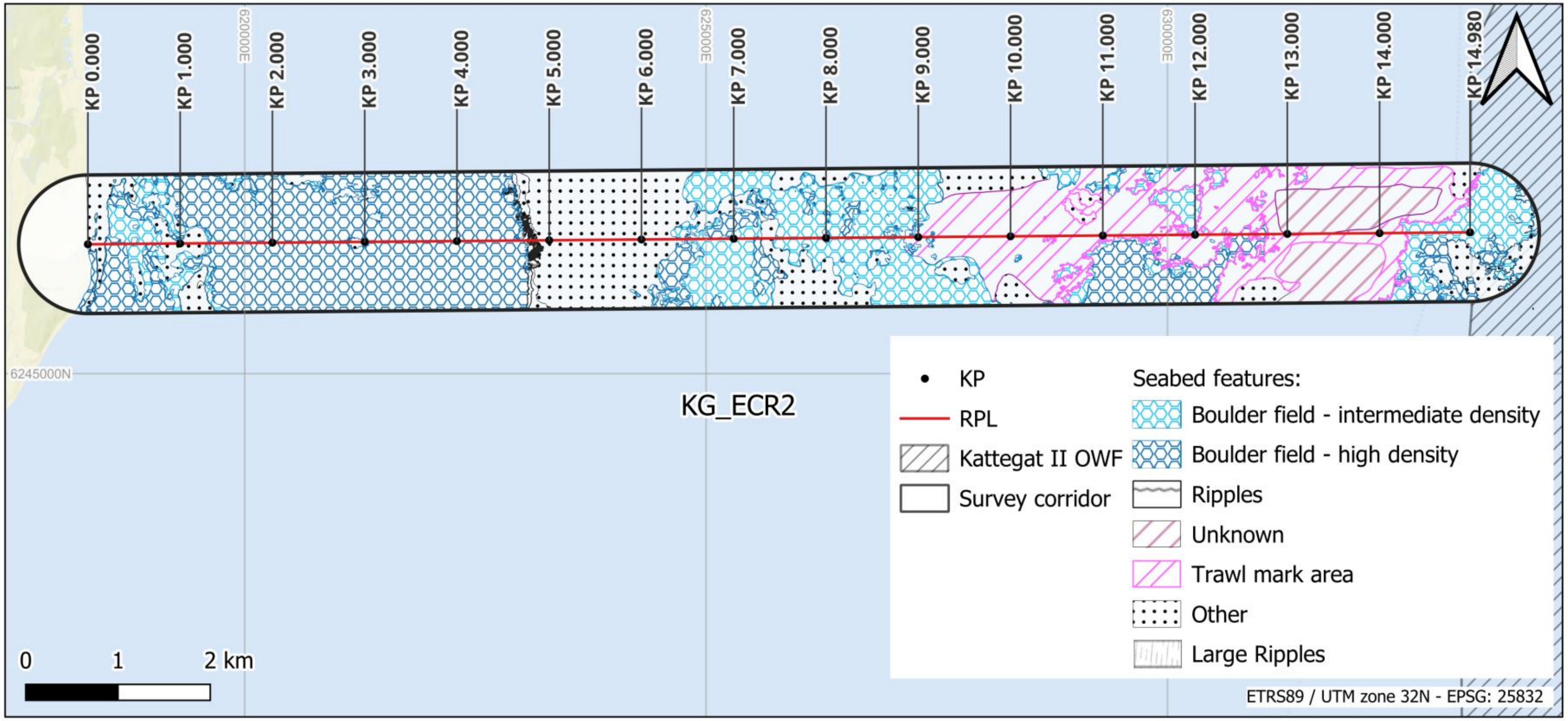


Figure 38: Seabed morphology classification

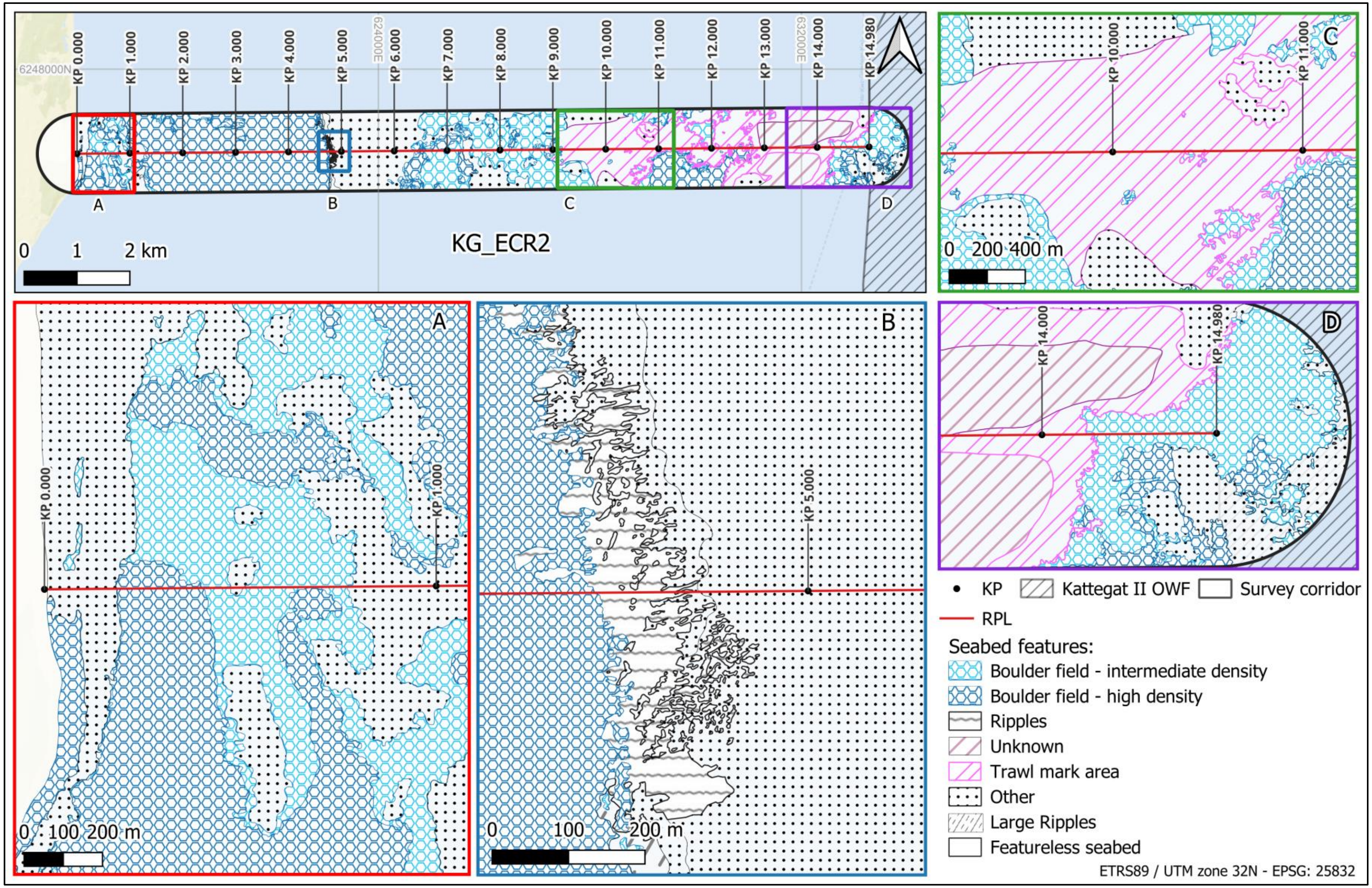


Figure 39: Seabed morphology classification western, central and eastern regions

6.5 SEABED SURFACE FEATURES

Seabed surface objects which are determined to be man-made objects (MMO) are outlined in Table 73 and Table 74 in both linear and point contacts.

Linear features have been determined from MBES and SSS data. Point seabed features have been determined as a Master target list without the man – made object point features. Polygon features have been detected from SSS and MBES data.

A total of 114 MMO linear objects were identified through the interpretation of the MBES, SSS, and MAG datasets. Of these objects, 24 have been detected in multiple sensors. There are an additional 14 linear seabed features identified as seabed scars.

A total of 14,016 point contacts were detected through the interpretation of the MBES, SSS, and MAG datasets within the survey area. 1741 contacts are identified within the MMO point file and 12,275 are identified within the seabed features point file and interpreted as boulders. It should be noted that some MMOs could be classified into more than one feature type (e.g., two objects have been classified as both linear and point contacts). Therefore, the sum of the amounts found in Table 73 and Table 74 does not amount to the total number of objects.

Table 73: Summary of linear contact man-made objects

Feature type	Total amount	Comment
Wrecks	0	No shipwrecks were identified on site.
Metallic	2	Two linear contacts found within a 5 m radius of a magnetic anomaly.
Ropes	102	102 contacts related to possible soft rope item.
Other contacts	10	Ten contacts are identified to be linear objects
Cable/pipeline	0	No cable nor pipeline infrastructure was identified.

Table 74: Summary of point contact man-made objects

Feature type	Total amount	Comment
Wrecks	0	No shipwrecks were identified on site.
Metallic	1,196	1,196 contacts found within a 5 m radius of a magnetic anomaly.
Anchor	2	Two anchors were found within the site.
Ropes	102	102 contacts related to possible soft rope item.
Other contacts	439	439 contacts are identified to be debris
Cable/pipeline	0	No cable nor pipeline infrastructure was identified.

6.5.1 Wrecks

No wrecks were identified within the Kattegat ECR 2 site.

6.5.2 Cables, wires and ropes

No infrastructure or communication cables were identified within the Kattegat ECR 2 site. However, a total of 114 linear man-made objects (MMOs) were found across the Kattegat site (Figure 40). These objects vary in length from 5.6 metres to 261 metres and are interpreted as possible cable, wire, or soft rope fragments, most likely related to fishing activities.

Within Figure 40, chart A, the only two linear metallic objects detected are highlighted, both of which were also identified in SSS data and believed to be potential cable or wire fragments. Additionally, 102 linear objects were detected in SSS and MBES data and interpreted as soft rope. Figure 41 shows a linear object, suspected to be a fragment of soft rope in the mid-section of the survey area (MMO ID 0968). The object measures approximately 104 metres in length. The remaining ten linear objects could not be positively identified and were subsequently recorded as 'other,' though they are most likely rope, cable, or wire fragments associated with fishing activities in the area. Figure 41 shows an example of a feature classified as ‘other’ (MMO ID 1721). This feature has a straight-edged linear shape, measuring 8.2 metres in length from end to end, and is visible in both MBES and SSS data. Although the feature does not exhibit magnetic characteristics, this may be due to its position between the surveyed lines.

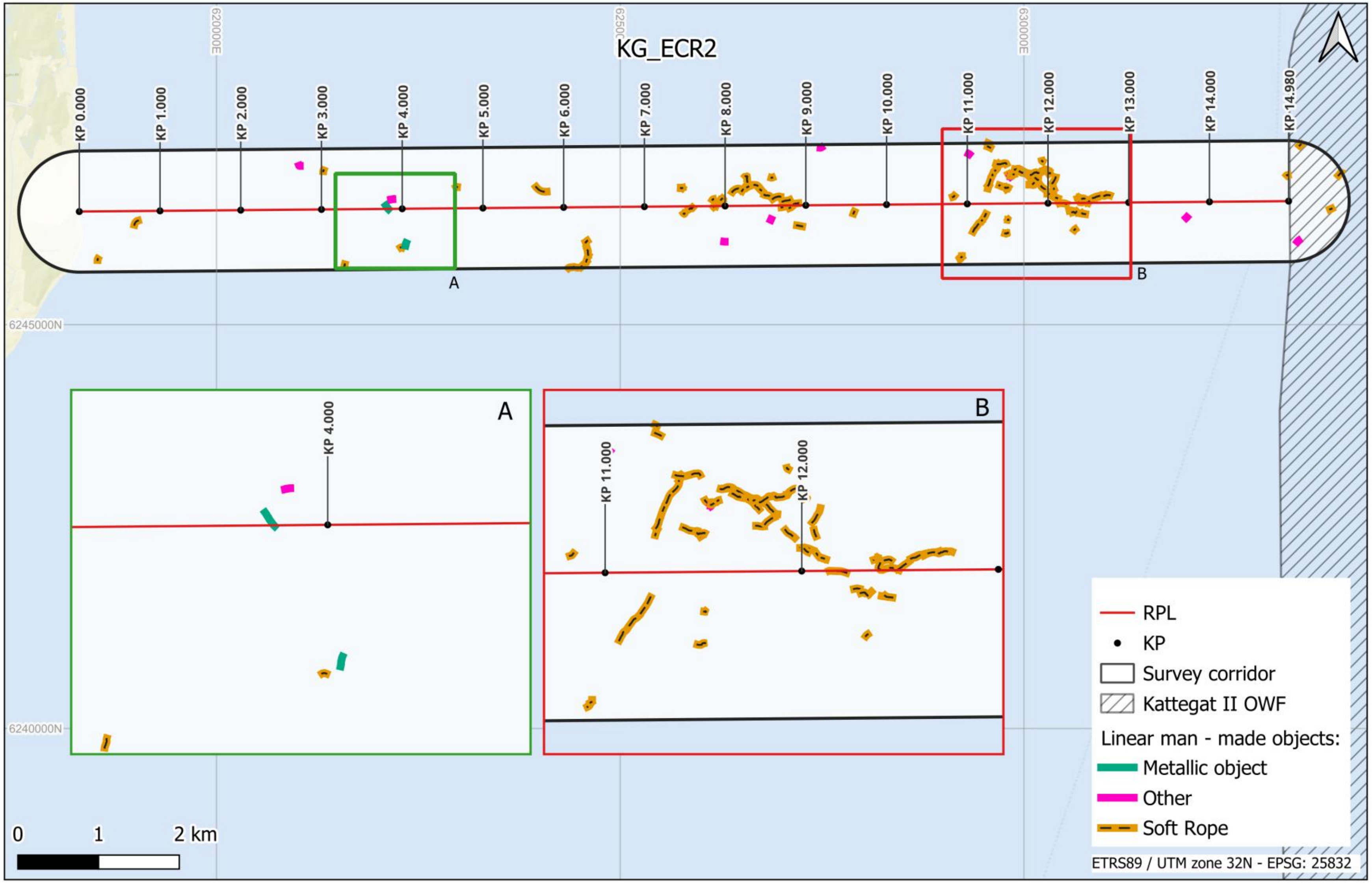


Figure 40: Overview of linear MMO found within the survey site

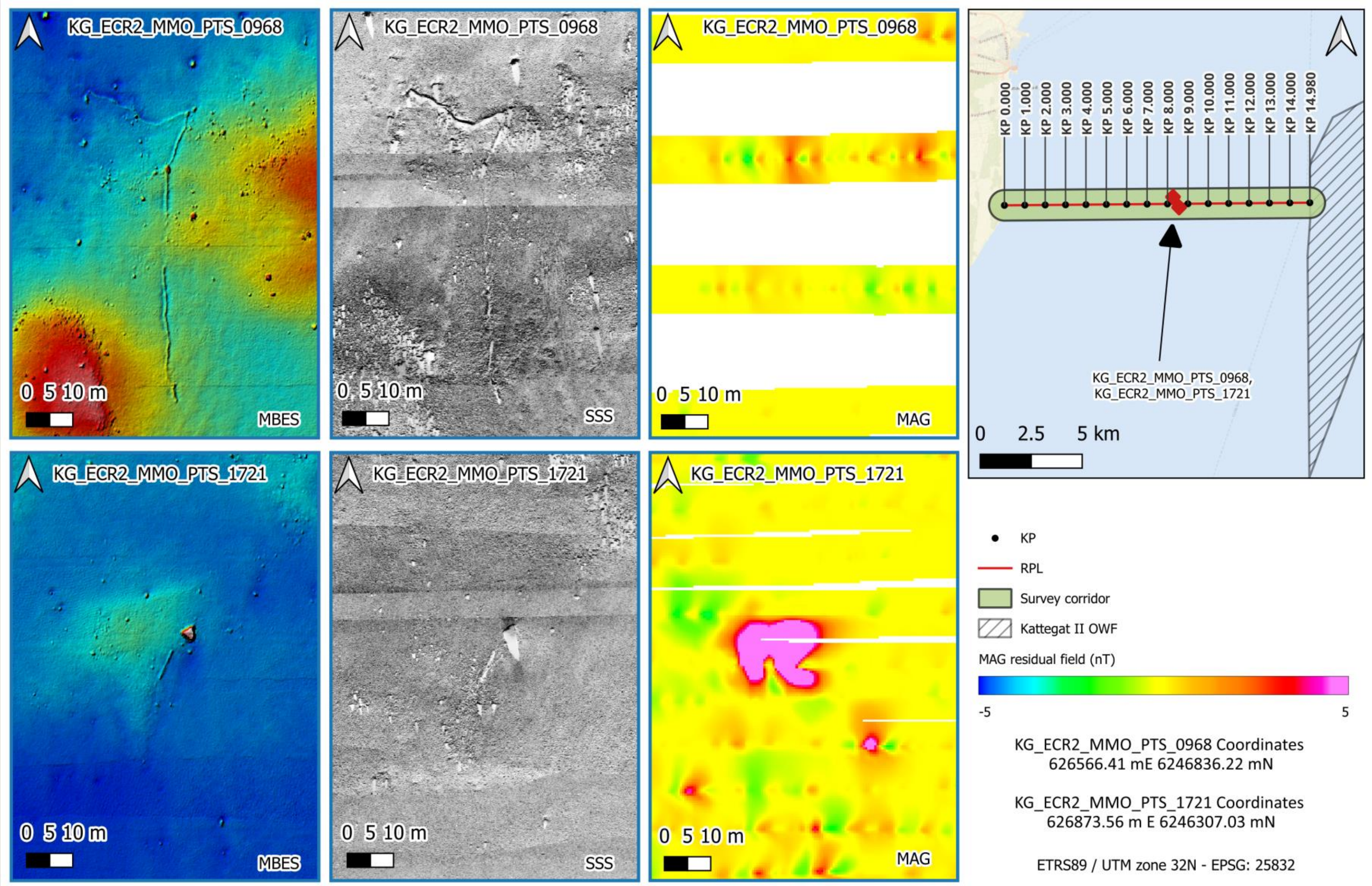


Figure 41: 'Soft rope' and 'other' examples - KG_ECR2_MMO_PTS_0968 and KG_ECR2_MMO_PTS_1721 respectively

6.5.3 Pipelines

No pipelines were identified within or crossing the within the Kattegat ECR 2 site.

6.5.4 Debris

Two possible anchors (KG_ECR2_MMO_PTS_1326 and KG_ECR2_MMO_PTS_0990) were observed within the Kattegat ECR 2 survey area (Figure 42). In general, anchor is a ferrous metal object, however, the magnetometer survey does not identify both anchors as a magnetic anomaly. This is likely due to the anchor locations being too far off from the survey lines. Both anchors are clearly noted in the SSS and MBES datasets.

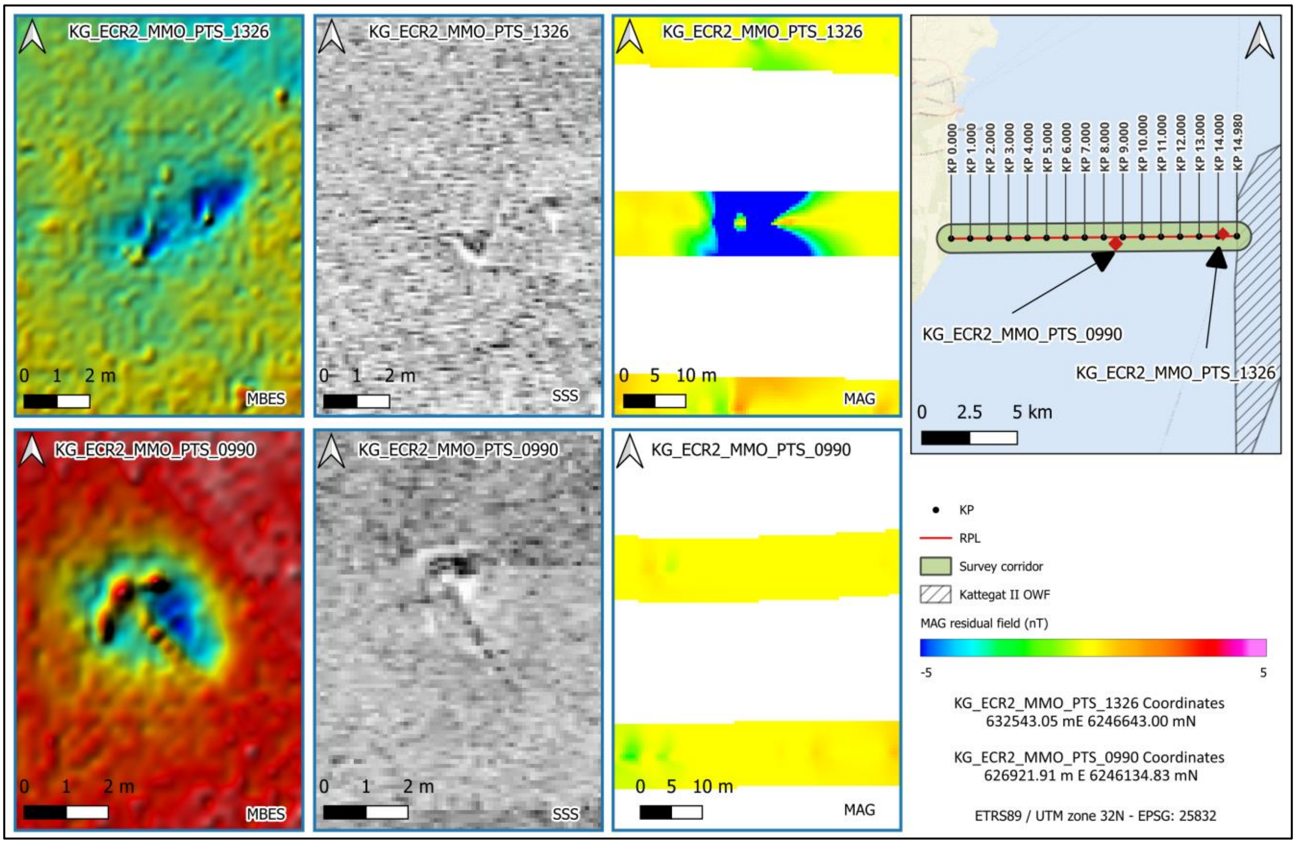


Figure 42: Possible anchors MMO ID KG_ECR2_MMO_PTS_1326 and KG_ECR2_MMO_PTS_0990

An object identified from SSS and MBES, confirmed to be within a 5-metre radius of a magnetic anomaly, is classified as a metallic object. A total of 1,138 metallic objects were identified within the Kattegat site, 1023 of which have associated SSS anomalies. These objects were either found as single entities or in clusters (Figure 43). The highest density of magnetic anomalies is located in the mid-western region of the survey area, between approximately KP 3.000 and KP 4.500, spanning the entire width of the survey area within this region, Figure 43.

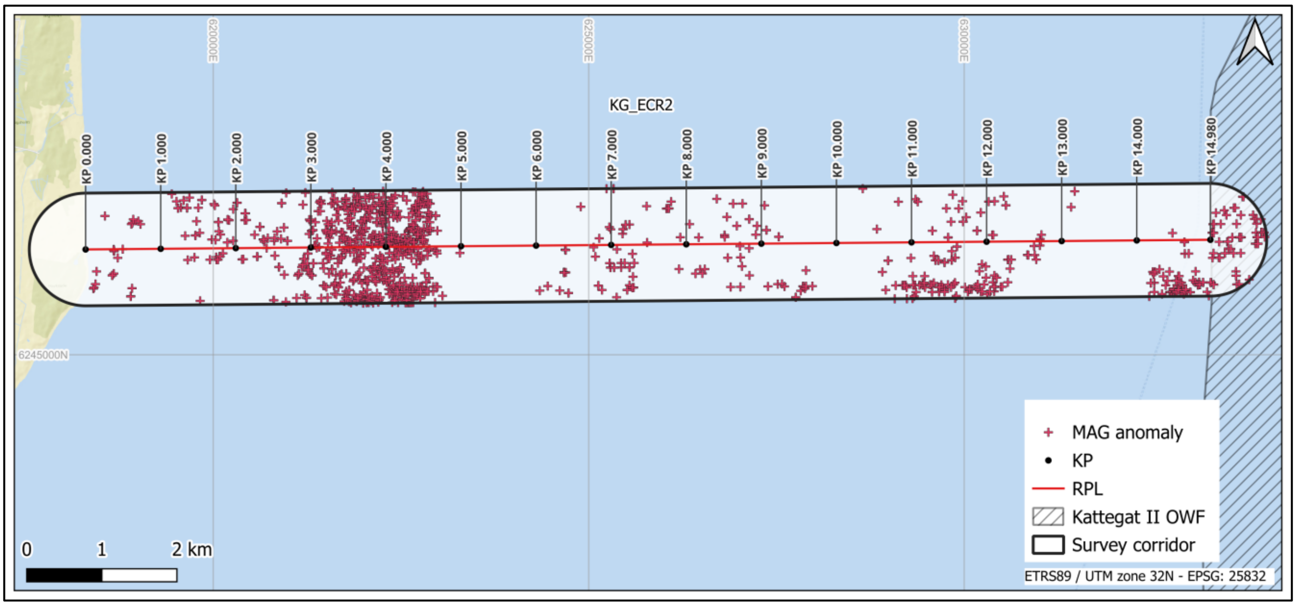


Figure 43: Overview of MAG anomaly items within the survey site

Figure 44 below provides a typical example of MAG anomalies within one of the highest density areas in the southwestern region of the survey area. These contacts are visible in all datasets and appear to represent boulders based on their acoustic reflective properties.

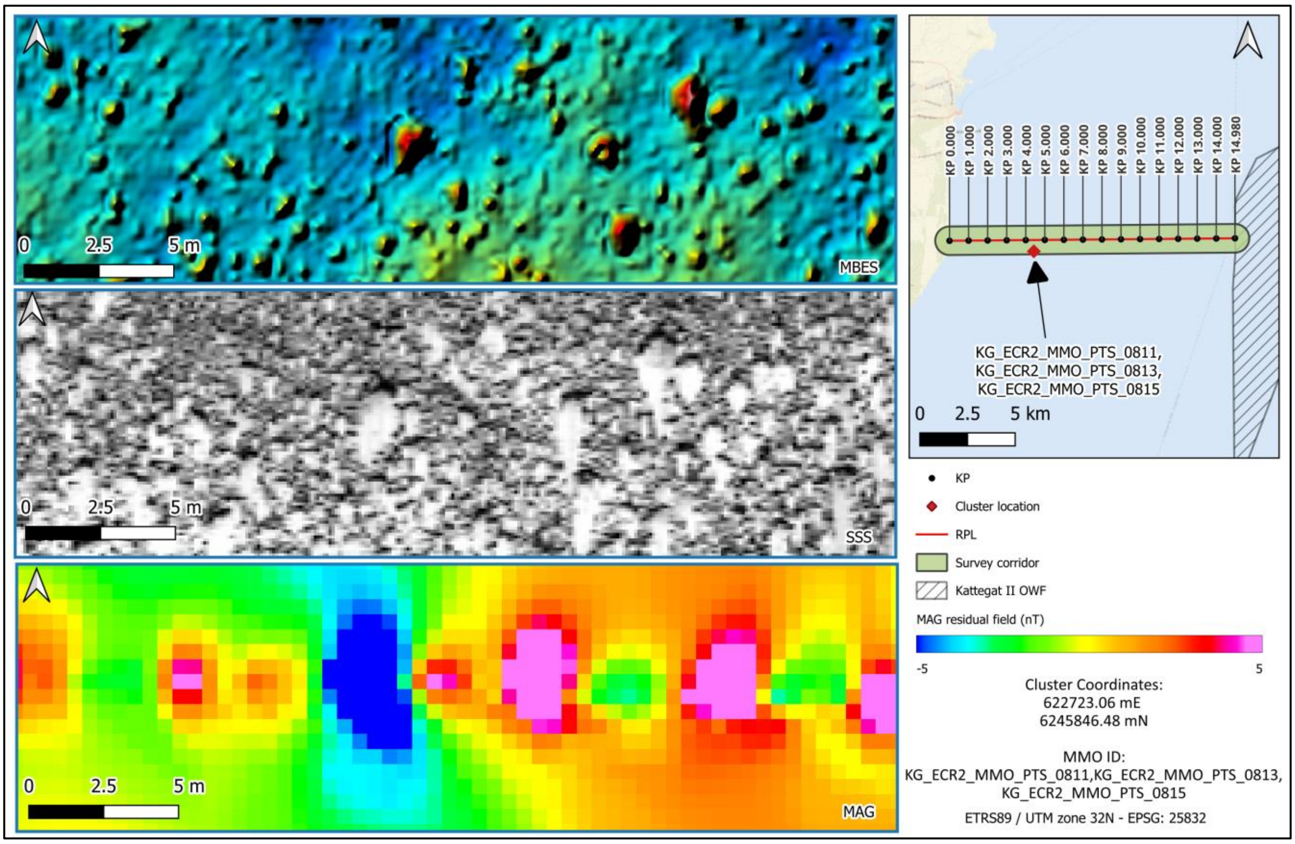


Figure 44: MAG anomalies, objects (MMO IDs KG_ECR2_MMO_PTS_0811,KG_ECR2_MMO_PTS_0813, KG_ECR2_MMO_PTS_0815)

A total of 443 additional items of debris point contacts were observed within the site. All of these were interpreted as non-ferrous objects and detected only in the SSS data.

6.5.5 Items related to fishing activities, and seabed disturbances

All trawl marks, ropes and wires identified within the Kattegat ECR 2 site are highly likely related to fishing activities.

6.5.6 Archaeological findings

No anthropogenic contacts identified have been associated with archaeological significance within the Kattegat ERC 2 site. Two anthropogenic contacts, i.e., possible anchors (MMO ID KG_ECR2_MMO_PTS_1326 and KG_ECR2_MMO_PTS_0990) presented in Figure 42, were observed within the survey area and discussed in detail in Section 6.5.4., yet GEOxyz cannot evaluate potential archaeological significance.

GEOxyz is not specialised in providing archaeological services. As such, the findings in this report are based on an interpretation of the data, which is a matter of opinion on which professionals may differ.

6.6 GEOTECHNICAL RESULTS

The following section presents a summary of the selected results from the geotechnical investigation conducted along the route.

Figure 45 and Figure 46 illustrate the locations of CPT and VC measurements, along with the achieved penetration depth.

Figure 47 to Figure 49 display the sample analysis results for each vibrocore, including:

- Description of the soil type
- D50 percentile value
- D90 percentile value
- Bulk density
- Water content

Figure 50 presents the cone resistance and friction resistance measurements for each CPT location along the route.

In Figure 51, the percentage of clay and the thermal resistivity values along the route are presented.

Figure 52 show the correlation between soil type and CPT derived parameters (undrained shear strength and relative density) with the main horizons highlighted from SBP interpretation.

A detailed account of the geotechnical dataset can be found in the geotechnical report. For full access to the results from the geotechnical investigation, please refer to the external document in Appendix C (Ref. "DOW 2030 - WPC, Kattegat, Factual Report, Rev. 01, 2024-11-12 REPORT").

6.6.1 Particle size distribution and soil type analysis

Sand, occasionally interbedded with gravel layers, dominates the shallowest parts of the VC along the route and was identified as the only soil type throughout the entire depth of VC samples at GT-080, GT-081, GT-087, GT-090, and GT-091. PSD analysis revealed that sand in the top 1 m of the stratigraphy tends to be coarser, while deeper sands show a finer gradation with increased silt content, as evidenced by variations in D50 and D90 values. Thin clay beds were observed at GT-086, while medium-thickness clay beds were detected at GT-088, GT-089, and between GT-092 and GT-095, indicating localized depositional variability.

Deeper glacial till sediments were identified at GT-082, GT-084—where till was interbedded with sand—and between GT-092 and GT-095. Depending on the location, these till sediments are either sand- or clay-dominated; however, PSD analysis, particularly the comparison of D50 and D90 values, revealed a low degree of sorting which is a common feature of glacially deposited material.

6.6.2 Moisture content, bulk density and dry Density

Moisture content measurements were conducted in the onshore laboratory and used to calculate dry densities (Figure 49). The results show significant variations in water content and density across different soil types and stratigraphic units.

The lowest dry density values were identified in glacial till sediments at GT-093 to GT-095, where moisture content reached a minimum of 9.5 %. These low moisture contents align with bulk density measurements exceeding 2.1 g/cm³, indicating a high degree of overconsolidation. This overconsolidation is attributed to glacial processes, where the weight of glacial ice sheets compressed the sediments, expelling pore water and increasing their density.

The highest moisture content values were observed in clay, with a maximum of 33.8 %, reflecting its higher porosity and water-retention capacity. In sands, moisture content generally ranged between 15 % and 20 %.

The complete dataset of moisture content measurements and derived dry density values is provided in the geotechnical report for further reference.

6.6.3 Thermal resistivity from TRT measurements

Thermal resistivity measurements from TRT conducted at four geotechnical stations (GT-080, GT-083, GT-088, and GT-093) illustrate the thermal response of different soil types encountered along the RPL, with values ranging from 0.3 to over 0.5 mK/W. The lowest thermal resistivity values (<0.4 mK/W) were recorded in the medium-coarse sands at GT-080, which aligns with the high density of these sands. Similar values were observed at GT-083, although slightly higher resistivity values (>0.4 mK/W) suggest higher presence of finer sediments, as supported by vibrocore descriptions indicating a siltier sand composition at this location.

At GT-088, thermal resistivity increases below 3 mbsb, corresponding to a transition from sand (top) to clay (bottom). The higher thermal resistivity values in the clay layer indicate a very compacted material, likely resulting from overconsolidation processes of glacial origin.

In GT-093, the deeper 2 m of TRT measurements reflect the properties of glacial till. Here, thermal resistivity values remain relatively low (<0.4 mK/W). Despite the likely overconsolidated state of these deposits, this may be attributed to a maintained high residual porosity, possibly resulting from the poor sorting typical of glacial sediments.

6.6.4 Correlation between derived CPT, and soil types and geophysical units

Undrained shear strength and relative density data derived from CPT measurements were correlated with soil type information from VC samples, enabling further characterization of the subsurface and validation of SBP-interpreted units. Cone resistance (Qc) measurements highlighted variations within the sand deposits, distinguishing between a superficial, less dense sand layer (Qc < 10 MPa) and a deeper, very dense sand with higher friction readings (Qc > 0.3 MPa) (Figure 50).

This differentiation facilitated a refined characterization of the stratigraphy. The shallow, coarser, and less dense sands correspond to post-glacial deposits (Unit I in section 6.7), while the finer, silty, and very dense sands are associated with the glacial unit (Unit III). These findings are consistent with grain size distributions and higher silt content observed in VC-recovered samples, as detailed in the geotechnical report.

Unit III predominantly comprises very dense silty sands, especially between GT-080 and GT-091, and glacial till, encountered between GT-092 and GT-095. Between GT-080 and GT-082, the post-glacial sands of Unit I form only a thin surface layer, with Unit III sands almost reaching the seabed. This interpretation aligns with the rough seafloor morphology observed in the area. From GT-083 onward, the uppermost stratigraphy at each station consists of 0.4 to 0.8 m of very loose to loose sands attributed to Unit I.

Overlying Unit I, the Late Glacial Unit II is characterized by localized deposits of medium to very high-density clay, interpreted as channel-filling features bounded at the base by horizon H20. This unit is identified at GT-

086, GT-088, GT-089, and between GT-092 and GT-094, as supported by alignment between VC and CPT data with SBP interpretations.

An overview summary of key geotechnical station results with the SBP interpretation is presented in Figure 52. This presents a bespoke soil grouping based on the vibrocore results of this site, as well as a characterisation of the subsurface using the derived CPT parameters; shear strength (Su) and relative density (Dr). The soil unit classes presented in the figure have been derived to best represent the soil types present in the area and do no align to any standards but help report the soil types present in the area in particular detail. These soil type and Su/Dr classifications have been added to the delivered Kingdom projects to aid interpretation and also allow subsequent QC and correlation. Comparison of the geotechnical data and the SBP interpretation is presented in the route analysis in Section 7.

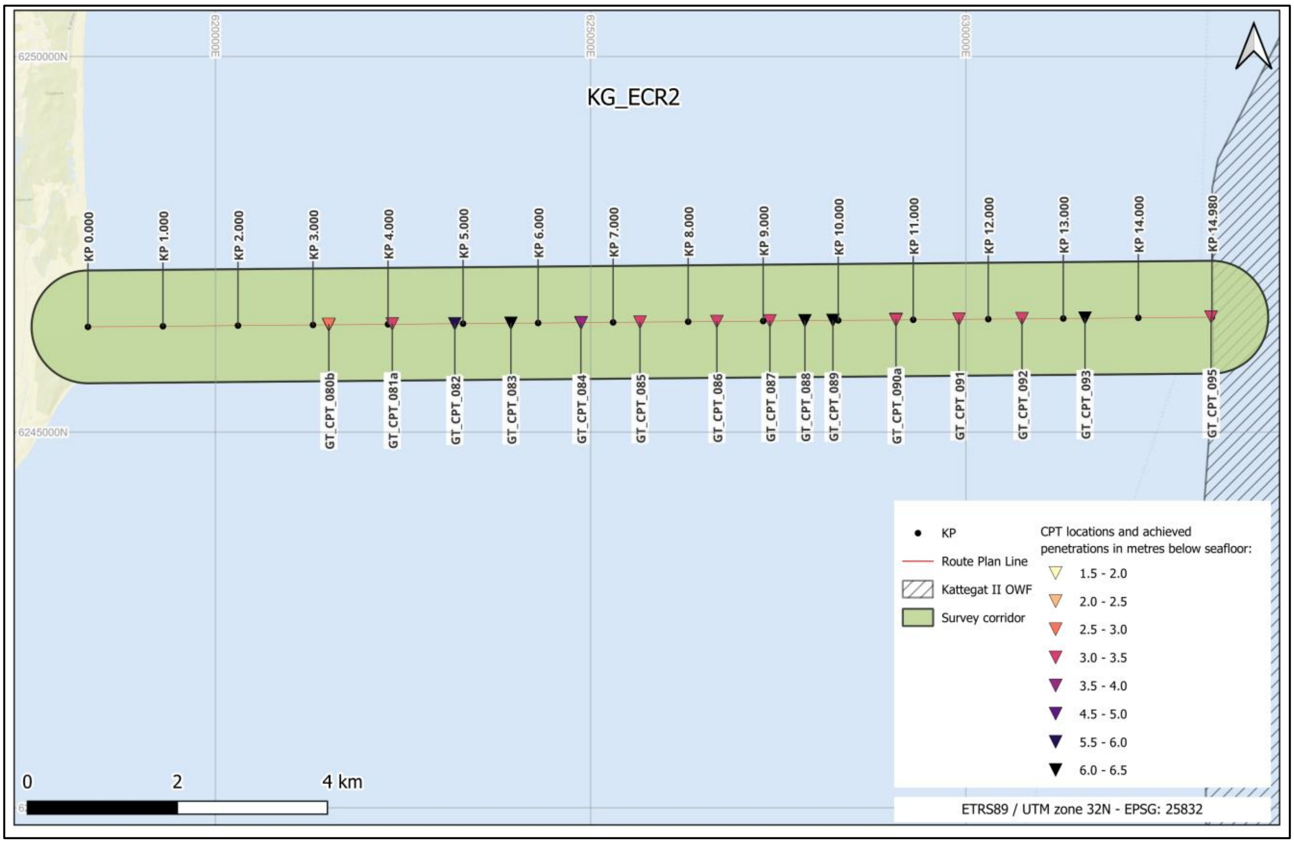


Figure 45: CPT locations overview with achieved depths below seabed

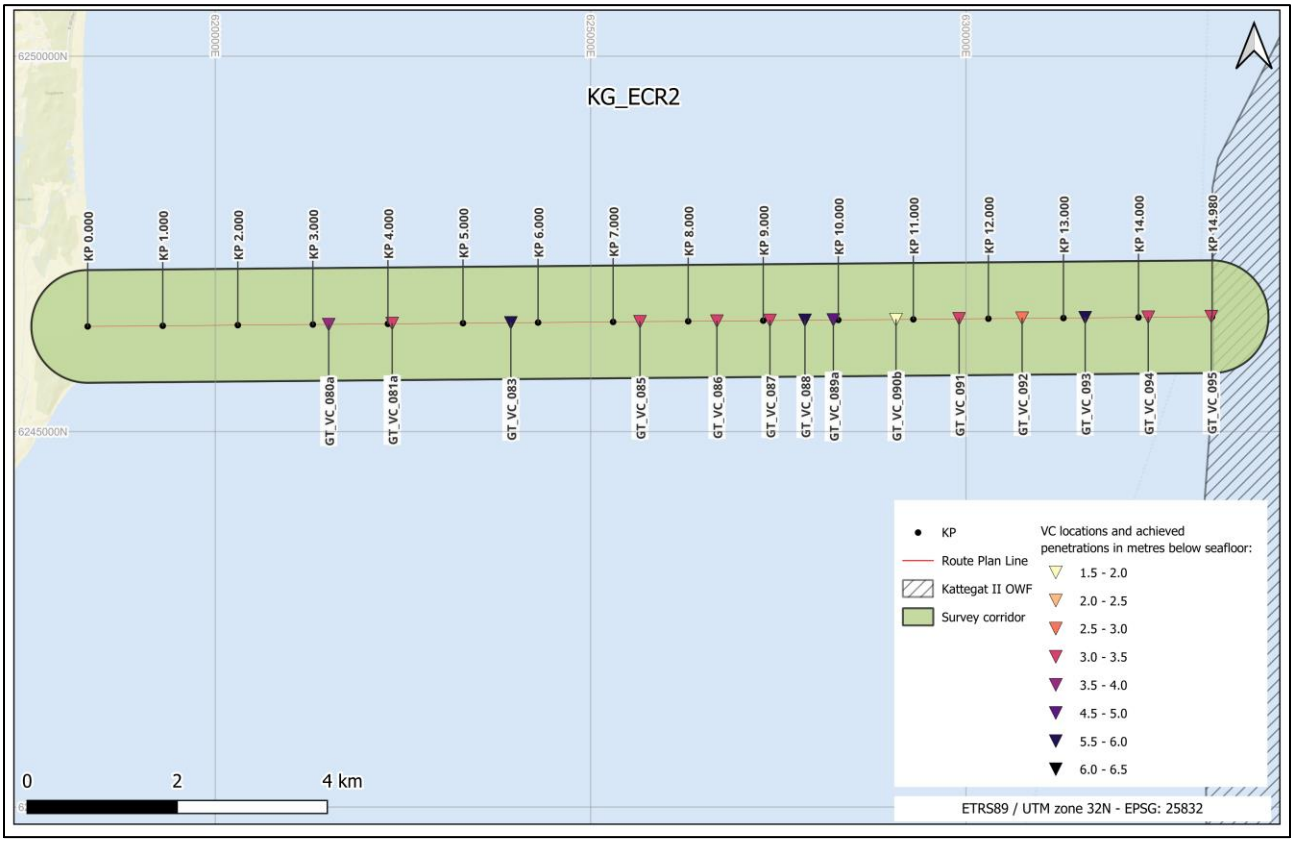


Figure 46: VC locations overview with achieved depths below seabed

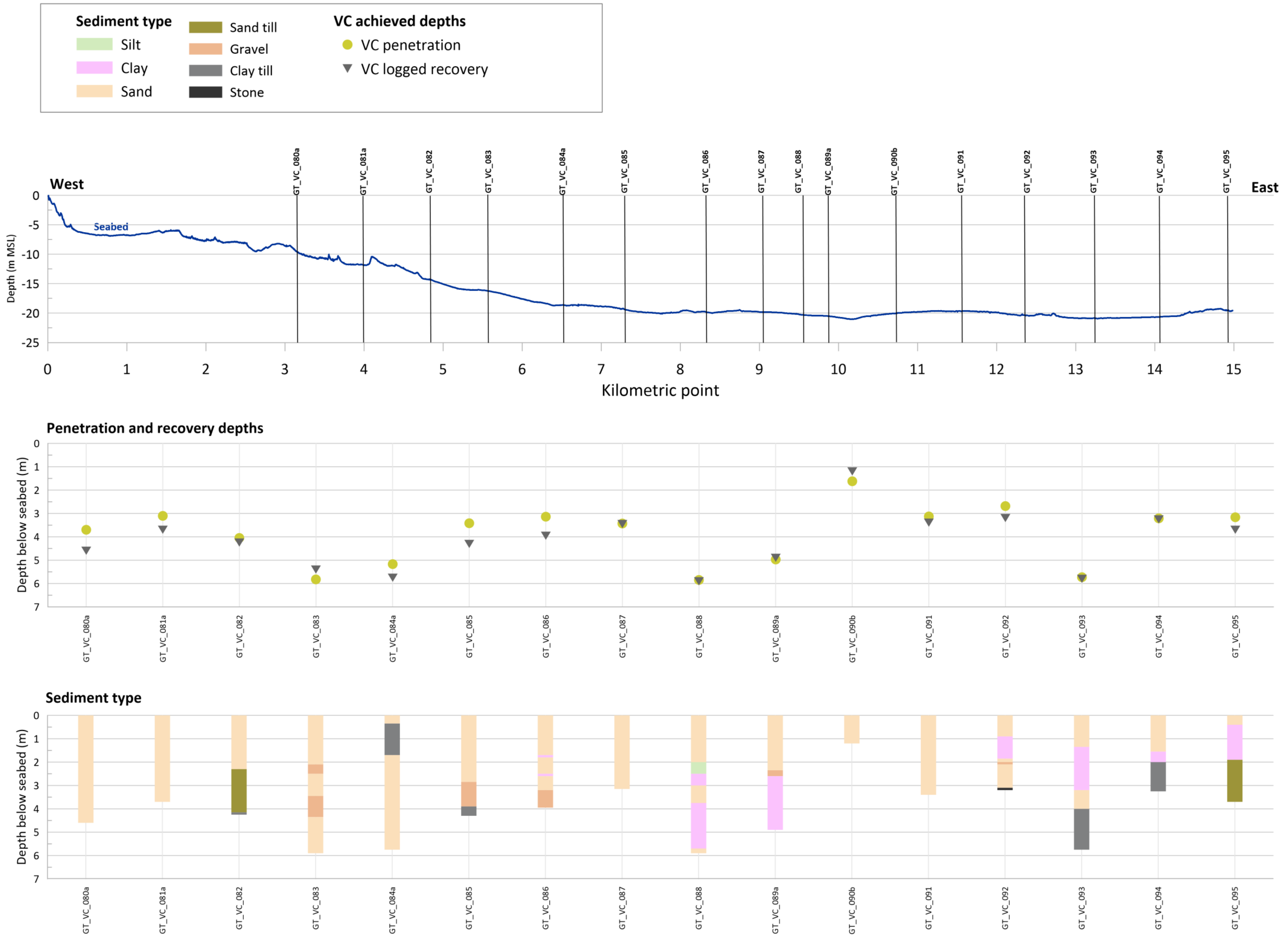


Figure 47: Sample analysis showing achieved depths and soil type distribution

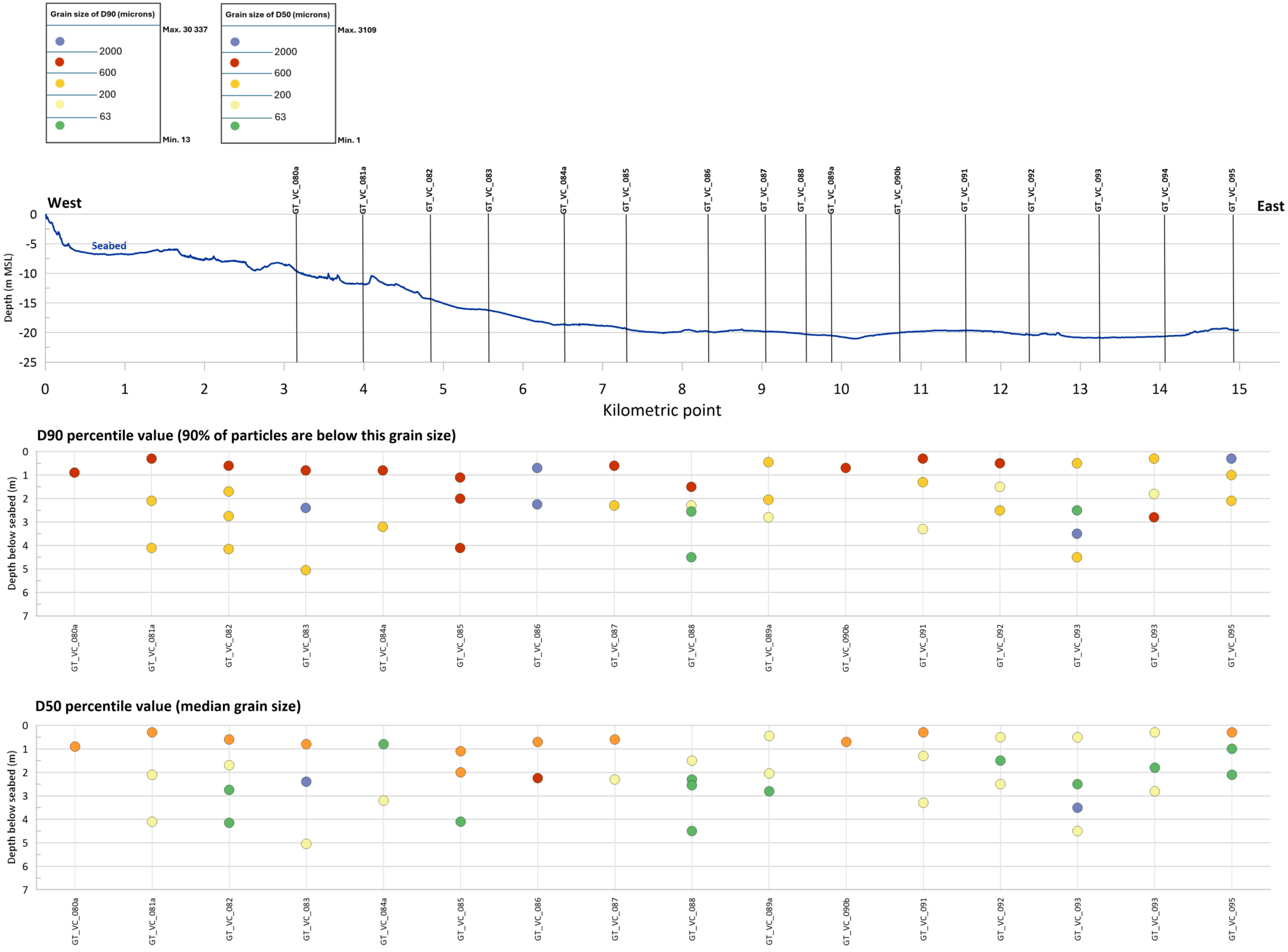


Figure 48: Sample analysis showing D50 and D90 grain size diameters

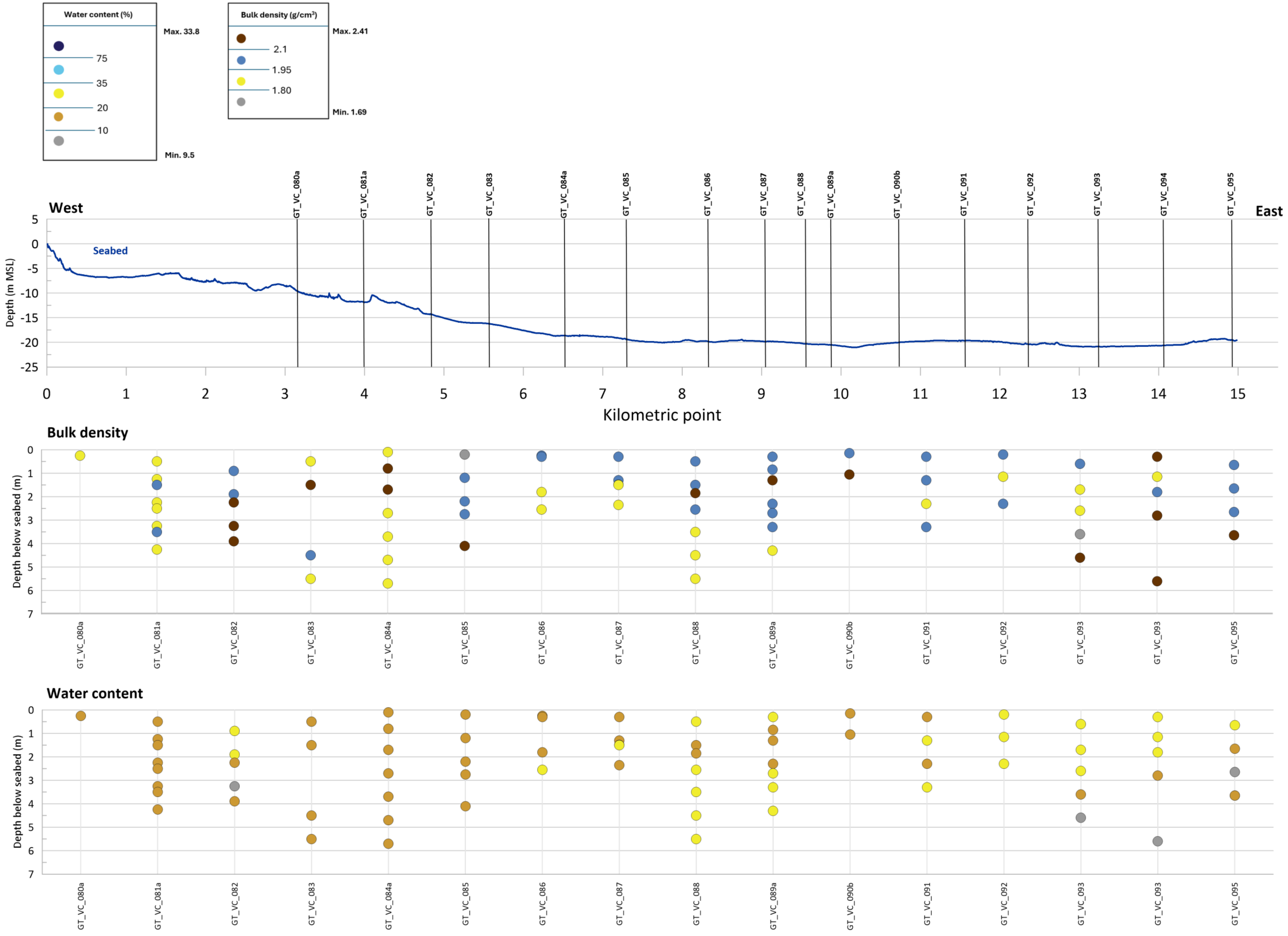


Figure 49: Sample analysis presenting bulk density (g/cm³) and water content (%)

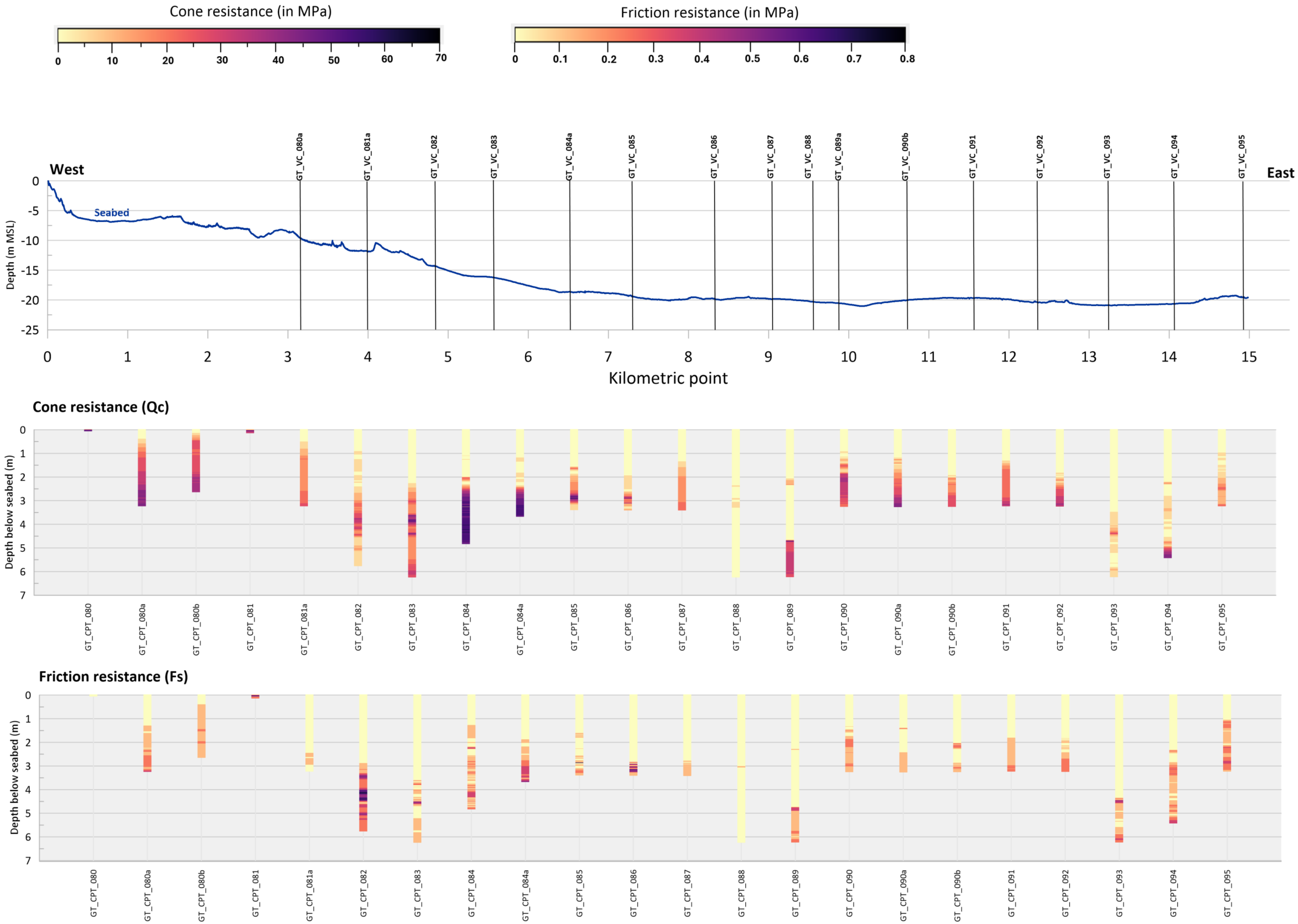


Figure 50: Sample analysis showing cone resistance and friction resistance in MPa

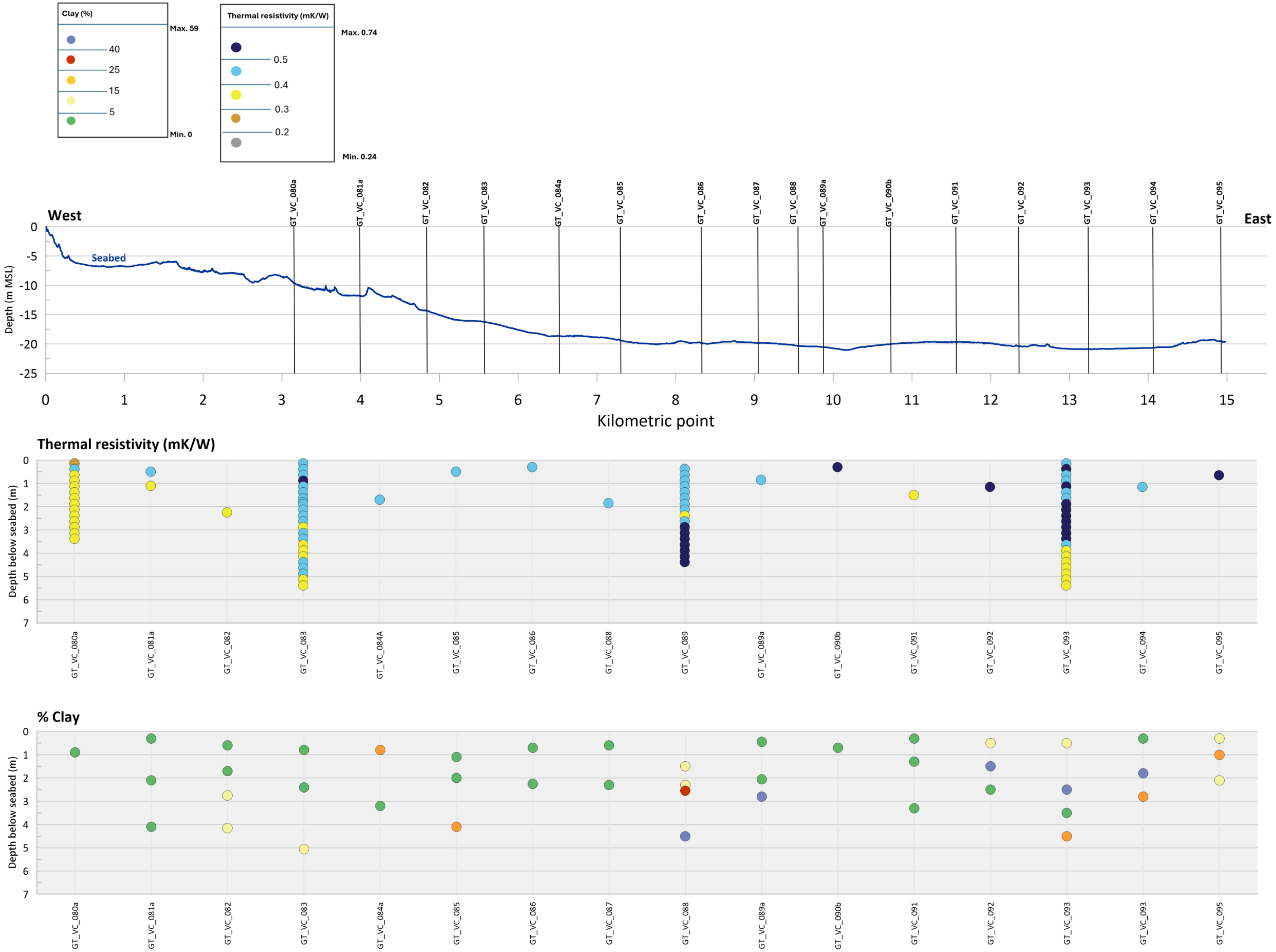


Figure 51: Sample analysis presenting clay (%) and thermal resistivity

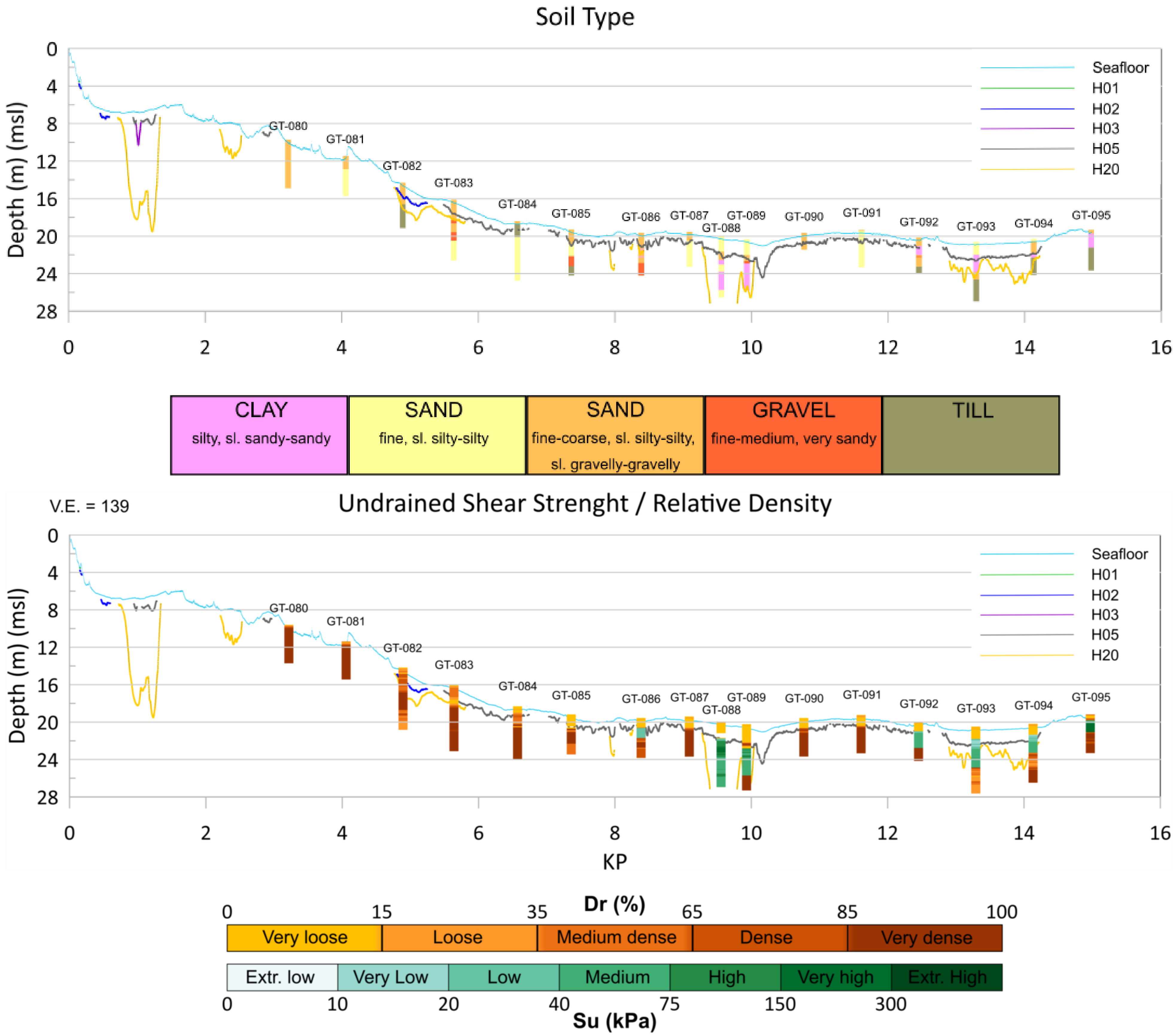


Figure 52: Soil types derived from VC and CPT data (top) and CPT parameters (bottom) compared with key horizons from SBP interpretation

6.7 SUB-SURFACE GEOLOGY

6.7.1 Regional geological history

The geological interpretation along the proposed Kattegat ER2 route is based upon the geophysical and geotechnical datasets acquired with reference to the supplied GEUS desk study. This desk study applies a stratigraphic model developed by Jensen et al. (2002) in conjunction with archive seismic data and limited ground truth information. There is generally a good correspondence between shallow geology imaged in this project's sub-seabed data and the desk study.

In general, the area has a glacial to post-glacial sequence. The post glacial sequence is of relatively recent sediments. Only the upper glacial, late glacial and post glacial deposits are discussed along the Kattegat route as top of bedrock is deeper than the installation zone of interest and not imaged on the SBP data.

6.7.2 Shallow geological overview

Along the Kattegat ECR2 export cable route the following units have been defined. The interpretation has been carried out based on the seismic acoustic nature of the SBP data, the adjoining Kattegat windfarm survey results report and the GEUS desk study. Geotechnical data, acquired by Geo DK, confirmed the age and depositional environments of the sediments. Table 75 summarises the interpretation, geological units and depositional environments below.

Table 75: Shallow Geological Units

Unit	Upper surface	Lower surface	Main Soil Description	Depositional Environment
Ia, Post Glacial (PG)	Seabed	H01	Fine to medium SAND	Post-glacial marine
Ib, Post Glacial (PG)	Seabed/H01	H02		
Ic, Post Glacial (PG)	Seabed	H03		
I, Post Glacial (PG)	Seabed	H05		
II, Late Glacial (LG)	Seabed/H05	H20	Variable, includes intervals of laminated CLAY and SAND-prone packages	Periglacial, glaciomarine
III, Glacial (GL)	Seabed/H05/H20		Variable, TILL, CLAY-prone, locally over-consolidated	Glacial with localized direct ice contact

6.7.3 Stratigraphy and general arrangement of units

The model below (Figure 53) shows the arrangement of units along the proposed Kattegat ECR 2 route. Table 75 shows the basic characteristics of the stratigraphic units. Key surfaces are the top of Unit III (H20/H05/seabed), which is the top of potentially over consolidated deposits. Sediments within Units I and II are less well consolidated, with fewer cobbles and boulders present than found in Unit III.

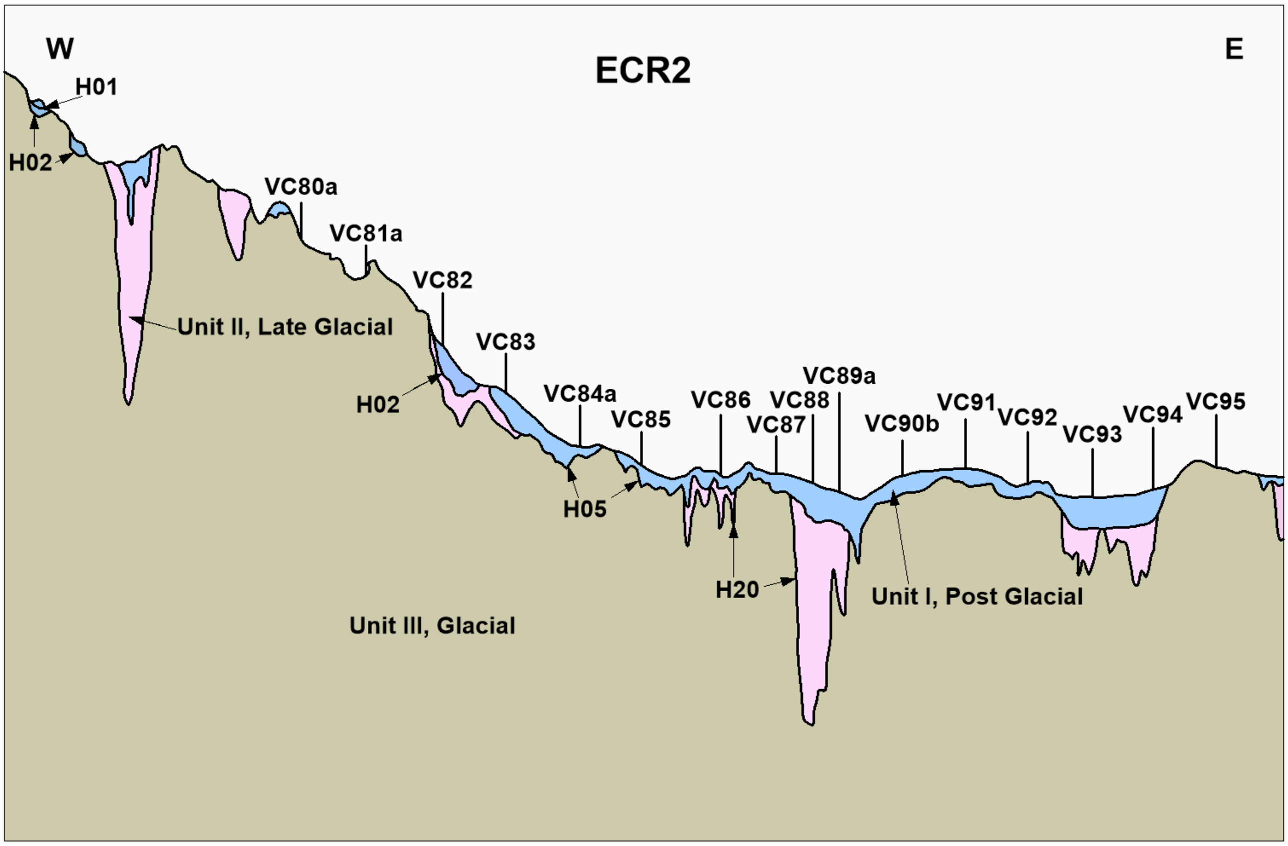


Figure 53: Geological schematic, general arrangement of units, with the approximate geotechnical locations

6.7.4 Deglaciation history / stratigraphic units

These bullet points are largely derived from information in the GEUS desk study. Here the stratigraphic units have been linked to the changing paleoenvironments.

- In Denmark the Scandinavian Ice Sheet reached its maximum extent about 22,000 years BP followed by retreat with evidence for short-lived advances over the following four thousand years. **Unit III was laid down in association with this ice sheet.**
- Marine transgression began around 18,000 years BP leading to rapid deglaciation and establishment of glaciomarine conditions. An isostatic regression occurred shortly after 18,000 years BP. This was followed by renewed marine transgression related to the wasting of the Baltic Ice Stream. **Unit II was laid down over this complex period.**
- After deglaciation the area generally experienced high-stand conditions, though glacio-isostatic rebound outstripped background sea level rise around 10,000-11,000 years ago, driving a local regression. **Unit I was deposited in this marine environment.**

a Post Glacial geology

Unit I is a package of post-glacial fine to medium SAND which is less than 1.5m thick over most of the site and reaches a maximum thickness of 4.3 m in a North-South trending channel at KP 10.160. The interval includes a veneer of seabed sediments, though this is interpreted to be very thin and seldom resolved in the SBP data. The Post Glacial sediments are widely distributed over the cable route corridor beyond KP 4.750 (Figure 55).

Geotechnical data shows the SAND to be loose to very loose, with the exception of the VC082 which contains medium dense, coarse to medium SAND.

Acoustically, the interval is almost featureless, with very low amplitude, concordant internal reflections. Locally there are very subtle unconformities. These may represent sea level variations related to the interplay of isostatic rebound and background sea level rise as well as shoreline transgressions and regressions.

The base Post Glacial is mapped as H05 (and sub-units by H01, H02 and H03 in the nearshore area). Over broad areas, where the unit is thin, it is interpreted to be an erosion surface – thickness variations are due to relief at this surface. The erosion at H05 may be related to the final regression of the area ~10,000 years ago when sea level dropped, potentially allowing storm erosion of the contemporary seabed.

There are very occasional bright spots which may possibly be organic material, although these have not been confirmed by geotechnical sampling.

The location of seismic profiles, which are presented throughout the report, are displayed in Figure 54 below.

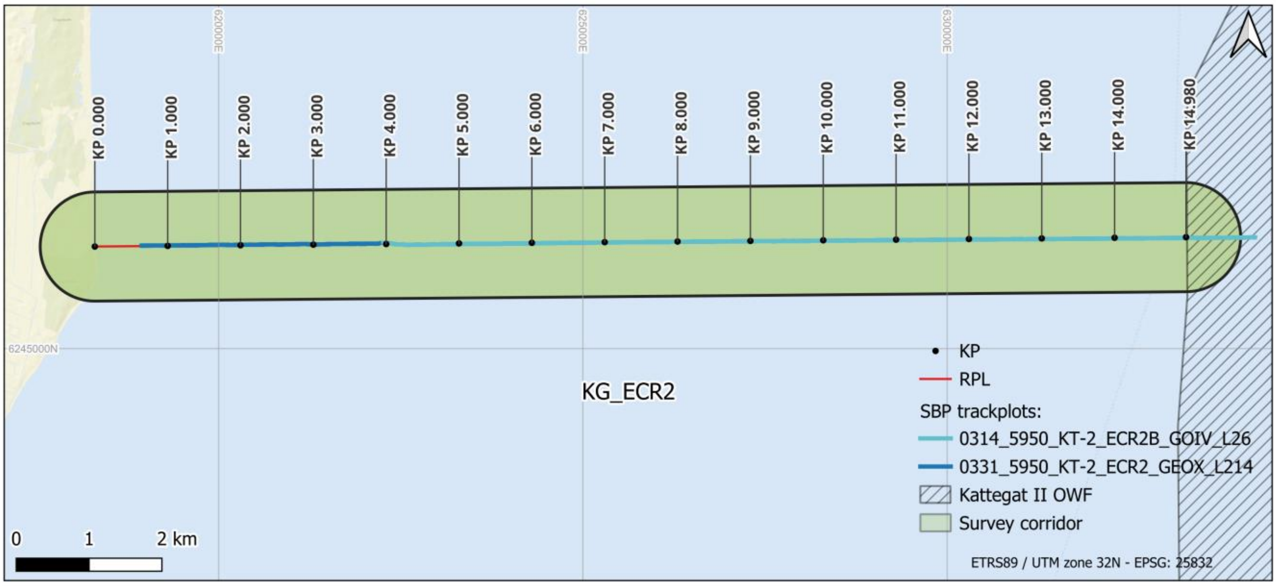


Figure 54: Location of the seismic profiles shown throughout the report

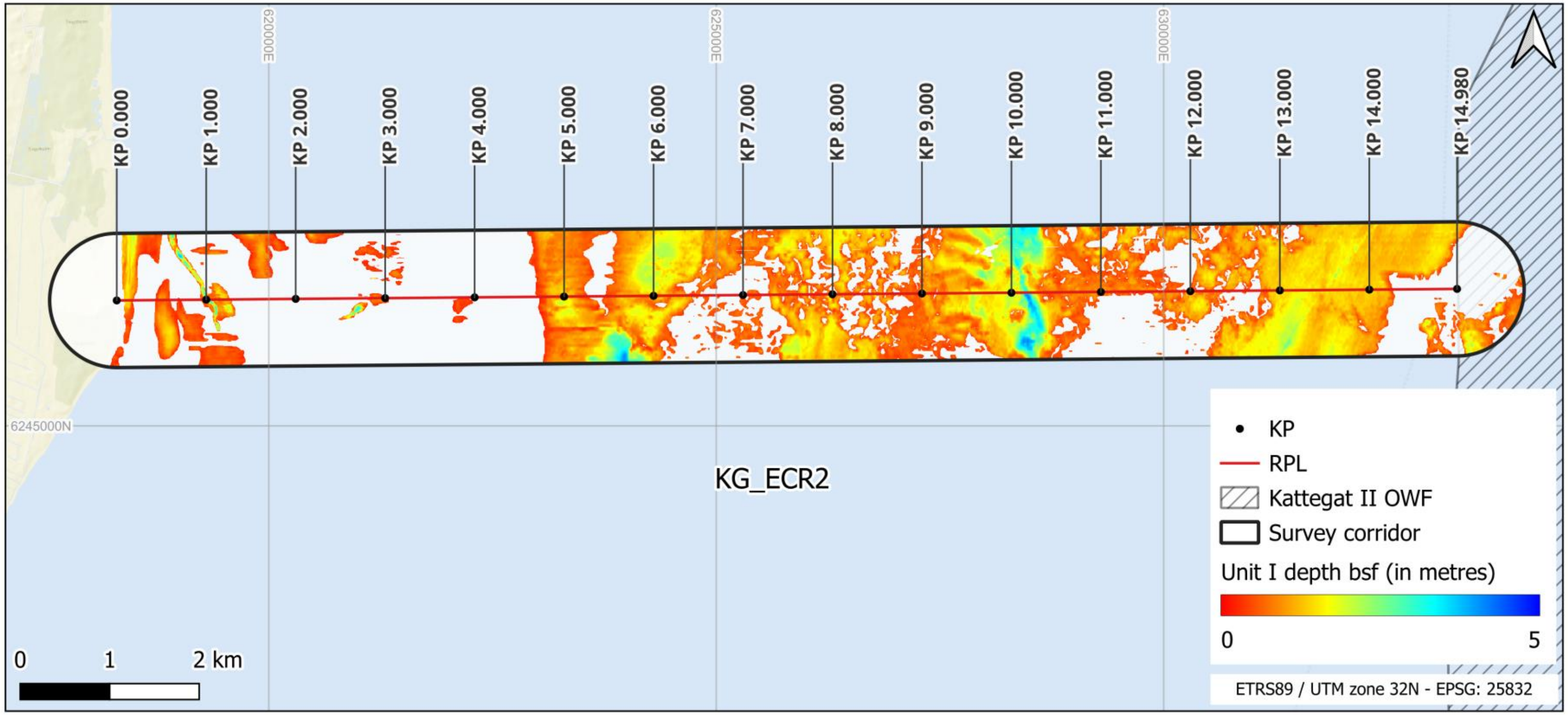


Figure 55: Extent and depth bsf (in metres) of Unit I

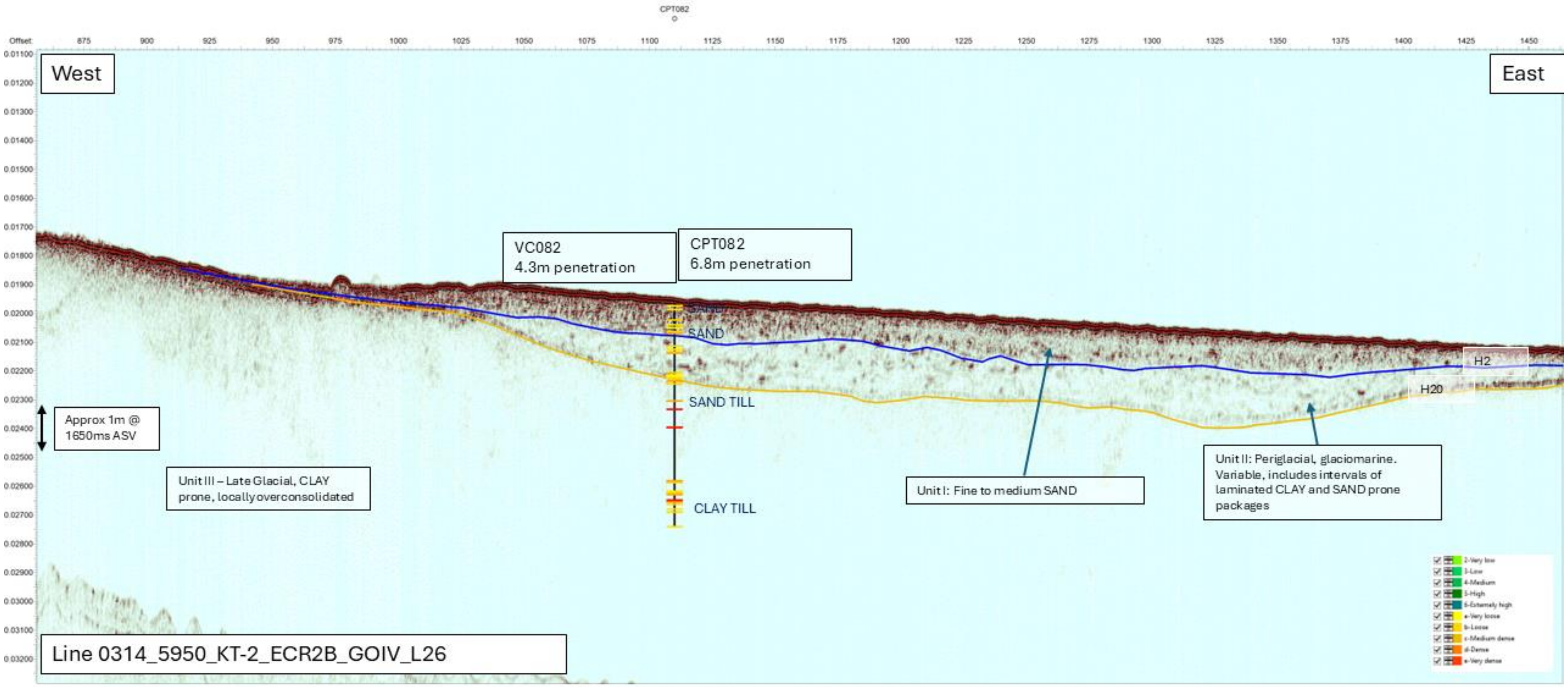


Figure 56: Seismic profile example - CPT & VC 82

b Quaternary geology

Unit II Late Glacial deposits

This interval is very complex due to the area's range of environmental conditions during the Late Weichselian and earliest Holocene. Some intervals show laminations indicative of clays and silts, others may represent sandy beach-type deposits. The unit is mapped with H20 at its base. This is generally at the top of deposits which show clear signs of ice contact, true glacial deposits. The relief at this basal surface strongly influences the thickness and distribution of the Unit II Late Glacial sediments.

Acoustically the interval is generally moderate amplitude and well bedded, with the bedding parallel with the high amplitude basal surface.

Geotechnical samples show the Unit comprises fine to medium SAND in the nearshore area, trending to SILT and CLAY in the middle and to CLAY at the eastern end of the ECR 2 route.

Along the route corridor Unit II, glaciomarine sediments infill steep sided channels eroded into the underlying Unit III tills. The extents of Unit II are shown in Figure 57 below.

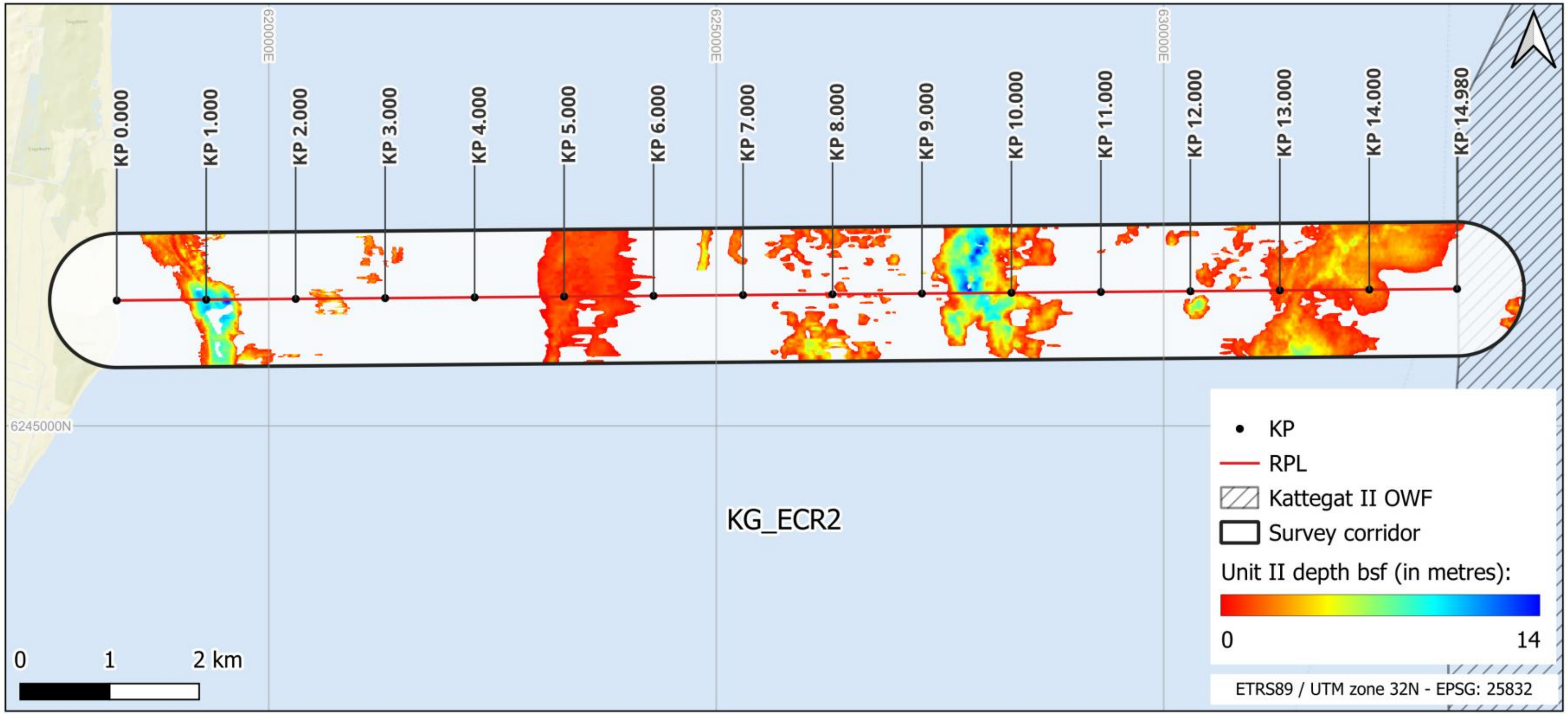


Figure 57: Extent and depth bsf (in metres) of Unit II

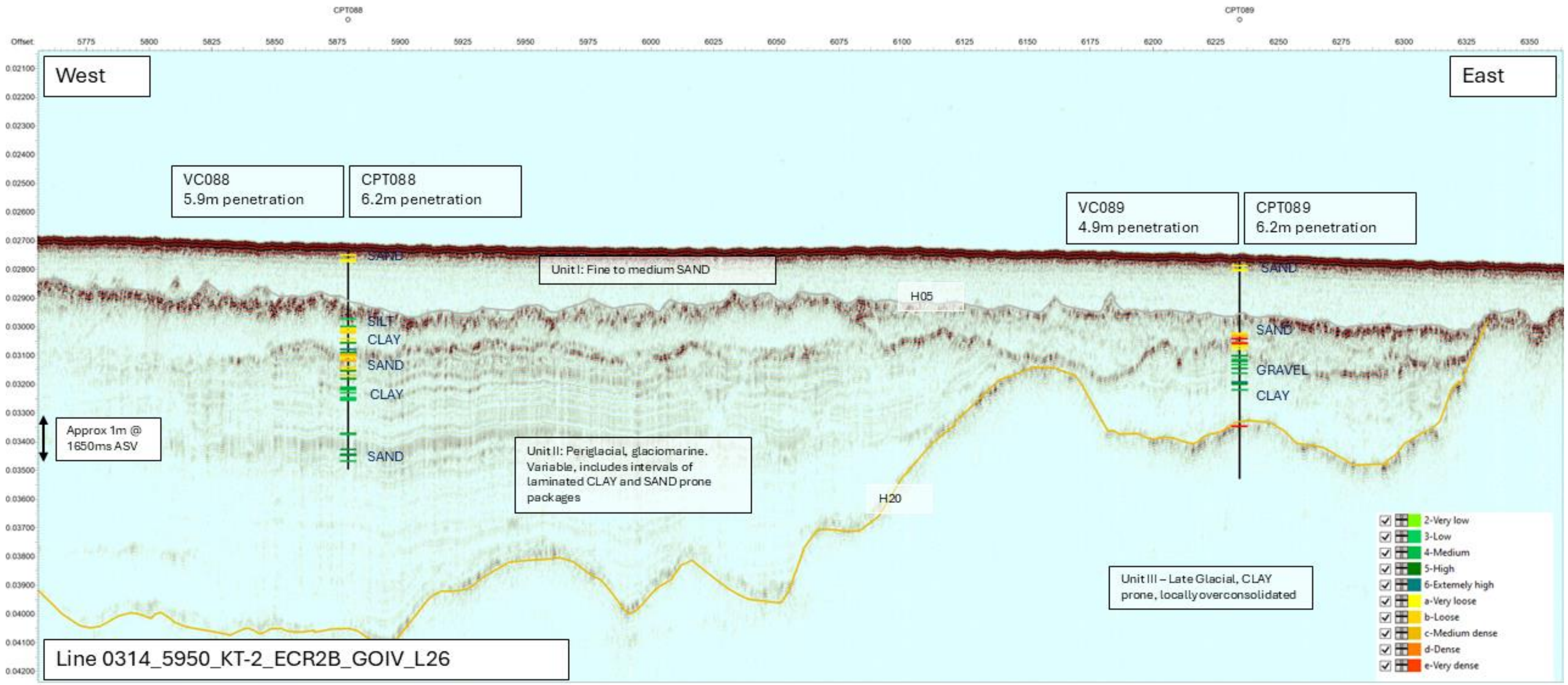


Figure 58: Illustrating CPT and VC 88 and 89

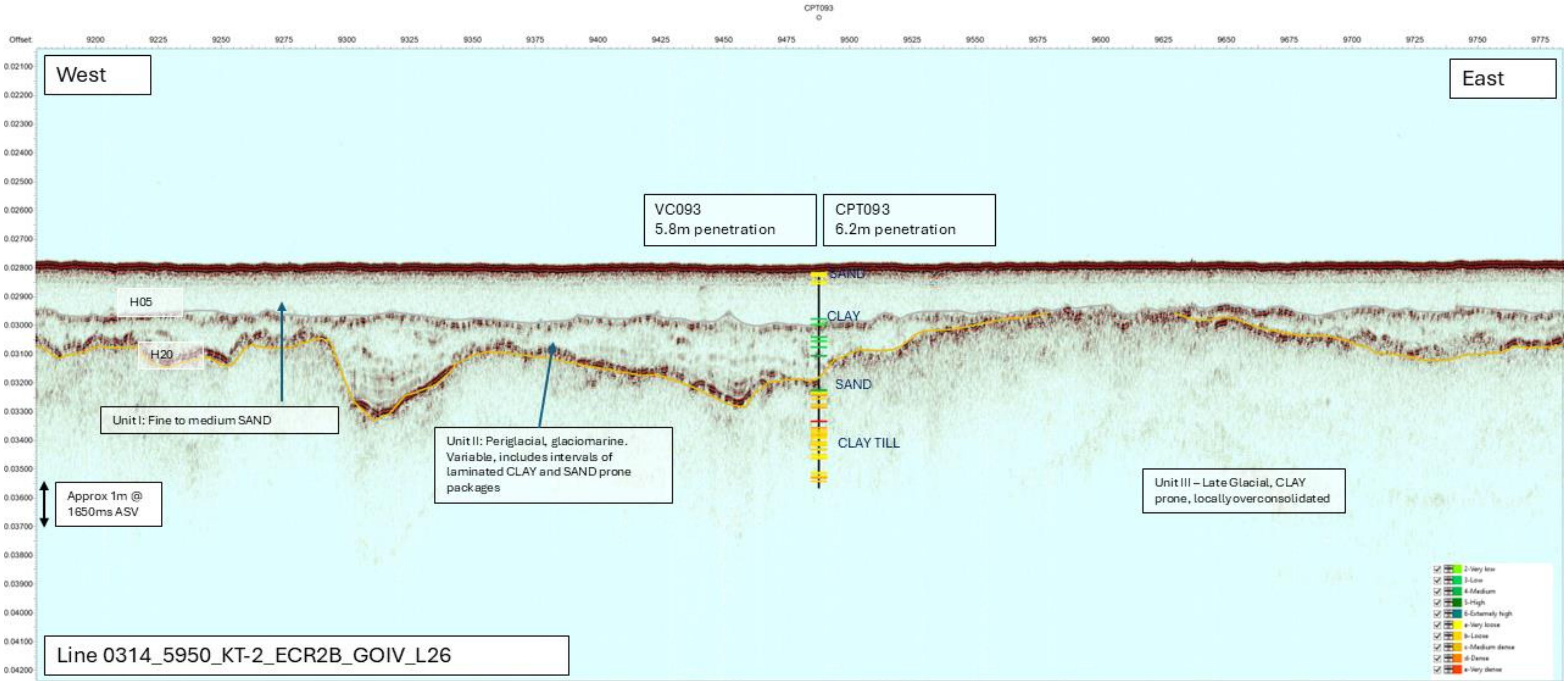


Figure 59: Illustrating geotechnical location 93

Unit III Glacial deposits

Unit III deposits occur along the route corridor, sub-cropping at seabed where Units I and II are thin or absent. The areas where there are many cobbles and boulders at seabed suggest Unit III (till) is at or close to seabed (Figure 60). Unit III is interpreted to be a till laid down in association with the last major ice advance over the area, approximately 22,000 years ago. The till forms a relatively thick blanket, to deeper than the depth of interest for cable burying. The base of the till/ top bedrock is not imaged within the export route corridor

Unit III is generally a glacial till which has been subjected to direct ice contact, though the unit contains other facies which may have been laid down in ice-marginal environments during oscillations of the ice front. The ice-contact facies may comprise a clay-prone diamicton which is likely to contain subordinate silt, sand, gravel, cobbles and boulders and will be over-consolidated. Consolidation levels may significantly vary over short distances.

Acoustically, the ice-contact facies are structureless with a very irregular upper surface, which probably forms a series of ridges.

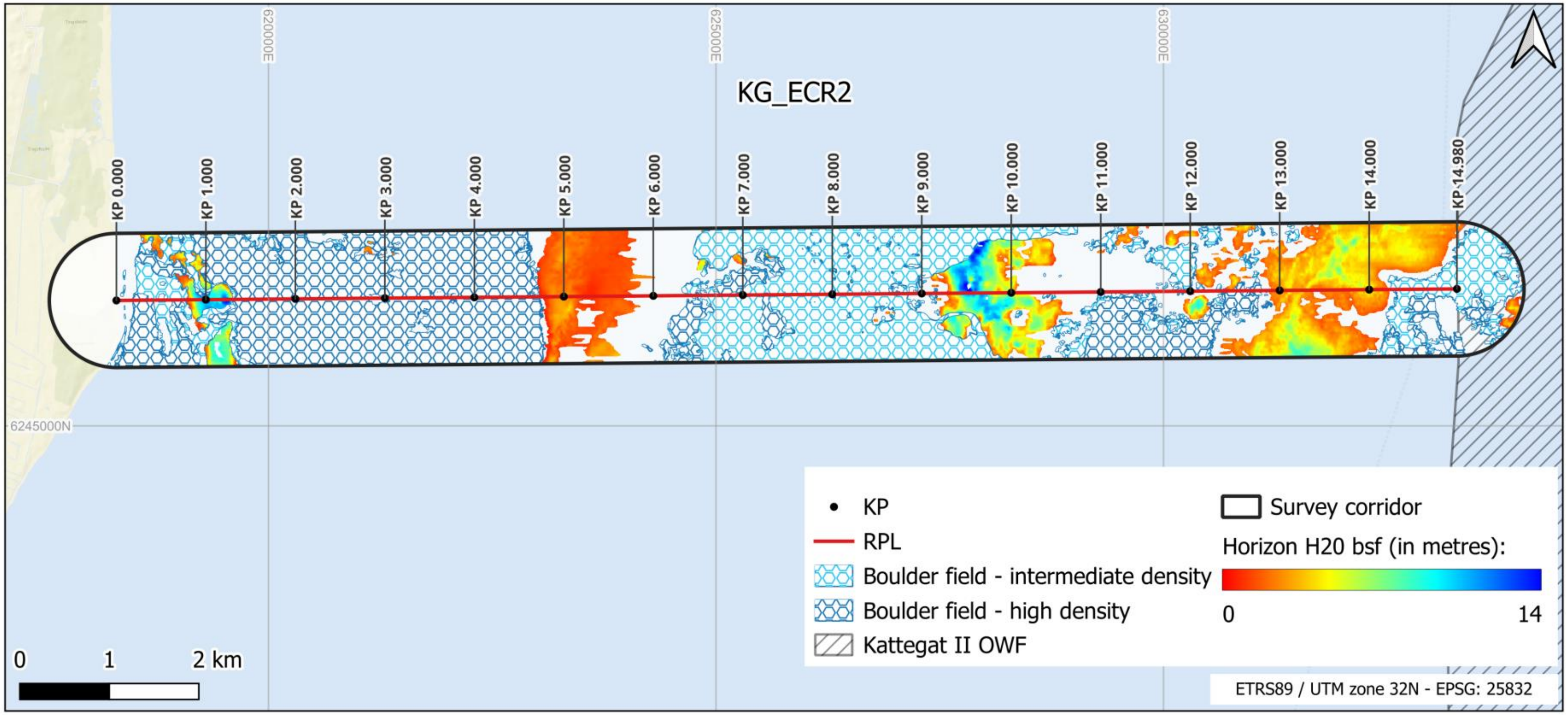


Figure 60: Comparison of boulder field and horizon H20 distribution

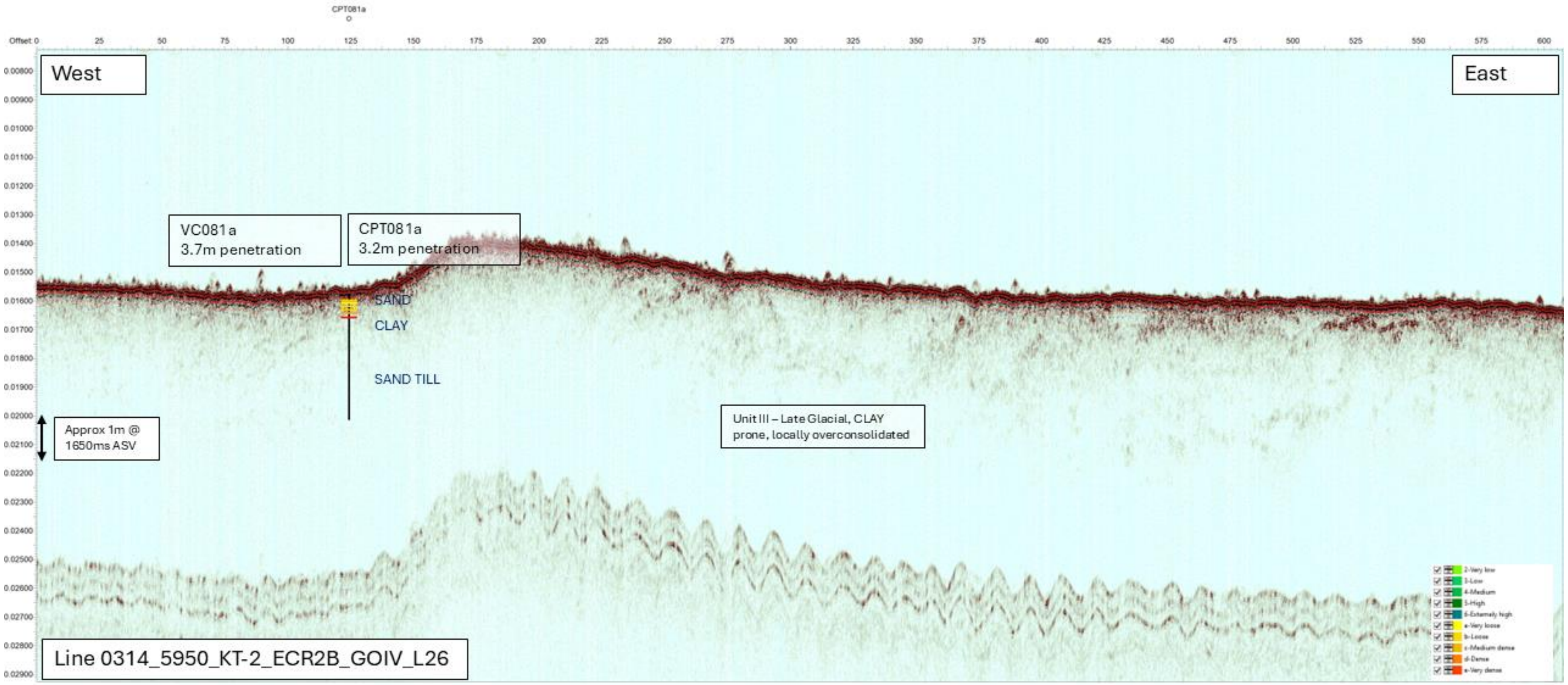


Figure 61: Unit III at Geotechnical location 081a

6.7.5 C14 Analysis

Carbon 14 analysis to determine soil age has been undertaken on two samples on adjacent cores, shown in

Figure 62 by the green text on core VC087 and VC088. The results show that the Unit III glacial sediments are dated to be older than the 43500 BP, which is the practical limit of the C14 methodology utilised in this lab analysis. This likely places Unit III as a late Pleistocene glacial deposit. The second C14 sample taken, that lies at the approximate interpreted interface been late glacial (unit II) and post glacial (unit I), is measured to be 8740 ±30 BP. It is difficult to determine if the sample location lies at the base of Unit I or the top of Unit II, but it shows that the sediments above Unit III are significantly younger than the tills represented in Unit III.

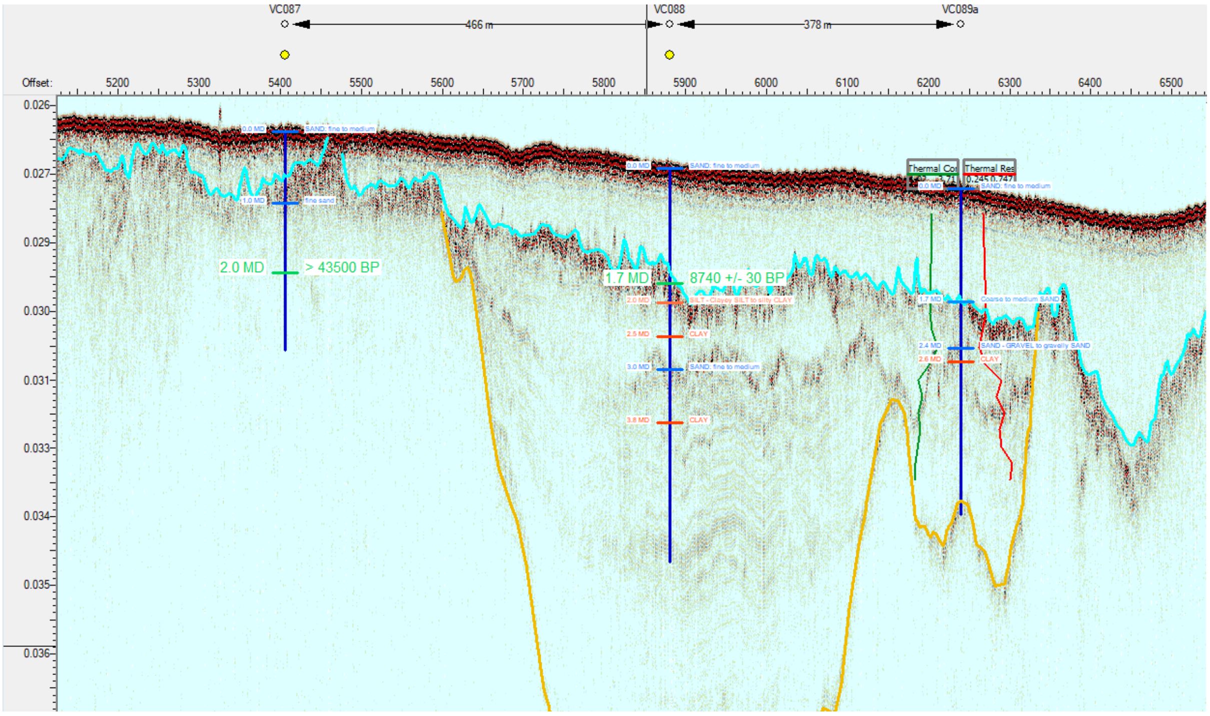


Figure 62: Seismic data example with C14 age results

7 KATTEGAT ECR 2 ROUTE ANALYSIS

A summarized route analysis along the Kattegat ECR 2 cable route, subdivided in 3 km sections, is displayed in Table 76 below. SBP images with geomodelling, in 3 km sections are presented in Appendix E. The route analysis is based on correlation between geotechnical and geophysical data.

Table 76: Overview per 3 km interval

From KP	To KP	Seabed Geology	Seabed Features	Seabed Topography	Shallow Geology	Environmental and geotechnical	
0	3	Geology predominantly Till with pockets of SAND and Mud and SANDY Mud.	Large boulder fields of high and intermediate boulder fields cover the corridor	Seabed slope from KP 0.000 to KP 0.500 drops sharply by 5-6 meters. The slope from KP 0.500 to KP 3.000 gradually declines by 2 meters. In the southeastern part of the corridor, from KP 2.000 to KP 3.000, there are local elevations—ridges—up to 2.7 meters in height.	H01,H02, H03, H05 and H20 present	Geotechnical	None
						Grab samples	KT-2_003_03 KT-2_002_03
3	6	Predominantly Till until KP 4.700 where the geology transitions to a band of Gravel and coarse SAND which spans the width of the cable corridor until KP 4.900 where the predominant seabed geology turns to SAND.	KP3 to KP4.72 a high density boulder field covers the corridor. At KP4.72 to KP 4.85 a band of ripples span the corridor.	The slope gradually decreases by 7-8 meters from KP 3.000 to KP 6.000. Throughout the corridor from KP 3.000 to KP 4.700, there are local elevations—ridges—up to 3 meters high. From KP	H02, H05 and H20 present	Geotechnical	VC080a VC081a VC082 VC083 CPT080a CPT081a CPT082 CPT083

From KP	To KP	Seabed Geology	Seabed Features	Seabed Topography	Shallow Geology	Environmental and geotechnical	
				4.700 to KP 6.000, the seabed forms a gentle slope.		Grab Samples	KT-2-001_003 KT-2-004_003 KT_ECR-2B-Grab1 KT_ECR-2B-Grab2 KT_ECR-2B-Grab3
6	9	Predominantly SAND with patches of outcropping Till throughout the corridor width.	Large boulder fields of high and intermediate boulder fields cover the majority of the corridor	From KP 6.000 to KP 7.600 the bottom is a gentle slope decreasing by 2 m. From KP 7.600 to KP 9.000 the bottom turns into a horizontal valley with hills up to 1 m high.	H05 and H20 present	Geotechnical	VC084a VC085 VC086 CPT084 CPT085 CPT086
						Grab Samples	KT_ECR-2B-Grab4 KT_ECR-2B-Grab5 KT_ECR-2B-Grab6
9	12	Predominantly SAND with large patches of Till and gravel and coarse SAND.	Trawl scar area until KP 11 where patches of intermediate boulder fields are found north of the RPL and a high density boulder field is found south of the RPL	From KP 9.000 to KP 9.500: A horizontal valley with hills up to 1 meter in height. From KP 9.500 to KP 11.000: A ravine across the entire width of the corridor, with slopes of equal gradient towards its	H05 and H20 present	Geotechnical	VC087 VC089a VC090b VC091 CPT087 CPT089 CPT090 CPT091

From KP	To KP	Seabed Geology	Seabed Features	Seabed Topography	Shallow Geology	Environmental and geotechnical	
				center, descending by 1.5 meters. From KP 11.000 to KP 12.000: A horizontal valley with ruts up to 0.5 meters deep.		Grab Samples	KT_ECR-2B-Grab7 KT_ECR-2B-Grab8 KT_ECR-2B-Grab9
12	15	Between KP 12.000 and 13.000 the seabed geology is predominantly SAND to the north of the RPL and TILL and gravel and coarse SAND to the south of the RPL. Between KP 13.000 and KP 14.250 the geology is predominantly gravel and coarse SAND and at KP 14.250 there is a large area of Till which presents until the end of the route.	KP 12 to KP 12.8 there is a high-density boulder field south of the RPL, north of the RPL are small patches of intermediate boulder fields. KP 12.8 to approx. KP 14.25 are two patches either side of the RPL with striations in a NE-SW directions. At KP 14.25 a boulder field of intermediate density and a patch of high density to the south of the RPL is present until KP15	In the central part of the corridor - From KP 12.000 to KP From KP 13.000 there is a slope with a decrease of 1 m. From KP 13.000 to KP 14.250 there is a slope with an increase of 0.3 m. From KP 14.250 to KP 15.000 there is a sharp slope with an increase of 1.3 m, extending from NW to SE along the entire width of the corridor	H05 and H20 present	Geotechnical	VC092 VC093 VC094 VC095 CPT092 CPT093 CPT094 CPT095
						Grab Samples	KT_ECR-2B-Grab10 KT_ECR-2B-Grab11 KT_ECR-2B-Grab12

7.1 KP 0.000 – KP 3.000

No vibrocores or CPTs were acquired in this section. Therefore, interpretation is based solely on the geophysical data. Two grab samples were acquired, both containing sandy, fine to coarse GRAVEL.

Post glacial sediments in several different sub-units are seen, bounded by H01, H02, H03 and H05. They are all interpreted to comprise SAND.

Unit Ia (bounded by H01) is only observed in the very shallow water (<5 m MSL) and reaches a maximum thickness of 1.1 m. It is acoustically quiet, with an irregular base.

Unit Ib (bounded by H02) occurs in isolated areas, often associated with positive relief features on the seabed. Acoustically it is moderate to high amplitude.

Unit Ic (bounded by H03) occurs in a single sinuous channel running from north-northwest to south-southeast, crossing the ECR 2 route at KP 1.020. The channel has a width of approximately 50 m, and reaches a maximum depth of 3.8 m below seabed. Acoustically, it is well bedded and may contain some finer grained sediments.

Other Unit I sediments (bounded by H05) are only seen sporadically in this section, close to the H03 channel, and in small patches between KP 2.000 and KP 3.000. Acoustically the unit is quiet, with a high amplitude basal reflector. They are generally less than 1 m thick but do reach a maximum of 3.3 m.

Unit II (bounded by H20) occurs as well bedded sediments deposited in erosional channels or depressions. A major channel runs north-northwest to south-southeast, approximately 500 m wide, and in excess of 13 m thick (it extends beyond the limit of penetration). The channel occurs between KP 0.720 and KP 1.340 along the ECR 2 route. Unit II sediments also infill a smaller depression between KP 2.210 and KP 2.530, reaching a maximum thickness of approximately 5 m. They also occur in small areas towards the northern edge of the survey corridor between KP 2.700 and KP 3.200.

Unit III outcrops at seabed over most of this section, which corresponds to the Till/diamicton interpreted from the side scan sonar data.

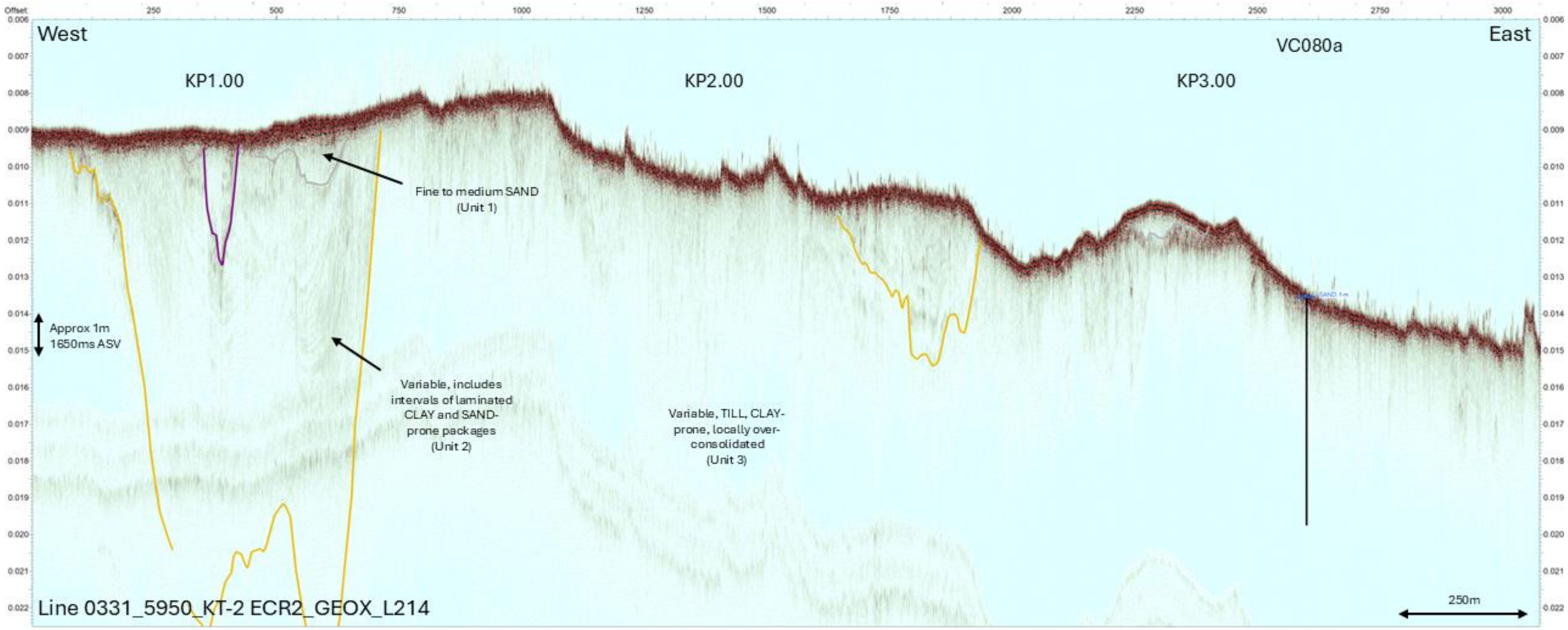
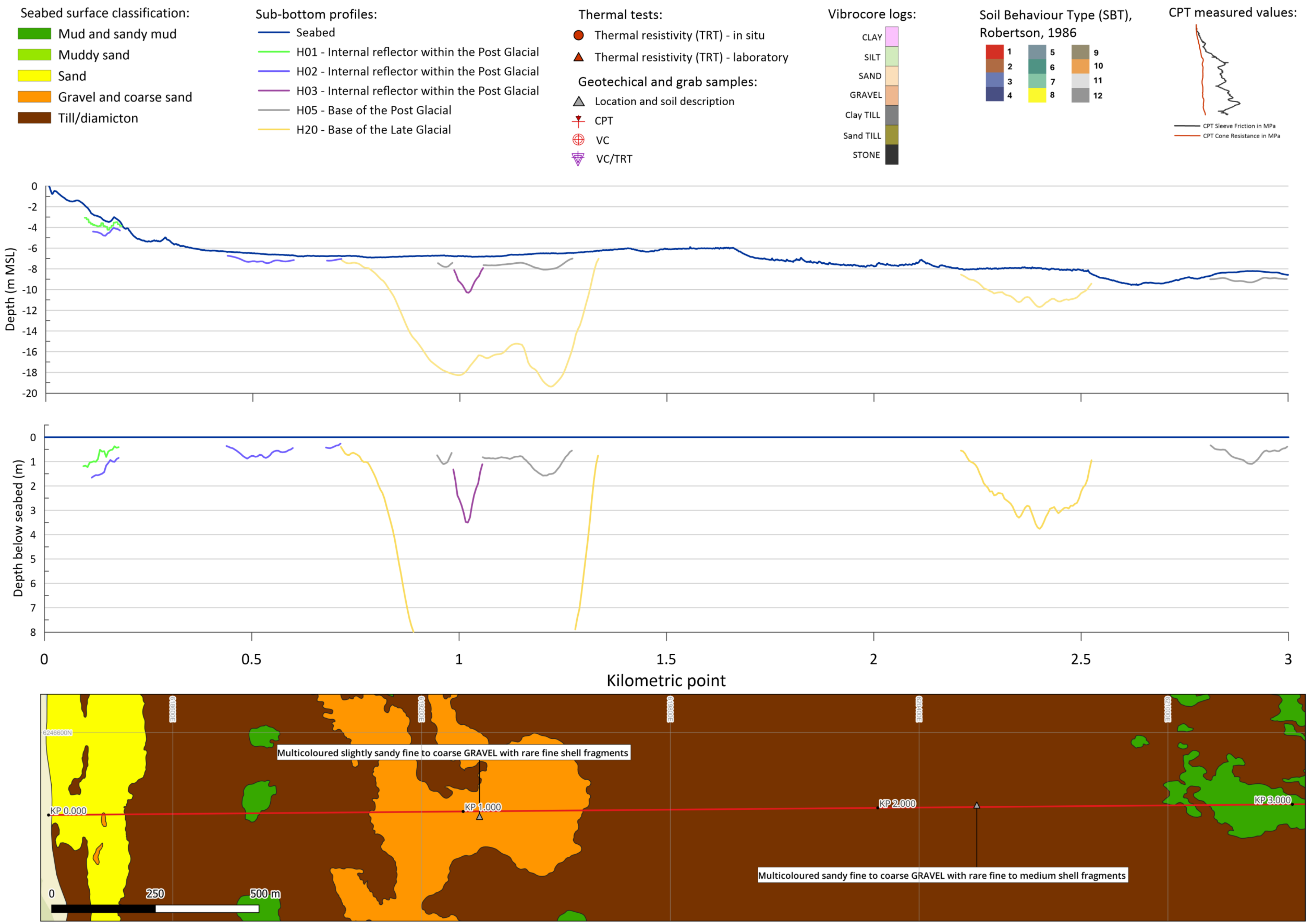


Figure 63: SBP and Geotech, KP 0.000 – KP 3.000



KG_ECR2 (KP 0.000 - KP 3.000)

Figure 64: Integrated geotechnical panel (KP 0.000 – KP 3.000)

7.2 KP 3.000 – KP 6.000

Four vibrocores, four CPTs and five grab samples were acquired in this section.

Unit Ib (bounded by H02) occurs in a north-south trending channel between KP 4.700 and KP 5.285. It reaches a maximum thickness of 2.6 m towards the southern edge of the survey corridor, but is generally less than 1.5 m thick, acoustically it is high amplitude.

Geotechnical samples VC082, CPT082 and a grab sample were acquired, showing the sediments to comprise medium to coarse SAND, increasing from very loose at seabed to dense at the base of the unit.

Other Unit I sediments (bounded by H05) are only seen sporadically in this section in small patches between KP 3.000 and KP 3.250; to the north of the survey corridor between KP 4.600 and KP 4.900: and more extensively beyond KP 5.400. Acoustically the unit is quiet, with a high amplitude basal reflector. They are generally less than 2 m thick but do reach a maximum of 4.2 m.

Geotechnical samples VC083, CPT083 and a grab sample were acquired, showing the sediments to comprise fine to medium SAND, increasing from very loose at seabed to medium dense at the base of the unit.

Unit II (bounded by H20) occurs as well bedded sediments deposited in erosional channels or depressions. A major channel runs north to south, approximately 1,000 m wide, and is up to 4 m thick. The channel occurs between KP 4.730 and KP 5.810 along the ECR 2 route.

Unit II sediments also occur in small areas towards the northern edge of the survey corridor between KP 2.700 and KP 3.200, reaching a maximum thickness of approximately 4 m.

Geotechnical samples VC082, VC083, CPT082 and CPT083 penetrated this unit, showing the sediments to comprise fine to medium SAND, predominantly dense to medium dense, but with loose layers towards the base of the unit.

Unit III outcrops at seabed over most of this section, which corresponds to the Till/diamicton interpreted from the side scan sonar data.

Geotechnical samples VC080a, VC081a, VC082, VC083, CPT080a, CPT081a, CPT082 and CPT083 penetrated this unit, showing the sediments to comprise a variety of different lithologies, as would be expected in a Till. Sediments vary from fine SAND to coarse GRAVEL, to SAND TILL and CLAY TILL.

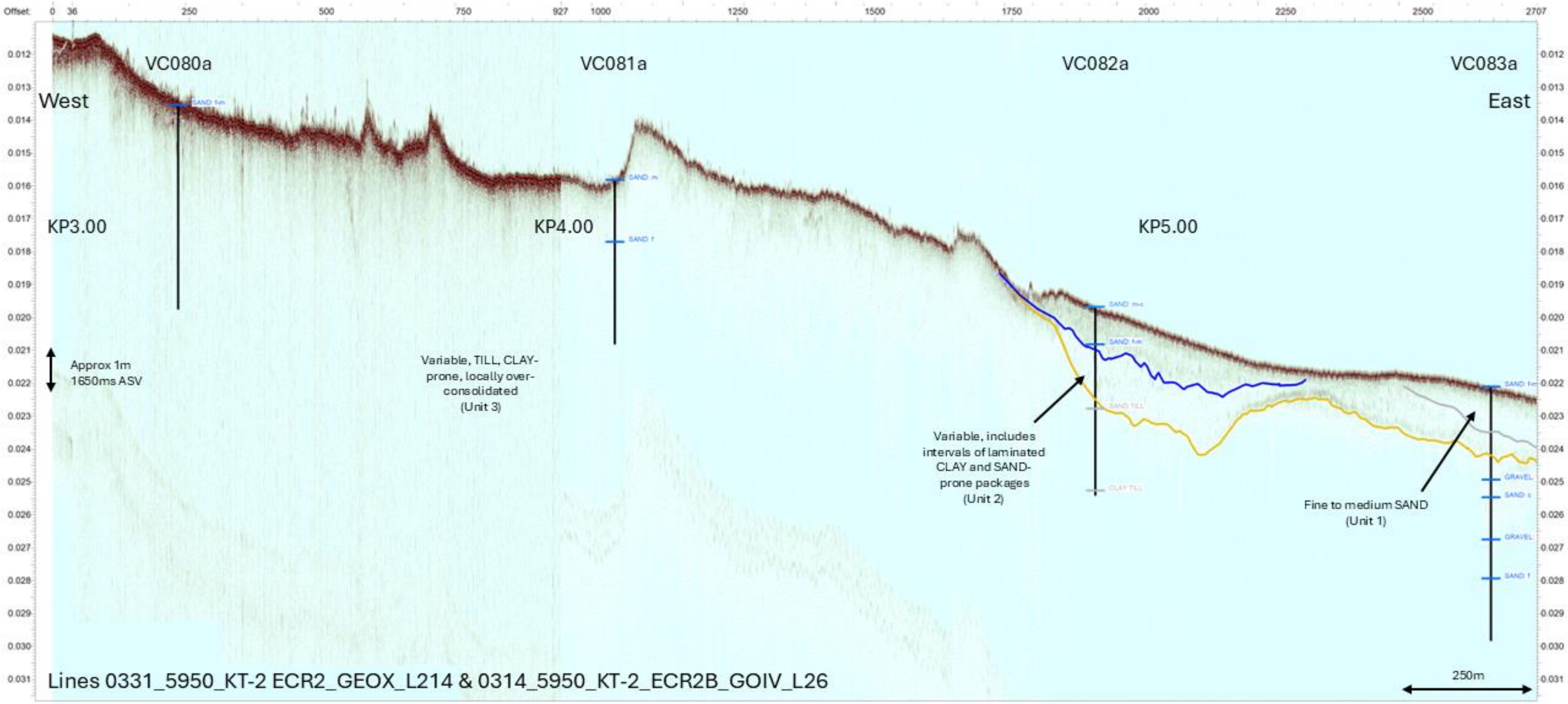


Figure 65: SBP and Geotech, KP 3.000 – KP 6.000

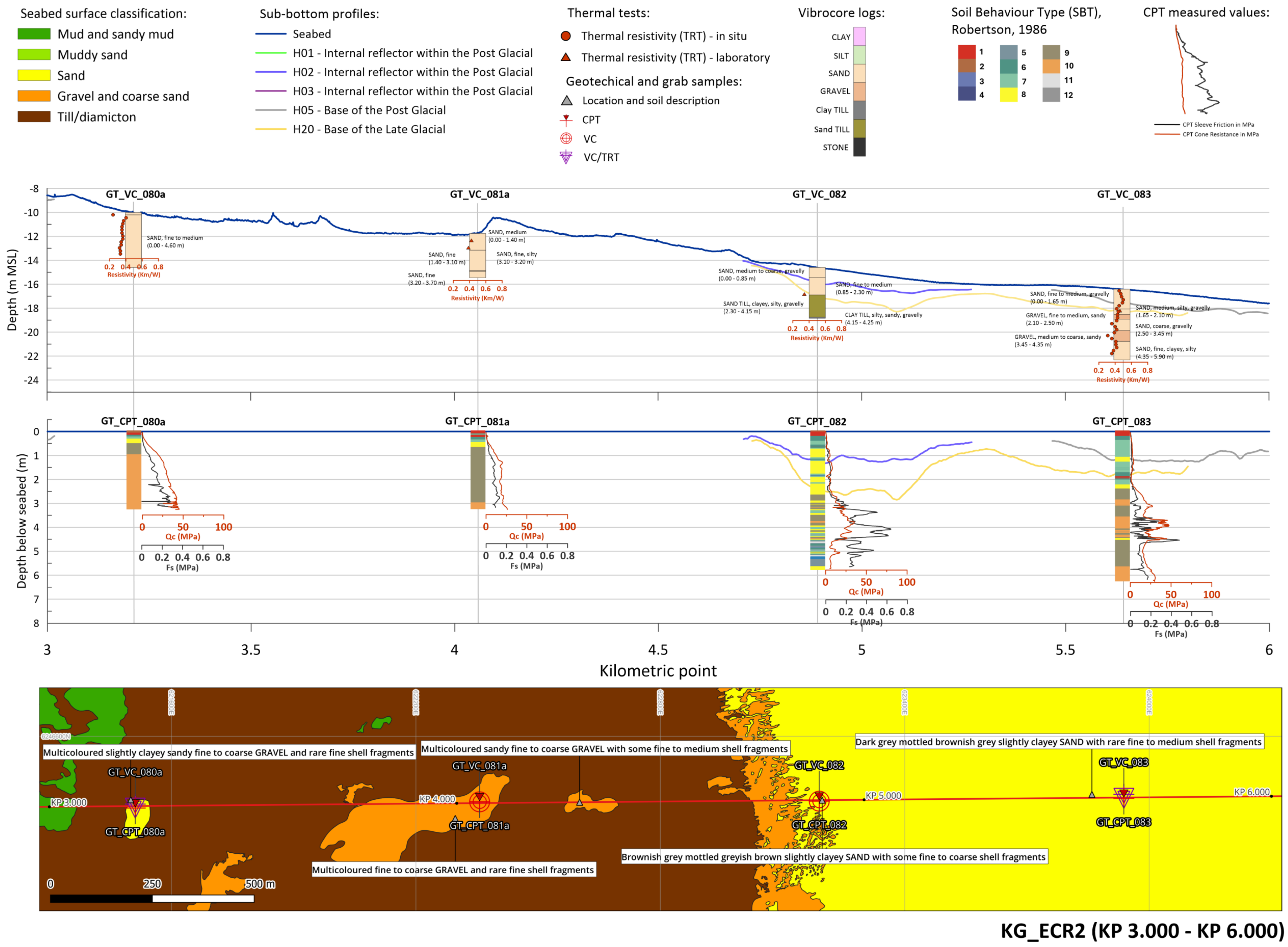


Figure 66: Integrated geotechnical panel (KP 3.000 – KP 6.000)

7.3 KP 6.000 – KP 9.000

Three vibrocores, three CPTs and three grab samples were acquired in this section.

Unit I sediments (bounded by H05) are seen extensively in this section. Acoustically the unit is quiet, with a high amplitude basal reflector. They are generally less than 1.5 m thick but do reach a maximum of 2.3 m.

Geotechnical samples VC084a, VC085, VC086, CPT084, CPT085 and CPT086 penetrated this unit, showing the sediments to comprise fine to medium SAND, increasing from very loose at seabed to loose at the base of the unit.

Unit II (bounded by H20) occurs as well bedded sediments deposited in erosional channels or depressions. Areas of Unit II occur to the north and south of the survey corridor, with only a few isolated pockets along the ECR 2 itself.

Geotechnical samples VC086 and CPT086 penetrated this unit, showing the sediments to comprise medium to coarse SAND with thin CLAY layers. The sands are very loose to dense, becoming very dense towards the base of the unit. The thin clay layers observed in the vibrocore are not observed in the CPT, and a 13 cm thick clay layer in the CPT at 1.12 m BSB is not seen in the vibrocore.

Unit III outcrops at seabed over parts of this section, which loosely corresponds to the intermittent Till/diamicton interpreted from the side scan sonar data.

Geotechnical samples VC084a, VC085, VC086, CPT084, CPT085, and CPT086 penetrated this unit, showing the sediments to comprise a variety of different lithologies, as would be expected in a till. Sediments vary from fine SAND to medium GRAVEL, to CLAY TILL and CLAY.

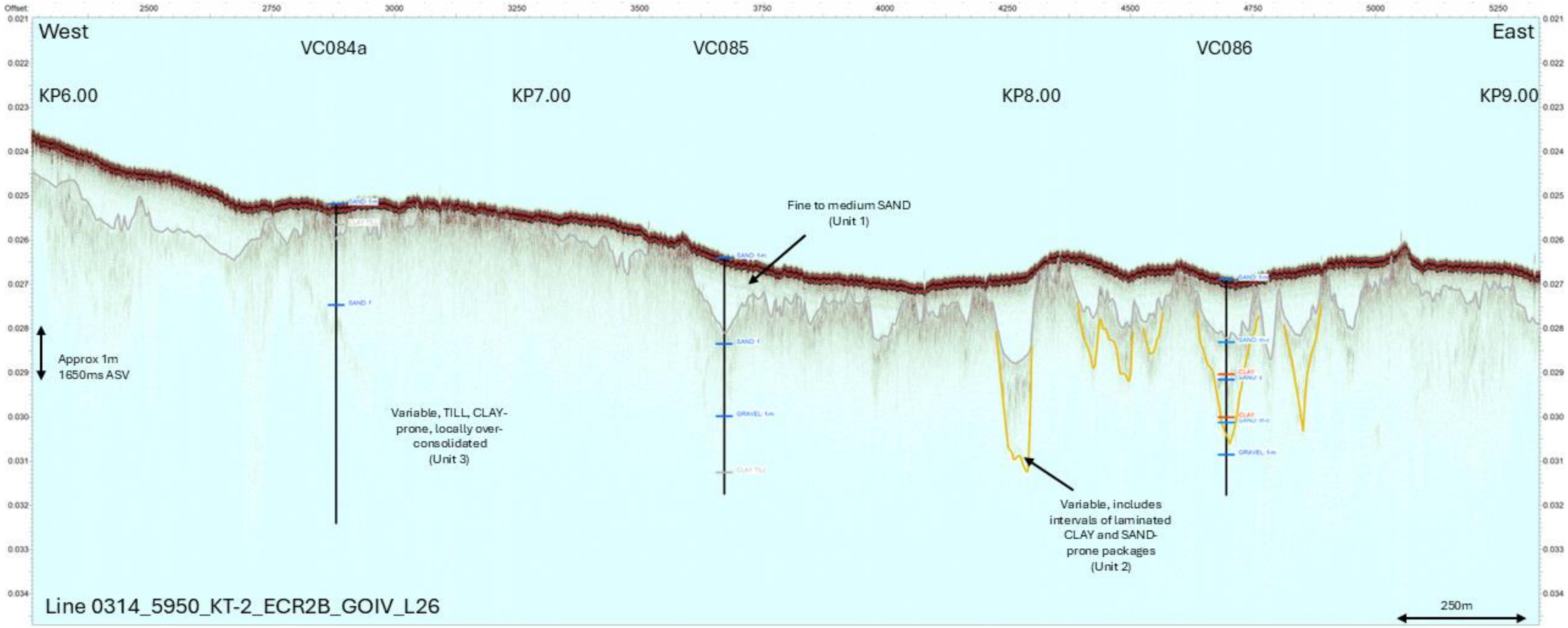
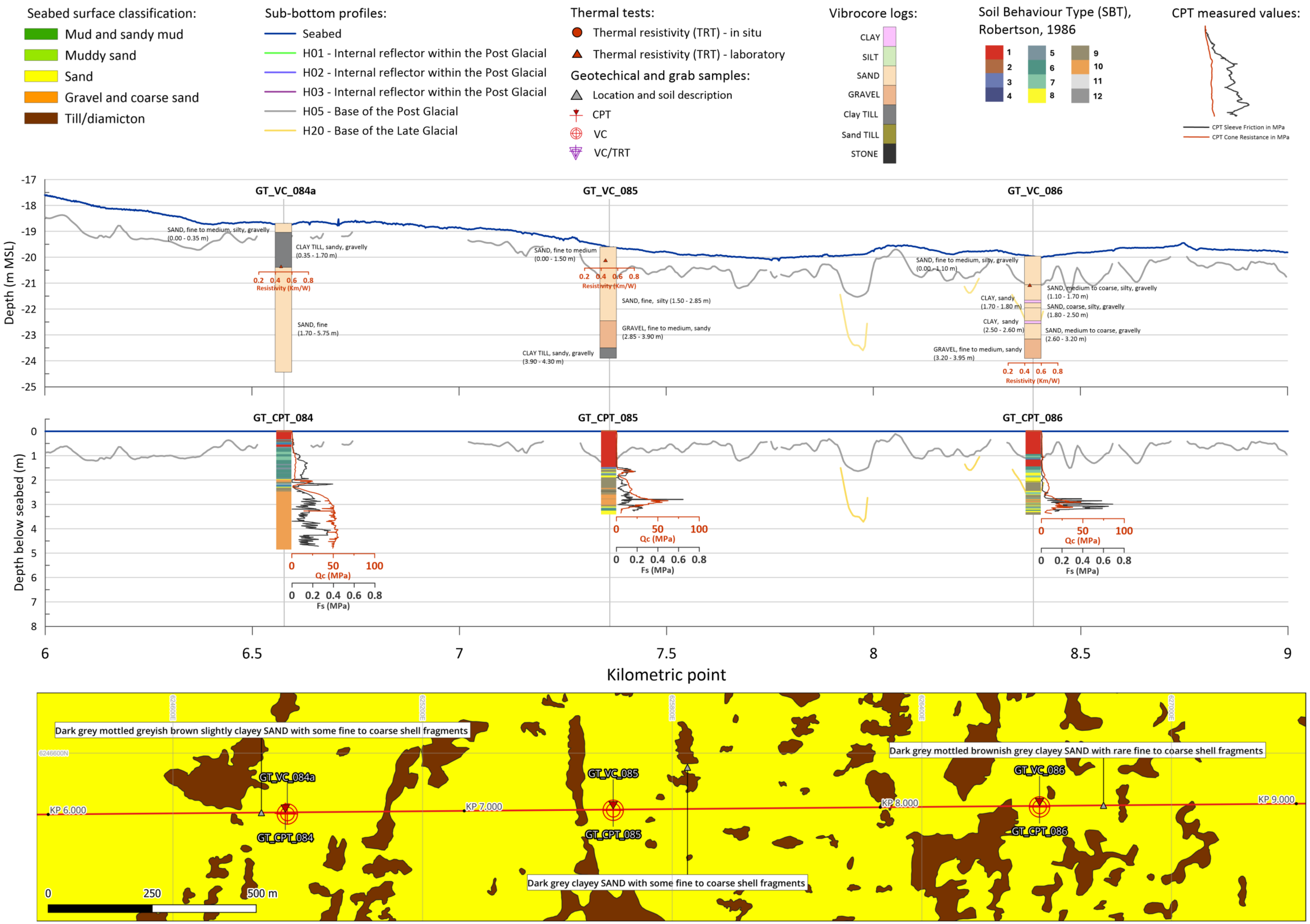


Figure 67: SBP and Geotech, KP 6.000 – KP 9.000



KG_ECR2 (KP 6.000 - KP 9.000)

Figure 68: Integrated geotechnical panel (KP 6.000 – KP 9.000)

7.4 KP 9.000 – KP 12.000

Five vibrocores, five CPTs and three grab samples were acquired in this section.

Unit I sediments (bounded by H05) are seen extensively in this section, though are mostly absent in the south of the survey corridor, between KP 10.500 and KP 12.000. Acoustically the unit is quiet, with a high amplitude basal reflector. They are generally less than 1.5 m thick but do reach a maximum of 4.2 m in a north-south trending channel, which crosses the ECR at KP 10.160.

All the geotechnical samples (VC087, VC088, VC089a, VC090b, VC091, CPT087, CPT088, CPT089, CPT090a and CPT091 penetrated this unit, showing the sediments to comprise fine to medium SAND, predominantly being very loose throughout the unit, with some thin layers of loose sediment near the seabed.

Radiocarbon dating was performed on VC088 at a depth of 1.70 m BSB, which corresponds to the base of Unit I. An age of 8,740 ± 30 years BP was obtained.

Unit II (bounded by H20) occurs as well bedded sediments deposited in erosional channels or depressions. In this section Unit II mainly occur in a channel, oriented north to south between KP 9.275 and KP 10.040, reaching a maximum depth of approximately 15 m BSB.

Geotechnical samples VC088, VC089a, CPT088 and CPT089 penetrated this unit, showing the sediments to be highly variable. CLAY, SILT, SAND and GRAVEL are all observed in the VCs. The CPTs showed the SAND to be predominantly medium dense; and the CLAY to be medium to high shear strength.

Minor inconsistencies are seen between the geophysics and the geotechnics. A clear reflector within Unit II can be seen at both VC088 and VC089a. But the VC logs mark this as the top of a fine to medium SAND in VC088, but the top of a CLAY layer in VC089a.

Unit III outcrops at seabed over parts of this section, which loosely corresponds to the intermittent Till/diamicton interpreted from the side scan sonar data.

Geotechnical samples VC087, VC089a, VC090b, VC091, CPT087, CPT089, CPT090 and CPT091 penetrated this unit, showing the sediments to comprise predominantly fine to medium SAND.

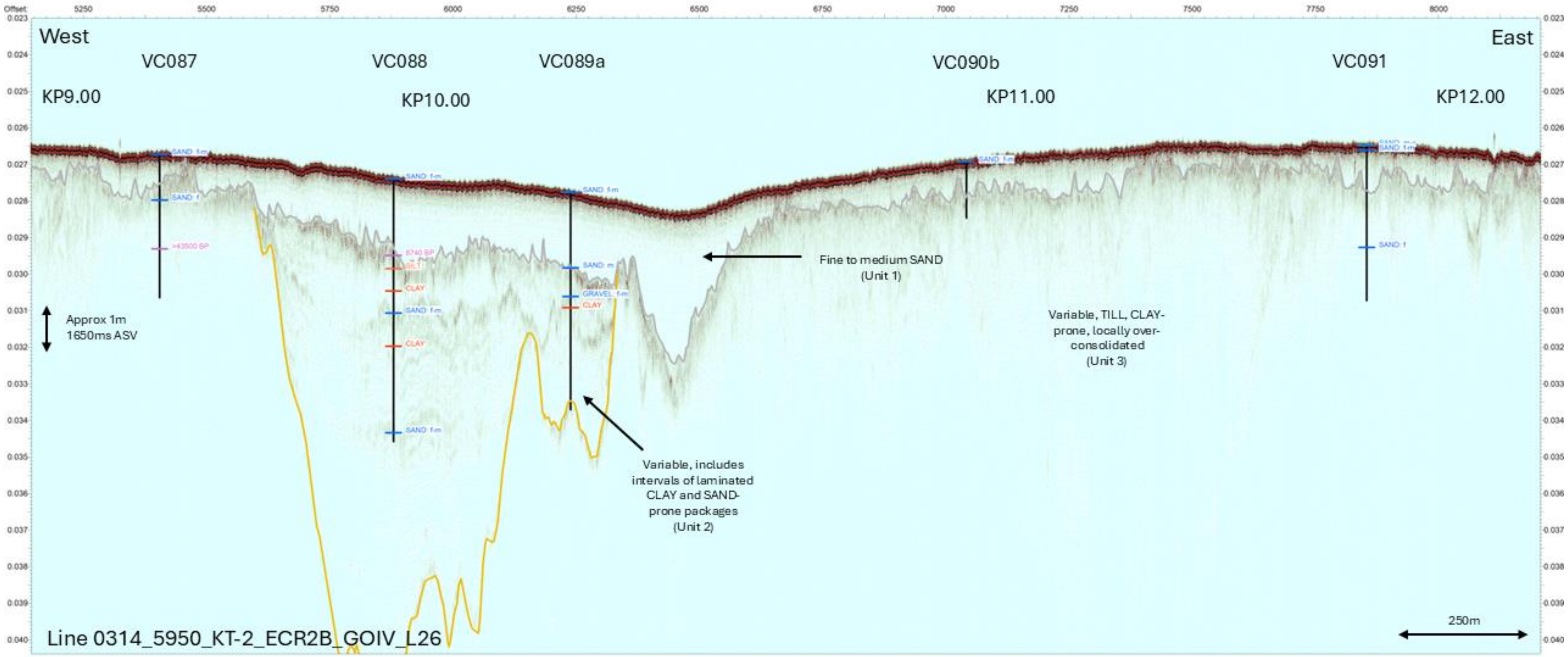
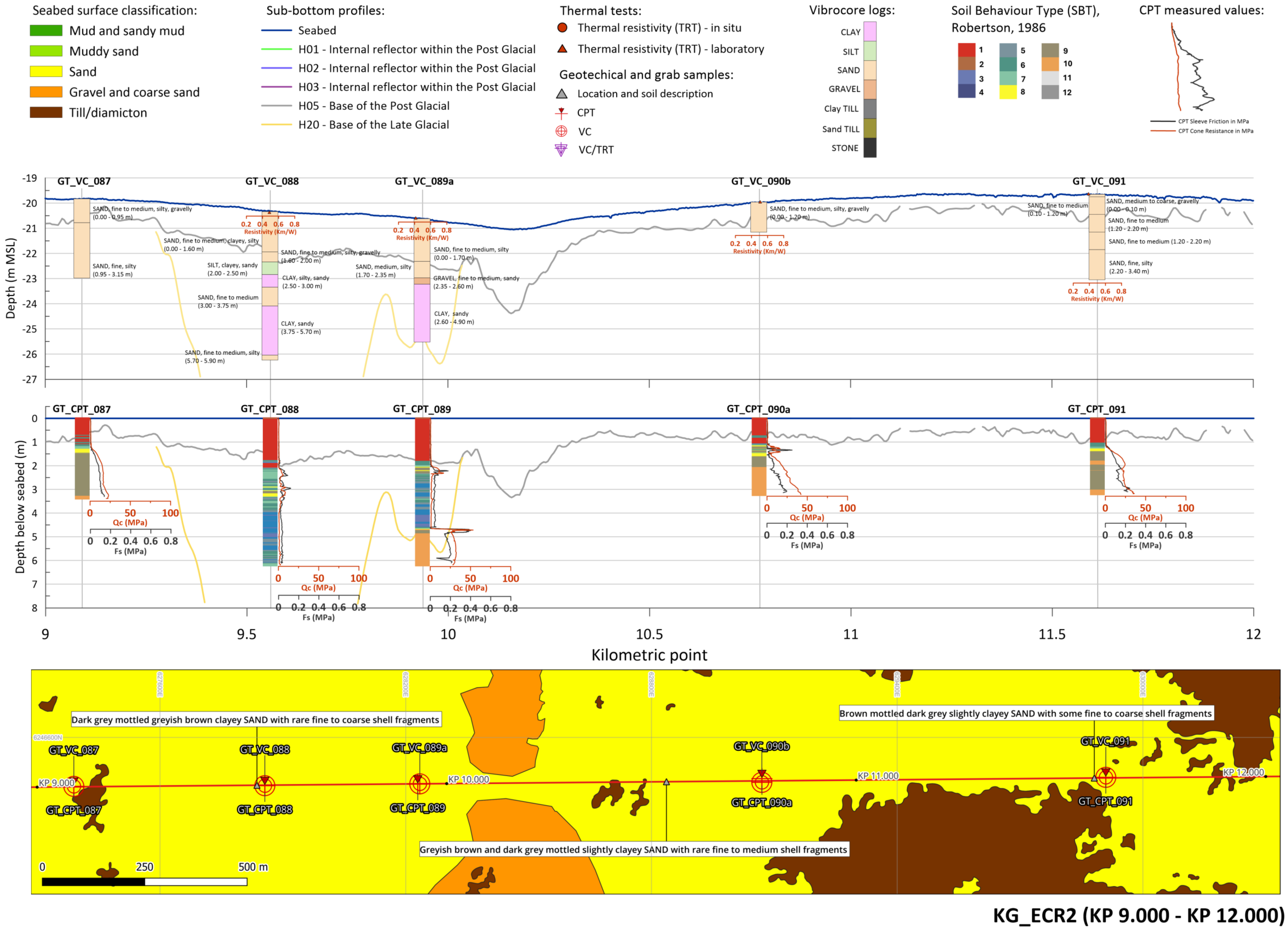


Figure 69: SBP and Geotech, KP 9.000 – KP 12.000



KG_ECR2 (KP 9.000 - KP 12.000)

Figure 70: Integrated geotechnical panel (KP 9.000 – KP 12.000)

7.5 KP 12.000 – KP 14.984

Four vibrocores, four CPTs and three grab samples were acquired in this section.

Unit I sediments (bounded by H05) are seen extensively in this section, though are mostly absent toward the end of the survey corridor, between KP 14.000 and KP 14.984. Acoustically the unit is quiet, with a high amplitude basal reflector. They are generally less than 1.5 m thick but do reach a maximum of 2.6 m in a broad, north-northeast to south-southwest trending channel, which crosses the ECR at KP 13.275.

Geotechnical samples VC092, VC093, VC094, CPT092, CPT093 and CPT094 penetrated this unit, showing the sediments to comprise fine SAND, predominantly being very loose throughout the unit, with some thin layers of loose sediment near the seabed.

Unit II (bounded by H20) occurs as well bedded sediments deposited in erosional channels or depressions. In this section Unit II mainly occur in a channel, oriented northeast to southwest between KP 12.900 and KP 14.220, reaching a maximum depth of approximately 9 m BSB.

Geotechnical samples VC093, VC094, CPT093 and CPT094 penetrated this unit, showing the sediments to be predominantly CLAY. CPT results show the CLAY as low to medium shear strength.

Unit III outcrops at seabed over parts of this section, which corresponds well to the intermittent Till/diamicton interpreted from the side scan sonar data.

All the geotechnical samples (VC092, VC093, VC094, VC095, CPT092, CPT093, CPT094 and CPT095) penetrated this unit, showing the sediments to be highly variable. CLAY, SAND, CLAY TILL, GRAVEL and STONE are all observed in the VCs. The CPTs showed the SAND to be predominantly medium to very dense; and the CLAY to be predominantly low to medium shear strength.

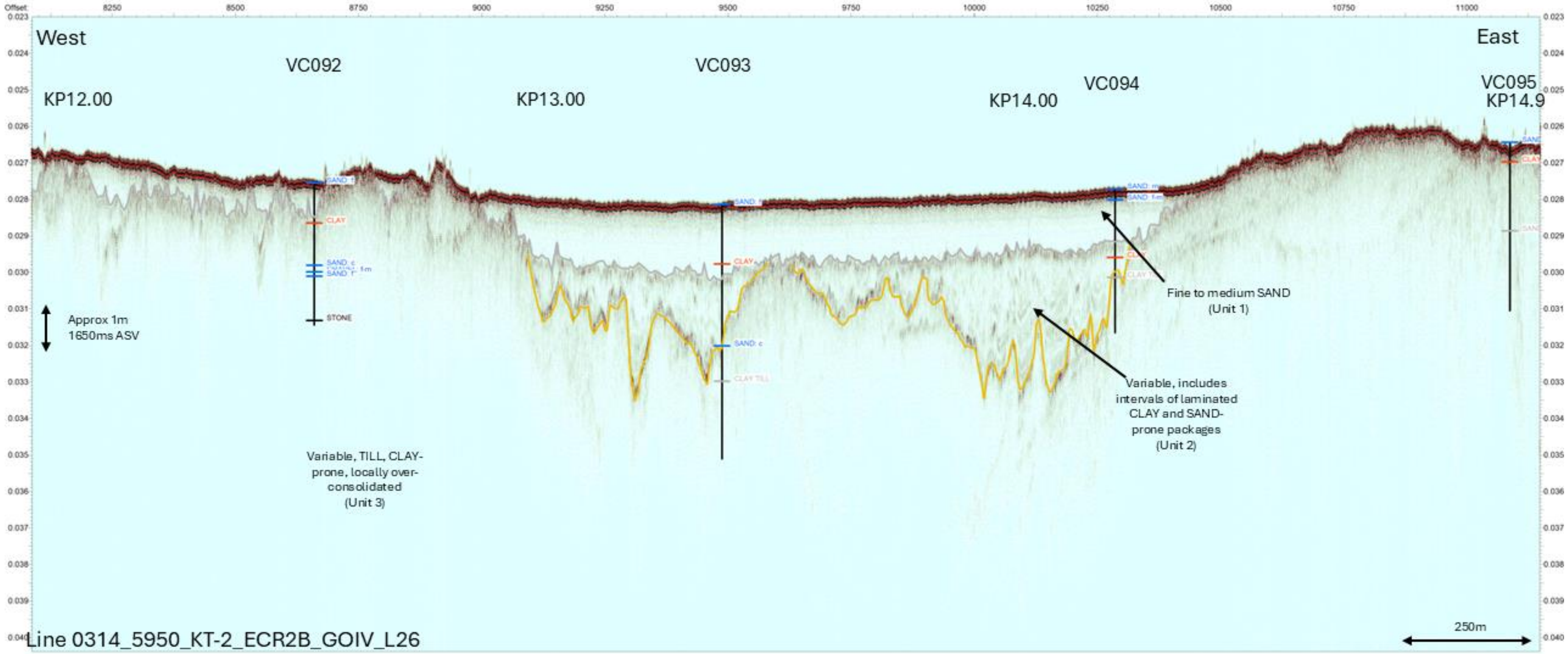


Figure 71: SBP and Geotech, KP 12.000 – KP 14.984

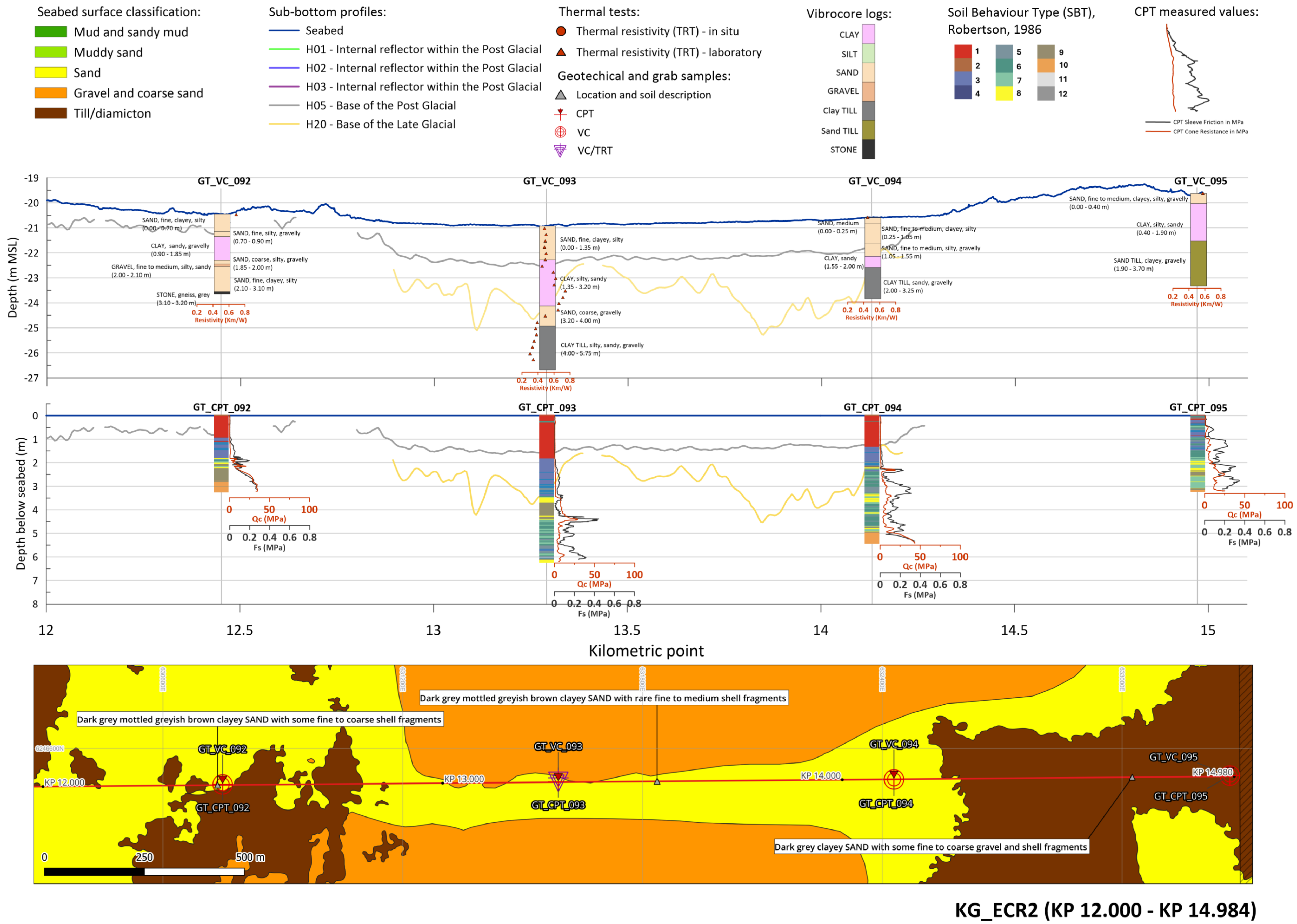


Figure 72: Integrated geotechnical panel (KP 12.000 – KP 14.984)

7.6 SHALLOW GEOLOGICAL INSTALLATION CONSTRAINTS AND GEOHAZARDS

Unit I sediments are very weak/soft. Their bearing capacity will be negligible and could cause retrieval difficulties related to settlement of seabed frames etc.

Units I and II possibly contain sparse occurrences of organic material.

Unit III may have variable levels of over-consolidation.

Unit III may contain numerous cobbles and boulders.

7.6.1 Cobbles and boulders

There are occasional indications of boulders within the sub-bottom profiler data. This data has been optimized to resolve the shallow stratigraphy and do not readily generate diffraction hyperbola, which are the usual seismic indication of point contacts in the sub-surface. A further complication is that the units most likely to contain boulders, Units II and III, have been deformed and compressed by ice confusing any returns from individual point contacts.

Due to these circumstances, appearance of clear hyperbolae that could be interpreted as isolated individual point targets relating to buried boulders have not been observed.

7.6.2 Organic Material

Small areas of organic material which have similar acoustic properties to gas have been identified in small areas within the cable corridor. Examples of such features are shown in Figure 73 and Figure 74, where the suspected organic material is marked with a red reflector. Some appear as unexpected bright spots/layers (Figure 73) and others have very weak indications of acoustic attenuation beneath the anomalous reflection (Figure 74). These areas are concentrated to the north of the RPL, the total interpreted extent is shown in Figure 75.

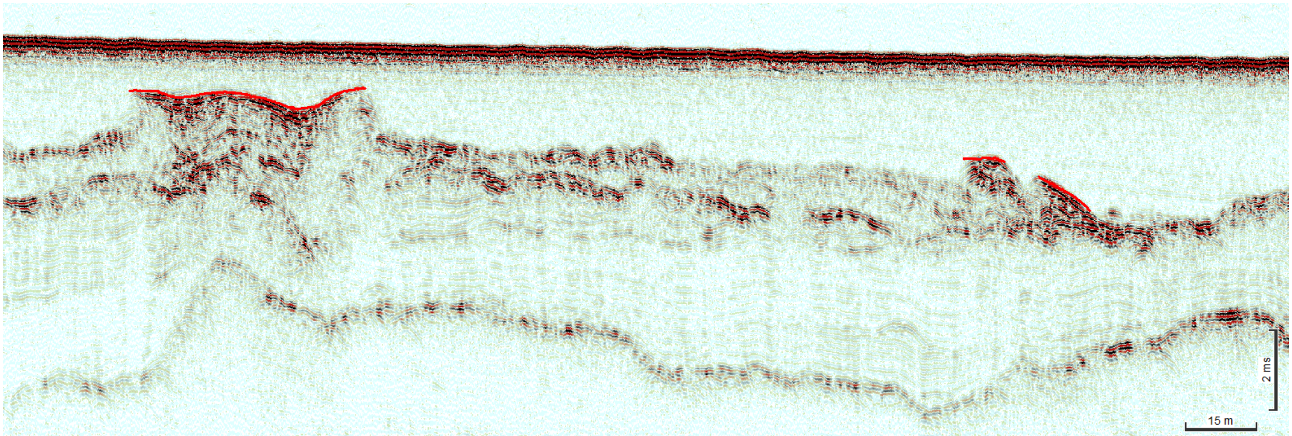


Figure 73: SBP data example of possible organic material appearing as anomalous bright reflectors

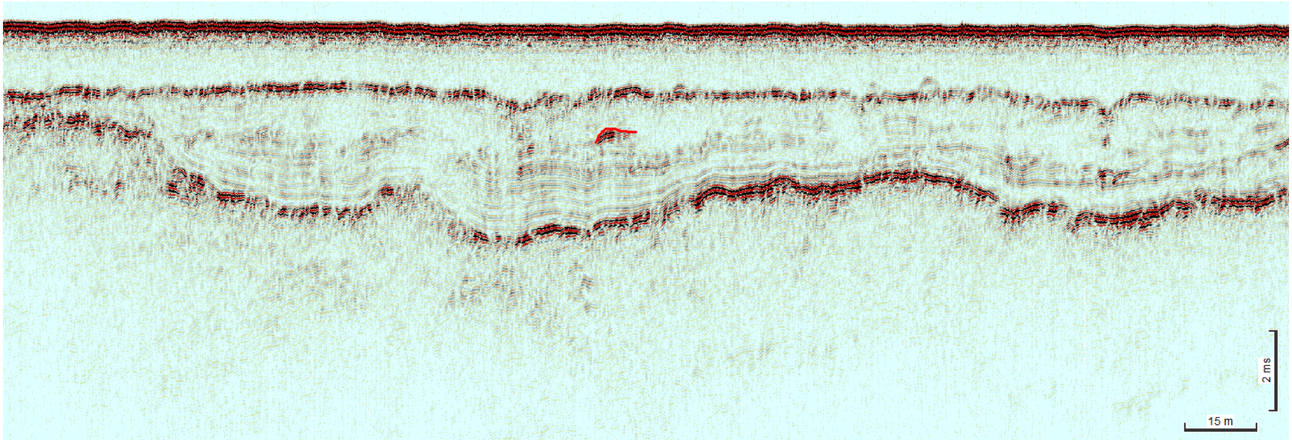


Figure 74: SBP data example of possible organic material appearing as bright spots with weak attenuation visible beneath

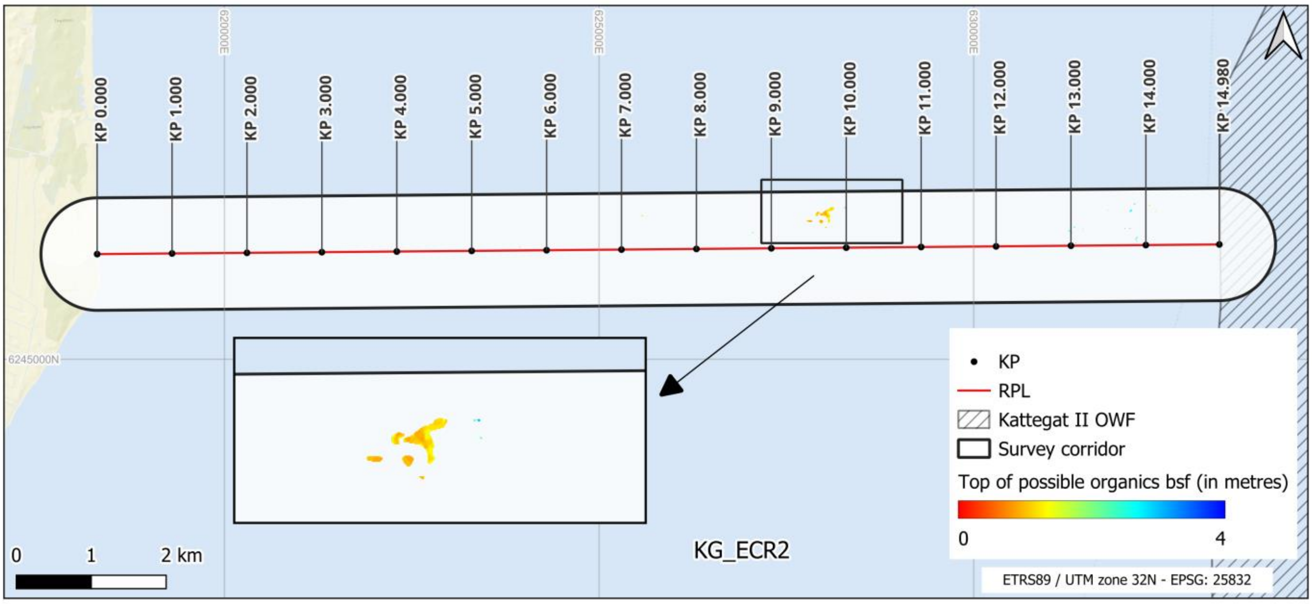


Figure 75: Interpreted organic material extent

7.7 COMPARISON BETWEEN SEABED AND SUB-SEABED FINDINGS

In the later stage of interpretation, surficial geology has been correlated to the SBP results. Where sub-seabed Unit III (i.e., base of H05/ H20) identified as a glacial till is at or near the seabed there is an abundance of boulders, these areas are delineated by “intermediate” and “high-density” boulder field seabed features (Figure 38/Figure 39) and as “Till/diamicton” in the seabed geology (Figure 36/Figure 37). There is a strong correlation between the occurrence of magnetic anomalies (Figure 43) and the Till/diamicton seabed geology/ near seabed glacial till. Inversely there is a strong correlation between the presence of sub-seabed Unit I/II (Figure 55/Figure 57) and the “SAND” and “Mud and Sandy Mud” surficial substrates.

8 CONCLUSIONS

The elevation along the Kattegat ECR 2 cable route range from 16.35 m MSL (topographic), in the western landfall, to -21.33 m MSL near the southwestern boundary of the survey corridor.

Starting at the landfall of KP zero, the gradient initially rises very steeply, i.e., at approximately 63° over half a metre, towards the west. Moving westwards, the gradient decreased to a moderate 6° over a distance of 21 metres as the route extends inland over foliage. Overall, the coastline exhibits varying characteristics, with generally a gentler gradient north of the landfall RPL, and a steep and abrupt ridge with gradients reaching up to 80° south of the landfall RPL. Further inland, the survey area is characterized by gently undulating topography and relatively flat land, interspersed with foliage, hedgerows, and farming fields. The maximum elevation, i.e., 16.35 metres above MSL, is located 200 metres northwest of the RPL landfall.

The seabed along the cable route is deepening with increasing KP values towards the east. A relatively constant gentle slope of approximately 0.14° occurs over a distance of 7.12 kilometres. Beyond this point, the slope is almost negligible, the seabed remains nearly flat. Overall, the slope characteristics within the survey area are predominantly gentle, with slopes less than 1°. Slopes ranging from 1° to 5° are present from KP 4.600 westward, where the seabed begins to rise as the landfall approaches. The highest slope values, i.e., very steep slopes greater than 15°, are associated with seabed features such as boulders.

The surface geology exhibits a relatively complex diversity of seabed surface geology, characterized primarily by extensive and irregular deposits of till/diamicton and sand. The western part of the area is mostly composed of till/diamicton, interspersed with pockets of mud and sandy mud, alongside sections of gravel and coarse sand. In the mid-eastern portion of the area, a strip of gravel and coarse sand is present, bordered by regions of sand. Another small patch of muddy sand was found just east of this strip.

The seabed morphology along the Kattegat ECR 2 area is mainly dominated by boulder fields. Within the first 4.5 kilometres, high-density and intermediate-density boulder fields were found, with few patches with featureless seabed and an area of ripples at KP 3.500. At approximately KP 4.500, a strip of ripples and large ripples runs perpendicular to the route, with a width of around 100 metres. Continuing towards KP 6.500, a 1.5-kilometre stretch classified as 'other,' shows a flat seabed with low to medium reflectivity and was interpreted as sand. Between KP 6.500 and KP 9.000, the survey area is dominated by intermediate boulder fields with occasional patches of high-density boulder fields. From KP 9.000 to KP 13.000, a mix of high and medium-density boulder fields, patches of 'other,' and areas with featureless seabed were detected. Anthropogenic influences, particularly trawl marks, are evident over sandy seabed areas. The area between KP 13.000 and KP 14.500 is marked by trawl marks and two patches of ‘unknown’ features. The latter areas show trending NE-SW streaks of coarser sediment. The final stretch of the cable route is predominantly characterized by intermediate boulder fields.

A total of 1,741 man-made point targets and 114 man-made linear targets, were identified within the survey boundaries. The highest density of metallic debris is located in the mid-western region of the survey area, between approximately KP 3.000 and KP 4.500. Two anchors were identified, yet one of these features has no associated magnetic anomaly. A total of 102 items, identified as varying lengths of soft rope, were found within the survey area. A total of 439 objects were classified as debris and a total of 1,198 objects were classified as metallic debris. 12,275 contacts were identified as boulders.

No subsea cables or pipelines, nor wrecks, were found within the Kattegat survey area.

The geological interpretation is based on the geophysical and geotechnical datasets acquired within the survey area, with reference to the supplied GEUS desk study. Details of specific correlations between the geophysical and geotechnical datasets can be found in the 3 km route analysis sections of the report.

Overall, the area generally has a glacial to post-glacial sequence of relatively recent post glacial sediments over much older bedrock.

The post glacial unit (Unit I) is a package comprising post-glacial fine to medium SAND. The post glacial sediments are widely distributed over the study area and are generally less than 1.5 m thick. The post glacial is very thin or absent (unmapped) in much of the nearshore section, until KP 4.600. The post glacial deposits are thickest where they partially infill a channel. Three prominent areas with thick post glacial deposits are found between KP 4.700 and KP 6.100, KP 9.300 and KP 10.100, and around KP 12.000. The base of the post glacial is mapped as horizon H05, which is interpreted to be a mild erosion surface. Thickness variations are due to relief at this surface level.

The Late Glacial deposits (Unit II) are very complex. Some intervals display laminations indicative of clays and silts, whereas others may represent sandy beach-type deposits. The glaciomarine sediments of Unit II infill steep-sided channels eroded into the underlying Unit III tills. Unit II is mapped with horizon H20 at its base.

The Glacial deposits (Unit III) is generally a glacial till which has been subjected to direct ice contact. The unit also contains other facies which may have been laid down in ice-marginal environments during oscillations of the ice front. The Unit III deposits occur along the route corridor, sub-cropping at the seabed where Units I and II are thin to absent. The areas marked by boulders and cobbles at the seabed correlate to areas where Unit III (till) is at or close to the seabed.

In general, Unit I sediments are very weak/soft. Their bearing capacity will be negligible and could cause retrieval difficulties related to settlement of seabed frames etc. Unit III may have variable levels of over-consolidation, and may contain numerous cobbles and boulders.

9 DIGITAL DATA DELIVERABLES OVERVIEW

9.1 DIGITAL DELIVERABLES SUMMARY

Table 77: Digital deliverables overview

Deliverable	Format
All sensors	
All sensors trackplots (line)	Shapefile
Man-made objects (point)	Shapefile
Man-made objects (line)	Shapefile
Man-made objects (polygon)	Shapefile
Seabed features (point)	Shapefile
Seabed features (line)	Shapefile
Seabed features (polygon)	Shapefile
Seabed geology (polygon)	Shapefile
Seabed substrate (polygon)	Shapefile
Catalogue of seabed objects	PDF
MBES	
Despiked, motion and tidal corrected point clouds	ASCII
Bathymetric average values gridded surface 0.25 m, 1 m and 5 m	ASCII
	Encoded TIF
Bathymetry Total Vertical Uncertainty values gridded surface 1 m	ASCII
	Encoded TIF
Bathymetric Total Horizontal Uncertainty values gridded surface	ASCII
	Encoded TIF
Hit count	Encoded TIF
Bathymetry contours 0.5 m	Shapefile
MBES targetlist (> 1 m)	Shapefile
Vessel tracks	Shapefile
SVP	
SVP logfiles	Native system format
Backscatter	
Gridded 1 m	Encoded TIF
SSS	
Processed SSS data	HF XTF
	LF XTF
SSS track	Shapefile
SSS mosaic HF, 0.1 m	RGB TIF
SSS mosaic LF, 1 m	RGB TIF
Navigation files	ASCII

Deliverable	Format
SonarWiz project	SonarWiz Project Files
SSS targetlist (> 1 m)	Shapefile
Magnetometer	
Processed magnetometric data	ASCII
MAG track (1 track per MAG)	Shapefile
MAG targetlist (Magnetic linear anomalies - ferrous mass > 50 kg buried up to 2 m below the seabed surface)	Shapefile
Total field grid, 0.5 m	Encoded TIF
Residual signal grid, 0.5 m	Encoded TIF
Oasis Montaj project	Oasis Montaj Project
SBP	
Processed SBP data	SEG-Y
Processed SBP data images	TIFF or PNG
SBP instrument tracks	Shapefile
Interpretation of post processed seismic data	ASCII
Processing project	
SBP targetlist	Shapefile
Depth SEG-Y format	SEG-Y
SBP TWT SEG-Y	SEG-Y
Horizon interpretation depth MSL gridded surface	ASCII
	Encoded TIF
Horizon interpretation depth below seabed gridded surface	ASCII
	Encoded TIF
Isochore gridded surface	ASCII
	Encoded TIF
Processing project	Kingdom Project Files
Grab Sampling	
Grab sample positions	Shapefile
Grab sample classifications	Excel Doc
Grab sample lab analysis	Excel Doc
Interim deliverables	
Trackplots (for CoG, MBES, SSS, SBP, MAG)	Shapefile
MBES hit count	Encoded TIF
MBES DTM	Encoded TIF
SSS coverage	RGB TIF
SSS mosaic	RGB TIF
SBP infills	Shapefile
SBP SEG-Y	SEG-Y

Deliverable	Format
SBP profile images	JPGE
Residual grid	Encoded TIF
Reports	
Mob and Cal report	PDF
Operations report	PDF
Geotechnical Report	PDF
Environmental Report	PDF
Cable route integrated report	PDF
GIS	
Trackplots (all sensors)	Shapefile
MBES contours	Shapefile
MBES anomalies	Shapefile
MBES grid 0.25 m, 1.0 m and 5.0 m	Encoded TIF
MBES THU Grid 1.0 m	Encoded TIF
MBES TVU Grid 1.0 m	Encoded TIF
Backscatter Grid 1.0 m	Encoded TIF
SSS anomalies	Encoded TIF
Magnetic anomalies	Encoded TIF
SBP anomalies	Encoded TIF
SBP horizon MSL grids H05	Encoded TIF
SBP horizon MSL grids H20	Encoded TIF
SBP horizon DBS grids H05	Encoded TIF
SBP horizon DBS grids H20	Encoded TIF
SBP isopach grids	Encoded TIF
Grab sample positions	Shapefile
Seabed surface geology (polygon)	Shapefile
Seabed surface type (polygon)	Shapefile
Seabed surface features (points)	Shapefile
Seabed surface features (line)	Shapefile
Seabed surface features (polygon)	Shapefile
Man-made objects (points)	Shapefile
Man-made objects (line)	Shapefile
Man-made objects (polygon)	Shapefile
Charting	
Trackplots and sampling locations	PDF
Bathymetry	PDF
Backscatter	PDF
Seabed surface classification	PDF
Seabed objects	PDF

Deliverable	Format
Seabed features	PDF
Sub-seabed geology	PDF
Lidar	
Trackplot	Shapefile
Integrated Despiked and motion and vertical corrected point clouds	ASCII
Integrated LIDAR average values gridded surface 1m	ASCII
	Encoded TIF
Integrated LIDAR average values gridded surface 5m	ASCII
	Encoded TIF
Integrated LIDAR average values gridded surface 0.25m	ASCII
	Encoded TIF
Topobathymetric contours 0.5 m	Shapefile

9.2 INTERPRETATION DELIVERABLES

Table 78: Interpretation deliverables overview

Deliverable	Format
Seabed surface geology (polygon)	Shapefile
Seabed substrate type (polygon)	Shapefile
Seabed surface features (point)	Shapefile
Seabed surface features (line)	Shapefile
Seabed surface features (polygon)	Shapefile
Man-made objects (point)	Shapefile
Man-made objects (line)	Shapefile
Man-made objects (polygon)	Shapefile

APPENDIX A. GRAB SAMPLE CLASSIFICATION

Point ID	Attempt	Easting	Northing	Elevation (m)	Lithology description	Carbonate content	Depositional Age	Depositional Environment	KP	Offset from RPL	KP reference
Nearshore											
KT-2_001_03	3	621498.41	6246443.68	9.93	Multicoloured slightly clayey sandy fine to coarse GRAVEL and rare fine shell fragments.	-	Glacial	Glacial	3.199	-14.91	SN2023_027_KP_ROUTE_LIN_UTM32N / Part 5
KT-2_002_03	1	620539.09	6246425.39	8.04	Multicoloured sandy fine to coarse GRAVEL with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	2.239	-4.88	SN2023_027_KP_ROUTE_LIN_UTM32N / Part 5
KT-2_003_03	1	619339.83	6246398.08	6.83	Multicoloured slightly sandy fine to coarse GRAVEL with rare fine shell fragments.	-	Post Glacial	Post-glacial marine	1.04	12.11	SN2023_027_KP_ROUTE_LIN_UTM32N / Part 5
KT-2_004_03	3	622296.04	6246398.85	11.94	Multicoloured fine to coarse GRAVEL and rare fine shell fragments	-	Glacial	Glacial	3.996	36.8	SN2023_027_KP_ROUTE_LIN_UTM32N / Part 5
Offshore											
KT-ECR-2B-GRAB1	4	622601.77	6246438.27	19.36	Multicoloured sandy fine to coarse GRAVEL with some fine to medium shell fragments.	Slightly calcareous	Glacial	Glacial	4.303	0	SN2023_027_KP_ROUTE_LIN_UTM32N / Part 5
KT-ECR-2B-GRAB2	1	623197.18	6246443.40	20.84	Brownish grey mottled greyish brown slightly clayey SAND with some fine to coarse shell fragments.	Slightly calcareous	Post Glacial	Post-glacial marine	4.898	0	SN2023_027_KP_ROUTE_LIN_UTM32N / Part 5
KT-ECR-2B-GRAB3	1	623859.39	6246457.45	20.43	Dark grey mottled brownish grey slightly clayey SAND with rare fine to medium shell fragments.	Slightly calcareous	Post Glacial	Post-glacial marine	5.561	-8.35	SN2023_027_KP_ROUTE_LIN_UTM32N / Part 5
KT-ECR-2B-GRAB4	3	624812.62	6246457.31	18.64	Dark grey mottled greyish brown slightly clayey SAND with some fine to coarse shell fragments.	Slightly calcareous	Post Glacial	Post-glacial marine	6.514	0	SN2023_027_KP_ROUTE_LIN_UTM32N / Part 5
KT-ECR-2B-GRAB5	1	625836.74	6246566.13	19.90	Dark grey clayey SAND with some fine to coarse shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	7.539	-100.01	SN2023_027_KP_ROUTE_LIN_UTM32N / Part 5
KT-ECR-2B-GRAB6	1	626836.71	6246474.74	19.19	Dark grey mottled brownish grey clayey SAND with rare fine to coarse shell fragments.	Slightly calcareous	Post Glacial	Post-glacial marine	8.538	0	SN2023_027_KP_ROUTE_LIN_UTM32N / Part 5
KT-ECR-2B-GRAB7	1	627836.67	6246483.35	20.32	Dark grey mottled greyish brown clayey SAND with rare fine to coarse shell fragments.	Slightly calcareous	Post Glacial	Post-glacial marine	9.539	0	SN2023_027_KP_ROUTE_LIN_UTM32N / Part 5
KT-ECR-2B-GRAB8	1	628836.63	6246491.97	20.30	Greyish brown and dark grey mottled slightly clayey SAND with rare fine to medium shell fragments.	Slightly calcareous	Post Glacial	Post-glacial marine	10.539	0	SN2023_027_KP_ROUTE_LIN_UTM32N / Part 5

Point ID	Attempt	Easting	Northing	Elevation (m)	Lithology description	Carbonate content	Depositional Age	Depositional Environment	KP	Offset from RPL	KP reference
KT-ECR-2B-GRAB9	1	629881.34	6246500.96	19.63	Brown mottled dark grey slightly clayey SAND with some fine to coarse shell fragments.	Slightly calcareous	Post Glacial	Post-glacial marine	11.584	0	SN2023_027_KP_ROUTE_LIN_UTM32 N / Part 5
KT-ECR-2B-GRAB10	4	630736.78	6246508.33	16.22	Dark grey mottled greyish brown clayey SAND with some fine to coarse shell fragments.	Slightly calcareous	Post Glacial	Post-glacial marine	12.439	0	SN2023_027_KP_ROUTE_LIN_UTM32 N / Part 5
KT-ECR-2B-GRAB11	2	631836.52	6246517.80	14.79	Dark grey mottled greyish brown clayey SAND with rare fine to medium shell fragments.	Slightly calcareous	Post Glacial	Post-glacial marine	13.539	0	SN2023_027_KP_ROUTE_LIN_UTM32 N / Part 5
KT-ECR-2B-GRAB12	4	633025.30	6246528.04	11.28	Dark grey clayey SAND with some fine to coarse gravel and shell fragments.	Slightly calcareous	Glacial	Glacial	14.729	0	SN2023_027_KP_ROUTE_LIN_UTM32 N / Part 5

APPENDIX B. GEOTECHNICAL RESULTS OVERVIEW TABLES

Point ID	TRT analysis	Easting (m)	Northing (m)	Surface elevation (m)	Elevation top (m)	Elevation bottom (m)	KP	Offset from RPL (m)	Penetration (m)	Recovery
Vibrocore										
GT_VC_080a	Yes	621511.3	6246429	10.01	0	6	3.212	4.92	3.70	4.6
GT_VC_081a	No	622351.1	6246436	11.76	0	3	4.057	-3.11	3.10	3.7
GT_VC_082	No	623190.1	6246440.5	14.60	0	6	4.891	2.4	4.04	4.25
GT_VC_083	Yes	623937.8	6246449.5	16.42	0	6	5.639	1.81	5.82	5.4
GT_VC_084a	No	624870.4	6246455	18.69	0	6	6.576	3.86	5.17	5.75
GT_VC_085	No	625658.2	6246463.5	19.60	0	3	7.36	1.62	3.41	4.3
GT_VC_086	No	626683	6246470.5	19.96	0	3	8.385	2.46	3.14	3.95
GT_VC_087	No	627389.8	6246480.5	19.83	0	3	9.091	-1.1	3.43	3.45
GT_VC_088	No	627855.2	6246482.5	20.34	0	6	9.558	1.24	5.85	5.9
GT_VC_089a	No	628229.7	6246486.5	20.62	0	6	9.936	0.02	4.97	4.9
GT_VC_090b	No	629069.4	6246494.5	19.96	0	3	10.772	3.57	1.62	1.2
GT_VC_091	No	629909.3	6246502.5	19.65	0	3	11.612	-1.48	3.13	3.4
GT_VC_092	No	630749.1	6246509	20.45	0	3	12.452	-1.68	2.69	3.2
GT_VC_093	Yes	631588.9	6246515.5	20.93	0	6	13.292	-0.96	5.73	5.8
GT_VC_094	No	632428.7	6246523	20.59	0	6	14.132	0.37	3.21	3.25
GT_VC_095	No	633268.4	6246532.5	19.63	0	3	14.973	-2.05	3.16	3.7

Point ID	Comment	Easting (m)	Northing (m)	Elevation surface (m)	Elevation top (m)	Elevation bottom (m)	KP	Offset from RPL (m)	Penetration (m)	Est_sett
Cone penetration test										
GT_CPT_080	Cone ID: GG60484. Cone size: 10	621511.3	6246429	10.01	0	6	3.216	-0.29	0.04	0.03
GT_CPT_080a	Cone ID: GG60484. Cone size: 10	621511.3	6246429	10.01	0	6	3.212	4.92	3.22	0
GT_CPT_080b	Cone ID: GG60484. Cone size: 10	621511.3	6246429	10.01	0	6	3.212	-3.49	2.62	0
GT_CPT_081	Cone ID: GG60482. Cone size: 10	622351.1	6246436	11.76	0	3	4.053	-5.49	0.12	0.16
GT_CPT_081a	Cone ID: GG60451. Cone size: 10	622351.1	6246436	11.76	0	3	4.057	-3.11	3.21	0.04
GT_CPT_082	Cone ID: GG60451. Cone size: 10	623190.1	6246441	14.6	0	6	4.891	2.4	5.74	0.07
GT_CPT_083	Cone ID: GG60451. Cone size: 10	623937.8	6246450	16.42	0	6	5.639	1.81	6.22	0.08
GT_CPT_084	Cone ID: GG60451. Cone size: 10	624870.4	6246455	18.69	0	6	6.571	2.46	4.81	0.1
GT_CPT_084a	Cone ID: GG60484. Cone size: 10	624870.4	6246455	18.69	0	6	6.576	3.86	3.65	0.06
GT_CPT_085	Cone ID: GG60484. Cone size: 10	625658.2	6246464	19.6	0	3	7.36	1.62	3.37	0.07
GT_CPT_086	Cone ID: GG60484. Cone size: 10	626683	6246471	19.96	0	3	8.385	2.46	3.39	0.08
GT_CPT_087	Cone ID: GG60484. Cone size: 10	627389.8	6246481	19.83	0	3	9.091	-1.1	3.39	0.07
GT_CPT_088	Cone ID: GG60484. Cone size: 10	627855.2	6246483	20.34	0	6	9.558	1.24	6.22	0.07
GT_CPT_089	Cone ID: GG60484. Cone size: 10	628229.7	6246487	20.62	0	6	9.931	0.43	6.21	0.07
GT_CPT_090	Cone ID: GG60451. Cone size: 10	629069.4	6246495	19.96	0	3	10.772	-0.8	3.24	0.07
GT_CPT_090a	Cone ID: GG60442. Cone size: 10	629069.4	6246495	19.96	0	3	10.772	-5.6	3.25	0.08
GT_CPT_090b	Cone ID: GG60450. Cone size: 10	629069.4	6246495	19.96	0	3	10.772	3.57	3.24	0.07
GT_CPT_091	Cone ID: GG60450. Cone size: 10	629909.3	6246503	19.65	0	3	11.612	-1.48	3.21	0.06
GT_CPT_092	Cone ID: GG60450. Cone size: 10	630749.1	6246509	20.45	0	3	12.452	-1.68	3.22	0.06
GT_CPT_093	Cone ID: GG60450. Cone size: 10	631588.9	6246516	20.93	0	6	13.292	-0.96	6.21	0.07

Point ID	Comment	Easting (m)	Northing (m)	Elevation surface (m)	Elevation top (m)	Elevation bottom (m)	KP	Offset from RPL (m)	Penetration (m)	Est_sett
GT_CPT_094	Cone ID: GG60450. Cone size: 10	632428.7	6246523	20.59	0	6	14.132	0.37	5.41	0.07
GT_CPT_095	Cone ID: GG60442. Cone size: 10	633268.4	6246533	19.63	0	3	14.973	-2.05	3.21	0.04