Danish Offshore Wind 2030 Cable Route Survey

Title	**Kriegers Flak II - Cable Route Integrated Report**
Project document code	BE5950H-711-RR-03
Client document code	SN2023_027-IR-KF
Revision	2.0

2.0	29/11/2024	For Client Review	VSA/SKA	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	22/08/2024	Internal revision	Minor corrections
1.0	27/08/2024	For Client review	
2.0	29/11/2024	For Client review	Ref. "Deliverable_Register_DOW2030_KFII_ECR_rev1.xlsx"

TABLE OF CONTENTS

Services warranty ... *2*
Revision history ... *3*
List of figures ... *10*
List of tables ... *13*
List of appendices ... *15*
Definitions and abbreviations ... *16*

1 EXECUTIVE SUMMARY ... 18
2 PROJECT INTRODUCTION AND BACKGROUND ... 21
2.1 Project overview ... 21
2.2 Cable routes ... 23
2.3 Existing infrastructure ... 24
2.4 Parties involved ... 25
2.5 Scope of work ... 26
2.5.1 Geophysical survey ... 26
2.5.2 Line planning ... 27
2.5.3 Geotechnical survey ... 29
2.5.4 General survey objectives ... 33
2.6 Reference documentation ... 33

3 GEODETIC PARAMETERS AND TRANSFORMATIONS ... 35
3.1 Horizontal datum ... 35
3.2 Vertical reference ... 35
3.3 Survey units ... 35
3.4 Time reference ... 36

4 SURVEY RESOURCES ... 37
4.1 Survey vessels ... 37
4.1.1 Offshore cable route geophysical survey ... 37
4.1.2 Nearshore geophysical survey ... 37
4.1.3 Landfall topographic survey ... 38
4.1.4 Geotechnical survey ... 38
4.2 Survey systems ... 38
4.3 Software ... 40
4.4 Towed passive acoustic monitoring system ... 40
4.5 Marine mammal reporting and analysis ... 41
4.6 General survey timeline ... 41

5 DATA PROCESSING AND WORKFLOW ... 42
5.1 Lidar ... 42
5.1.1 Data acquisition ... 42
5.1.2 Processing ... 42

5.1.3 Data quality assessment ... 42
5.2 Multibeam echosounder ... 42
5.2.1 Data acquisition ... 42
5.2.2 MBES processing ... 44
5.2.3 MBES target picking ... 47
5.2.4 MBES and backscatter data quality assessment ... 47
5.3 Side scan sonar ... 51
5.3.1 Data acquisition ... 51
5.3.2 SSS processing ... 52
5.3.3 SSS target picking ... 56
5.3.4 SSS data quality assessment ... 58
5.4 Magnetometer ... 59
5.4.1 Data acquisition ... 59
5.4.2 MAG processing ... 60
5.4.3 MAG target picking ... 63
5.4.4 MAG data quality assessment ... 63
5.5 Sub-bottom profiler ... 64
5.5.1 Data acquisition ... 64
5.5.2 SBP processing ... 65
5.5.3 Geology interpretation ... 68
5.5.4 SBP data quality assessment ... 68
5.5.5 Depth SBP data ... 71
5.6 Grab sampling ... 72
5.7 Geotechnical sampling and analysis ... 73
5.7.1 CPT testing ... 74
5.7.2 Vibrocore sampling ... 74
5.7.3 In-Situ TRT ... 74
5.7.4 Laboratory testing ... 75
5.8 Ground truthing for acoustic data interpretation ... 77
5.9 Classification criteria ... 77
5.9.1 Seabed gradient classification criteria ... 77
5.9.2 Confidence interval classification for targets ... 77
5.9.3 Boulder field classification ... 78
5.9.4 Mobile bedform classification ... 78
5.9.5 Sediment classification ... 78
6 KRIEGERS FLAK II ROUTE OVERVIEW ... 80
6.1 Results ... 80
6.2 Bathymetry & topography ... 80
6.2.1 Landfall & topography ... 82
6.2.2 Bathymetry overview ... 82

6.3 Seabed surface geology ... 92
6.4 Seabed surface morphology ... 98
6.5 Seabed surface features ... 105
6.5.1 Wrecks ... 106
6.5.2 Cables, wires, and ropes ... 109
6.5.3 Pipelines ... 115
6.5.4 Debris ... 115
6.5.5 Items related to fishing activities, and seabed disturbances ... 118
6.5.6 Archaeological findings ... 118
6.6 Geotechnical results ... 119
6.6.1 Particle size distribution and soil type analysis ... 119
6.6.2 Moisture content, bulk density and dry density ... 120
6.6.3 Thermal resistivity from TRT measurements ... 120
6.6.4 Correlation between derived CPT parameters, soil types and geophysical units ... 121
6.7 Sub-surface geology ... 131
6.7.1 Regional geological history ... 131
6.7.2 Shallow geological overview ... 131
6.7.3 Stratigraphy and general arrangement of units ... 131
6.7.4 Quaternary Deglaciation History / stratigraphic units ... 132
7 KRIEGERS FLAK II ROUTE ANALYSIS ... 143
7.1 Kriegers Flak – 3 km section South route cable descriptions ... 151
7.1.1 KP 0.000 – KP 3.000 ... 151
7.1.2 KP 3.000 – KP 6.000 ... 153
7.1.3 KP 6.000 – KP 9.000 ... 156
7.1.4 KP 9.000 – KP 12.000 ... 159
7.1.5 KP 12.000 – KP 15.000 ... 162
7.1.6 KP 15.000 – KP 18.000 ... 165
7.1.7 KP 18.000 – KP 21.000 ... 168
7.1.8 KP 21.000 – KP 24.000 ... 171
7.1.9 KP 24.000 – KP 27.000 ... 174
7.1.10 KP 27.000 – KP 30.000 ... 177
7.1.11 KP 30.000 – KP 33.000 ... 180
7.1.12 KP 33.000 – KP 36.000 ... 183
7.1.13 KP 36.000 – KP 39.000 ... 186
7.1.14 KP 39.000 – KP 42.000 ... 189
7.1.15 KP 42.000 – KP 45.000 ... 192
7.1.16 KP 45.000 – KP 47.122 ... 195
7.2 Kriegers Flak – 3 km section North route cable descriptions ... 198
7.2.1 KP 0.000 – KP 3.000 ... 198
7.2.2 KP 3.000 – KP 6.000 ... 198
7.2.3 KP 6.000 – KP 9.000 ... 198

7.2.4 KP 9.000 – KP 12.000 ... 198
7.2.5 KP 12.000 – KP 15.000 ... 198
7.2.6 KP 14.000 – KP 17.000 ... 198
7.2.7 KP 17.000 – KP 20.000 ... 201
7.2.8 KP 20.000 – KP 23.180 ... 204
7.3 Shallow geological installation constraints ... 207
7.3.1 Cobbles and Boulders ... 207
7.3.2 Organic Material ... 207
7.4 Comparison between seabed and sub-seabed findings ... 207
8 CONCLUSIONS ... 208
9 DIGITAL DATA DELIVERABLES OVERVIEW ... 211
9.1 Digital deliverables summary ... 211
9.2 Interpretation deliverables ... 214
APPENDIX A. GRAB SAMPLE CLASSIFICATION ... 215
APPENDIX B. GEOTECHNICAL RESULTS OVERVIEW TABLES ... 219

LISTS OF TABLES

Table 1: Abbreviations used in this document 16
Table 2: Areas of investigation for the cable route surveys 21
Table 3: The coordinates of the Kriegers Flak II export cable route 23
Table 4: Summary of crossings and third-party assets 24
Table 5: Geotechnical works summary 29
Table 6: Client reference documentation 33
Table 7: Company and project documentation 33
Table 8: Other references 34
Table 9: Project reports 34
Table 10: Datum parameters 35
Table 11: Projection parameters 35
Table 12: GOIV survey vessel specifications 37
Table 13: GSXVII survey vessel specifications 37
Table 14: GSV survey vessel specifications 38
Table 15: DP II Connector vessel specifications 38
Table 16: GOIV geophysical survey equipment specifications 38
Table 17: GSXVII geophysical survey equipment specifications 39
Table 18: : GSV survey equipment 39
Table 19: Connector survey equipment 40
Table 20: Primary software list 40
Table 21: General survey timeline 41
Table 22: MBES specifications 42
Table 23: GOIV MBES acquisition settings 43
Table 24: GSV MBES acquisition settings 43
Table 25: GSXVII MBES acquisition settings 44
Table 26: Data import into Qimera and initial QC 44
Table 27: Positioning QC 44
Table 28: Data de-spiking 45
Table 29: Data QC 45
Table 30: SSS specifications 51
Table 31: SSS system settings – GOIV 51
Table 32: SSS system settings – GSV 51
Table 33: SSS system settings – GSXVII 52
Table 34: Importing SSS data into SonarWiz 52
Table 35: Navigation correction in SonarWiz 52
Table 36: SSS signal processing 53
Table 37: SSS infill assessment 53
Table 38: SSS contact picking 53
Table 39: SSS mosaic creation 54
Table 40: SSS seabed classification 54
Table 41: Target identification workflow 56
Table 42: MAG specifications 59
Table 43: MAG system settings – GOIV 60

Table 44: MAG system settings - GSV ... 60
Table 45: MAG system settings - GSXVII ... 60
Table 46: Magnetometer navigation processing ... 62
Table 47: Magnetometer altitude processing ... 62
Table 48: Magnetometer data QC ... 62
Table 49: Magnetometer background calculation ... 63
Table 50: Magnetometer residual field calculation ... 63
Table 51: Magnetometer target picking ... 63
Table 52: SBP specifications ... 64
Table 53: Settings onboard GOIV ... 64
Table 54: Settings onboard GSXVII ... 65
Table 55: Settings onboard GSV ... 65
Table 56: SBP data import and data QC ... 65
Table 57: SBP acquisition and processing methodology ... 66
Table 58: Overview of classification test on VC samples ... 75
Table 59: Analysis on vibrocores and CPTs integrated in our results ... 77
Table 60: Slope classification ... 77
Table 61: Confidence interval classification for targets ... 77
Table 62: Boulder field classification criteria ... 78
Table 63: Bedform classification criteria ... 78
Table 64: GEUS Seabed Sediment Classification for Danish Waters ... 79
Table 65: Acoustic characteristics of the sediment types within the Kriegers Flak II site ... 94
Table 66: Morphological interpretation ... 99
Table 67: Summary of linear contact man-made objects ... 105
Table 68: Summary of point contact man-made objects ... 105
Table 69: Shallow geological units ... 131
Table 70: Overview per 3 km interval South cable route ... 143
Table 71: Overview per 3 km interval North cable route ... 149
Table 72: Digital deliverables, overview ... 211
Table 73: Interpretation deliverables, overview ... 214

LIST OF FIGURES

Figure 1: Project overview map – Kriegers Flak II 22
Figure 2: Kriegers Flak II survey extents 23
Figure 3: Landfall location overview - Rødvig........ 24
Figure 4: Overview map of the crossings within the Kriegers Flak II ECR area 25
Figure 5: Parties involved in the project........ 26
Figure 6: Kriegers Flak II offshore geophysical line plan 28
Figure 7: Kriegers Flak II nearshore geophysical line plan........ 28
Figure 8: CTP geotechnical locations overview 30
Figure 9: TRT/VC geotechnical locations overview 31
Figure 10: VC geotechnical locations overview........ 32
Figure 11: MBES processing workflow 46
Figure 12: THU coverage map of the survey area 48
Figure 13: TVU coverage map of the survey area 48
Figure 14: Backscatter data intensity 49
Figure 15: The comparison of GSV and GeoX backscatter mosaic........ 50
Figure 16: The data example before changing the vertical referencing (a) and after changing the vertical referencing (b)........ 50
Figure 17: SSS data processing workflow 55
Figure 18: Automated boulder detection progress........ 57
Figure 19: Pycnocline artefact before (above image) and after (below image) removal in the SSS dataset.. 58
Figure 20: SSS coverage plot........ 59
Figure 21: Magnetometer data processing workflow........ 61
Figure 22: Example of the geological noise reduction applied in the nearshore dataset in the Kriegers Flak survey area 64
Figure 23: SBP processing workflow........ 67
Figure 24 SBP data example from GOIV - nearshore........ 68
Figure 25 SBP data example from GOIV - offshore 69
Figure 26 SBP data example from GSXVII........ 70
Figure 27 SBP data example from GSV........ 71
Figure 28: Grab sampling locations overview 73
Figure 29: GeoCeptor - Combined Vibrocore and CPTU rig 74
Figure 30: Wentworth Scale – classifying sediment particles 79
Figure 31: Bathymetry and topographic combined overview presents a comprehensive overview of the bathymetry within the Kriegers Flak II export cable routes survey area 81
Figure 32: Topographic overview........ 82
Figure 33: Bathymetry overview of the survey area 83
Figure 34: Depth and slope profile along the north route RPL 84
Figure 35: Depth and slope profile the south route RPL........ 85
Figure 36: Bathymetry overview at the start of the route 86
Figure 37: Bathymetry and slope map of the intermediate boulder field area near KP 27.000........ 87
Figure 38: Bathymetry and slope map of the wreck and pipeline 87
Figure 39: Bathymetry and slope map of the submarine cables........ 88
Figure 40: Till/diamicton area at the end of the northern route 89
Figure 41: Channel feature between till/diamicton outcrops........ 90

Figure 42: Slope overview of the survey area ... 91
Figure 43: Seabed geology classification as confirmed by grab sample results, compared with the LF SSS data in KFII ... 92
Figure 44: Wentworth Scale – classifying sediment particles ... 96
Figure 45: Seabed surface geology classifications ... 97
Figure 46: Seabed surface morphology classification ... 104
Figure 47: Location of wreck KFII_ECR_MMO_PTS_0350 ... 107
Figure 48: Location of wreck KFII_ECR_MMO_PTS_0390 ... 108
Figure 49: A comparison of as-found cables and pipelines with existing data on their locations ... 110
Figure 50: Segment of the Baltic cable ... 111
Figure 51: Overview of linear MMO found within the survey site (without cables and pipelines) ... 112
Figure 52: Example of an MMO labelled as "Soft rope" - KFII_ECR_MMO_LIN_0112 ... 113
Figure 53: Example of an MMO labelled as "Other" - KFII_ECR_MMO_LIN_0007 ... 114
Figure 54: Distribution of MMO contacts with associated MAG anomalies ... 116
Figure 55: Anchors detected within the survey area ... 117
Figure 56: CPT locations overview with achieved depths below seabed ... 123
Figure 57: VC locations overview with achieved depths below seabed ... 123
Figure 58: Sample analysis: Achieved depths and soil type distribution ... 124
Figure 59: Sample analysis: D50 and D90 grain size diameters ... 125
Figure 60: Sample analysis: Bulk density (g/cm^3) and water content (%) ... 126
Figure 61: Sample analysis: Cone resistance and friction resistance in MPa ... 127
Figure 62: Sample analysis presenting clay (%) and thermal resistivity ... 128
Figure 63: Soil types derived from VC and CPT data (top) and CPT parameters (bottom) compared with key horizons from SBP interpretation along Kriegers Flak II – North Route ... 129
Figure 64: Soil types derived from VC and CPT data (top) and CPT parameters (bottom) compared with key horizons from SBP interpretation along Kriegers Flak II – South Route ... 130
Figure 65: Geological schematic, general arrangement of units ... 132
Figure 66: Illustrating extent and thickness of Unit I ... 135
Figure 67: Unit Ia thickness – version 1 ... 136
Figure 68: Illustrating Unit I and Unit Ia typical structure and arrangement ... 137
Figure 69: Examples of CHALK in vibrocore samples ... 138
Figure 70: Illustrating Extents and depth BSB to Base Unit II ... 140
Figure 71: Illustrating Geotechnical sampling into Unit II ... 141
Figure 72: Location of the seismic profiles shown throughout the report ... 151
Figure 73: Integrated geotechnical panel KP 0.000 – KP 3.000 – Southern route ... 152
Figure 74: SBP and Geotech, KP 3.000 – KP 6.000 - Southern route ... 154
Figure 75: Integrated geotechnical panel KP 3.000 – KP 6.000 – Southern route ... 155
Figure 76: SBP and Geotech, KP 6.000 – KP 9.000 – Southern route ... 157
Figure 77: Integrated geotechnical panel KP 6.000 – KP 9.000 – Southern route ... 158
Figure 78: SBP and Geotech, KP 9.000 – KP 12.000 – Southern route ... 160
Figure 79: Integrated geotechnical panel KP 9.000 – KP 12.000 – Southern route ... 161
Figure 80: SBP and Geotech, KP 12.000 – KP 15.000 – Southern route ... 163
Figure 81: Integrated geotechnical panel KP 12.000 – KP 15.000 –Southern route ... 164
Figure 82: SBP and Geotech, KP 15.000 – KP 18.000 – Southern route ... 166
Figure 83: Integrated geotechnical panel KP 15.000 – KP 18.000 –Southern route ... 167

Figure 84: SBP and Geotech, KP 18.000 – KP 21.000 – Southern route 169
Figure 85: Integrated geotechnical panel KP 18.000 – KP 21.000 –Southern route 170
Figure 86: SBP and Geotech, KP 21.000 – KP 24.000 – Southern route 172
Figure 87: Integrated geotechnical panel KP 21.000 – KP 24.000 –Southern route 173
Figure 88: SBP and Geotech, KP 24.000 – KP 27.000 – Southern route 175
Figure 89: Integrated geotechnical panel KP 24.000 – KP 27.000 –Southern route 176
Figure 90: SBP and Geotech, KP 27.000 – KP 30.000 – Southern route 178
Figure 91: Integrated geotechnical panel KP 27.000 – KP 30.000 –Southern route 179
Figure 92: SBP and Geotech, KP 30.000 – KP 33.000 – Southern route 181
Figure 93: Integrated geotechnical panel KP 30.000 – KP 33.000 –Southern route 182
Figure 94: SBP and Geotech, KP 33.000 – KP 36.000 – Southern route 184
Figure 95: Integrated geotechnical panel KP 33.000 – KP 36.000 –Southern route 185
Figure 96: SBP and Geotech, KP 36.000 – KP 39.000 – Southern route 187
Figure 97: Integrated geotechnical panel KP 36.000 – KP 39.000 –Southern route 188
Figure 98: SBP and Geotech, KP 39.000 – KP 42.000 – Southern route 190
Figure 99: Integrated geotechnical panel KP 39.000 – KP 42.000 –Southern route 191
Figure 100: SBP and Geotech, KP 42.000 – KP 45.000 – Southern route 193
Figure 101: Integrated geotechnical panel KP42.000 – KP 45.000 –Southern route 194
Figure 102: SBP and Geotech, KP 45.000 – KP 47.122 – Southern route 196
Figure 103: Integrated geotechnical panel KP45.000 – KP 47.122 –Southern route 197
Figure 104: SBP and Geotech, KP 15.000 – KP 18.000 – Northern route 199
Figure 105: Integrated geotechnical panel KP14.000 – KP 17.000 –Northern route 200
Figure 106: SBP and Geotech, KP 18.000 – KP 21.000 – Northern route 202
Figure 107: Integrated geotechnical panel KP17.000 – KP 20.000 –Northern route 203
Figure 108: SBP and Geotech, KP 21.000 – KP 23.179 – Northern route 205
Figure 109: Integrated geotechnical panel KP20.000 – KP 23.179 –Northern route 206

LIST OF TABLES

Table 1: Abbreviations used in this document ... 16
Table 2: Areas of investigation for the cable route surveys ... 21
Table 3: The coordinates of the Kriegers Flak II export cable route ... 23
Table 4: Summary of crossings and third-party assets ... 24
Table 5: Geotechnical works summary ... 29
Table 6: Client reference documentation ... 33
Table 7: Company and project documentation ... 33
Table 8: Other references ... 34
Table 9: Project reports ... 34
Table 10: Datum parameters ... 35
Table 11: Projection parameters ... 35
Table 12: GOIV survey vessel specifications ... 37
Table 13: GSXVII survey vessel specifications ... 37
Table 14: GSV survey vessel specifications ... 38
Table 15: DP II Connector vessel specifications ... 38
Table 16: GOIV geophysical survey equipment specifications ... 38
Table 17: GSXVII geophysical survey equipment specifications ... 39
Table 18: : GSV survey equipment ... 39
Table 19: Connector survey equipment ... 40
Table 20: Primary software list ... 40
Table 21: General survey timeline ... 41
Table 22: MBES specifications ... 42
Table 23: GOIV MBES acquisition settings ... 43
Table 24: GSV MBES acquisition settings ... 43
Table 25: GSXVII MBES acquisition settings ... 44
Table 26: Data import into Qimera and initial QC ... 44
Table 27: Positioning QC ... 44
Table 28: Data de-spiking ... 45
Table 29: Data QC ... 45
Table 30: SSS specifications ... 51
Table 31: SSS system settings – GOIV ... 51
Table 32: SSS system settings – GSV ... 51
Table 33: SSS system settings – GSXVII ... 52
Table 34: Importing SSS data into SonarWiz ... 52
Table 35: Navigation correction in SonarWiz ... 52
Table 36: SSS signal processing ... 53
Table 37: SSS infill assessment ... 53
Table 38: SSS contact picking ... 53
Table 39: SSS mosaic creation ... 54
Table 40: SSS seabed classification ... 54
Table 41: Target identification workflow ... 56
Table 42: MAG specifications ... 59
Table 43: MAG system settings – GOIV ... 60
Table 44: MAG system settings - GSV ... 60

Table 45: MAG system settings - GSXVII ... 60
Table 46: Magnetometer navigation processing ... 62
Table 47: Magnetometer altitude processing ... 62
Table 48: Magnetometer data QC ... 62
Table 49: Magnetometer background calculation ... 63
Table 50: Magnetometer residual field calculation ... 63
Table 51: Magnetometer target picking ... 63
Table 52: SBP specifications ... 64
Table 53: Settings onboard GOIV ... 64
Table 54: Settings onboard GSXVII ... 65
Table 55: Settings onboard GSV ... 65
Table 56: SBP data import and data QC ... 65
Table 57: SBP acquisition and processing methodology ... 66
Table 58: Overview of classification test on VC samples ... 75
Table 59: Analysis on vibrocores and CPTs integrated in our results ... 77
Table 60: Slope classification ... 77
Table 61: Confidence interval classification for targets ... 77
Table 62: Boulder field classification criteria ... 78
Table 63: Bedform classification criteria ... 78
Table 64: GEUS Seabed Sediment Classification for Danish Waters ... 79
Table 65: Acoustic characteristics of the sediment types within the Kriegers Flak II site ... 94
Table 66: Morphological interpretation ... 99
Table 67: Summary of linear contact man-made objects ... 105
Table 68: Summary of point contact man-made objects ... 105
Table 69: Shallow geological units ... 131
Table 70: Overview per 3 km interval South cable route ... 143
Table 71: Overview per 3 km interval North cable route ... 149
Table 72: Digital deliverables, overview ... 211
Table 73: Interpretation deliverables, overview ... 214

LIST OF APPENDICES

Appendix A: Grab sample classification (included in this report)

Appendix B: Geotechnical results overview tables (included in this report)

Appendix C: Geotechnical Operational Report

Appendix D: MMO catalogue

Appendix E: SBP Images with Geomodelling

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

Abbreviation	Definition	Abbreviation	Definition
BS	Backscatter	MBES	Multi Beam Echo Sounder
CMP	Common Mid-Point	MCA	Maritime and Coastguard Agency
CPT	Cone Penetration Test	MCR	Mobilisation & Calibration Report
CPTU	Cone Penetration Test with Pore Pressure	MMO	Marine Mammal Observer/Man-Made Object
CTV	Crew Transfer Vessel	MRU	Motion Reference Unit
DGPS	Differential Global Positioning System	mbsb	Metres below seabed
DP	Dynamic Positioning	MSL	Mean Sea Level
DTM	Digital Terrain Model	OWF	Offshore Wind Farm
DTS	Desktop Study	PAM	Passive Acoustic Monitoring
ECR	Export Cable Route	QA	Quality Assurance
EEZ	Exclusive Economic Zone	QC	Quality Control
EGN	Empirical Gain Normalisation	QINSy	Quality Integrated Navigation System
EPSG	European Petroleum Survey Group	QPS	Quality Positioning Services B.V.
ETRS	European Terrestrial Reference System	RPL	Route Position List
FMGT	Fledermaus GeoCoder Toolbox	RTK	Real Time Kinematic
FO	Fiber Optic (telecom cable)	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
GS	Grab Sampling	SWL	Safe Working Limit
GSV	Geo Surveyor V	TD	Target Depth

Abbreviation	Definition	Abbreviation	Definition
GSXVII	Geo Surveyor XVII	THU	Total Horizontal Uncertainty
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
KF	Kriegers Flak	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

1 EXECUTIVE SUMMARY

Kriegers Flak II Cable Route			
Survey dates	Geophysical survey	Start	04/08/2024
		End	01/06/2024
	Geotechnical survey	Start	21/03/2024
		End	26/03/2024
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 33N (EPSG: 25833)	
Bathymetry and topography			
Elevation	9.96 m MSL (Topographic) – 34.36 m MSL (Bathymetric)		
Site characteristics	The seabed gradient along the route varies significantly, starting from KP 0.000, where it deepens to 10 metres below MSL with an average slope of 5.4 degrees. This section is characterized by a rocky beach with steep slopes due to geological features. The slope becomes gentler south-eastward, with two sand bedforms observed around KP 2.175 to KP 3.000. From KP 3.000 to KP 11.630, the seabed slopes slightly, with a maximum depth of 19.2 metres below MSL. Continuing to KP 29.400, the seabed deepens further, reaching 28.5 metres, with steep slopes near KP 16.000 and a shipwreck site. In the area between KP 14.000 and KP 23.173, the seabed slopes gently at 0.3 degrees, with steep slopes observed near trench areas and till/diamicton outcrops. Beyond KP 29.400, very steep slopes are found within boulder fields, with irregular bathymetry until KP 41.000. The route ends at 31.5 metres below MSL, with the seabed covered mainly in sand and muddy sand, except for steep patches near KP 45.000. Starting at KP 0 and moving landward, the elevation quickly rises from 0 to 3 metres MSL over a short distance. The terrain in the southern half of the shoreline is more rugged compared to the gentler northern half, where the planned landfall is located. Adjacent to the landfall, the flat agricultural land slopes slightly from 3 to 6-7 metres in the west. West of this field lies low-lying land (1 m MSL) crossed by a creek. The surveyed area also includes slightly inclined residential zones (4 to 8 metres MSL) and flat forested areas (2 to 4 m MSL), with the elevation peaking just below 10 metres, likely due to a tall building or other man-made structure.		
Seabed surface: Geology			
The seabed geology across the Kriegers Flak II ECR area is diverse with no predominant substrate. The area near KP 0.000 to KP 2.000 consists of till/diamicton, which becomes sparser moving east as sand and gravel dominate up to KP 11.000. Beyond this, till and diamicton are predominant in the central southern RPL branch, with patches of muddy sand in the eastern half. In the final kilometres, till/diamicton transitions			

Kriegers Flak II Cable Route	
to muddy sand and sand. The branch near the Kriegers Flak II North windfarm features a mix of till/diamicton, sand, quaternary clay, silt, and predominantly muddy sand in the central part.	
Seabed surface: Morphology	
The initial stretch of the survey area shows no detectable seabed features. However, till/diamicton regions are marked by intermediate-density boulder fields, with some sediment waveform and ripple areas. Between KP 3.000 and KP 11.000, featureless seabed alternates with large ripples and sediment waves. From KP 11.000 to KP 41.000, intermediate-density boulder fields dominate, with featureless strips in the eastern half. Beyond KP 41.000, boulder fields give way to trawl marks, featureless areas, and Mytilus edulis beds at the southern end. The branch near the northern windfarm features a mix of boulder fields, possible biostructures, and featureless patches.	
Seabed surface: Man-made features and site-specific hazards	
Wrecks	Two shipwrecks were identified on site
Metallic objects	Eight metallic linear contacts and 345 metallic point contacts found within a 5 m radius of a magnetic anomaly
Anchors	Two anchors were found within the site.
Other contacts	176 linear and 460 point contacts are identified to be debris
Rope	19 linear and 19 point contacts related to possible soft rope item
Cables	12 linear contacts and two point contacts related to cables were found
Pipelines	Three linear contacts and three point contacts related to pipelines were found
Boulders	31965 boulders were identified within the site
Sub-seabed soil units	
Unit I	Post Glacial – Fine to medium SAND
Unit Ia	Post Glacial – Variable SAND, with occasional CLAY/GRAVEL beds, PEAT and GYTTJA
Unit II	Late Glacial - Variable, includes intervals of laminated CLAY, SAND-prone packages
Unit III	Glacial - Variable, CLAY-prone, locally overconsolidated
Geology	
The area has a glacial to post-glacial sequence. Only the upper glacial, late glacial and post glacial deposits have been interpreted, however some CHALK has been identified which has been interpreted as part glacial sequence representing a glacially disturbed layer of chalk.	
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. Unit III may have variable levels of overconsolidation. Unit III may contain numerous cobbles and boulders. There are occasional indications of boulders within the sub-bottom profiler data. These data have 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	

Kriegers Flak II Cable Route
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. There is no evidence of gas within the Kriegers Flak cable route corridor. However organic soils; PEAT and GYTTJA have both been identified. Some CHALK has also been identified in vibrocore data, and is interpreted as glacial derived eroded bedrock. The presence of CHALK is occasionally at or near the seabed and may present engineering constraints, though it has not been able to be identified as clear reflectors in the SBP data.

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 Baltic Sea (Kriegers Flak) to connect further offshore wind energy to the Danish mainland. The Kriegers Flak II project location is displayed in Figure 1.

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 investigation. The areas of investigation are summarized in Table 2 below.

Table 2: Areas of investigation for the cable route surveys

Export Cable Route	Route length	Route width	Water depth
Kriegers Flak II North – Export Cable	23.18 km	1500 m	0-28 m
Kriegers Flak II South – Export Cable	47.12 km	1500 m	0-34 m

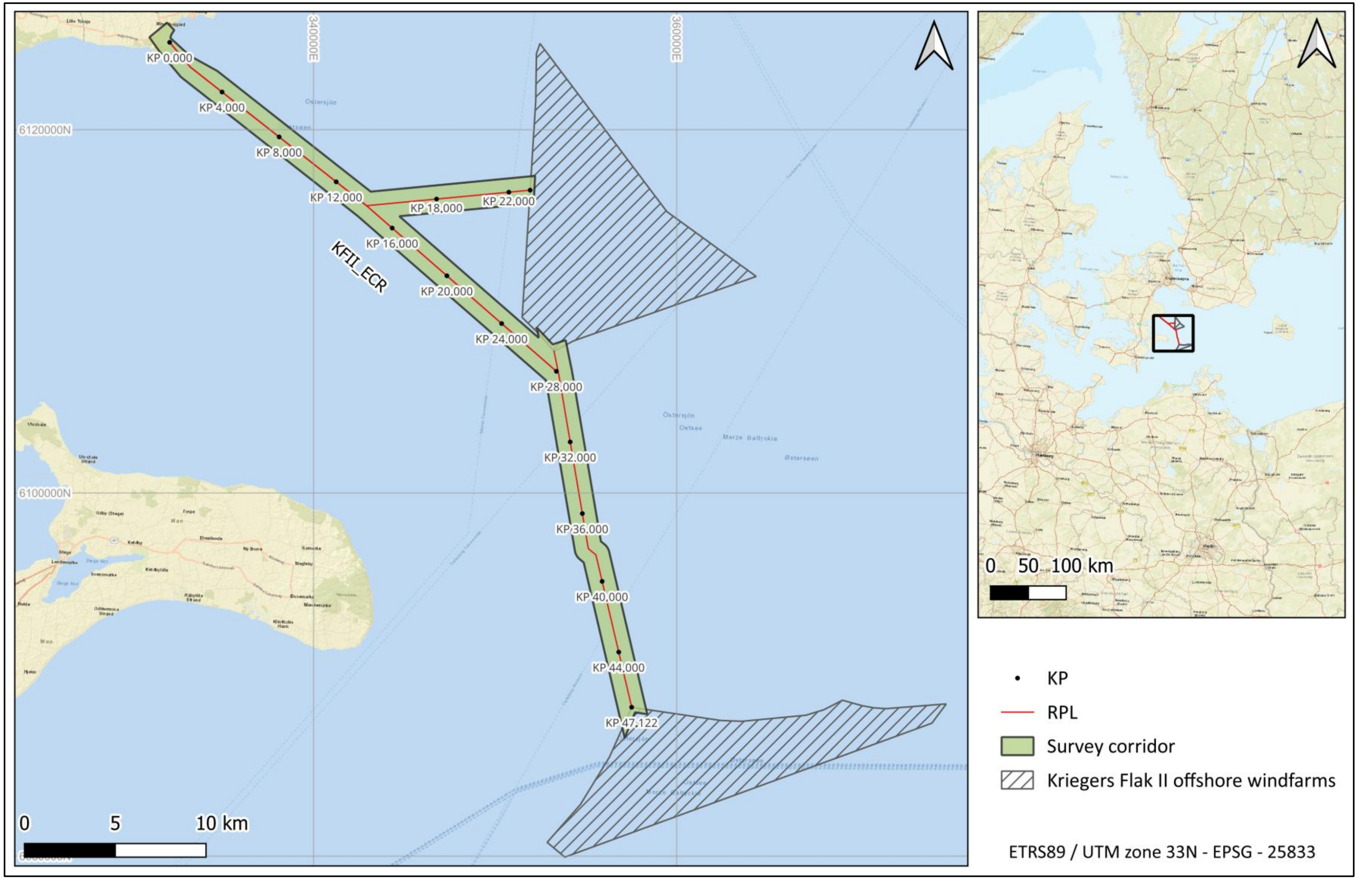


Figure 1: Project overview map – Kriegers Flak II

2.2 CABLE ROUTES

The Kriegers Flak II export cable route survey site is located in the Danish Baltic Sea (east of Møn, south of Skåne, north of Rügen). A summary of coordinates and the cable route extents are displayed in Figure 2 and Table 3 below.

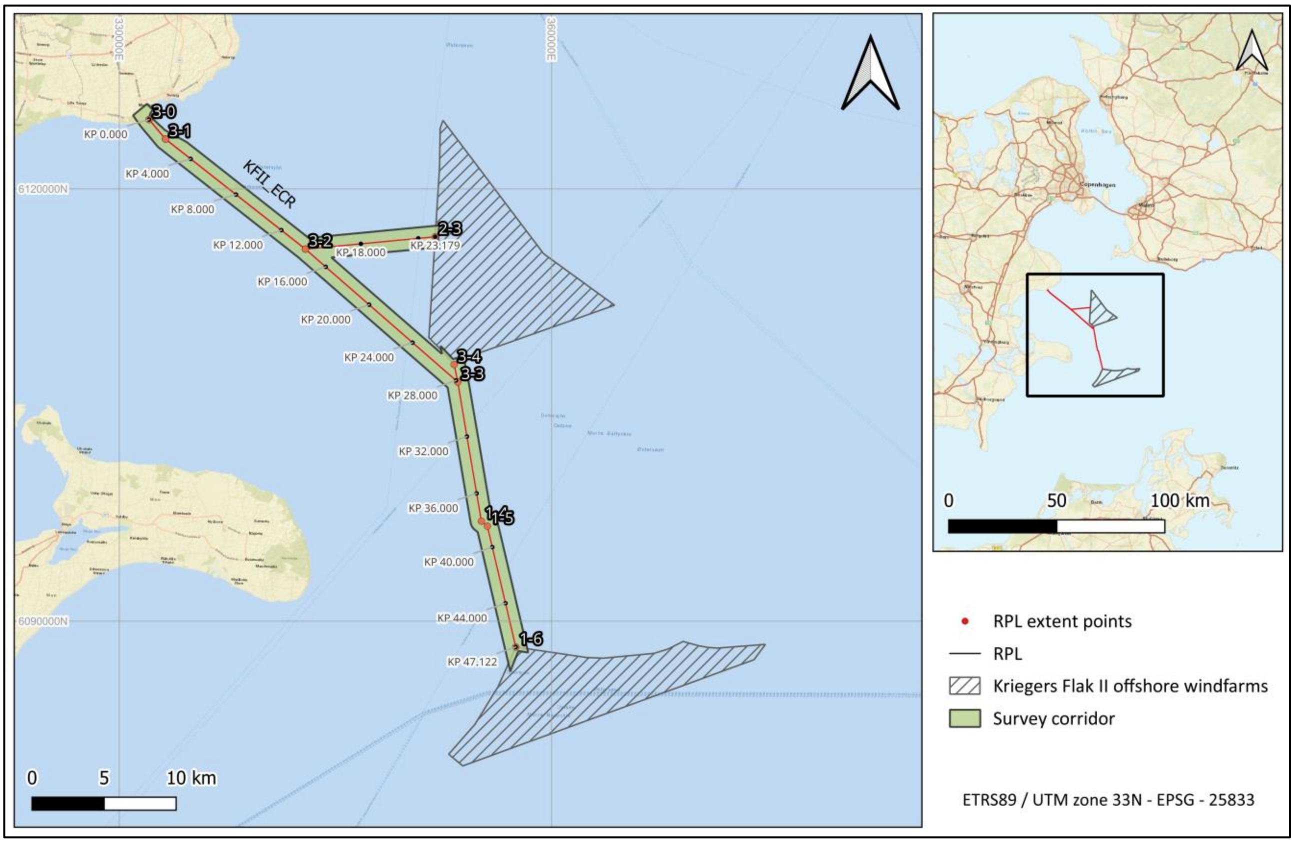


Figure 2: Kriegers Flak II survey extents

Table 3: The coordinates of the Kriegers Flak II export cable route

Point ID	KP	Easting	Northing	Latitude	Longitude
1-0	0	332072	6124815.5	55° 14.473' N	12° 21.518' E
1-1	1.7744936	333210.4	6123454.283	55° 13.763' N	12° 22.640' E
1-2	14.1274636	342920.7	6115818.524	55° 9.841' N	12° 32.046' E
1-3	28.1594579	353495.5	6106595.104	55° 5.067' N	12° 42.282' E
1-4	37.9606056	355136.9	6096932.386	54° 59.890' N	12° 44.118' E
1-5	38.5030701	355556	6096587.884	54° 59.711' N	12° 44.521' E
1-6	47.1221221	357526	6088197	54° 55.225' N	12° 46.617' E
2-0	0	332072	6124815.5	55° 14.473' N	12° 21.518' E
2-1	1.7744936	333210.4	6123454.283	55° 13.763' N	12° 22.640' E
2-2	14.1274636	342920.7	6115818.524	55° 9.841' N	12° 32.046' E
2-3	23.179466	351932.266	6116674.815	55° 10.469' N	12° 40.499' E
3-0	0	332072	6124815.5	55° 14.473' N	12° 21.518' E
3-1	1.7744936	333210.4	6123454.283	55° 13.763' N	12° 22.640' E

Point ID	KP	Easting	Northing	Latitude	Longitude
3-2	14.1274636	342920.7	6115818.524	55° 9.841' N	12° 32.046' E
3-3	28.1594579	353495.5	6106595.104	55° 5.067' N	12° 42.282' E
3-4	29.39425732	353248.75	6107805	55° 5.714' N	12° 42.013' E

The Kriegers Flak II survey area's landfall site is situated on the beach at Rødvig, as presented in Figure 3.

Figure 3: Landfall location overview - Rødvig

2.3 EXISTING INFRASTRUCTURE

The Kriegers Flak II ECR survey corridor crosses eight (8) other cables, pipelines and other assets (Table 4 and Figure 2). Crossings were identified with a desktop study (Ref. "Danish Offshore Wind 2030 - Utility Desk Study") and supplementary research from the EMODnet and HELAS databases. The findings of the survey can be found in the WPD Crossing Report (Ref. "BE5950H-771-CRS-01-1.0 Crossing Survey Report – Kriegers Flak").

Table 4: Summary of crossings and third-party assets

Asset number	Asset description/cable	Database info
(FL) 01	ENDK HK22008 Kriegers Flak BE-Rødvig	Energinet cable detected on MAG
(FL) 02	ENDK HK22007 Kriegers Flak A-Rødvig	Energinet cable detected on MAG

Asset number	Asset description/cable	Database info
(FL) 03	Baltic Pipe – Baltic Sea	Baltic Pipeline (GAZSYSTEM) Operational 34' Gas pipe Utility visible on MAG 145 m south of database position.
	Transitrørledninger, olie og gas	Baltic Pipeline Operational Gas pipe Utility visible on MAG
(FL) 04	Sweden to Germany Cable (ID 622)	Operational - HOLAS 2 dataset
	Sweden to Germany Cable (Feature 75)	Sweden to Germany. Helcom 2010 dataset
(FL) 05	Denmark to Poland Pipeline	Denmark to Poland – Status: Application Submitted
(FL) 06	Electricity Cable (ID 6318)	Status: Under construction HOLAS 2 dataset
(FL) 07	Electricity Cable (ID 611)	Status: Operational HV cable HOLAS 2 dataset
	Baltic Export Cable (ID 5)	Status: Operational export cable
	Sweden to Germany HV cable	Status: Operational
(FL) 08	Cable Unknown	Status: Operational

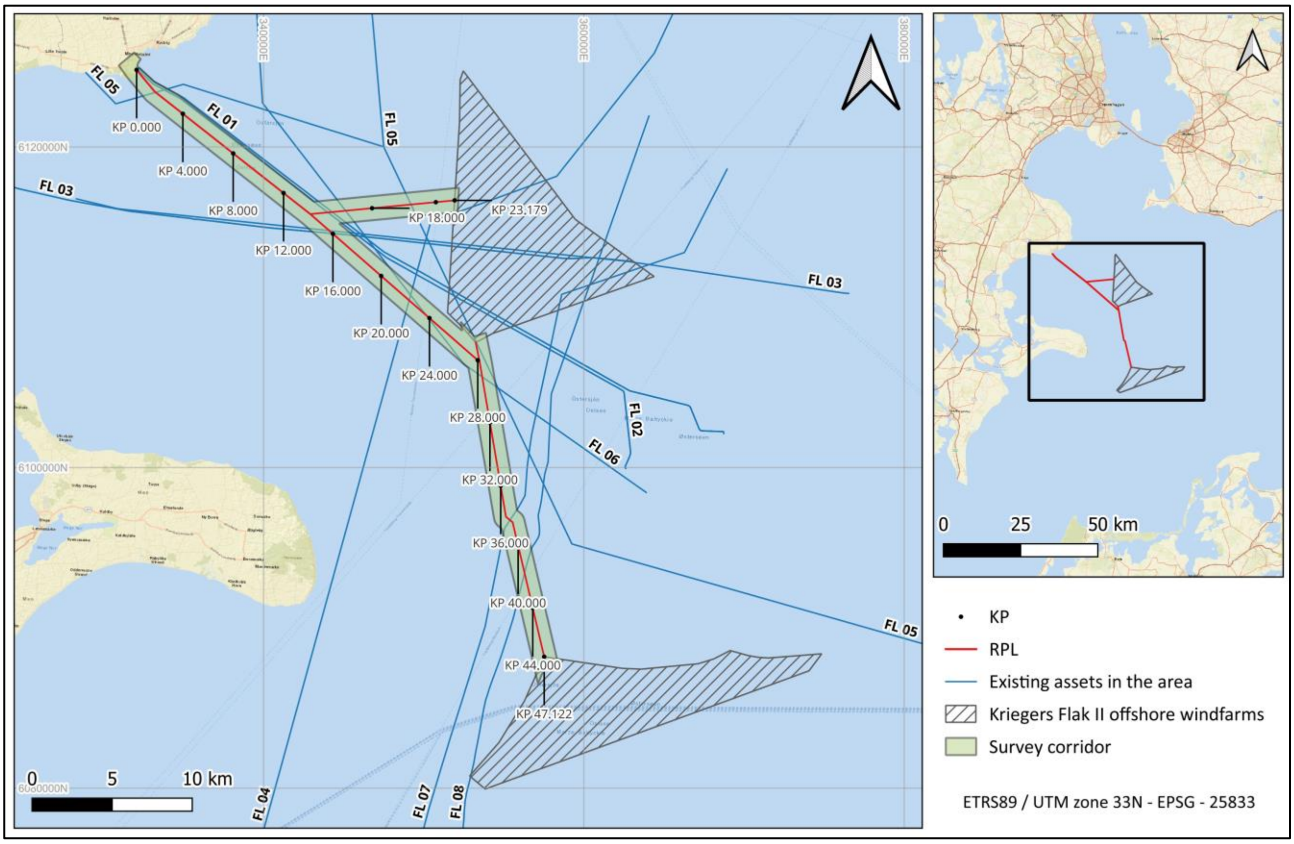


Figure 4: Overview map of the crossings within the Kriegers Flak II ECR area

2.4 PARTIES INVOLVED

The parties involved in the project are represented by the organogram given in Figure 5.

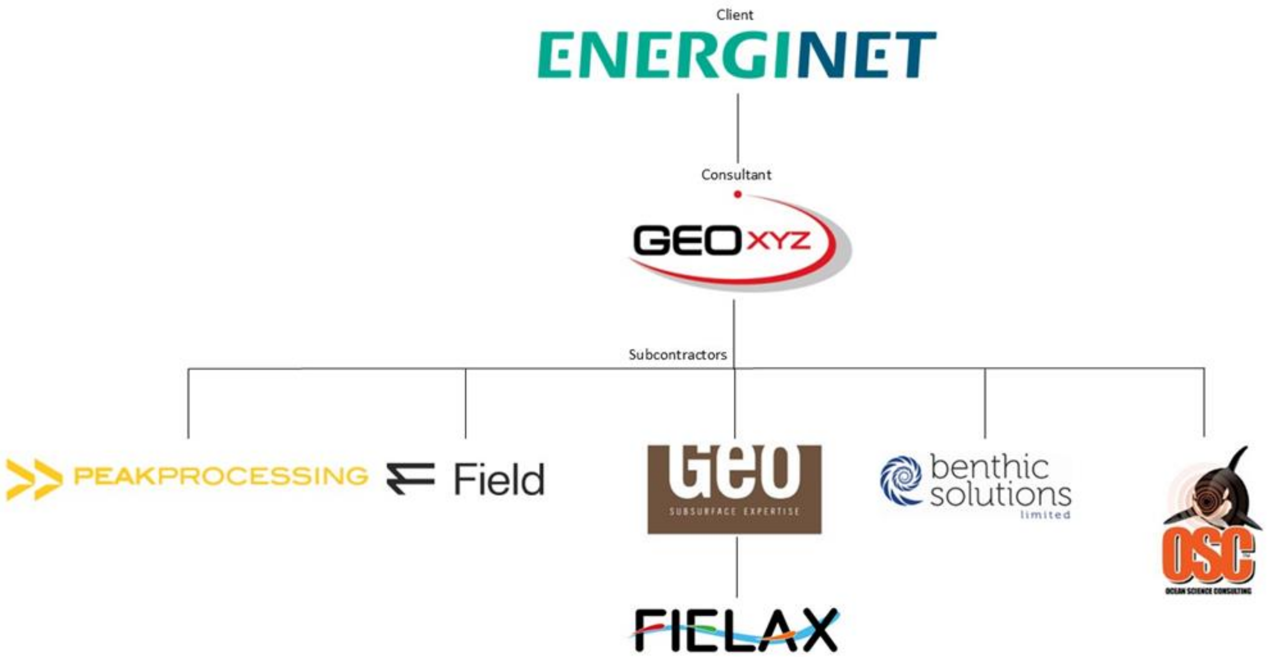


Figure 5: Parties involved in the project

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 sites
- Geo and Fielax – To process and interpret the Geotechincal 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

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 acquisition:

- Multibeam Echo-sounding survey with full bathymetric coverage. The data quality accommodated the preparation of digital elevation models (DTMs) of the bathymetry with 25 cm spatial resolution (minimum 4 pings per 0.25 cm^2).
- Dual frequency side scan sonar with greater than 200 % coverage to ensure overlap with the nadir of adjacent survey lines, detecting all objects larger than 0.5 m.
- Single magnetometer or gradiometer towed after the vessel along all survey lines.
- Sub-bottom profiling with one high-resolution and relatively high-frequency single-channel system, covering 10 m depth along all survey lines.
- Horizontal positioning uncertainty less than 0.5 m for vessels.
- Horizontal positioning uncertainty less than 2.0 m for towed equipment.
- Vertical positioning uncertainty in compliance with IHO, S-44 Special Order.
- Grab sampling at approximately one sample per route kilometre.

2.5.2 Line planning

For the offshore geophysical survey, the survey lines comprised of main lines spaced at 30 or 50 m depending on the water depth, and cross lines, for MBES and SSS, spaced every 2000 m. The nearshore and landfall survey comprised of lines spaced every 10 metres. Both offshore and nearshore areas have a minimum overlap of 250 m.

Figure 6 and Figure 7 show example schematic diagrams of the line plans for offshore and nearshore work, respectively.

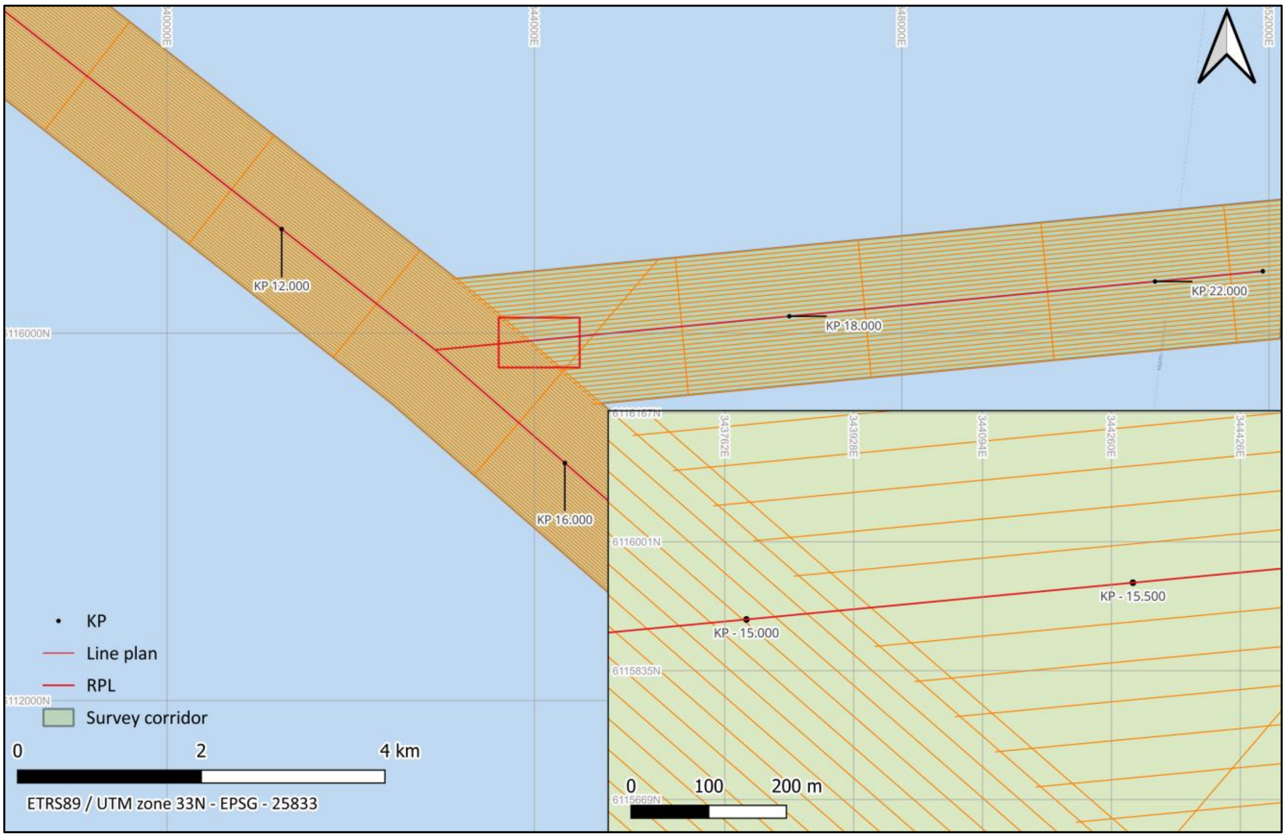


Figure 6: Kriegers Flak II offshore geophysical line plan

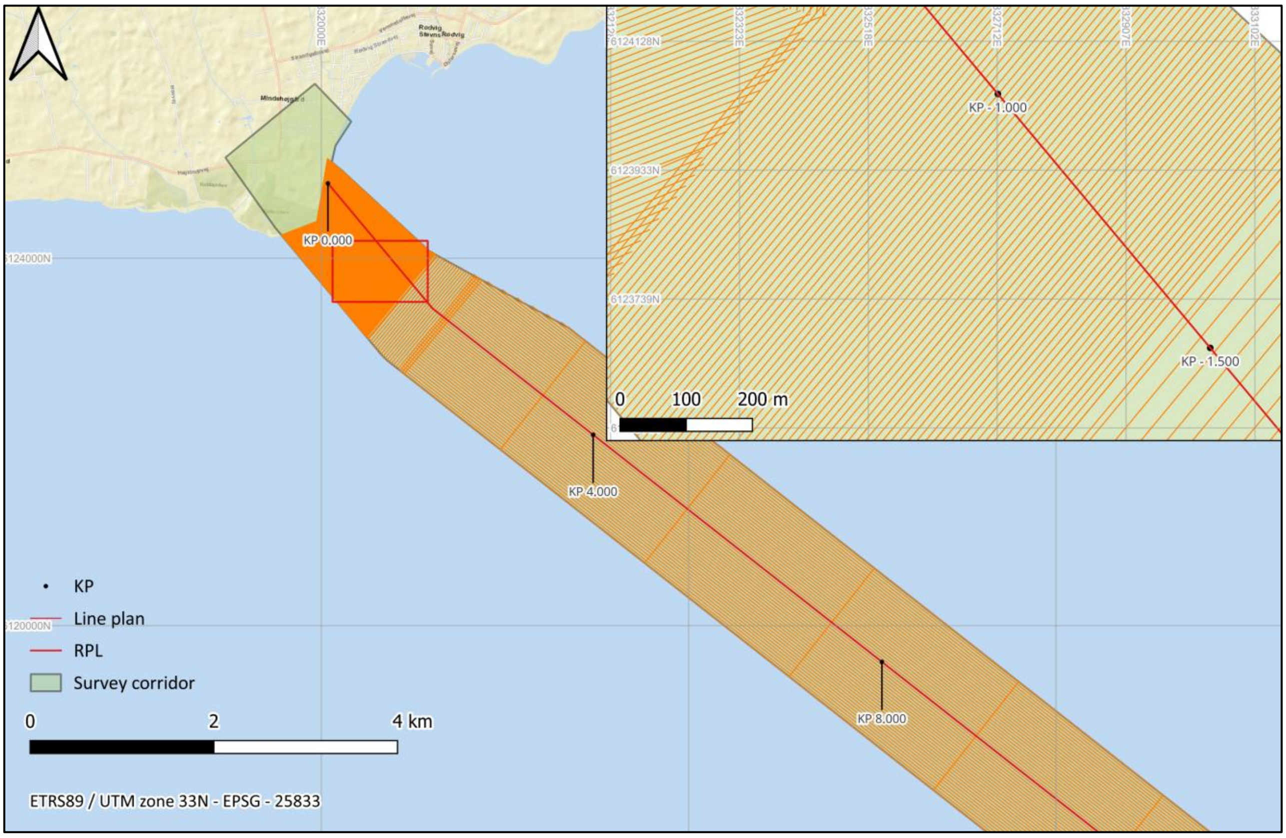


Figure 7: Kriegers Flak II nearshore geophysical line plan

2.5.3 Geotechnical survey

The geotechnical survey of Kriegers Flak II export cables was performed from the 21st of March to the 26th 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 5, and overview of geotechnical locations is presented in Figure 8 to Figure 10. Detailed overview of geotechnical locations is presented in APPENDIX A.

Table 5: Geotechnical works summary

Type of test	Planned tests	Performed tests
CPT	27	34
VC	27	35
In-situ TRT	14	15

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

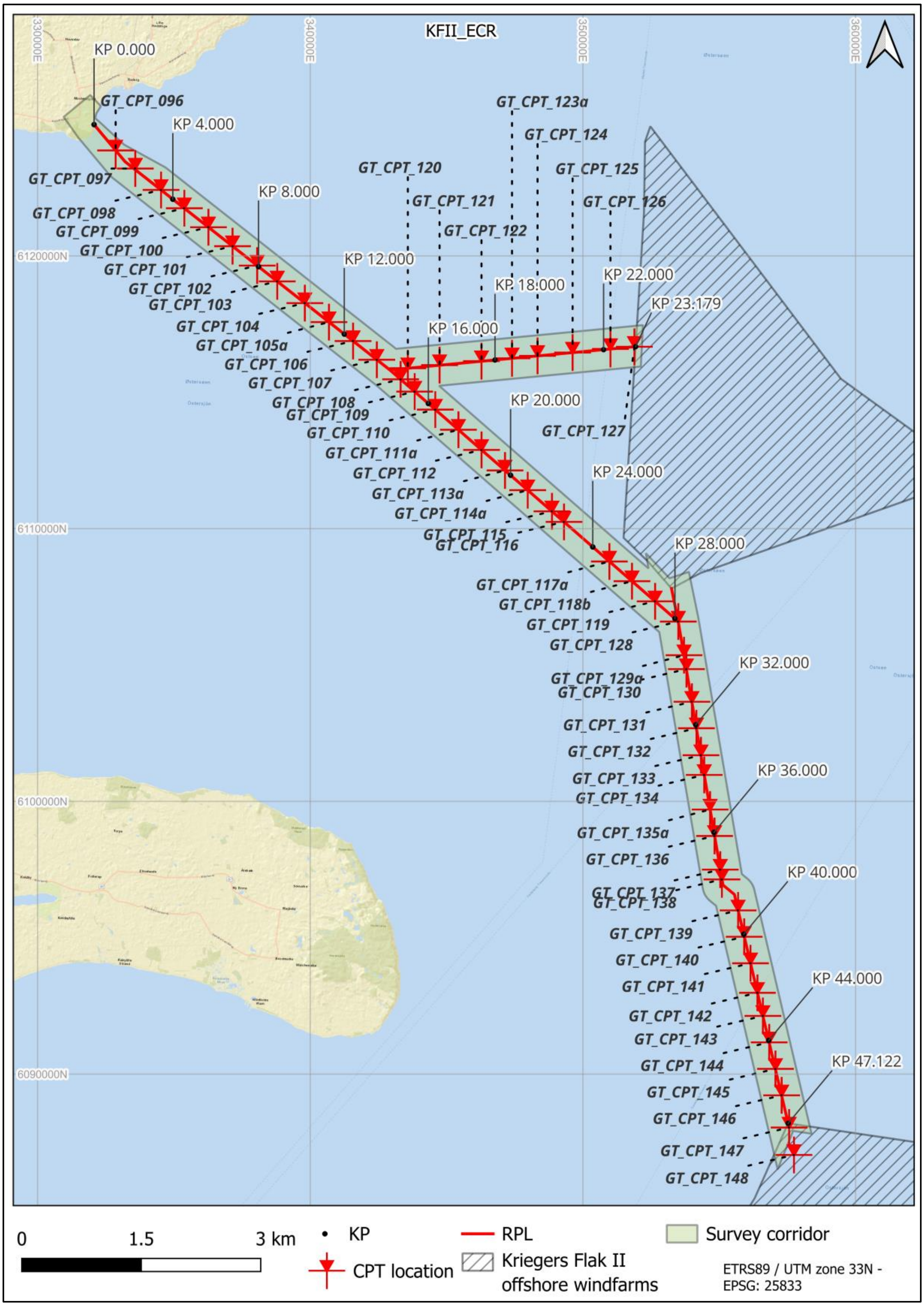


Figure 8: CTP geotechnical locations overview

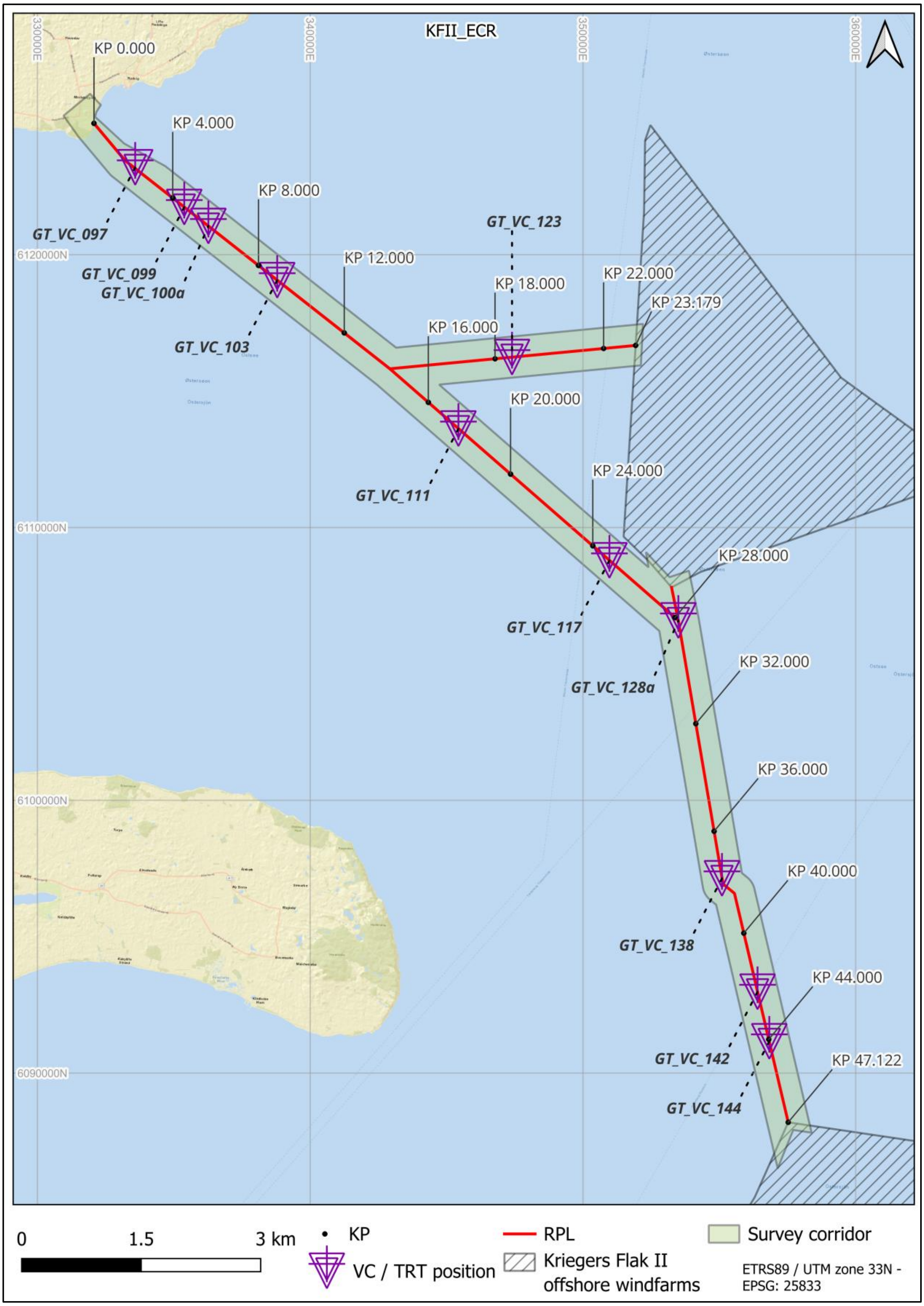


Figure 9: TRT/VC geotechnical locations overview

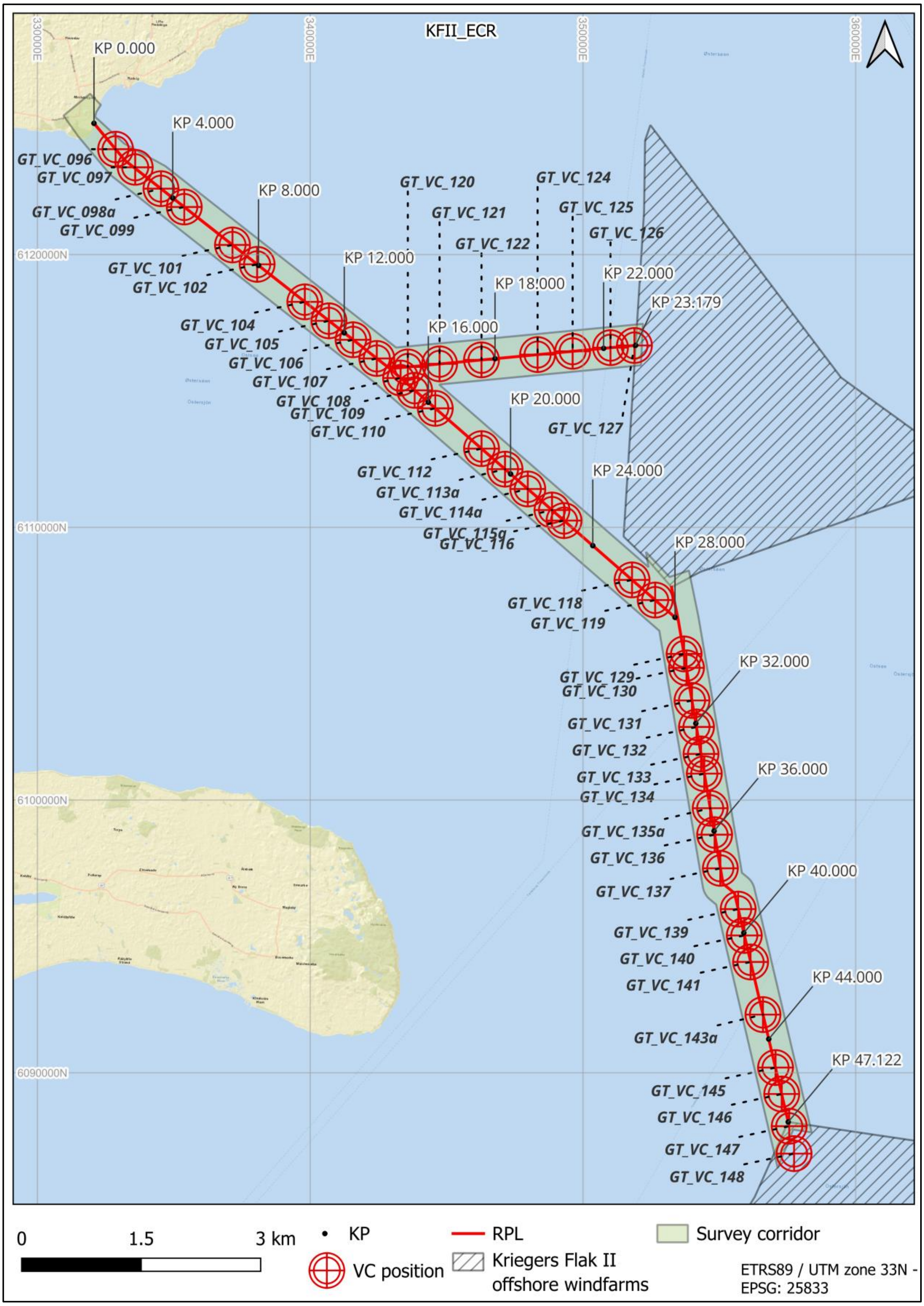


Figure 10: VC geotechnical locations overview

2.5.4 General survey objectives

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

- Verification of the feasibility of the investigated cable route.
- Marine archaeological assessment.
- Planning of environmental investigation and assessment of environmental conditions.
- Design of subsea cable burial.
- Assessment of conditions for installation and maintenance.
- Site information enclosed the tender for offshore cable and installation.

2.6 REFERENCE DOCUMENTATION

Key project and corporate documentation are listed below.

Client reference documents

Documentation provided by the Client for the project is listed in Table 6 below.

Table 6: 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 7 below.

Table 7: 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 8: Other references

Title	Resource
SN2023_027_KFII_ECR_RPL_v2.shp	RPL shapefile
Danish Offshore Wind 2030 - Utility Desk Study	Crossing DTS
BE5950H-771-MP-03-1.0_Krieger Flak Geo Ocean IV Noise Monitoring Logs	Noise Monitoring Logs
EMODnet	Online database
GEOxyz (2024) Geophysical Surveys for Danish Offshore Wind 2030 – Kriegers Flak II North & South, BE5376H-711-03-RR, rev3.0	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 9 lists all the reports delivered as part of this survey, with this report highlighted in bold.

Table 9: Project reports

Title	Type of Report
Mobilization and Calibration Report - GOIV	Mobilisation and Calibration Report
Mobilization and Calibration Report - GSXVII	Mobilisation and Calibration Report
Mobilisation and Calibration Report - GSV	Mobilisation and Calibration Report
DOW2030 KFII_ECR_OPS_Report_Offshore_Survey_Geophysical-rev1.2	Offshore Operational Report
Operations Report - Kriegers Flak Geophysical Nearshore Survey	Nearshore Operational Report
Danish Offshore Wind 2030 - WPC, Kriegers Flak, Operational Report, Rev. 00, 2024-04-17	Geotechnical Operational Report
DOW 2030 - WPC, KF, Factual Report, Rev. 01, 2024-11-12 REPORT	Geotechnical Report
MMO-PAM report Krieger Flak GeoOcean 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
Crossings Survey Report - Kriegers Flak	Crossings Survey Report
Kriegers Flak II – Cable Route Integrated Report	**Results report**

3 GEODETIC PARAMETERS AND TRANSFORMATIONS

3.1 HORIZONTAL DATUM

The geodetic parameters for the project are listed in Table 10 and Table 11.

Table 10: 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 11: Projection parameters

Parameter	Details
Area of Use	Kriegers Flak II
EPSG Coordinate Reference Code	25833
EPSG Map Projection Code	16033
Projection	UTM
UTM Zone	33 N
Central Meridian	15° 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 will be expressed in international metres (m)

- Angular units will be 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 cable route geophysical survey

For the geophysical surveys, the survey vessels Geo Ocean IV (GOIV) was utilised to complete the work across the offshore cable route survey area. The specifications of the GOIV vessel are summarised in Table 12.

Table 12: GOIV 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 GEOxyz's Geo Surveyor XVII (GSXVII) and Geo Surveyor V (GSV). Specifications of the utilized vessels is presented in Table 13 and Table 14.

Table 13: GSXVII 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 14: GSV survey vessel specifications

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

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 GeoDK, presented in Table 15.

Table 15: DP II Connector vessel specifications

Connector	Specifications	
	Owner	Geo DK
	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 on 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

System	Manufacturer & model	Equipment specifications
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: < 2 nT throughout range. Freq: up to 40 Hz
SSS	Edgetech 4205MP 300/900kHz	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 k Hz
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 GSXVII vessel was mobilized with the equipment listed in Table 17.

Table 17: GSXVII geophysical survey equipment specifications

System	Manufacturer – Model
GNSS	Stema 982 POE
INS (motion, heading)	SBG Apogee
SVP	Valeport Swift
MBES	R2Sonic 2024
USBL	Sonardyne Mini Ranger 2
Magnetometer	Geometrics G882
SSS	Edgetech 4200 series (300/600 kHz)
SBP	Innomar SES-2000 Standard

The GSV 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: 0.008 m; DGNSS: 0.25 m Vertical: RTK: 0.015 m; DGNSS: 0.50 m
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° @ 520 kHz, 0.29° @ 850 kHz

System	Manufacturer – Model	Equipment Specifications
		Resolution Across Track: 1cm @ 520 kHz, 0.9 cm @ 850 kHz
SBP	Innomar SES-2000 Medium	2-22 kHz - 1-5 cm resolution

The equipment onboard the Connector vessel is listed in Table 19.

Table 19: 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

4.3 SOFTWARE

The primary software that was used to acquire and process the data is listed in Table 20.

Table 20: Primary software list

Type	Software	Related equipment
Acquisition	QPS QINSy	Navigation, MBES, GNSS, SSS, MAG
	BeamworkX 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 Kriegers Flak 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

The survey vessel Geo Ocean IV was used to complete the offshore scope of the survey (WD > 10 m). The vessels Geo Surveyor XVII and Geo Surveyor V were utilized to complete nearshore sections (WD < 10 m). The vessel Connector was applied for geotechnical part of the scope. A summary of the survey operations is outlined in Table 21.

Table 21: General survey timeline

Section	Vessel	Dates	Activity
Offshore	Geo Ocean IV	02/10/2023 – 08/10/2023	Mobilisation and calibrations
		08/10/2023 – 16/10/2023	Geophysical operations
		18/12/2023 – 04/01/2024	
		10/01/2024 – 15/01/2024	
		18/02/2024 – 24/02/2024	
		24/02/2024	Demobilisation
Nearshore	Geo Surveyor XVII	18/09/2023 – 22/09/2023	Mobilisation and calibrations
		22/09/2023 – 26/09/2023	Geophysical operations
		26/09/2023	Demobilisation
	Geo Surveyor V	04/08/2023 – 06/08/2023	Mobilisation and calibrations
		07/09/2023	
		08/09/2023 – 10/09/2023	Geophysical operations
		11/09/2023	Demobilisation
Geotechnical	Connector	21/03/2024 – 26/03/2024	Geotechnical operations
		26/03/2024	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. “BE5950_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 22 below.

Table 22: MBES specifications

Item	Client specification
Data density	16 hits/m^2

Item	Client specification
MBES mode	Equi-distant
Gridded	0.25 m cell size
Hit count survey	4 hits per 0.25 x 0.25 m after processing (97.5% of site)
THU/TVU	Follow IHO special order
Coverage	100 %
Target size detecting	0.5 m (height, width and length)

The MBES acquisition setting onboard are outlined in Table 23, Table 24, Table 25, split per vessel.

Table 23: 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 24: GSV MBES acquisition settings

Item	Settings
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 25: GSXVII MBES acquisition settings

Item	Settings
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 26 to Table 29. Figure 11 displays the general MBES processing workflow. A processing checklist was populated while processing.

Table 26: 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
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 27: 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 28: 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 29: 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 x 1 m. Ensure the THU and TVU requirements are met (depth dependant).

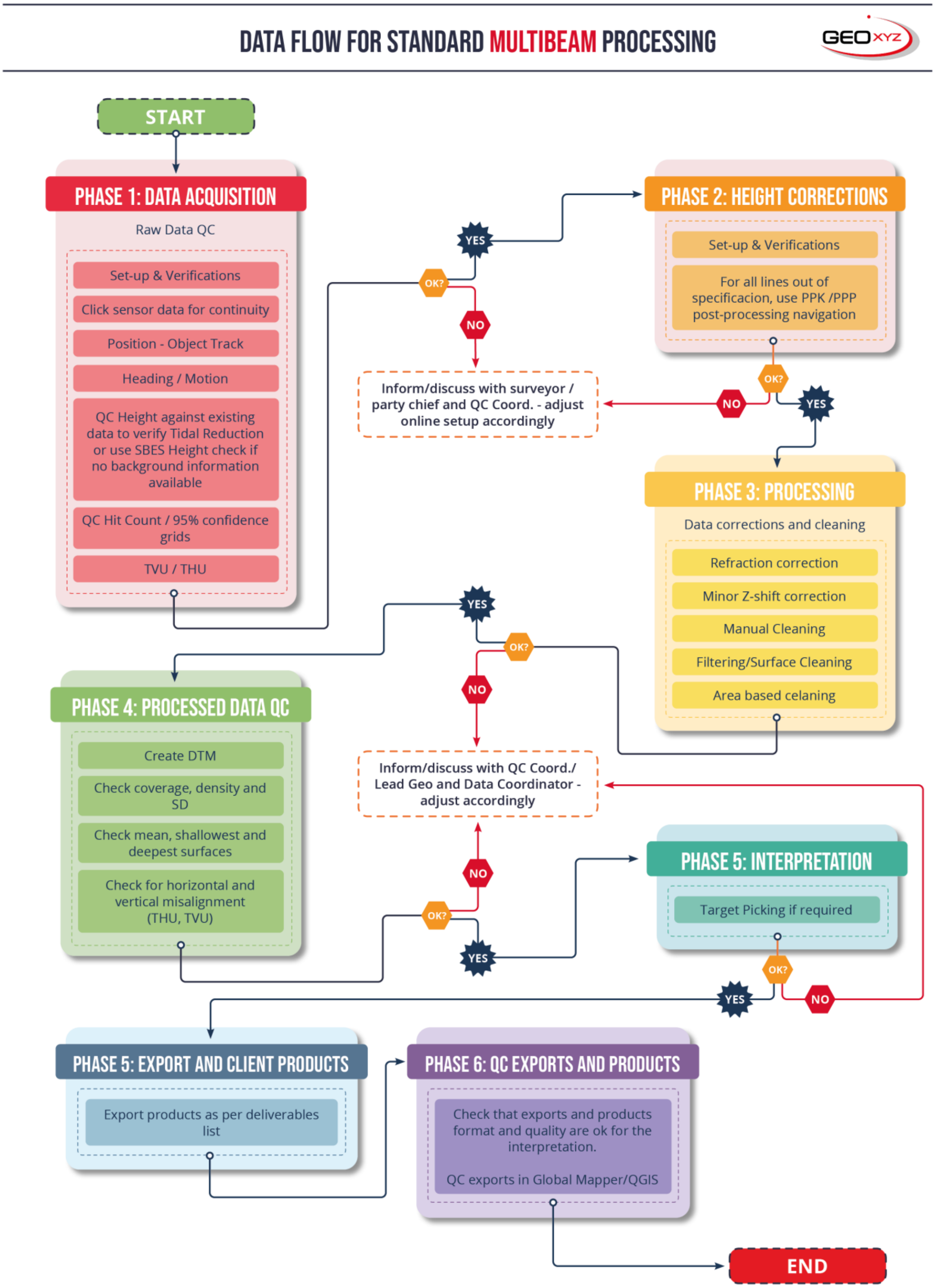


Figure 11: MBES processing workflow

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 metres were flagged, and vessel names were added to the target IDs.

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.

The THU and TVU coverage maps of the survey area are shown in Figure 12 and Figure 13, respectively.

Backscatter data intensity of the survey area is shown in Figure 14.

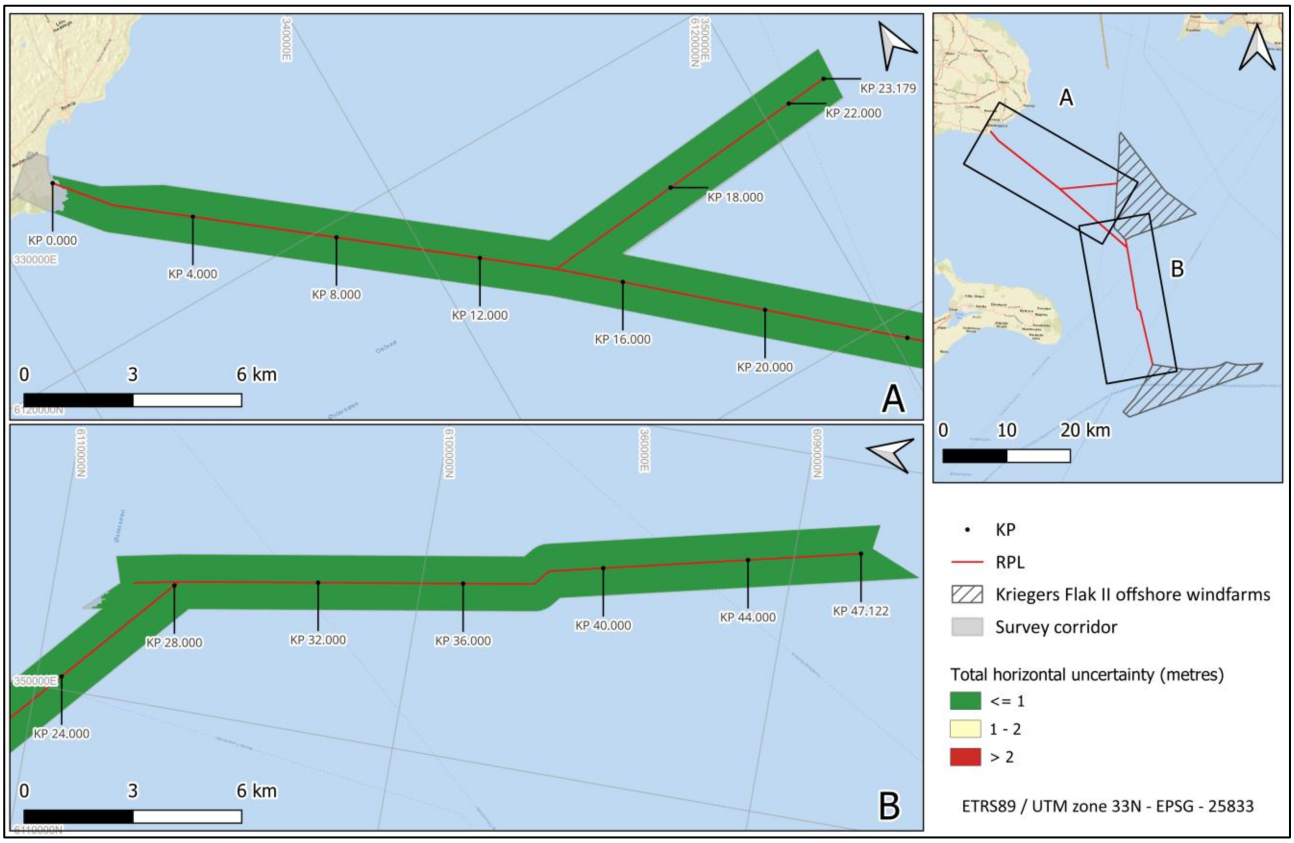


Figure 12: THU coverage map of the survey area

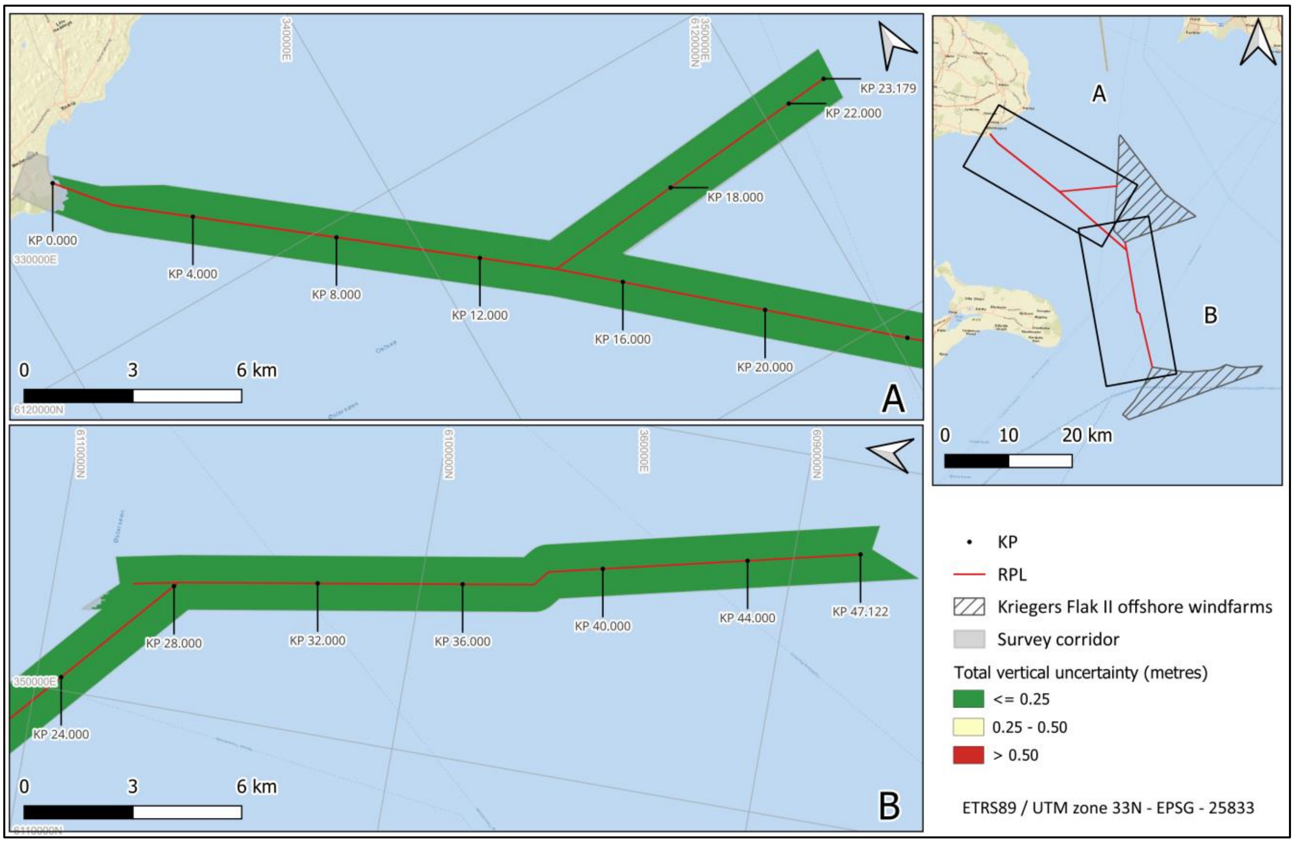


Figure 13: TVU coverage map of the survey area

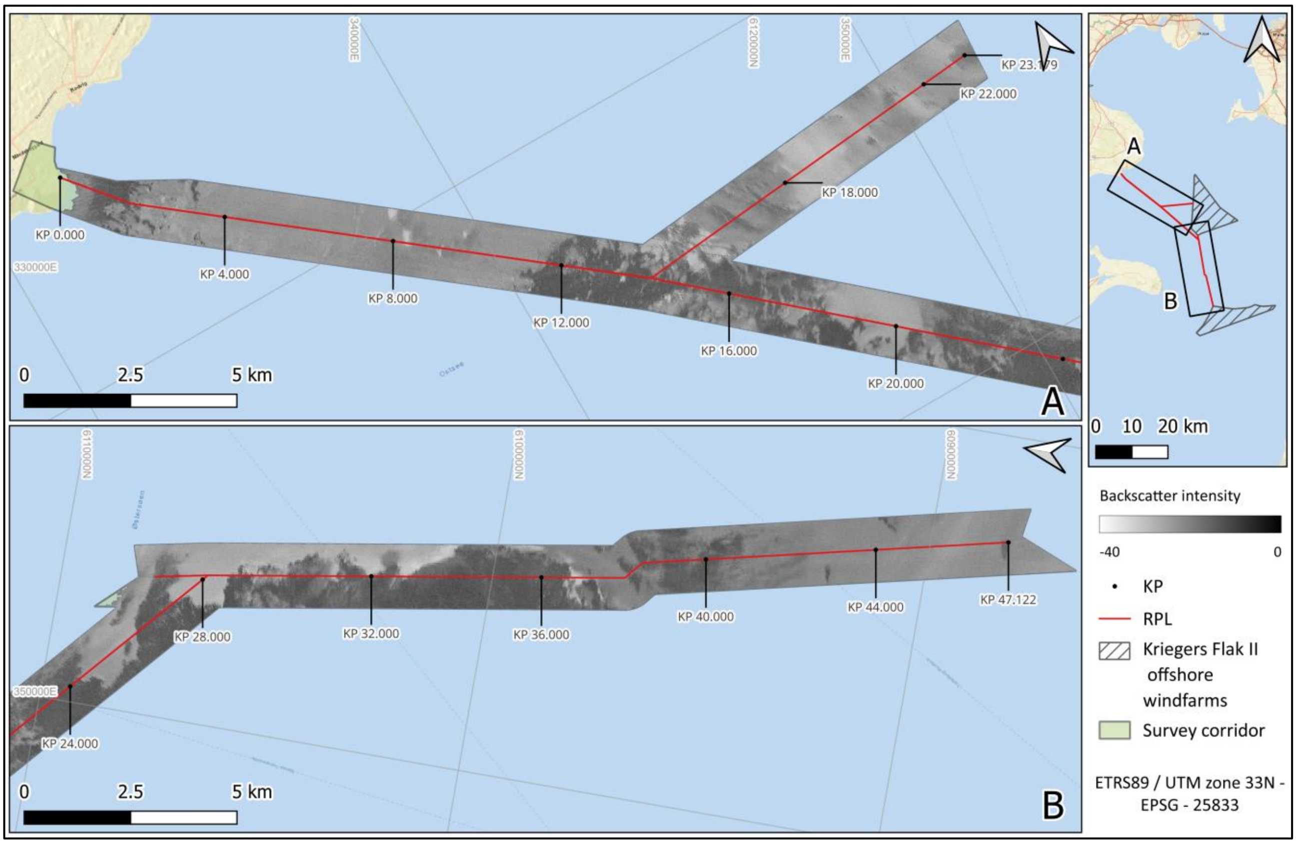


Figure 14: Backscatter data intensity

Geo Surveyor V data

Overall, good data quality was observed. The data was noisier than the deeper part, but was 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 was obtained from SSS raw files, resulting in a different values scale compared to backscatter from MBES of the rest of vessels. In Figure 15, a comparison of GSV and GeoX backscatter mosaic is presented, before merging (Figure 15, a) and after merging without normalising mosaics (Figure 15, b).

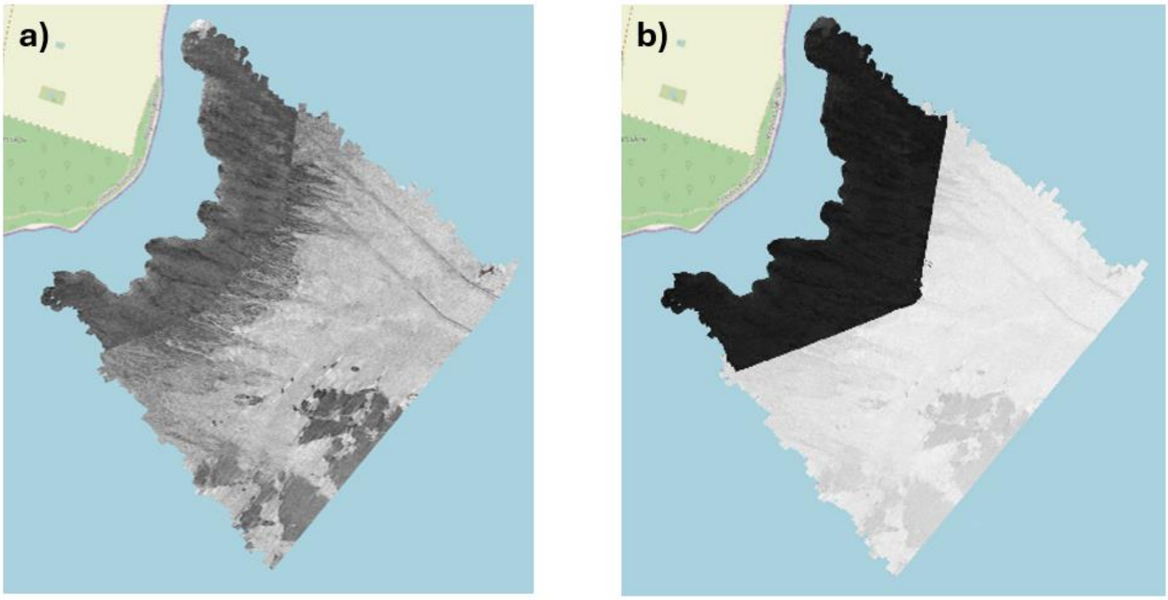


Figure 15: The comparison of GSV and GeoX backscatter mosaic

GSXVII data

Good data quality was found 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 it back the vertical referencing from Trimble to SBG.

In Figure 16 is presented an example of Kriegers Flak GSXVII data before changing the vertical referencing (a) and after changing the vertical referencing (b).

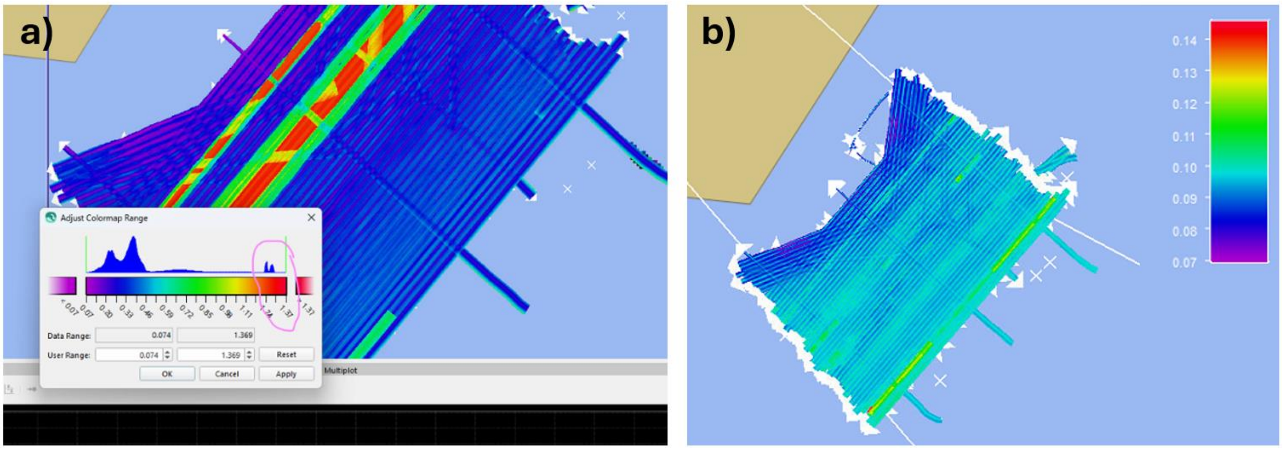


Figure 16: The data example before changing the vertical referencing (a) and after changing the vertical referencing (b)

Bathymetry data showed no problems and could be processed normally.

Geo Ocean IV data

Overall, high data quality was acquisitioned for MBES and backscatter.

5.3 SIDE SCAN SONAR

5.3.1 Data acquisition

Side scan sonar data was acquired following specifications listed in Table 11 below.

Table 30: SSS specifications

Item	Client specification
Low frequency	1 m
High frequency	0.1 m
Coverage	200 % (including nadir)
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 27, Table 28 and Table 29, split per vessel.

Table 31: SSS system settings – GOIV

Item	Settings
System type	Edgetech 4200 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 32: SSS system settings – GSV

Item	Settings
System type	Edgetech 6205 s2 520/850 kHz
Survey speed	Average 4.5 knots
Positioning	GNSS
Mean fish altitude	Pole mounted
Trigger	Low Frequency = Master
TVG/Gain	Recording RAW (*.jsf)
Range	35 m

Table 33: SSS system settings – GSXVII

Item	Settings
System type	Edgetech 4200 300/900kHz
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

5.3.2 SSS processing

Side Scan Sonar (SSS) data were processed and interpreted using Chesapeake SonarWiz software. The SSS processing steps are outlined in Table 34 to Table 40.

Figure 17 outlines the SSS processing workflow used for the project.

Table 34: 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 35: 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 36: 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 37: 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 38: 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, • 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 39: 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 40: 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

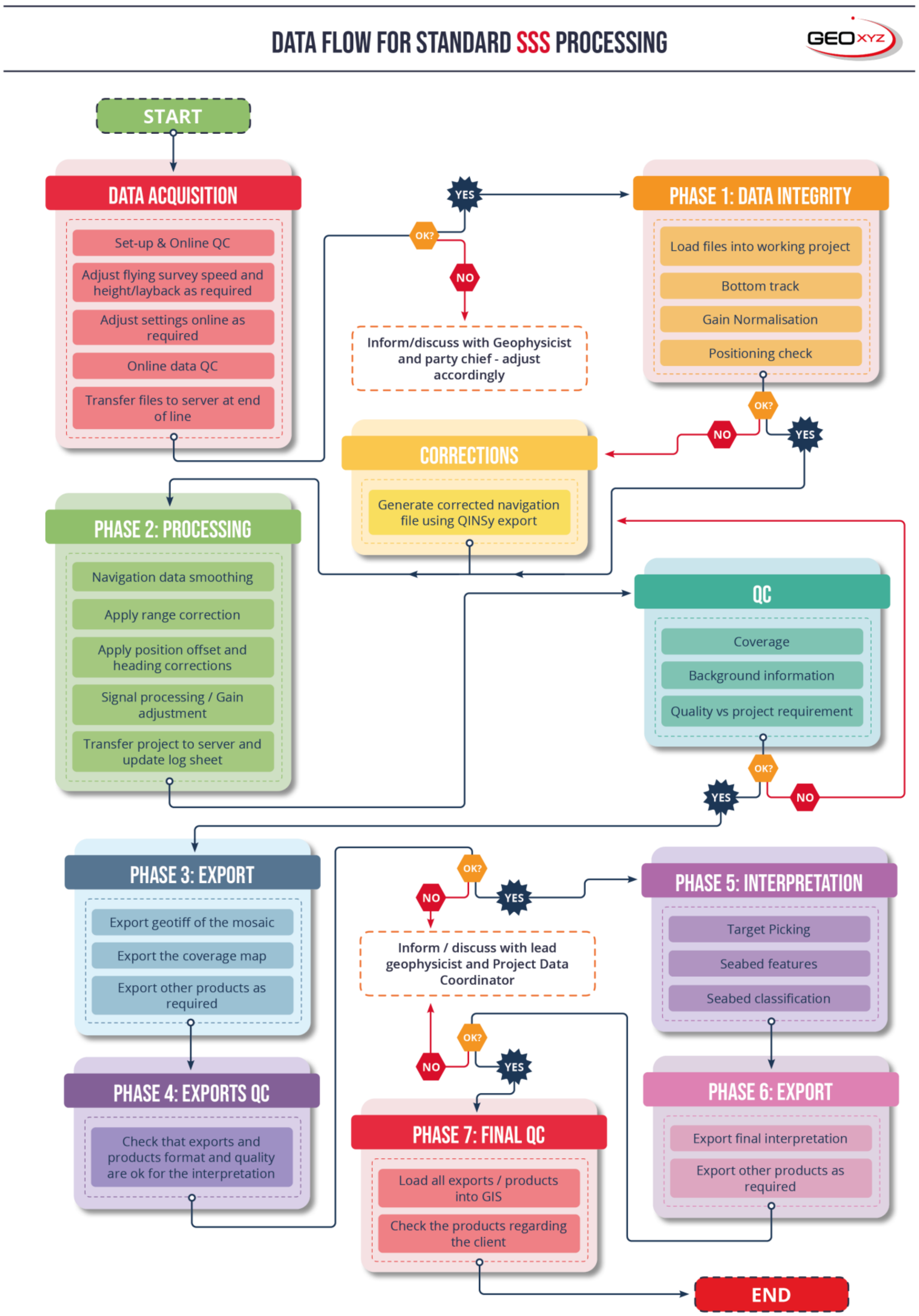


Figure 17: SSS data processing workflow

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 is 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, depending of contact reflectivity, 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 visible within the mosaic.

The steps of target identification are presented in Table 41.

Table 41: 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 was.

The detection process, as presented in Figure 18, 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.

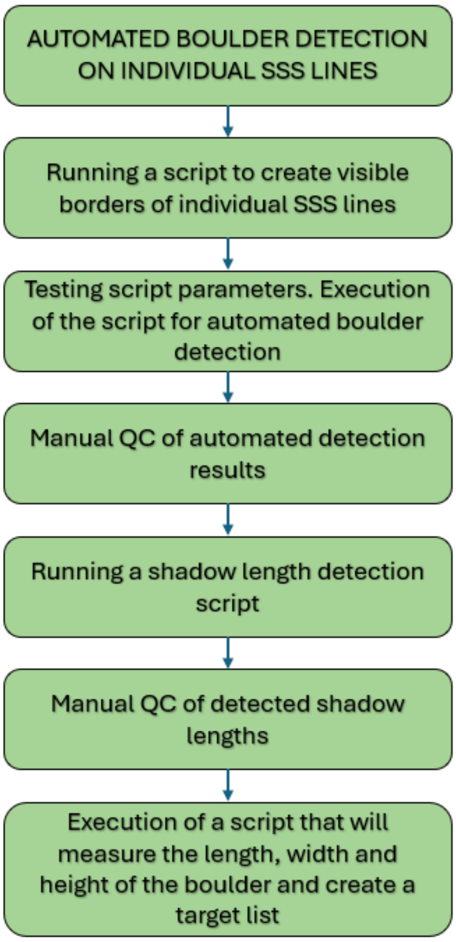


Figure 18: Automated boulder detection progress

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 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 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 slightly affected the data within the survey area. The pycnocline resulted in marginal or reduced data quality in the outer range for few section of SSS lines. The affected section were removed during processing and good quality data was used for mosaic exports and target picking.

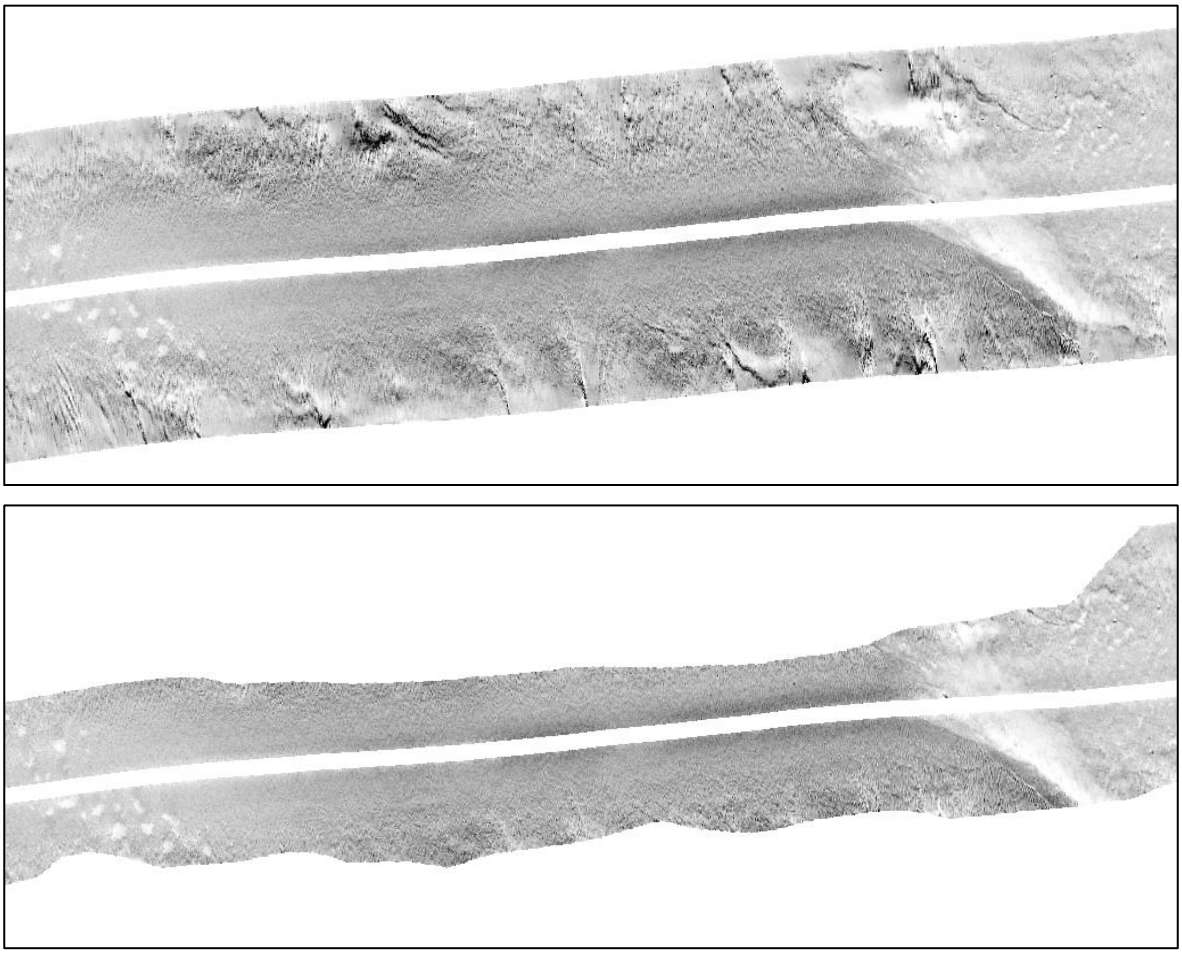


Figure 19: Pycnocline artefact before (above image) and after (below image) removal in the SSS dataset

Figure 20 below shows the achieved SSS data coverage within Kriegers Flak II.

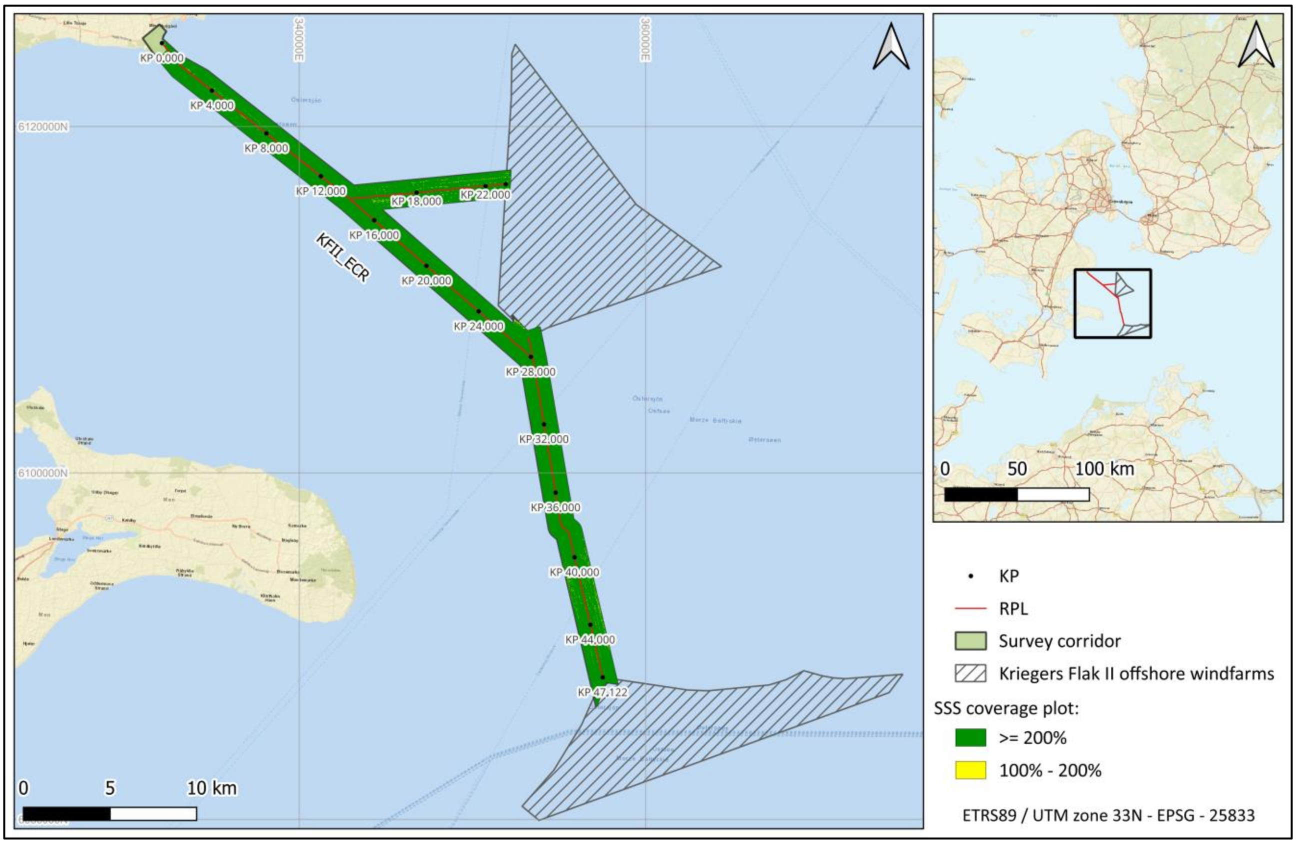


Figure 20: SSS coverage plot

5.4 MAGNETOMETER

5.4.1 Data acquisition

Magnetometer data was acquired following specifications listed in Table 42 below.

Table 42: 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 and GSXVII are presented in Table 43, Table 44 and Table 45, respectively.

Table 43: MAG system settings – GOIV

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

Table 44: MAG system settings - GSV

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

Table 45: MAG system 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

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 grid was derived by subtracting a background field derived using a set of non-linear and smoothing filters. 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 general workflow is outlined in Figure 21, and processing steps used for the project are outlined from Table 46 to Table 51.

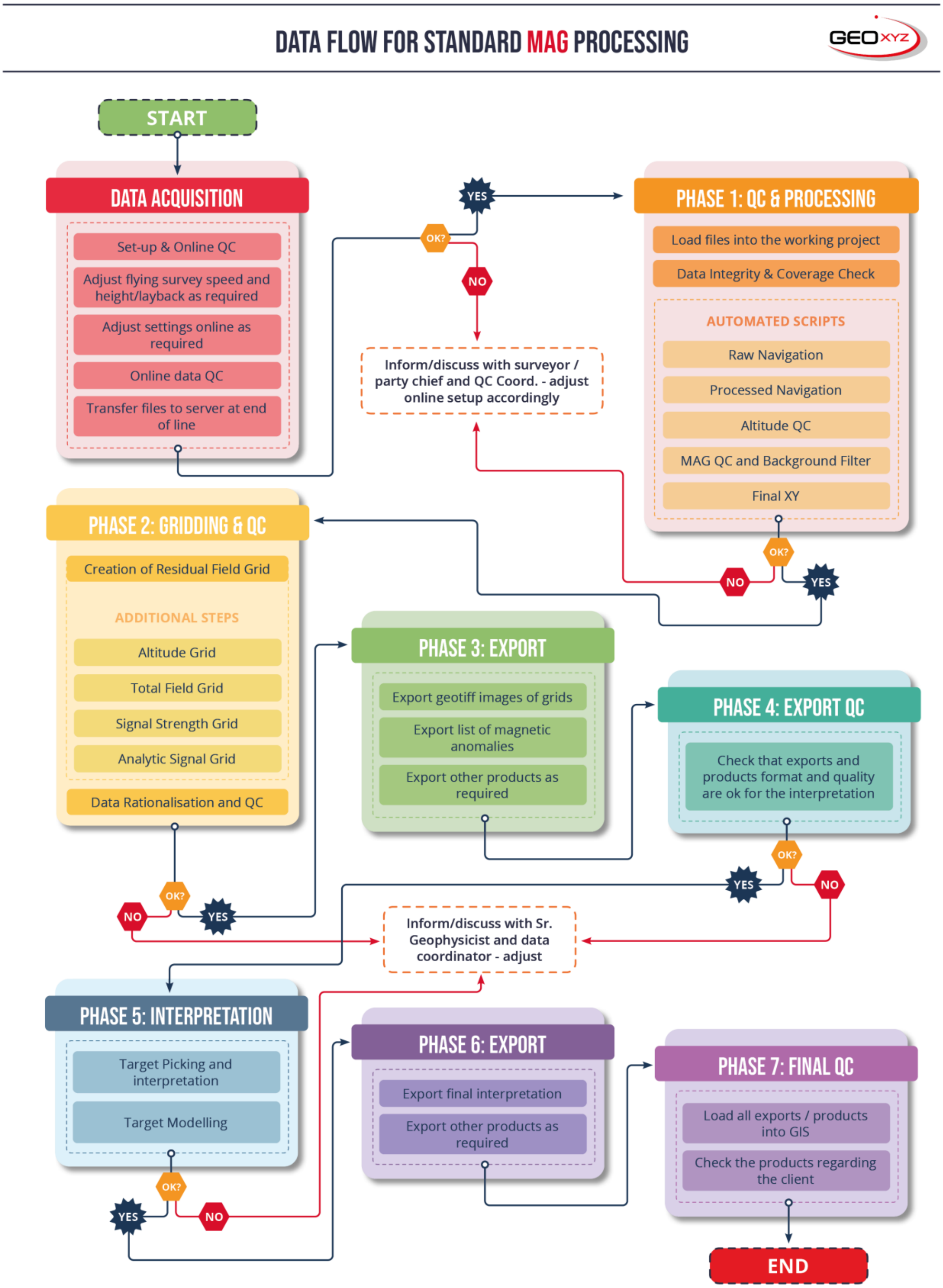


Figure 21: Magnetometer data processing workflow

Table 46: 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 47: 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 48: 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.
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	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

Step 3	Magnetometer data QC
magnetic signal to Easting and Northings	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 49: 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 50: 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. Coverage assessment for infills were based in dynamic coverage analysis.

Table 51: 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 10 nT were kept only if they have a corresponding SSS target within 5 m, or if were related to known assets. 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

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 for Kriegers Flak 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. Additionally, known asset positions were checked to ensure that background filters clearly showed all known crossings.

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

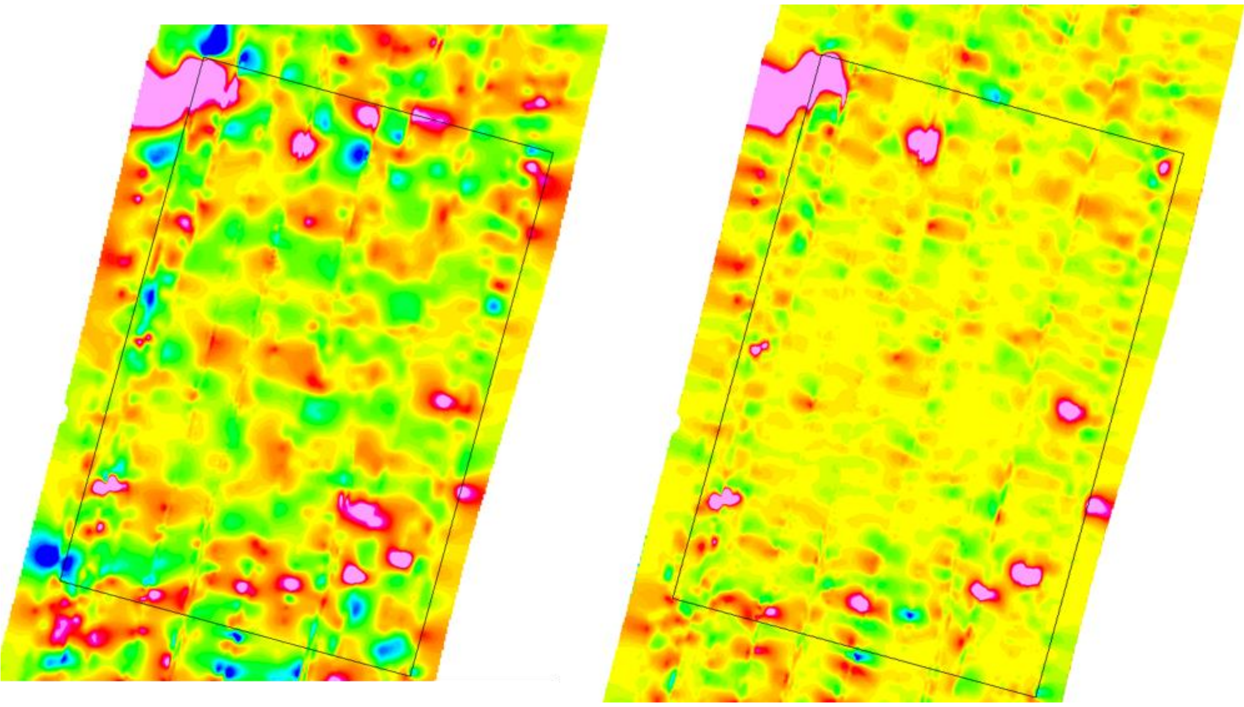


Figure 22: Example of the geological noise reduction applied in the nearshore dataset in the Kriegers Flak survey area

5.5 SUB-BOTTOM PROFILER

5.5.1 Data acquisition

SBP data was acquired following specifications listed in below.

Table 52: SBP specifications

Item	Client Specification
Penetration	10 m
Vertical resolution	0.3 m

The acquisition settings that were used onboard the GOIV, GSXVII and GSV are presented in Table 53, Table 54, and Table 55, respectively.

Table 53: Settings onboard GOIV

General parameters GOIV	
System type	Innomar SES-2000 Medium 100
Survey speed	4.2 knots

General parameters GOIV	
Source frequency	8 kHz
Power setting	100 %
LF gain	4 dB
LF pulse	1

Table 54: Settings onboard GSXVII

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

Table 55: Settings onboard GSV

General parameters GSV	
System type	Innomar SES-2000 Standard
Survey speed	Average 4.5 knots
Source Frequency	10 kHz
Power Setting	100 %
LF Gain	-6
LF Pulse	1

Sub-Bottom Profiler (SBP) data was recorded 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 56 and Table 57. SBP processing workflow diagram is presented in Figure 23.

Table 56: SBP data import and data QC

Steps	SBP data import and QC
Import of SEG-Ys	Import SEG-Y

Steps	SBP data import and QC
	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 57: 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

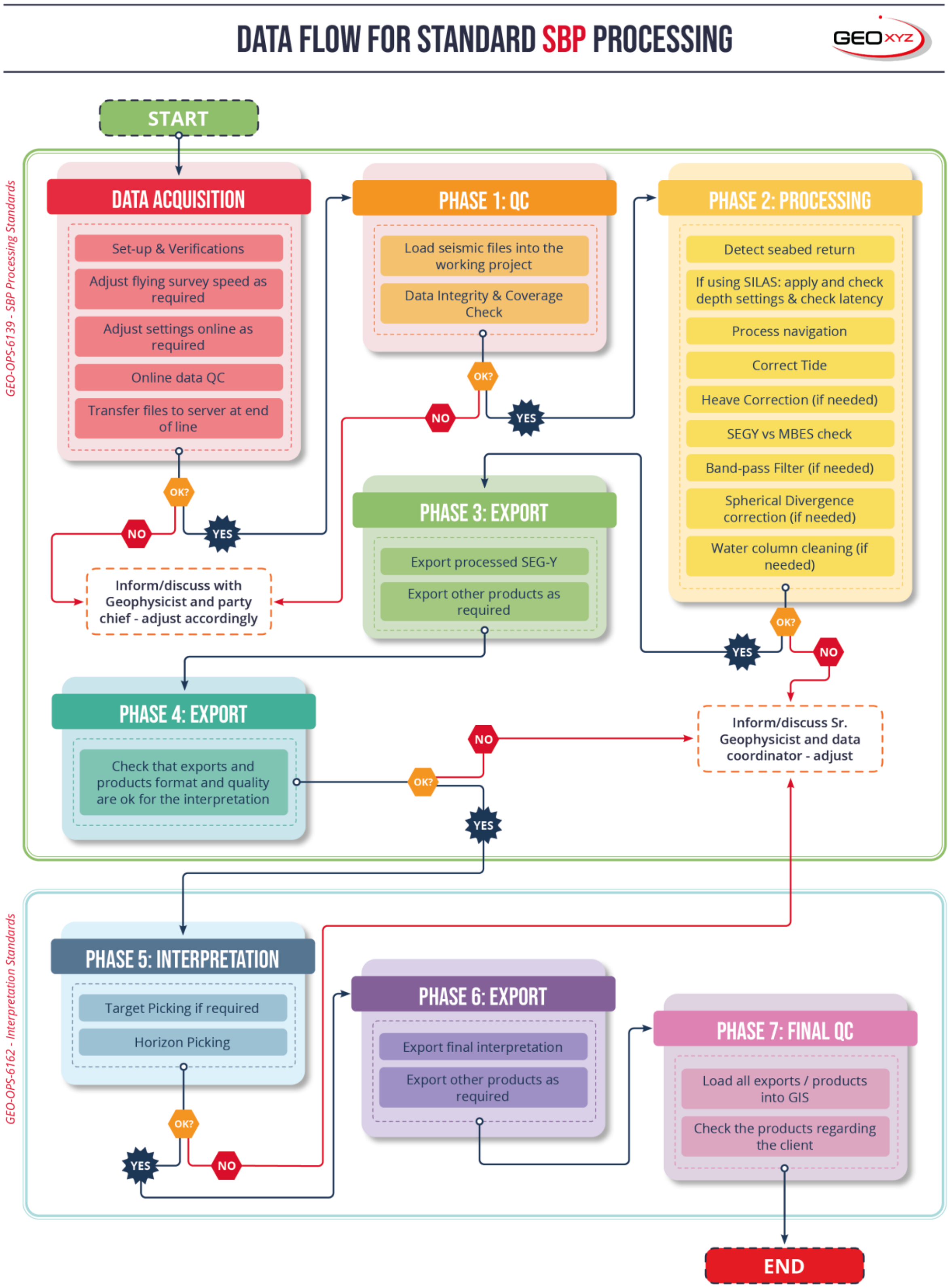


Figure 23: SBP processing workflow

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 are 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 missties 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

The data quality along the survey lines is generally good and meets the project requirements, with all intended horizons successfully mapped throughout the survey area. Penetration is primarily constrained by the underlying geology, particularly where the glacial till is near the seabed, rather than by limitations in the SBP system's depth reach.

Data acquired by GOIV in the nearshore area is presented in Figure 24, 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 moderate, 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.

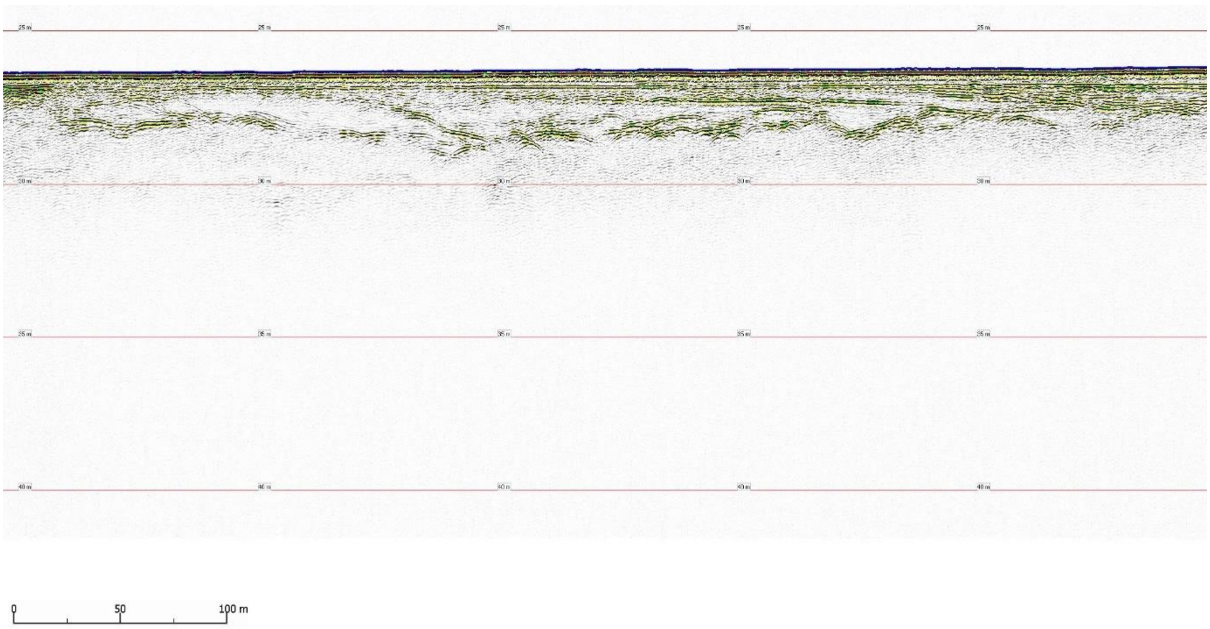


Figure 24 SBP data example from GOIV - nearshore

Further offshore the geology allowed for greater penetration. Figure 25 shows data demonstrating the SBP data recording >10m of penetration, maintaining good vertical resolution throughout the profile, through softer sediments. Data offshore was generally free of noise, apart from occasional weather effects that did not limit the interpretability of the dataset.

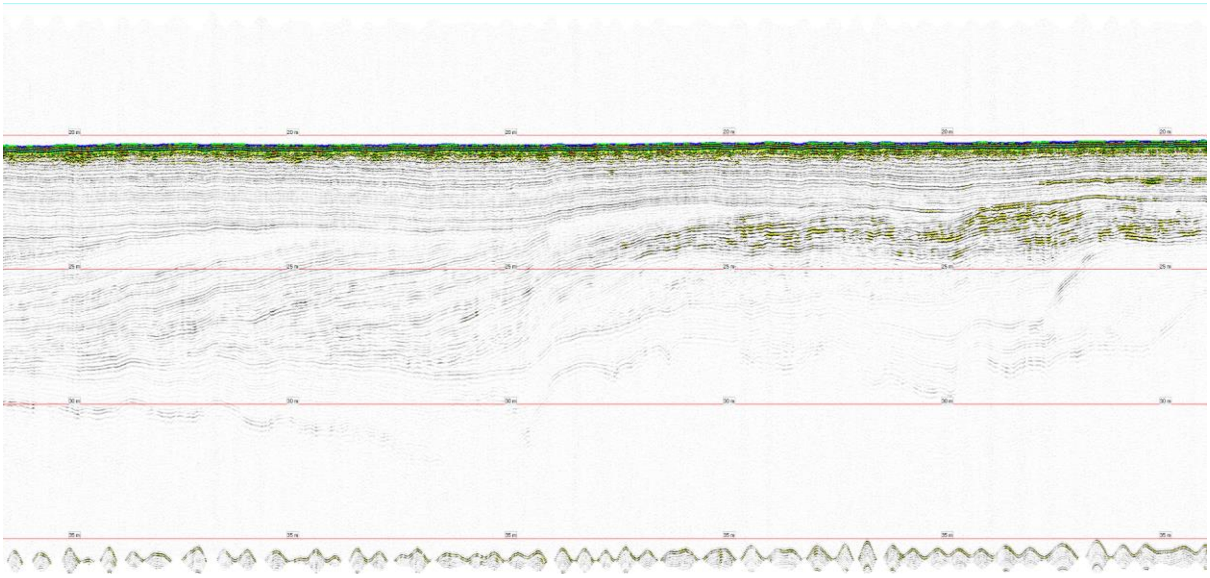


Figure 25 SBP data example from GOIV - offshore

Data acquired by GSXVII is presented in Figure 26, which shows some minor ambient noise in the dataset, possible sea conditions or from the vessel. This background noise does no limit the interpretability of the dataset, and reflectors are still clearly delineated. Data resolution is shown to be excellent, where fine laminations are visible within the channel feature. Data penetration is good through finer sediments, but appears to be limited by geology in places where interpreted till is close to the surface, in in the case of the data example, where the first multiple appears in the dataset. A minor sea-surface reflection artefact is present approximately 1.0-1.5m below the seabed, but is easily identified as such and does not present issues with interpretation.

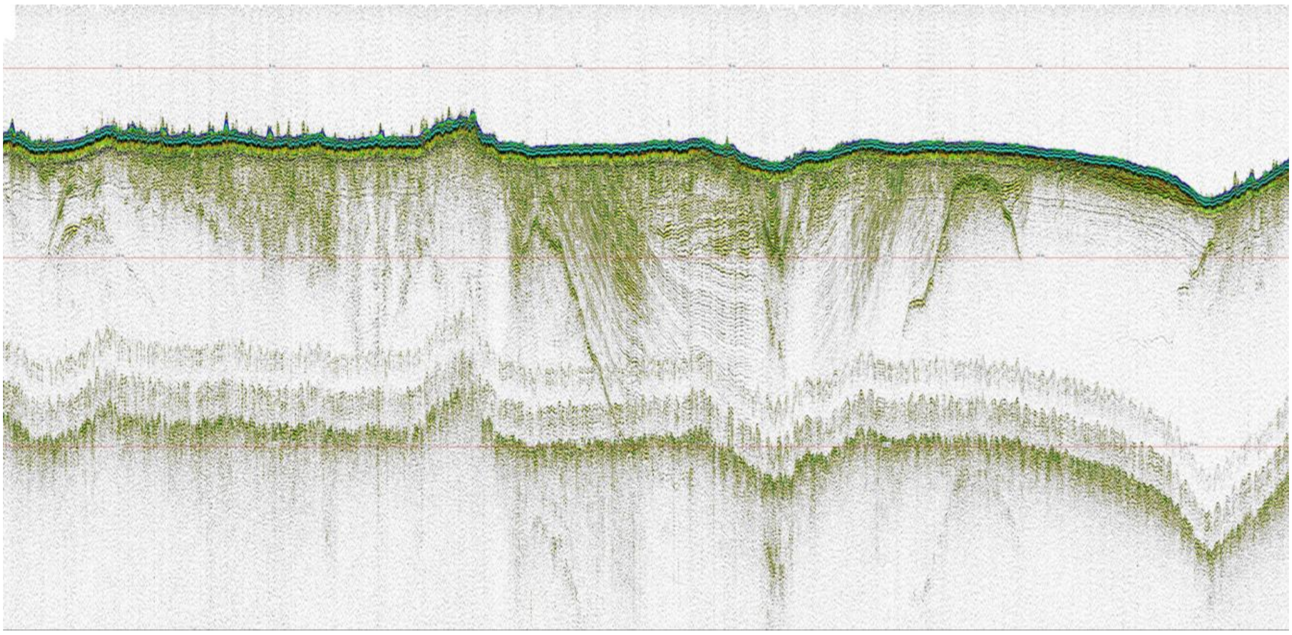


Figure 26 SBP data example from GSXVII

Data acquired by GSV is presented in Figure 27, which shows some variable ambient noise. Data acquired by GSV was in shallow waters, hence penetration of SBP data were limited by both geology and the first multiple. Figure 27 shows the variability in penetration achieved within the channel to the left and the lower penetrations achieved away from this feature. Some data do contain vertical bursts of noise and/or signal attenuation, generally these have been caused by debris or obstruction in the water column, however on occasion some larger bursts and caused by engine noise whilst maintaining line heading. These bursts do no 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. Occasional lines show increased burst noise likely due to adverse sea conditions, but data remains fit for interpretation.

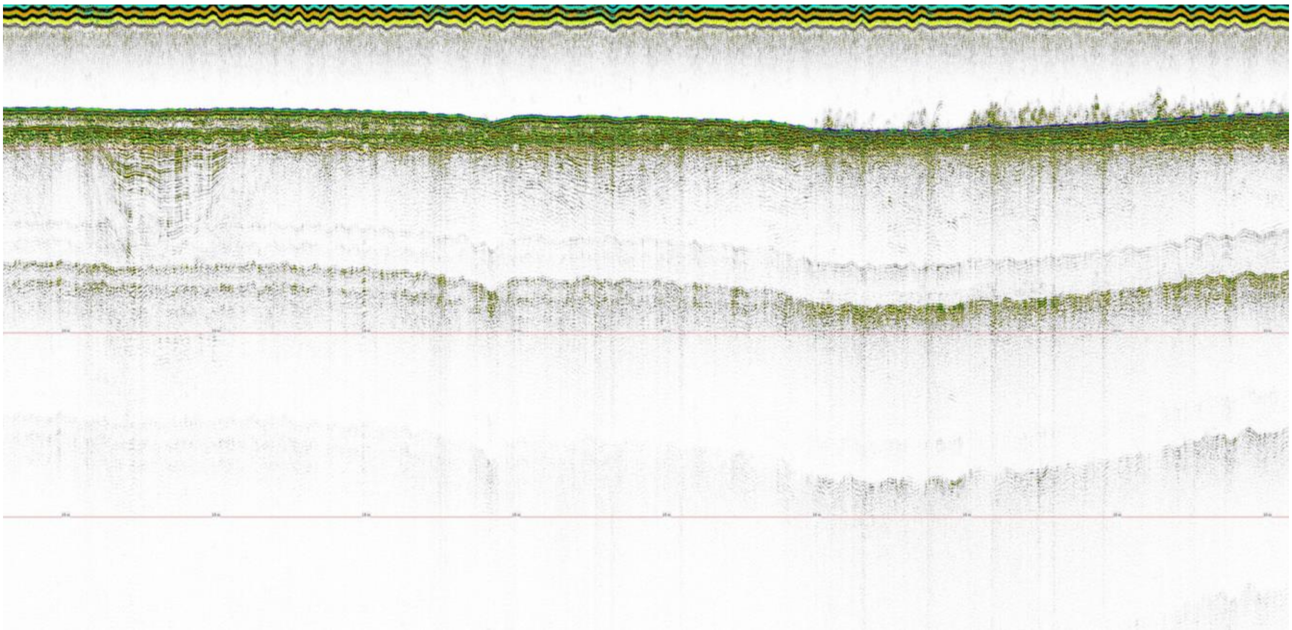


Figure 27 SBP data example from GSV

5.5.5 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 1450 m/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.

There may be small miss ties at the intersection of depth SEG-Y lines which are not present in the parent time versions of the lines. This is due to differences in depth conversion velocities which, in time, only influence signal characteristics rather than vertical position.

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 28.

Detailed overview of grab samples and results is presented in APPENDIX A.

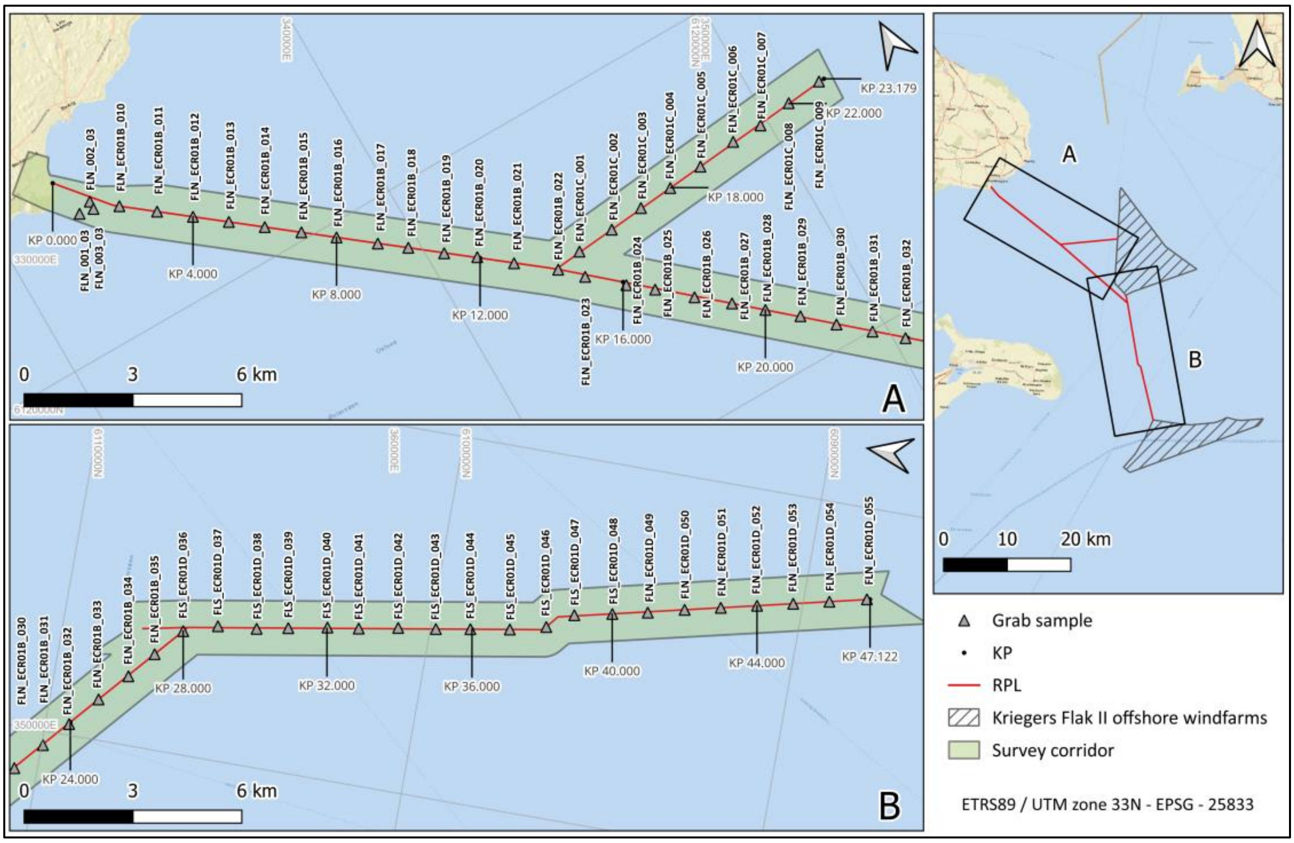


Figure 28: Grab sampling locations overview

5.7 GEOTECHNICAL SAMPLING AND ANALYSIS

The offshore geotechnical survey was conducted from the DP II vessel Connector and included 53 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 29). 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. An overview of the exact CPTU, VC and TRT test quantities, outlined per cable route, can be found in Section 6.6.

A summary of the selected results from the geotechnical investigation for Kriegers Flak II is presented in Section 6.6.

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 as Appendix C (Ref. "DOW 2030 - WPC, KF, Factual Report, Rev. 01, 2024-11-12 REPORT").

Figure 29: GeoCeptor - Combined Vibrocore and CPTU rig

5.7.1 CPT testing

A total of 68 seabed CPTUs were performed across 53 locations, with target depths of 3 m and 6 m. Penetration depths ranged from a minimum of 0.7 mbsb to maximum 6.4 mbsb, with an average penetration of 5.0 mbsb for tests targeting 6 m and 2.6 mbsb for tests targeting 3 m. 15 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 67 VCs were performed across the 53 geotechnical locations, with target depths of 3 m and 6 m. (maximum target depth for VC is 5.7 when TRT equipment is mounted), including 14 re-runs, achieving penetration depths between 0.8 mbsb and 6.1 mbsb. As for CPTs, re-runs were identified by appending "a" or "b" to the original location ID. The average recovery was 2.8 m, with individual recoveries ranging from 0.7 m to 5.8 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 on 14 locations and successfully conducted at 15 of the CPTU/VC locations. Geo DK’s subcontractor, Filax, 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 59 provides types and amounts of laboratory testing performed on recovered sample.

Table 58: 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	90	Cohesive	ASTM D8121/D8121M_9
Pocket Penetrometer	69	Cohesive	ISO 19901-8:2014(F)
Geotester	29	Cohesive	ISO 19901-8:2014(F)
Moisture Content	45	All	ISO 17892-1:2014
Bulk / Dry Density	206	All	EN ISO 17892-2:2014
Particle Size Distribution	122	All	DS/EN ISO 17892-4:2016
Atterberg Limits	62	Cohesive	DS/EN ISO 17892-12:2018 |
Max. and Min. dry density	13	All	DGF Bulletin 15
Thermal Conductivity	53	All	ASTM D5334-14
Loss on Ignition	57	Organic	ASTM D2974-20
Particle density	123	All	DS/EN ISO 17892-4:2016
C14 dating	6	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 58 and Figure 59). A total of 122 sieve analyses and 29 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. Forty 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. Thirteen 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 % in Clay TILL to highest 245.3 % in PEAT 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 CLAY, where the bulk density reached 2.37 g/cm³ and the dry density measured 2.09 g/cm³ at the depth of 0.20 metres below seabed.

Atterberg Limits

The liquid and plastic limits were determined on 62 specimens. The plasticity index for 60 of the specimens varies between 4 and 34 %. Two samples were non-plastic (VC_121 specimen 2.1D and VC_128a specimen 1.3D).

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 0.3 – 47.1 %. 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 section 6.6 and APPENDIX C.

5.8 GROUND TRUTHING FOR ACOUSTIC DATA INTERPRETATION

Geotechnical parameters reported in Table 59 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. The complete description of the geotechnical dataset is provided in the geotechnical report in Appendix C.

Table 59: 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 CLASSIFICATION CRITERIA

5.9.1 Seabed gradient classification criteria

Seabed gradient has been classified as per Table 60**Error! Reference source not found.** below.

Table 60: Slope classification

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

5.9.2 Confidence interval classification for targets

Confidence interval classification for targets has been classified as per Table 61.

Table 61: Confidence interval classification for targets

Confidence interval	Criteria
Low	Visible on a single SSS line
Medium	Seen on more than one SSS line

Confidence interval	Criteria
High	Seen on one or more SSS lines and correlated with MBES

5.9.3 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 62 below.

Table 62: 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

5.9.4 Mobile bedform classification

Nomenclature for mobile bedform classification is presented in Table 63 below.

Table 63: 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

5.9.5 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 30, with the GEUS seabed sediment classification for Danish waters in Table 64.

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 30: Wentworth Scale – classifying sediment particles

Table 64: 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 KRIEGERS FLAK II ROUTE OVERVIEW

6.1 RESULTS

This report section provides a detailed analysis of the findings from topography, bathymetry, 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.

6.2 BATHYMETRY & TOPOGRAPHY

The elevation levels across the Kriegers Flak II export cable route corridor exhibit a range of elevations, from the shallowest location of 9.96 metres above MSL in the western part of the surveyed landfall area, to the deepest location of 34.36 metres below MSL in the vicinity of coordinates 357768.2 mE, 6090328.3 mN, towards the southern boundary of the survey area.

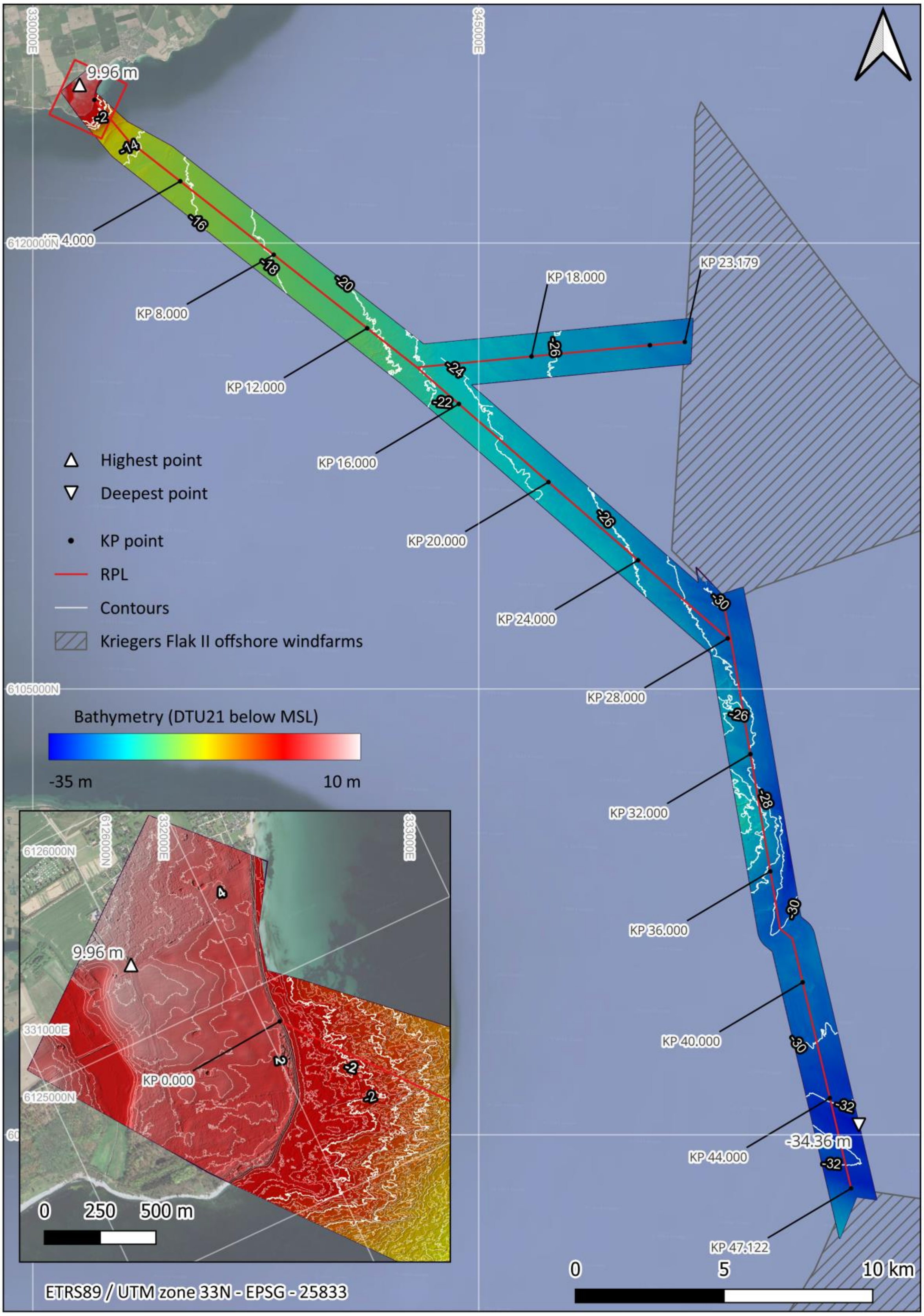


Figure 31: Bathymetry and topographic combined overview presents a comprehensive overview of the bathymetry within the Kriegers Flak II export cable routes survey area

6.2.1 Landfall & topography

Starting at the KP 0 and moving landward, the elevation rises steeply from 0 to 3 metres MSL within a few metres of horizontal distance across the entire surveyed shoreline. However, in the southern half of the surveyed shoreline, the landfall terrain is more rugged, as opposed to gentler land configuration in the northern half (including the planned landfall at KP 0 of the RPL).

The landfall is located adjacent to a strip of agricultural land, which is mostly flat, slightly sloping from 3 m at the shoreline to 6-7 metres in the western parts of the field. To the west of the field, a strip of low-lying land (1 m MSL) is cut across by a creek. The northern and southern parts of the surveyed area are composed of slightly inclined residential areas (4 to 8 metres MSL) and flat forested areas (2 to 4 m MSL), respectively.

The elevation peaks at just below 10 metres, located in the residential part of the area. The highest point likely corresponds to the roof of a tall building or another man-made structure.

An overview of the entire area covered by the topographic survey, including the RPL position, is provided in Figure 32, offering a comprehensive view of the general topographic features of the site.

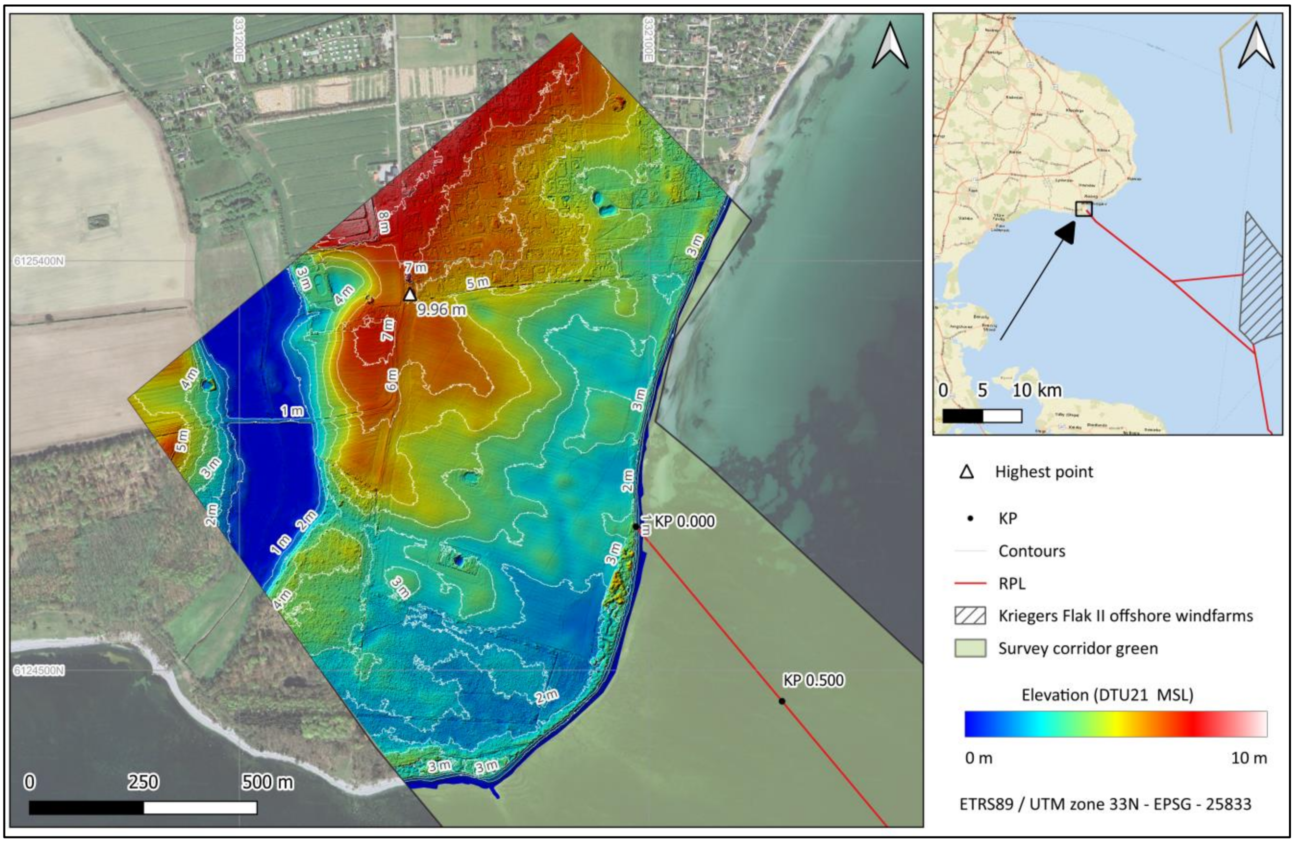


Figure 32: Topographic overview

6.2.2 Bathymetry overview

A comprehensive overview of the bathymetry within the Kattegat II ECR 2 survey area is illustrated in Figure 33. Detailed bathymetry profiles along the RPLs are depicted in Figure 34 and Figure 35, where profiles are divided into routes connecting Kriegers Flak II North and Kriegers Flak II South windfarms. Vertical exaggeration (VE) is stated on the graphs.

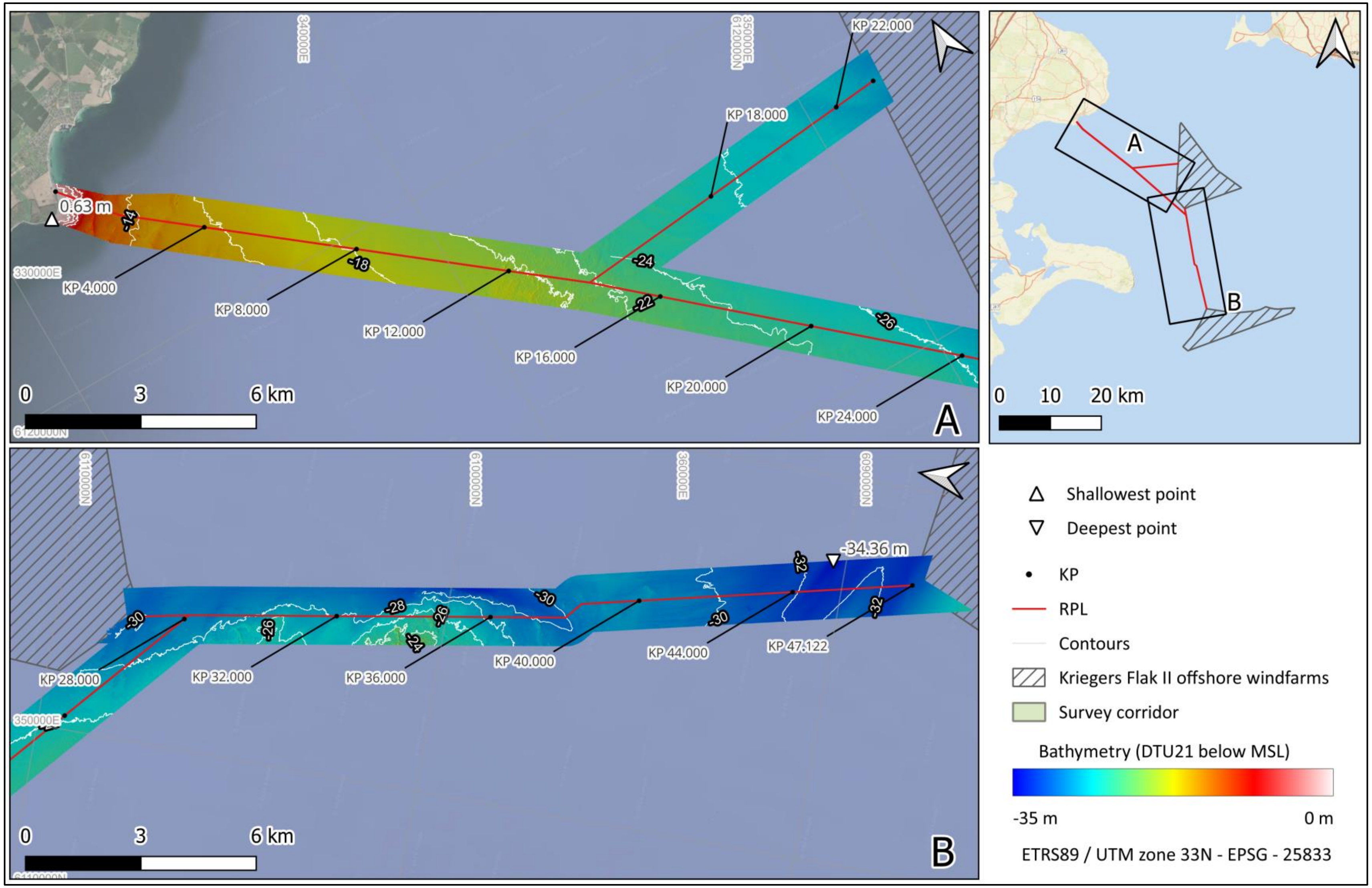


Figure 33: Bathymetry overview of the survey area

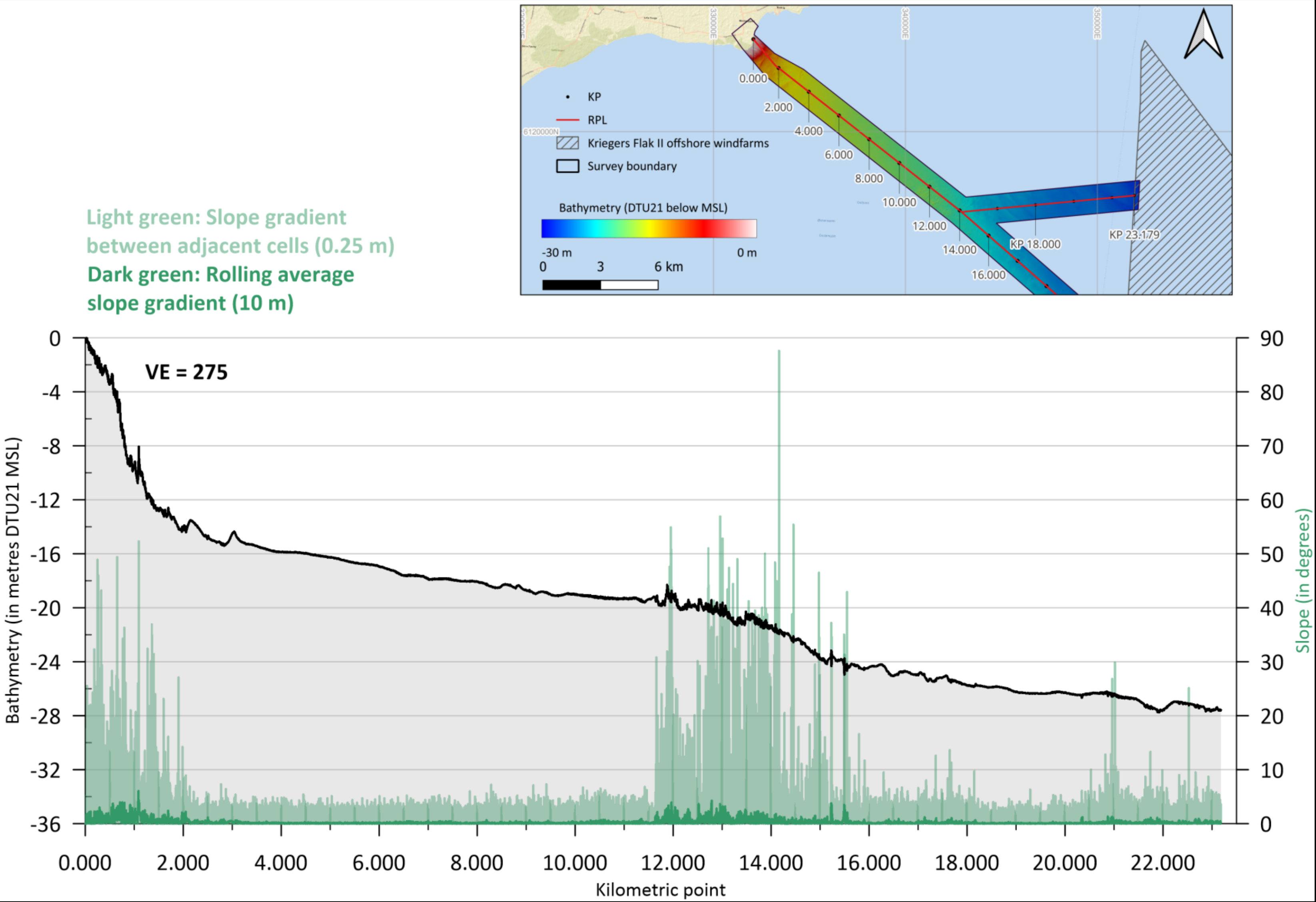


Figure 34: Depth and slope profile along the north route RPL

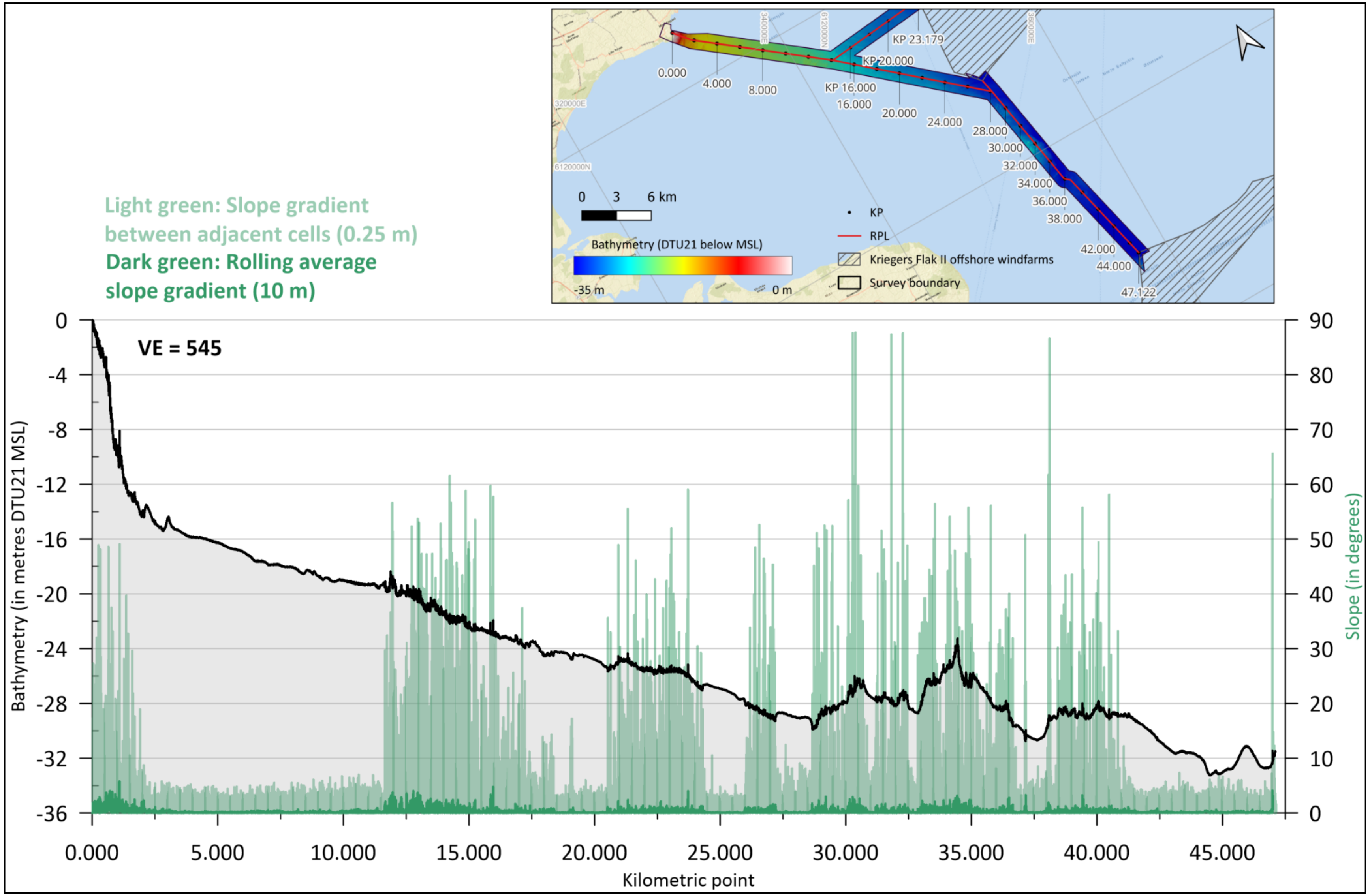


Figure 35: Depth and slope profile the south route RPL

In the nearshore part of the route, from KP 0.000 to KP 1.000, the seabed gradient deepens along the RPL to 10 metres below MSL, with an average slope of 5.4 degrees across 0.25 x 0.25-metre cells and 1.5 degrees over a 10-metre interval. In this section, the route is situated on a rocky beach (till/diamicton). The very steep slope values are attributed to this geological feature and the presence of intermediate boulder areas. The slopes and seabed surface tend to become gentler going south-eastward. Around KP 2.175 and KP 3.000, two sand bedforms with orientation SW - NE are visible within the dataset, as presented in Figure 36.

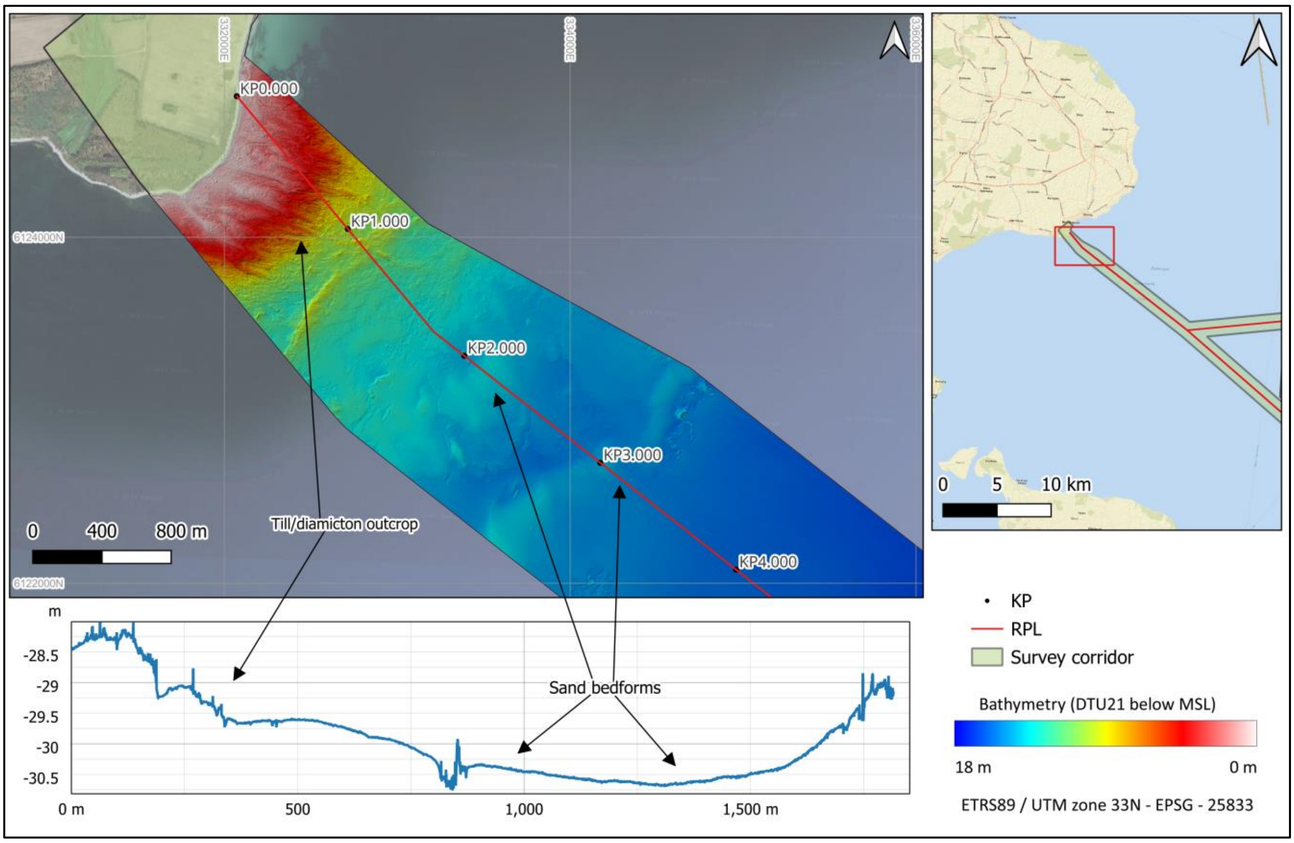


Figure 36: Bathymetry overview at the start of the route

As the route continues southeastwardly, from KP 3.000 to KP 11.630, the elevation changes from 14.5 meters to 19.2 meters below MSL. In this section, the route predominantly traverses through sand with few patches of muddy sand, and the slope is negligible. The average slope between cells is 0.9 degrees, with a maximum slope value of 3.7 degrees.

From KP 11.630 to KP 29.400, the seabed continues to deepen slowly south-eastward, ranging from 19.2 metres to 28.5 metres below MSL. This section features irregular bathymetry with moderate to very steep slopes due to areas of till/diamicton and boulder fields (Figure 37). The steepest slopes in this part of the route reach approximately 50 degrees between cells and around 4.5 degrees over a 10-metre interval, particularly near KP 16.000 of the southern RPL route. Around KP 16.000 (southern RPL route), the Baltic cables (FL03) are visible in the multibeam echosounder (MBES) and slope datasets. A steep area is also visible at the location 345271.45 mN, 6114647.80 mE, where a wreck is observed. This wreck lies on the seabed approximately 660 metres northeast of the RPL (Figure 38).

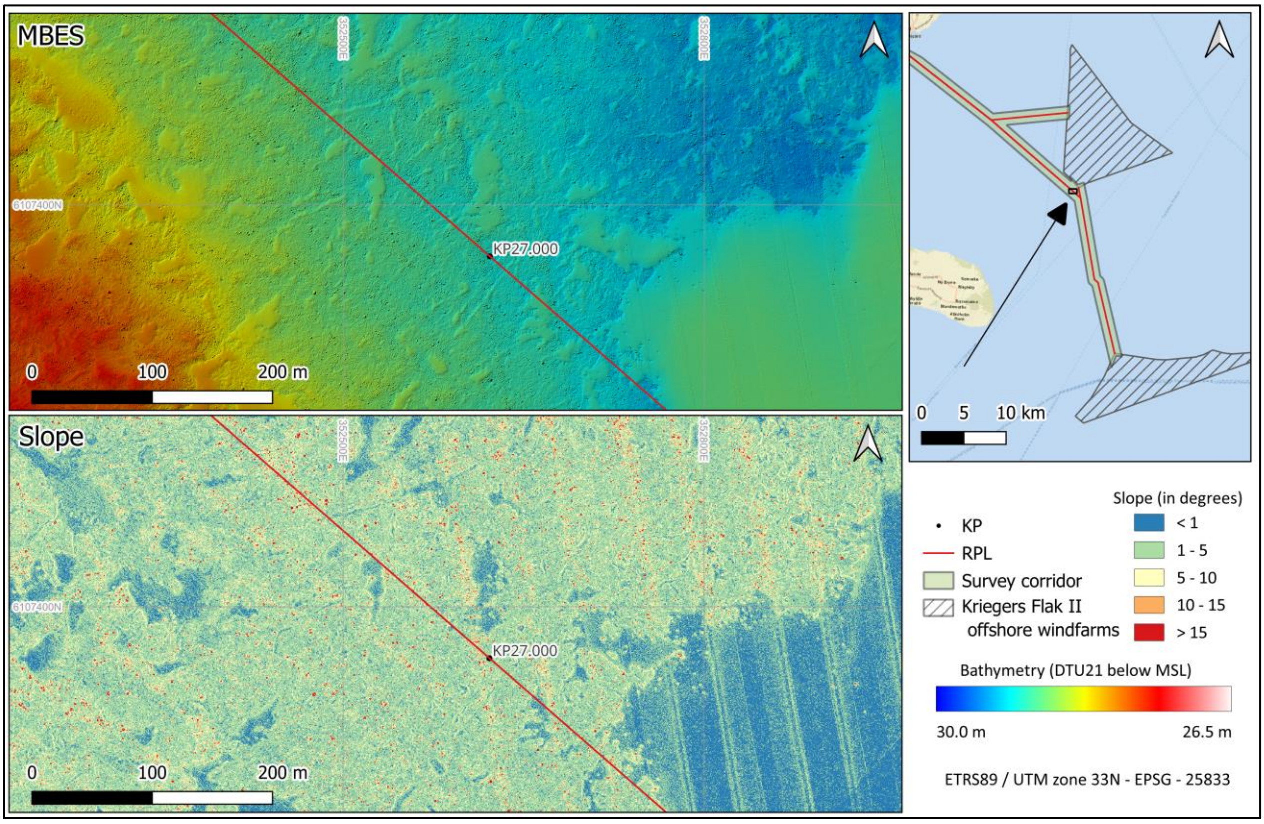


Figure 37: Bathymetry and slope map of the intermediate boulder field area near KP 27.000

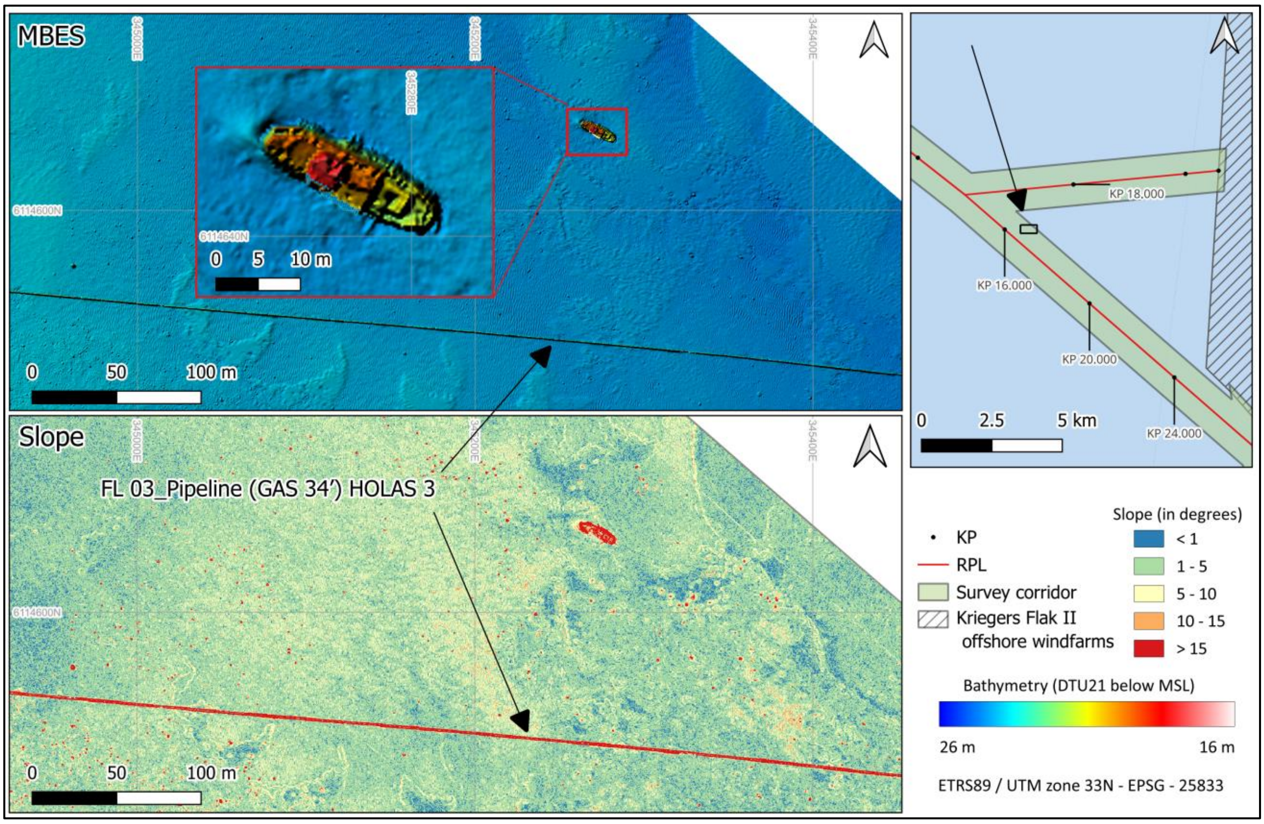


Figure 38: Bathymetry and slope map of the wreck and pipeline

Along the route connecting Kriegers Flak II North windfarm, from KP 14.000 to KP 23.173, the seabed terrain gradually deeper to 28 metres below MSL, with average slope of 0.3 degrees across 10-metre interval. The highest slope values are observed in the trench areas and where the survey corridor traverses boulder fields and till/diamicton outcrops. In the vicinity of KP 15.231 and KP 15.495, linear seabed features corresponding to cables ENDK HK22008 Kriegers Flak BE-Rødvig and ENDK HK22007 Kriegers Flak A-Rødvig form approximately 7-metre-wide trenches. In these trench areas, the slope is around 20 degrees (Figure 39). Furthermore, the steep values (15-20 degrees) are measured from KP 21.000 until the end of the route that connects northern windfarm, where the area crosses till/diamicton outcrops. This area is depicted in Figure 40.

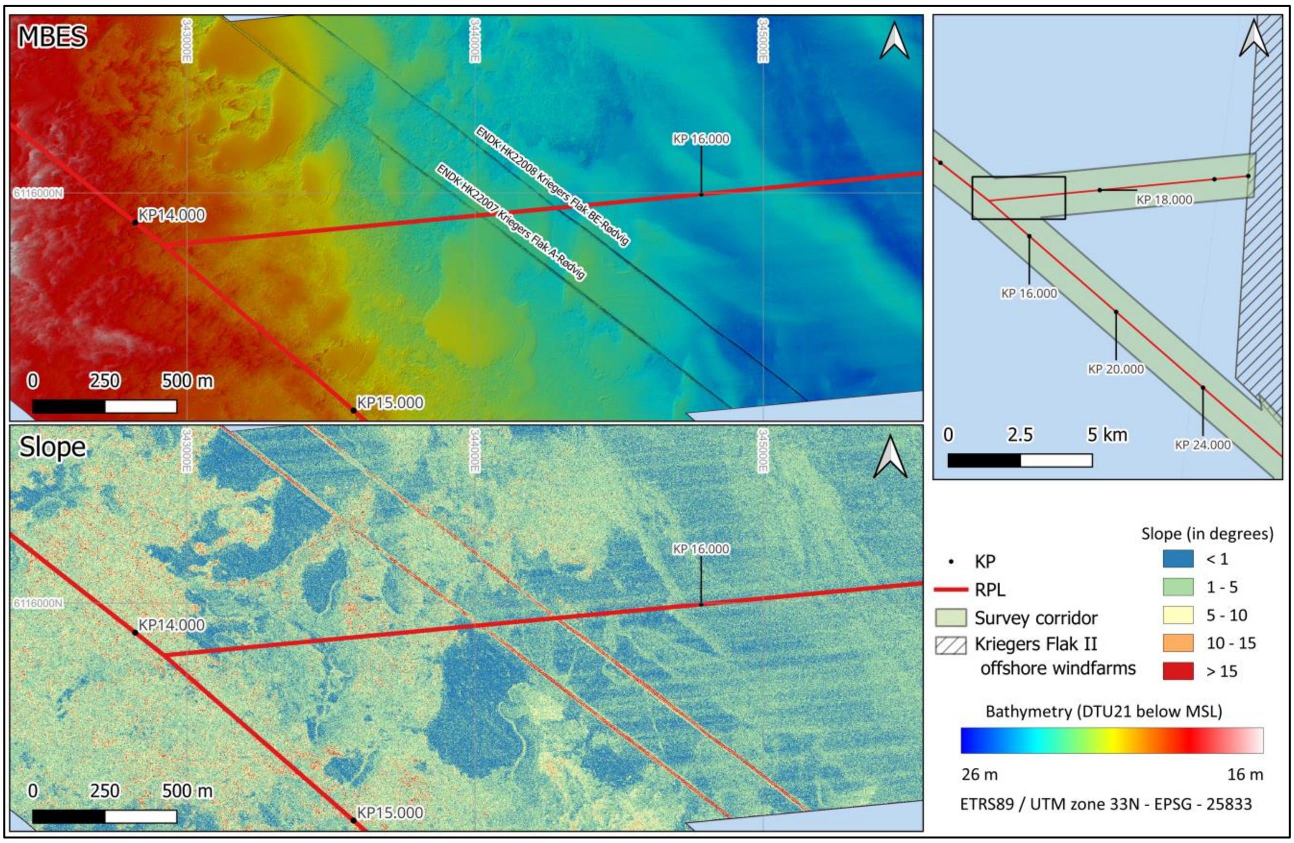


Figure 39: Bathymetry and slope map of the submarine cables

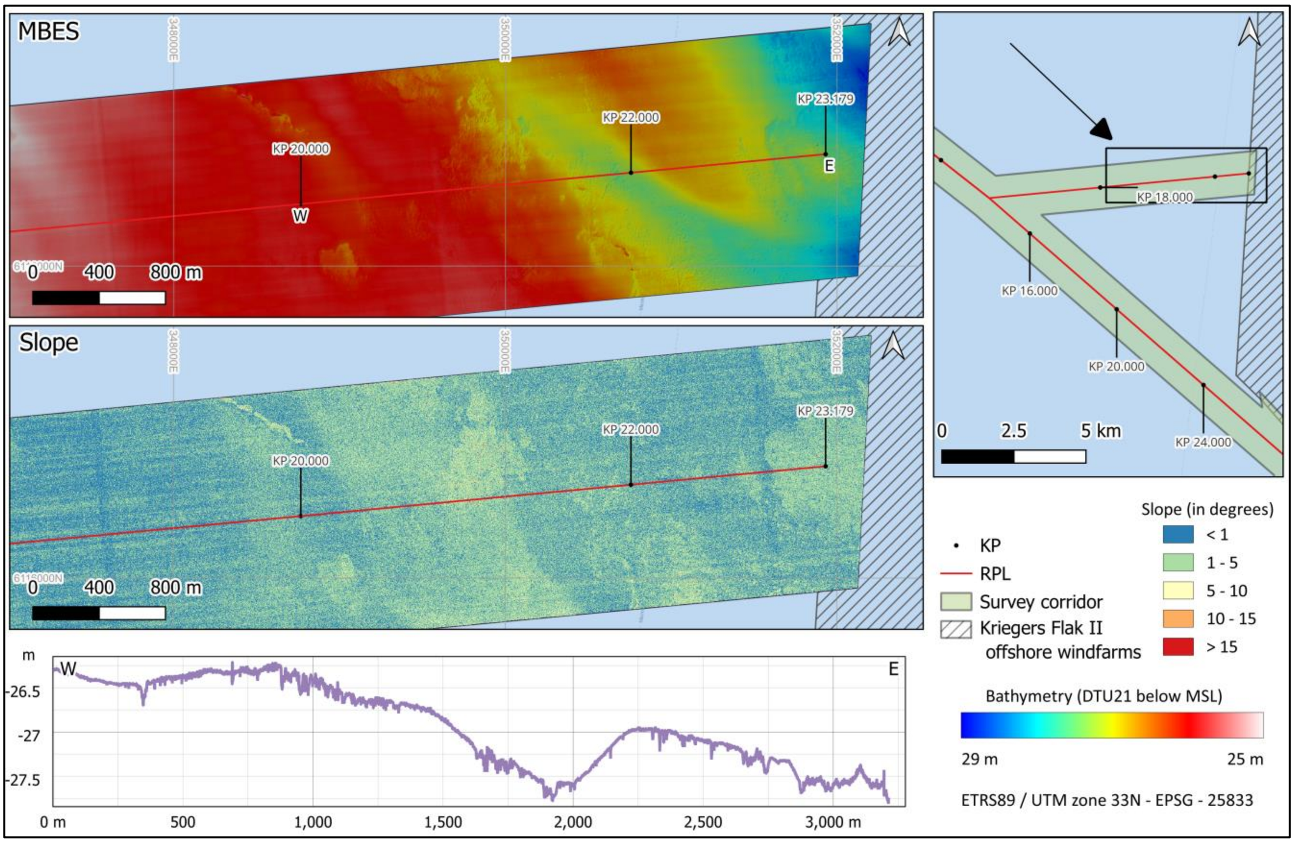


Figure 40: Till/diamicton area at the end of the northern route

Commencing at KP 29.400 and continuing to KP 41.000 of the southern RPL route, very steep slopes are observed, mostly situated within boulder fields. The bathymetry in this area is irregular and deviates from the previously observed consistent depth increase. Instead, the terrain exhibits a slight rise, characterized by larger areas of till/diamicton outcrops. In the vicinity of KP 37.500, a channel filled with sand is visible, as presented in Figure 41.

From KP 41.000 to the end of the route, the seabed is predominantly covered with sand and muddy sand, with a negligible slope, except for a few patches of elevated boulder fields around KP 43.000, KP 44.500, and KP 47.500. In the vicinity of KP 45.000, the deepest location within the survey boundary is measured. The route ends at 31.5 meters below mean sea level.

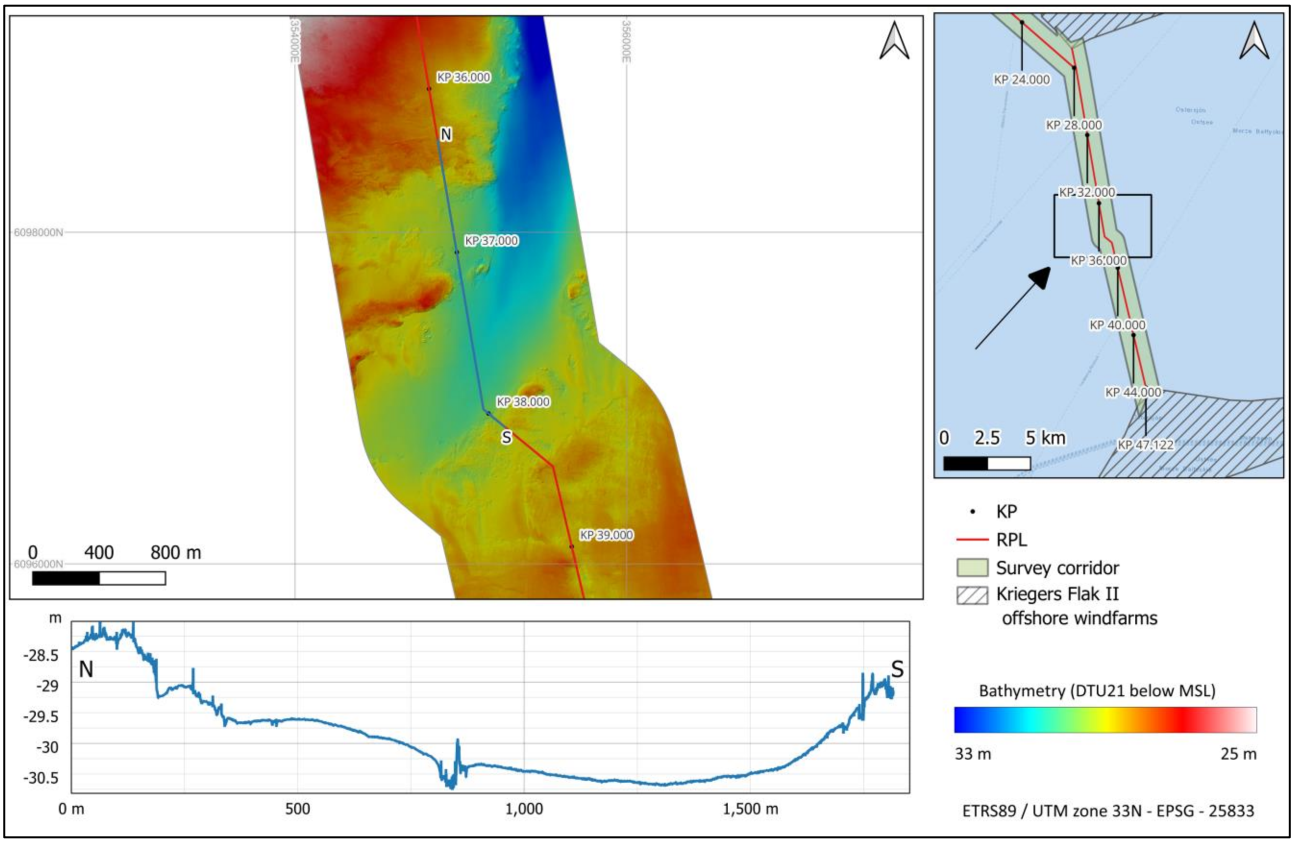


Figure 41: Channel feature between till/diamicton outcrops

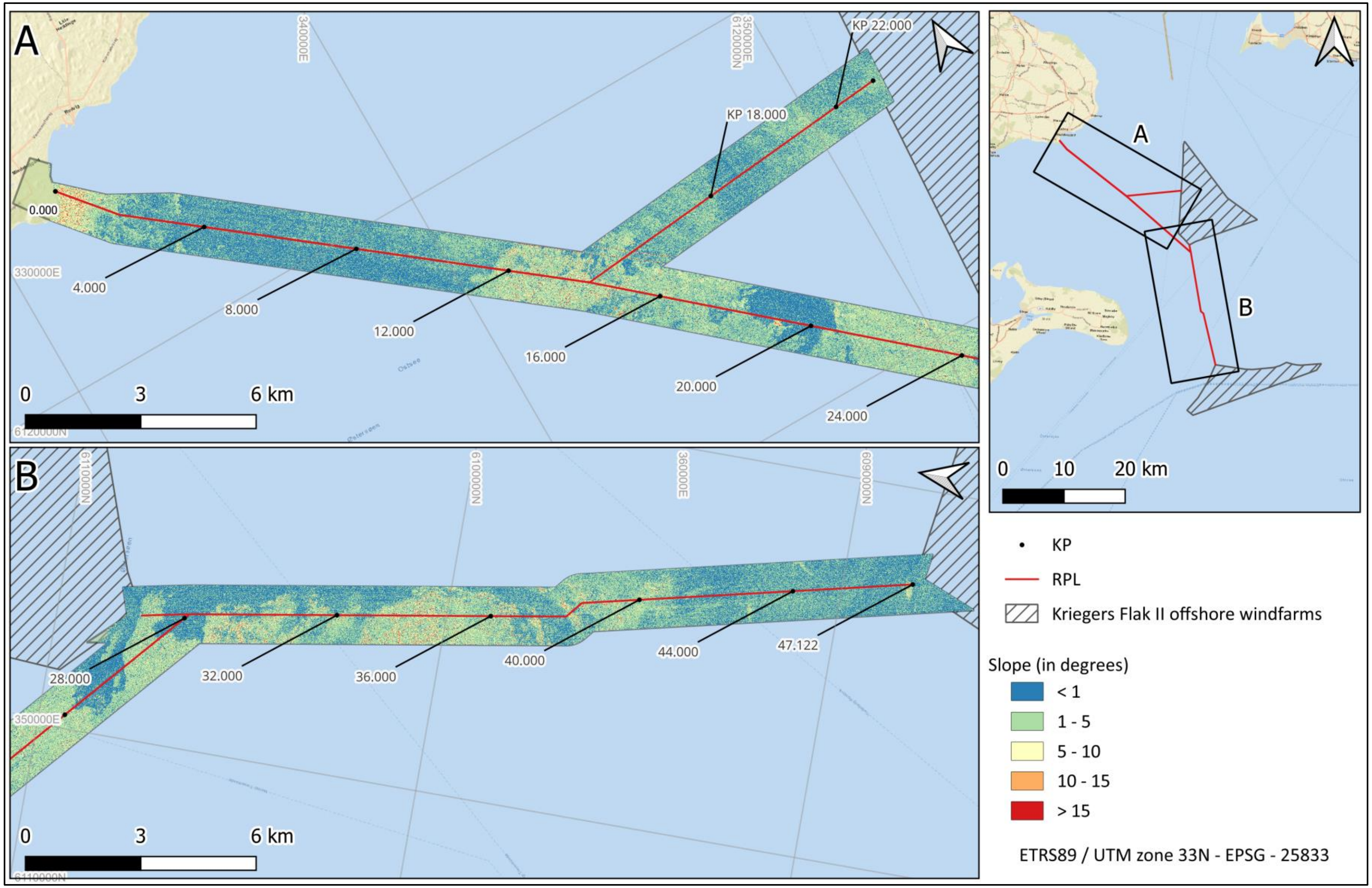


Figure 42: Slope overview of the survey area

6.3 SEABED SURFACE GEOLOGY

The seabed geology across the Kriegers Flak II South area 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 65). GEUS terminology was used to define the identified seafloor sediment in the survey area. Bathymetric data aided the interpretation.

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 30) in accordance to BS EN ISO 17892-4. Seabed geology was also correlated to Vibrocore Top Geology (seabed) results.

An example of the grab sample results, integrated with the results from the SSS data within the Kriegers Flak survey area, is shown in Figure 43. Grab sample 'FLN_ECR01B_032' was described as 'Unlithified (H1) / moderately sorted / 2.5YR_3/1 gravel' and in contrast, grab sample 'FLN_ECR01B_033' was described as 'Unlithified (H1) / well sorted / 2.5 Y 3/1 clay'. These results correlate with the high contrast between sediment types observed in the SSS data and have subsequently been classified as either 'Till/Diamicton' or 'Muddy Sand'.

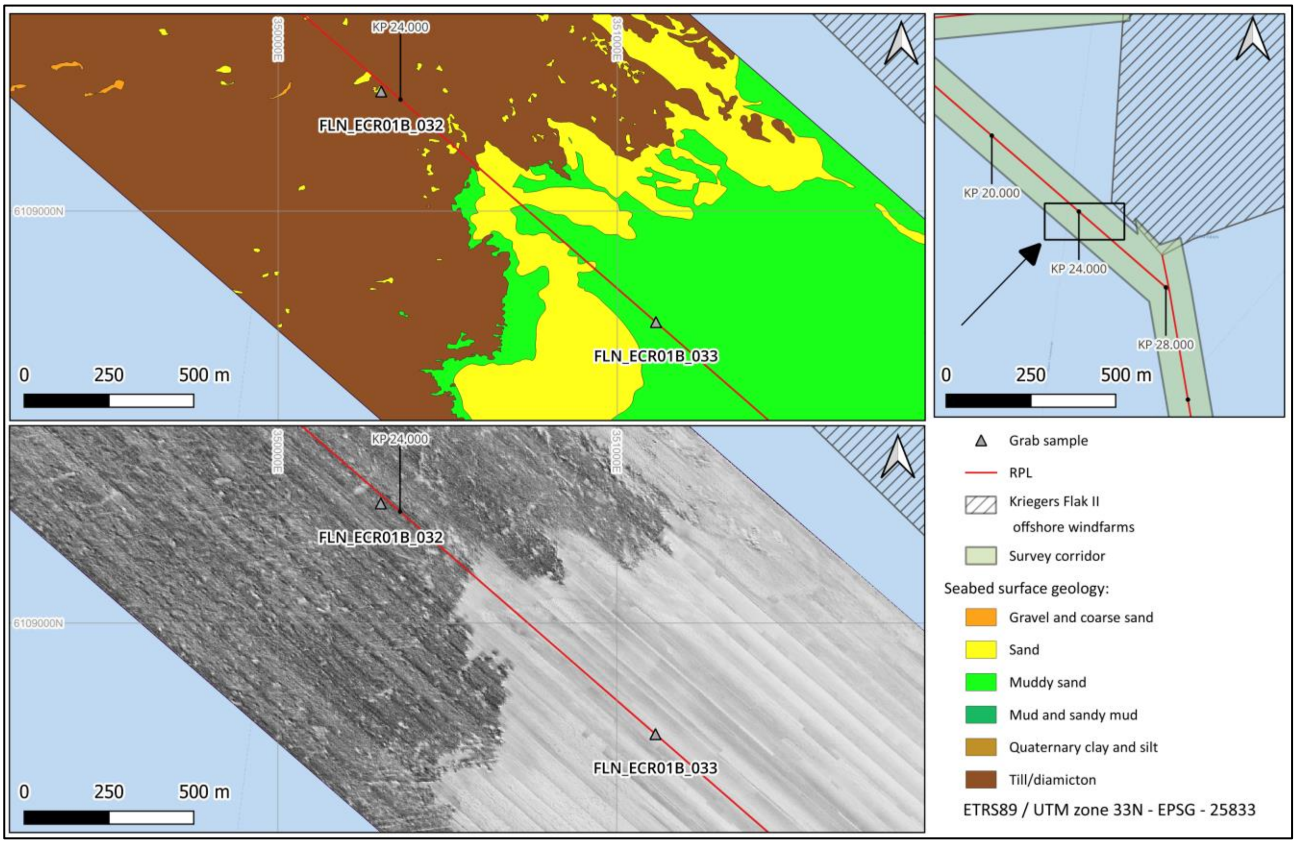
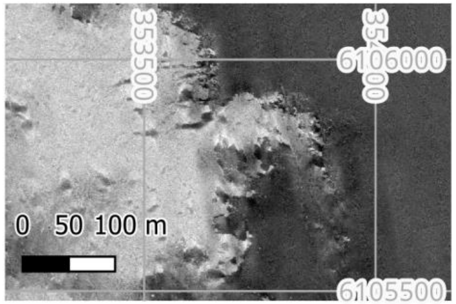
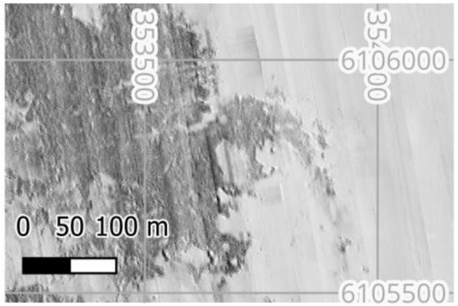
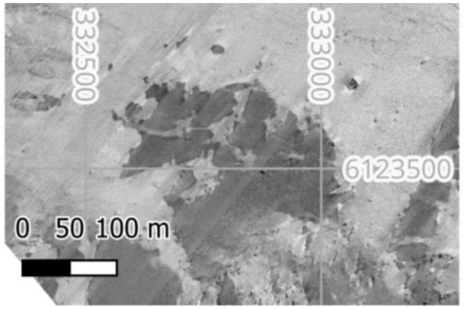
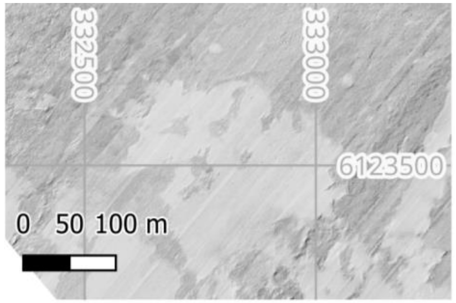
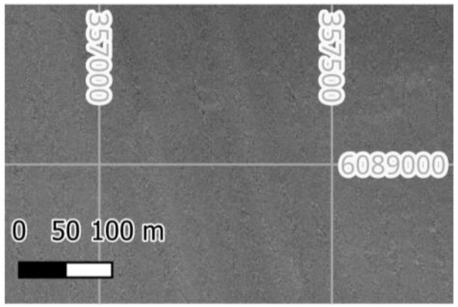
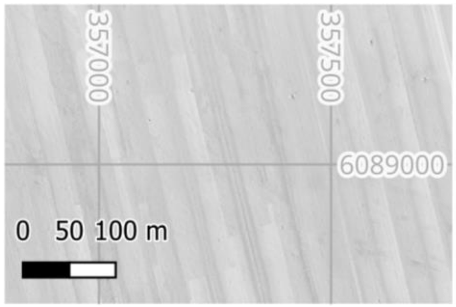
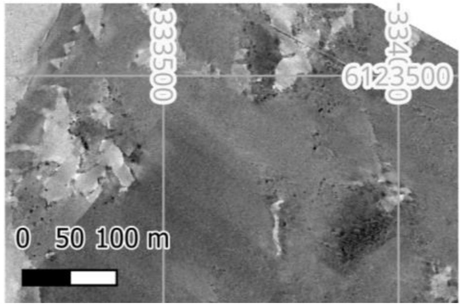
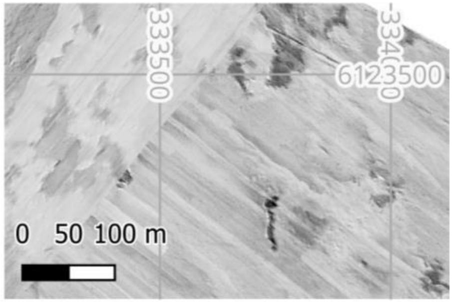
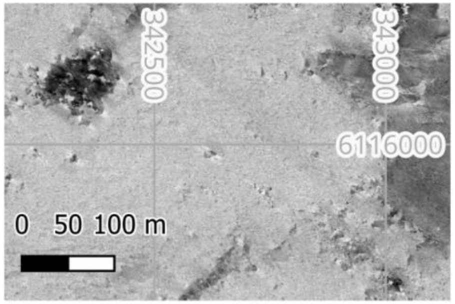
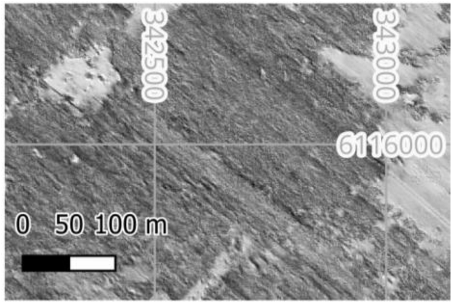
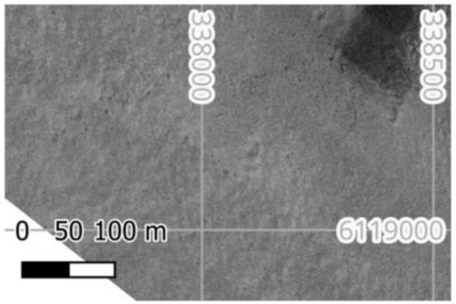
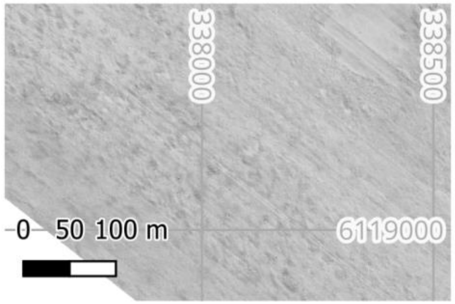


Figure 43: Seabed geology classification as confirmed by grab sample results, compared with the LF SSS data in KFII

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.

Table 65: Acoustic characteristics of the sediment types within the Kriegers Flak II 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 or 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.		
Quaternary clay and silt	31	Predominately silt.	Low acoustic reflectivity. No texture. Texture indicates wave and stream working of the sediment.		

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 44: Wentworth Scale – classifying sediment particles

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

The seabed surface geology across the Kriegers Flak II ECR 2 area exhibits a relatively complex diversity without a predominant substrate or geology type (Figure 45). The area around KP 0 and in the initial 2-kilometre stretch is composed of till/diamicton which grows sparser towards the east as sand, gravel and coarse sand become the predominant substrate up until KP 11.000. From this point, till and diamicton dominate the surface for most of the central part of the southern RPL branch. Locally, they are interspersed with smaller pockets of other sediments, with significant patches of muddy sand throughout the eastern half of the survey corridor. In the final several kilometres of the southern section of the route, till and diamicton give way to patches of muddy sand and sand. The survey corridor branch closest to the Kriegers Flak II North windfarm exhibits a mosaic of surface geology types with alternating patches of till/diamicton, sand, quaternary clay and silt and especially muddy sand which is predominant in the central part of this branch of the corridor.

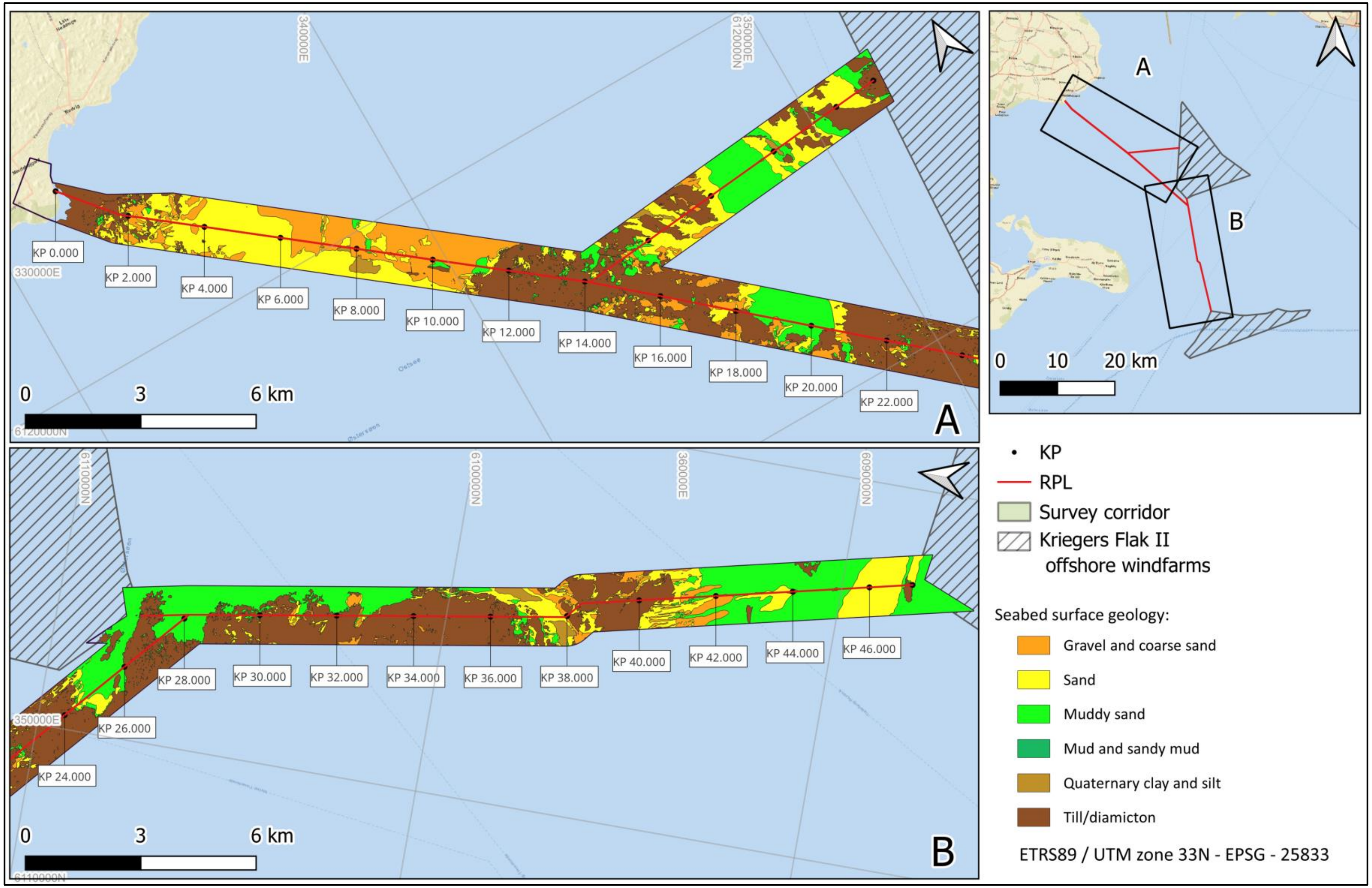
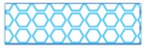
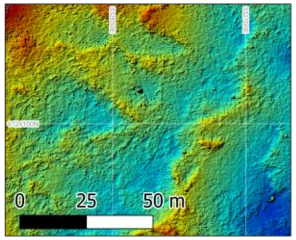
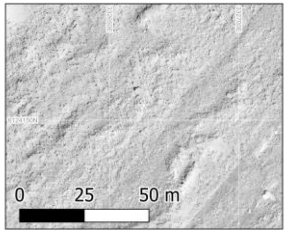
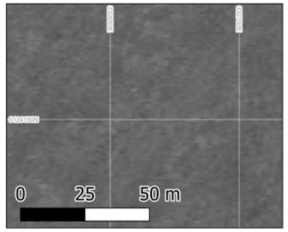
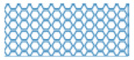
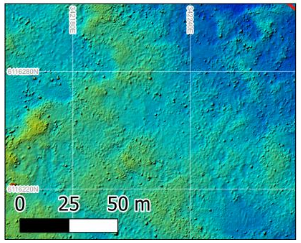
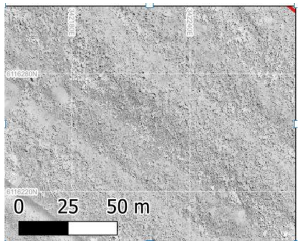
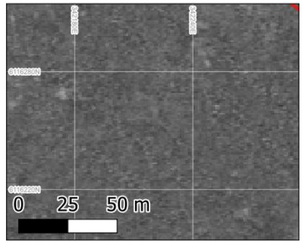
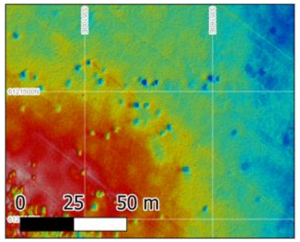
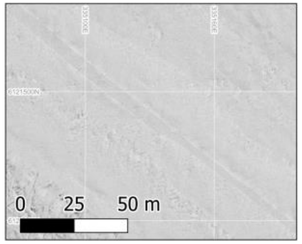
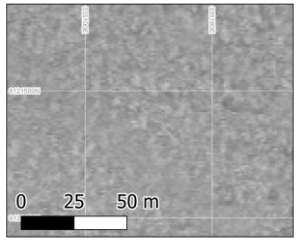
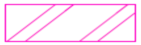
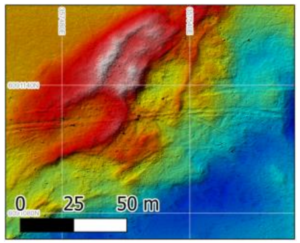
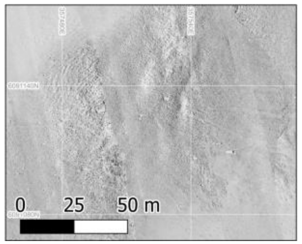
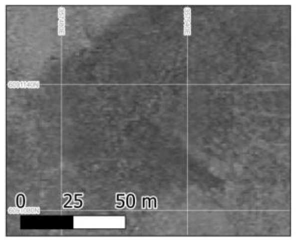


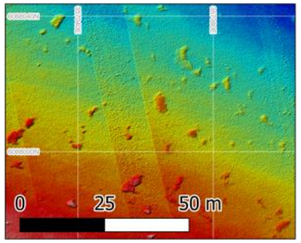
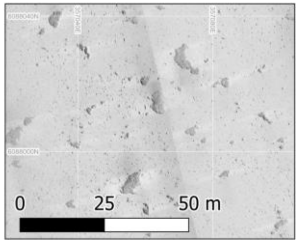
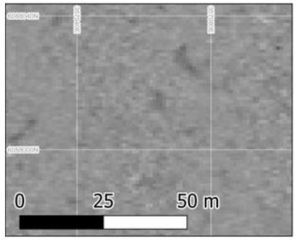
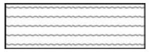
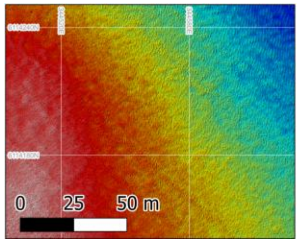
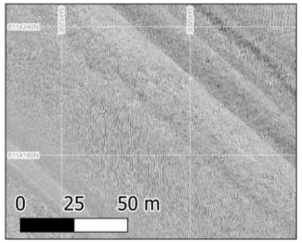
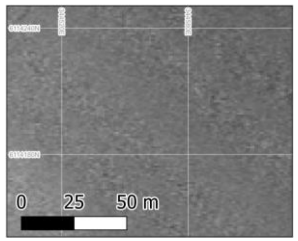
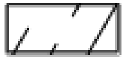
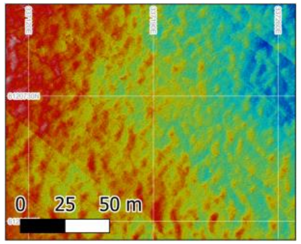
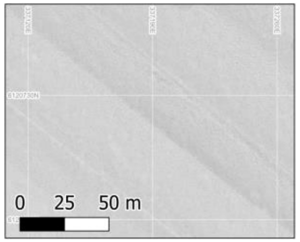
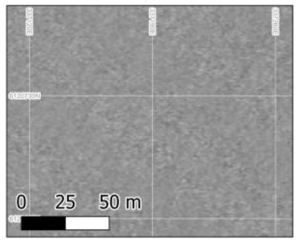
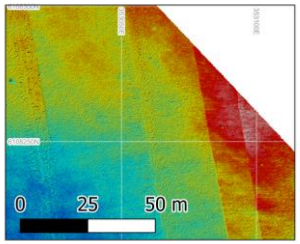
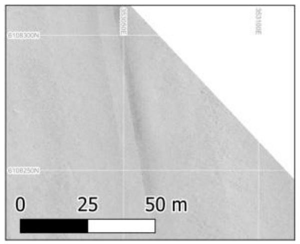
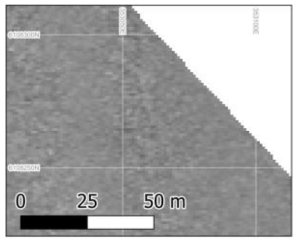
Figure 45: Seabed surface geology classifications

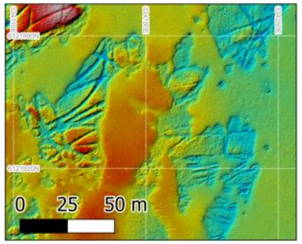
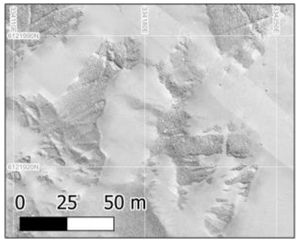
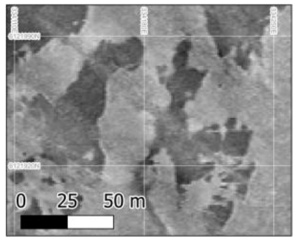
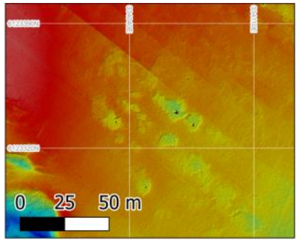
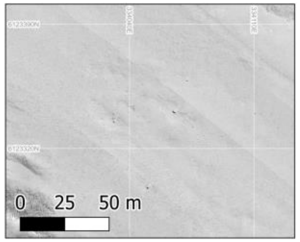
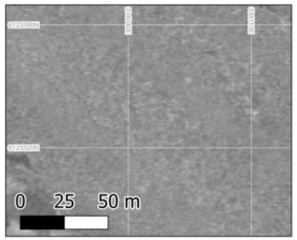
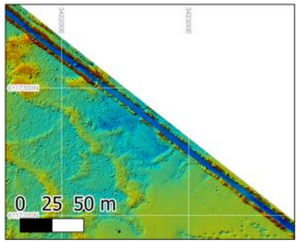
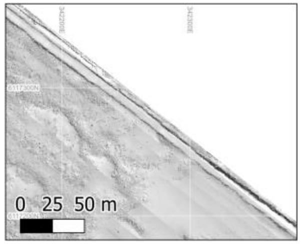
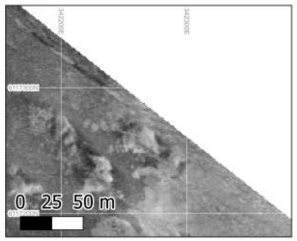
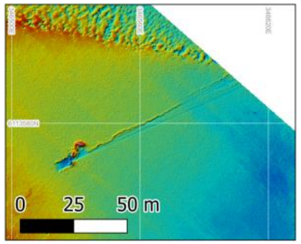
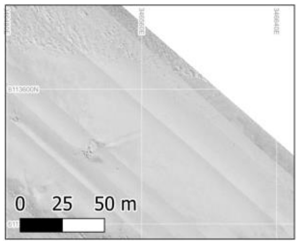
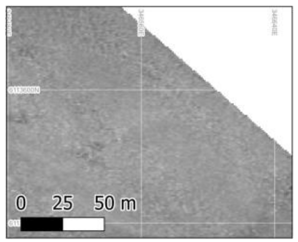
6.4 SEABED SURFACE MORPHOLOGY

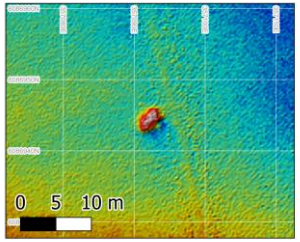
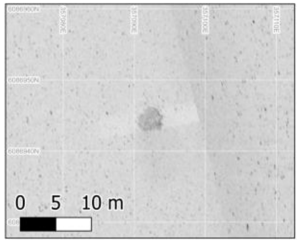
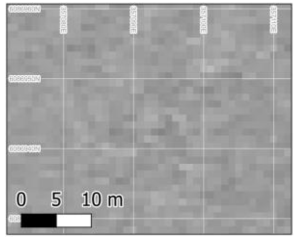
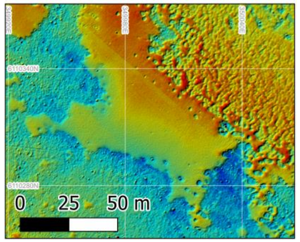
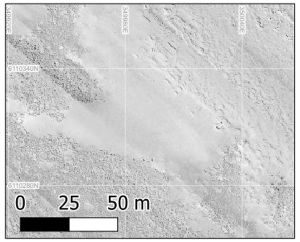
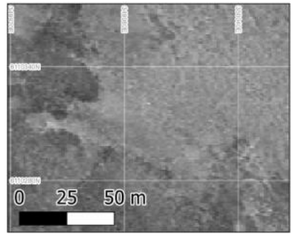
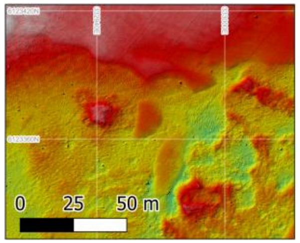
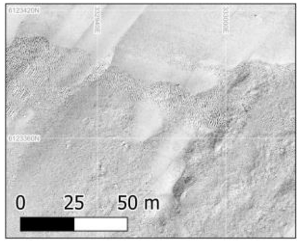
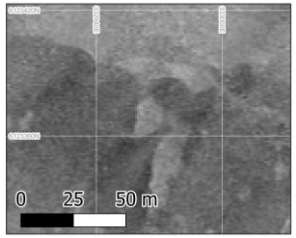
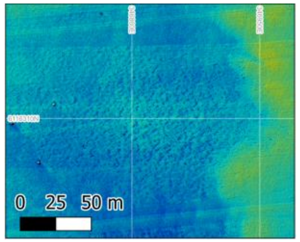
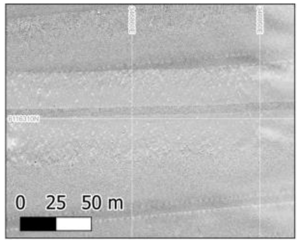
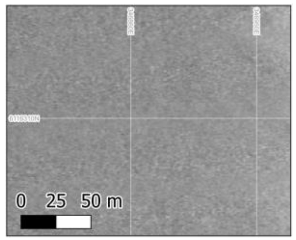
The seafloor morphology and seabed features were analysed using SSS (Side Scan Sonar), BKS (Backscatter), and MBES (Multibeam Echo Sounder) datasets, with additional insights derived from SBP (Sub-Bottom Profiler) data. The acoustic characteristics of the interpreted seabed features at the Kriegers Flak II ECR site are detailed in Table 66. 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.

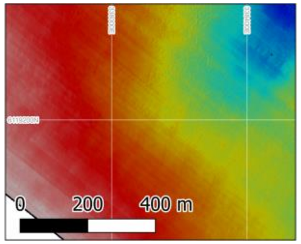
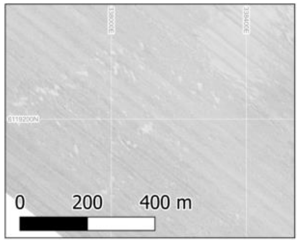
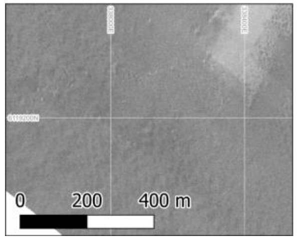
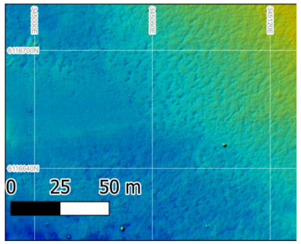
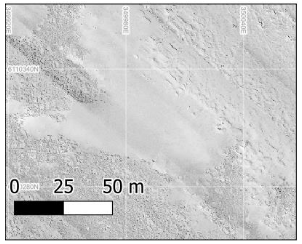
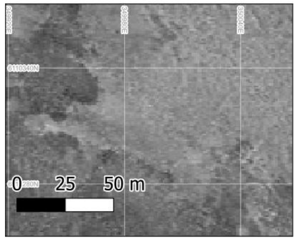
Table 66: Morphological interpretation

Seabed Feature	Symbology	Description	MBES image	HF SSS image	Backscatter
Boulder Field – intermediate density (Class 1)		High reflectivity contacts of intermediate density (10 to 20 boulders in a 50 x 50 m box), visible in MBES			
Boulder field - high density (Class 2)		High reflectivity contacts of high density (more than 20 boulders in a 50 x 50 m box), visible in MBES			
Pitted Seabed		Medium reflectivity circular depressions, possibly formed by scour around boulders			
Trawl marks		Low to medium reflectivity linear features, visible in MBES			

Seabed Feature	Symbology	Description	MBES image	HF SSS image	Backscatter
Biology – Area of *Mytilus edulis* beds		Patches of high reflectivity, interpreted to be Mytilus edulis beds			
Ripples		Low to high reflectivity alternating areas. Clear in MBES. Wavelength (<5 m) and height <0.01m -0.1m) are the primary classifiers			
Large ripples		Low to high reflectivity alternating areas. Visible in MBES. Wavelength, 5-15 m, height 0.1m -1m.			
Sandwaves		Low to high reflectivity alternating areas. Visible in MBES. Wavelength, 25 – 70 m			

Seabed Feature	Symbology	Description	MBES image	HF SSS image	Backscatter
Other – Seabed scar area		Seabed scar area – High reflectivity seabed with linear scars, likely related to sub cropping till			
Other – Bedforms		Low to medium reflectivity, appear as elongated area, visible in MBES. Related to sediment transport and deposition			
Other – Submarine cable trench		Low to medium reflectivity linear scars forming a pattern, visible in MBES			
Other – Seabed scars/disturbed possibly related to the construction of a HK22007 cable		Low to high reflectivity. Clearly distinguishable in BKS and MBES cable			

Seabed Feature	Symbology	Description	MBES image	HF SSS image	Backscatter
Other – Seabed mount		Patches of high reflectivity, likely associated with the Mytilus edulis beds			
Other – Featureless seabed		Areas of no significant seabed features (exception of boulders)			
Unknown - Possible erosional bedform features		Low reflectivity with irregular high reflectivity patches, distinguishable in SSS, MBES and subtle appearance in BKS			
Unknown - Possible biostructures		Low to medium reflectivity patches, visible in MBES			

Seabed Feature	Symbology	Description	MBES image	HF SSS image	Backscatter
Unknown - Patches of lower reflectivity, not visible on MBES		Low reflectivity irregular patches, distinguishable only in SSS.			
Unknown - Patches of lower reflectivity		Low to medium reflectivity patches, visible in MBES and SSS			

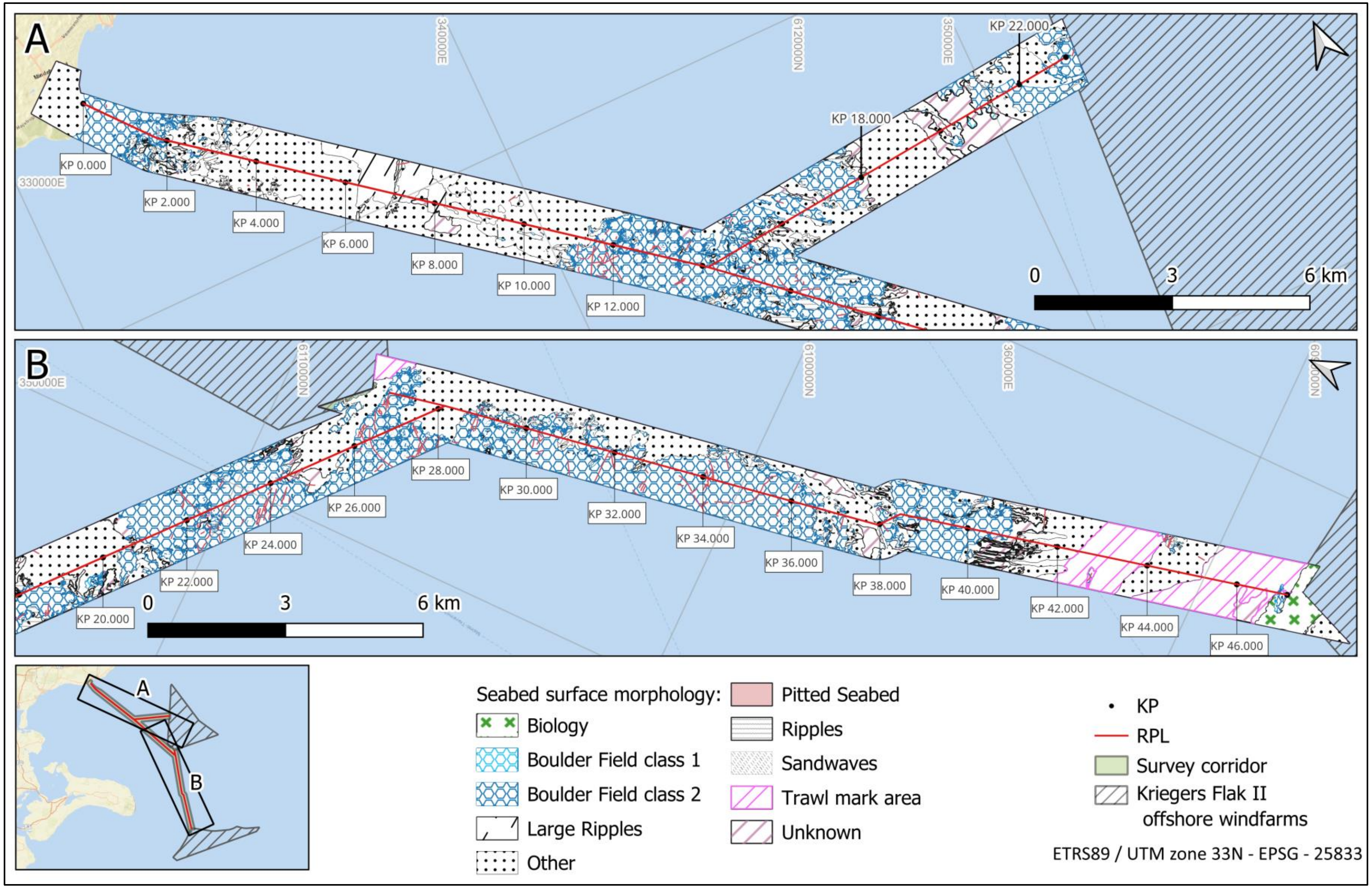


Figure 46: Seabed surface morphology classification

The seabed surface morphology interpretation is presented in Figure 46.

The initial stretch of the survey area, spanning several hundreds of metres, shows no detectable seabed features. However, the area corresponding to till/diamicton in terms of surface geology is characterized by boulder fields of intermediate density, interspersed with sediment waveform and ripple areas. In the subsequent several kilometres (roughly KP 3.000 to KP 11.000), patches of featureless seabed alternate with patches of large-ripple areas and sediment-waveform areas. From around KP 11.000 until roughly KP 41.000, boulder fields of intermediate density dominate the survey corridor area, with significant strips of featureless areas throughout the eastern half of the survey corridor. From KP 41.000 onwards, boulder fields transition to areas featuring either trawl marks or no features, with an area of Mytilus edulis beds appearing at the southernmost part of the survey corridor.

The survey corridor branch closest to the Kriegers Flak II North windfarm exhibits a mosaic of surface morphology with alternating patches of intermediate-density boulder fields, areas of possible biostructures and areas without detected seabed features.

6.5 SEABED SURFACE FEATURES

Seabed surface objects which are determined to be man-made objects (MMO) are outlined in Table 67 and Table 68 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 point features. Polygon features have been detected from SSS and MBES data.

A total of 218 linear objects were identified through the interpretation of the MBES, SSS, and MAG datasets. Of these objects, 115 have been detected in multiple sensors.

A total of 32,798 point contacts were detected through the interpretation of the MBES, SSS, and MAG datasets within the survey area. 833 contacts were identified within the MMO point file and 31,965 contacts were 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 67 and Table 68 does not amount to the total number of objects.

Table 67: Summary of linear contact man-made objects

Feature type	Total amount	Comment
Metallic	8	Eight linear contacts found within a 5 m radius of a magnetic anomaly.
Ropes	19	19 linear contacts related to possible soft rope item.
Other contacts	176	176 linear sonar contacts are identified to be linear objects
Cable/pipeline	15	12 linear contacts related to cables were found, along with three contacts related to pipeline infrastructure.

Table 68: Summary of point contact man-made objects

Feature type	Total amount	Comment
Wrecks	2	Two shipwrecks were identified on site.
Metallic	345	345 contacts found within a 5 m radius of a magnetic anomaly.

Feature type	Total amount	Comment
Anchor	2	Two anchors were found within the site.
Ropes	19	19 contacts related to possible soft rope item.
Other contacts	460	460 sonar contacts are identified to be debris
Cable/pipeline	5	There are two point contacts related to detected cable (Baltic Cable) and three contacts related to detected pipeline (Baltic Pipe) on site.

6.5.1 Wrecks

Wreck KFII_ECR_MMO_PTS_0350

Figure 47 presents the location of the unidentified wreck KFII_ECR_MMO_PTS_0350.

This unknown wreck is located at 338413 E, 6118603 N and lies in water depths of around 18 metres below MSL with dimensions of 23 m x 16 m x 1 m (L x W x H). The surrounding seabed is featureless.

Looking at the residual magnetic field, the wreck displays a large footprint, with a peak-to-peak anomaly of >700 nT.

Wreck KFII_ECR_MMO_PTS_0390

Figure 48 presents the location of the unidentified wreck KFII_ECR_MMO_PTS_0390.

This unknown wreck is located at 345273 E, 6114647 N and lies in water depths of around 24 metres below MSL with dimensions of 23 m x 6.5 m x 6.5 m (L x W x H). The surrounding seabed features sporadic boulders and ripples.

Looking at the residual magnetic field, the wreck displays a large footprint, with a peak-to-peak anomaly of >2300 nT.

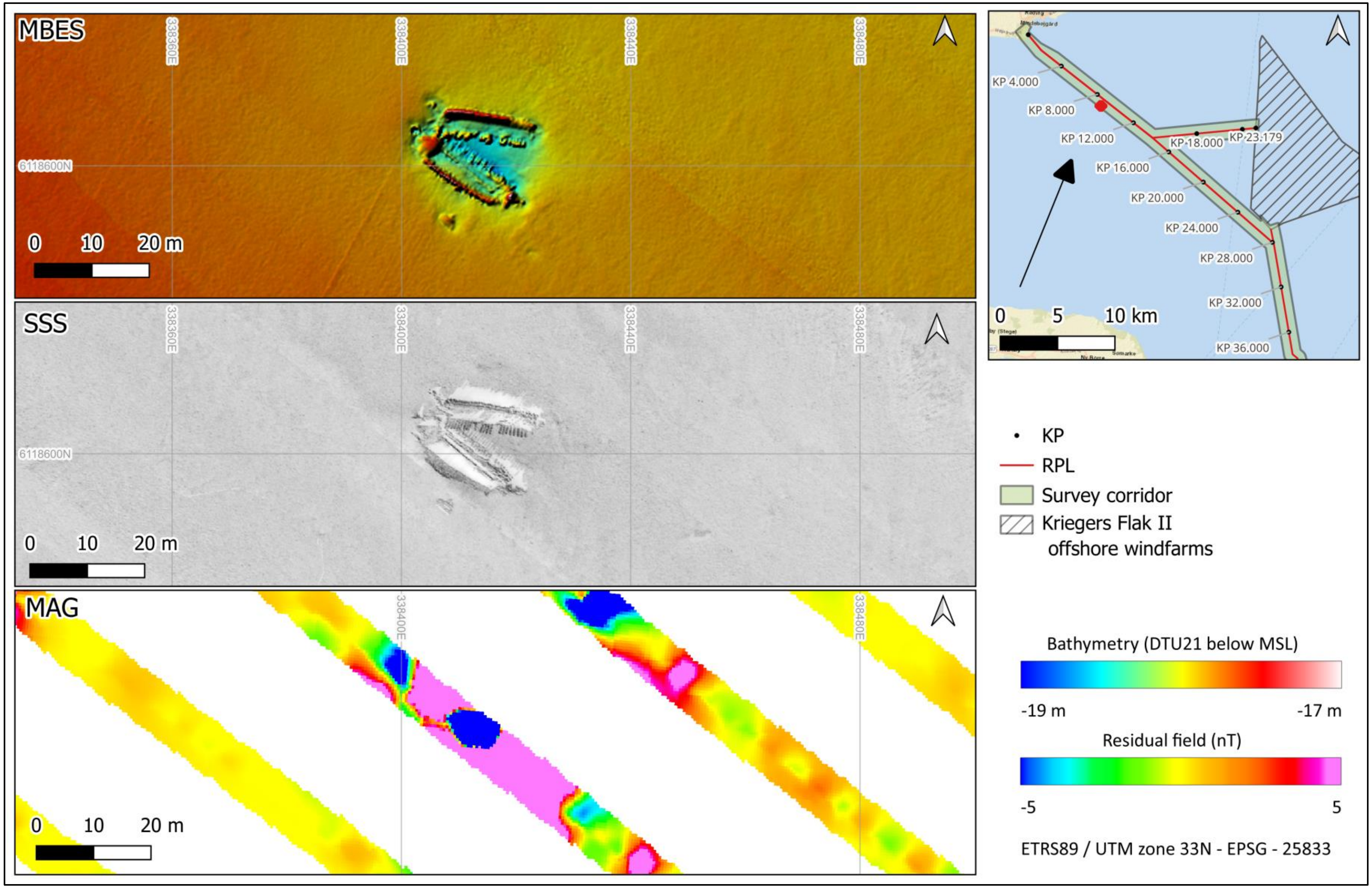


Figure 47: Location of wreck KFII_ECR_MMO_PTS_0350

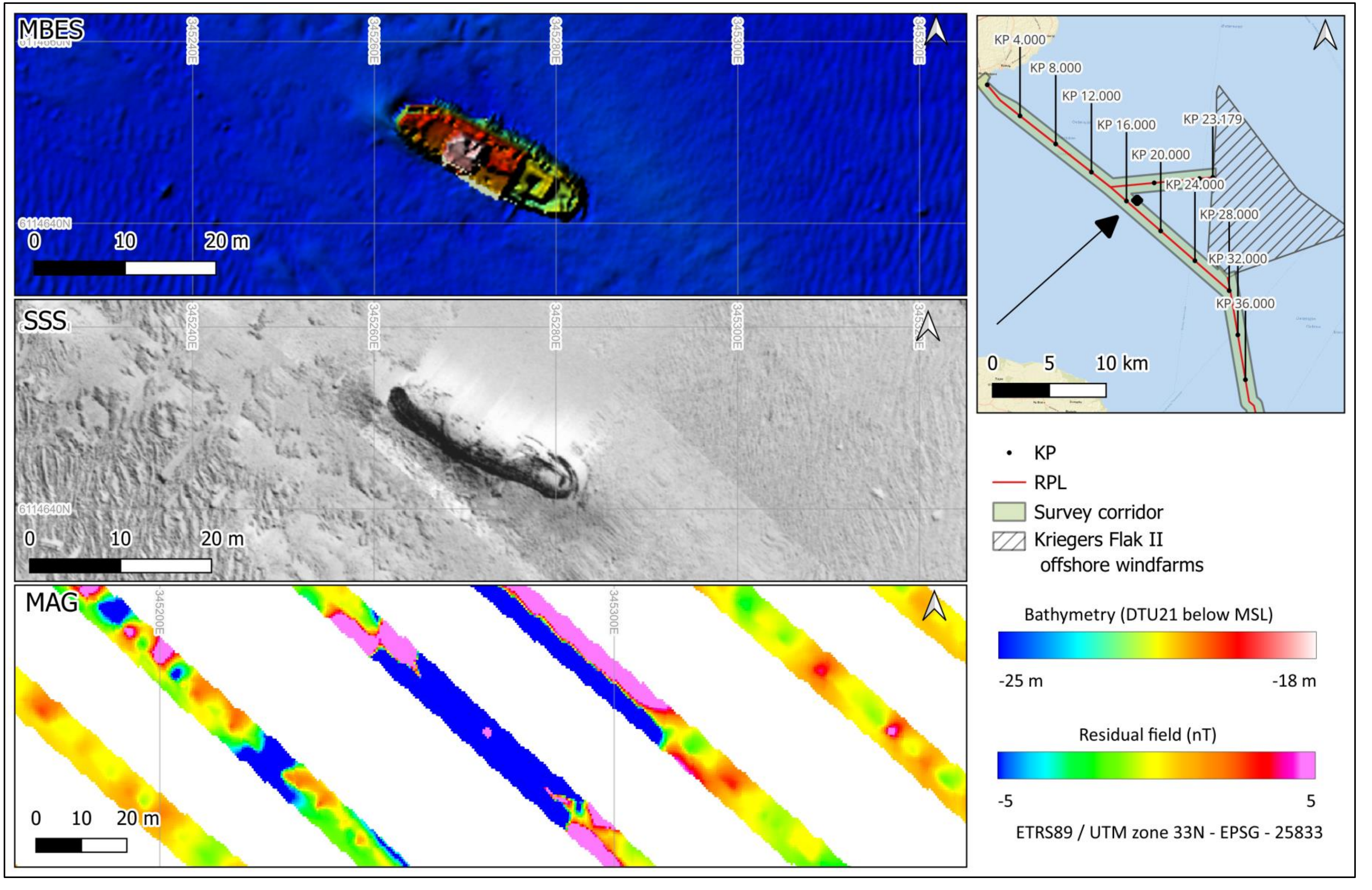


Figure 48: Location of wreck KFII_ECR_MMO_PTS_0390

6.5.2 Cables, wires, and ropes

Twelve linear and two point contacts are related to cables located within the survey corridor. These contacts correspond to five cables seen in Figure 49. A closer view of one of the detected cables, Baltic cable, in MBES, SSS and MAG, is presented in Figure 50.

Other linear man-made object, such as metallic objects, soft ropes and targets labelled as “Other” have been displayed in Figure 51. There are eight linear metallic object, 19 soft rope items and 176 other contacts. The highest density of targets is present in the initial, nearshore section of the cable route, spanning the entire width of the survey area within this region.

An example of a soft rope is shown in Figure 52 and an example of a contact classified as “Other” is shown in Figure 53.

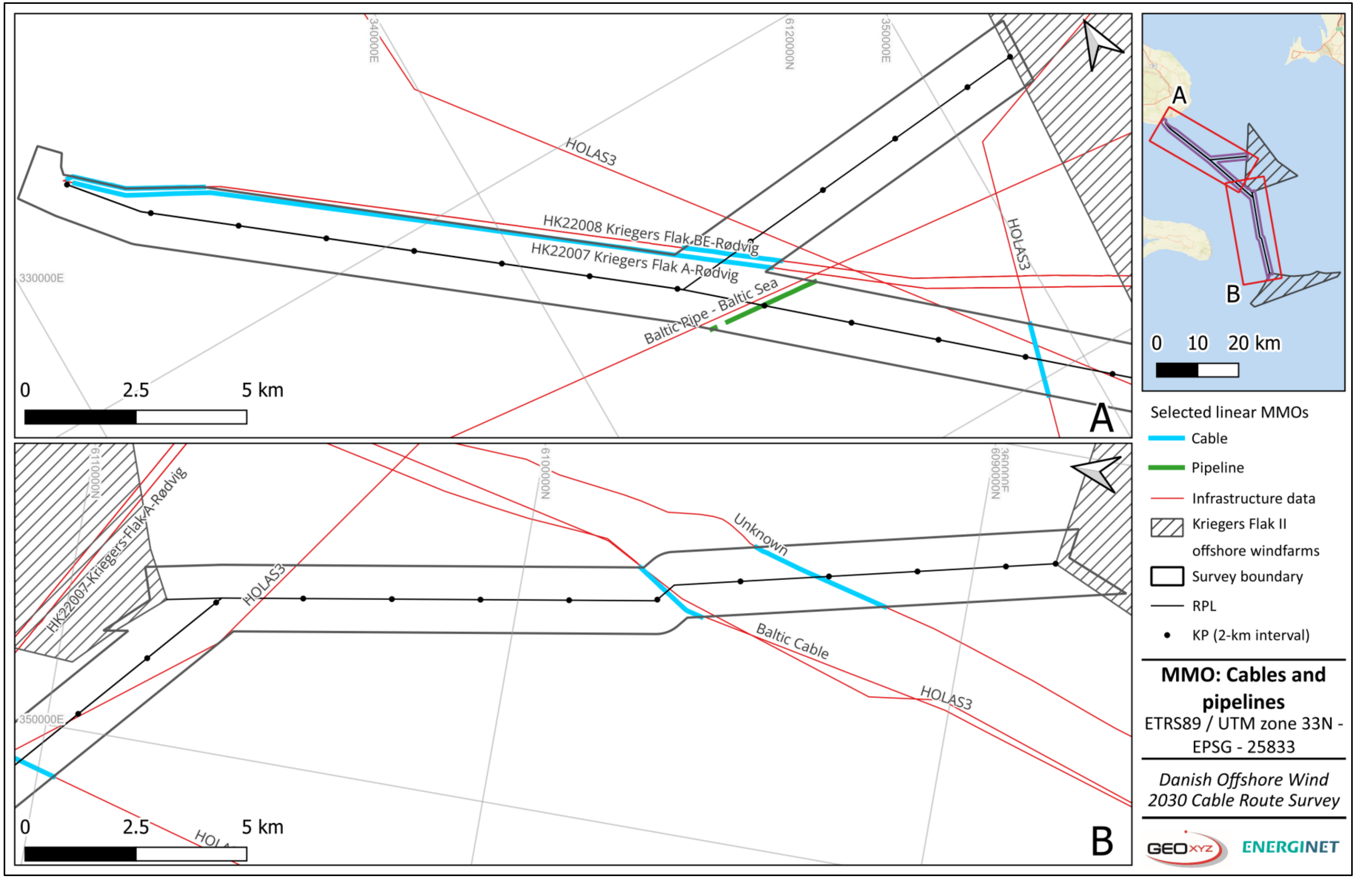


Figure 49: A comparison of as-found cables and pipelines with existing data on their locations

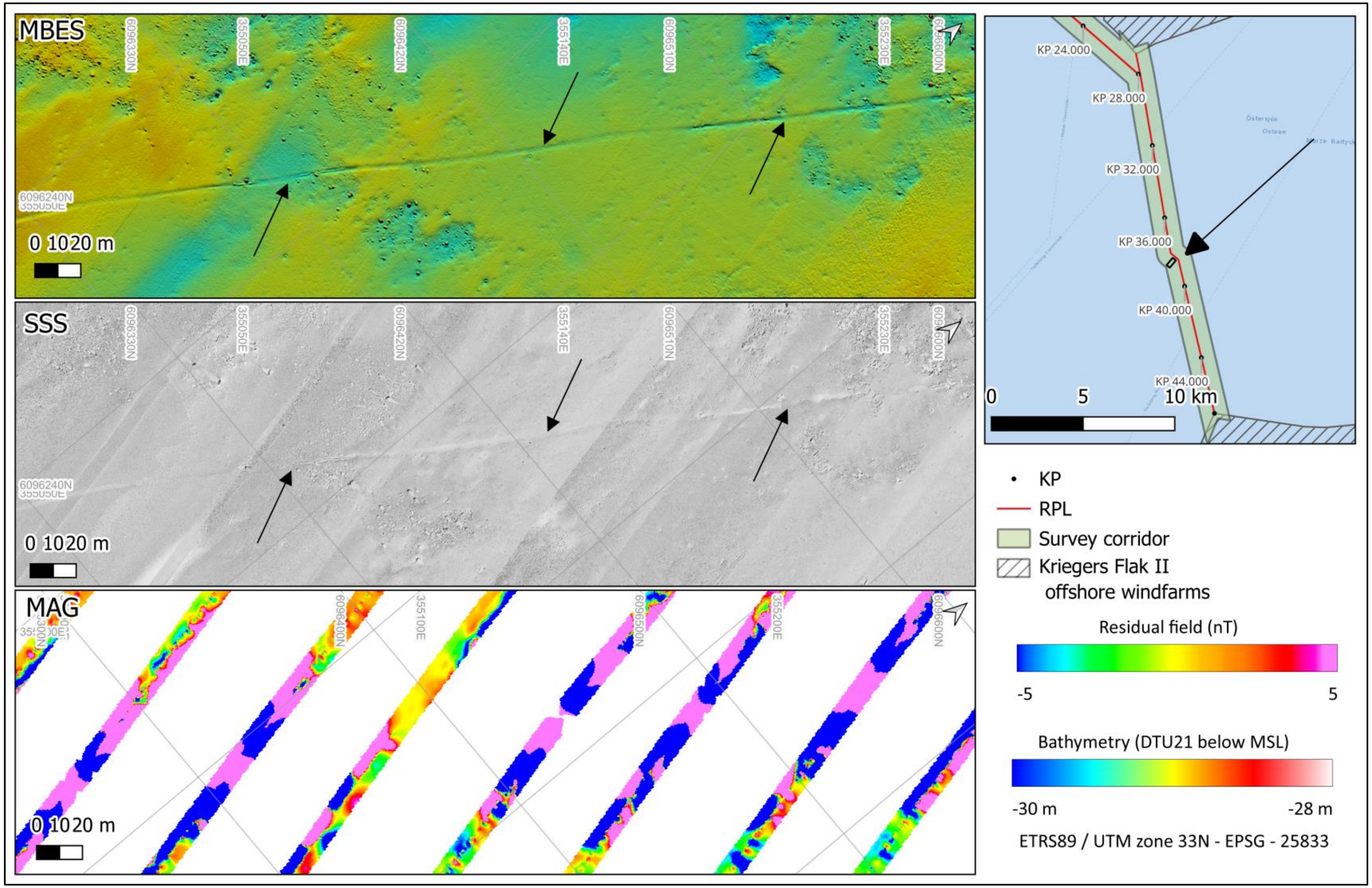


Figure 50: Segment of the Baltic cable

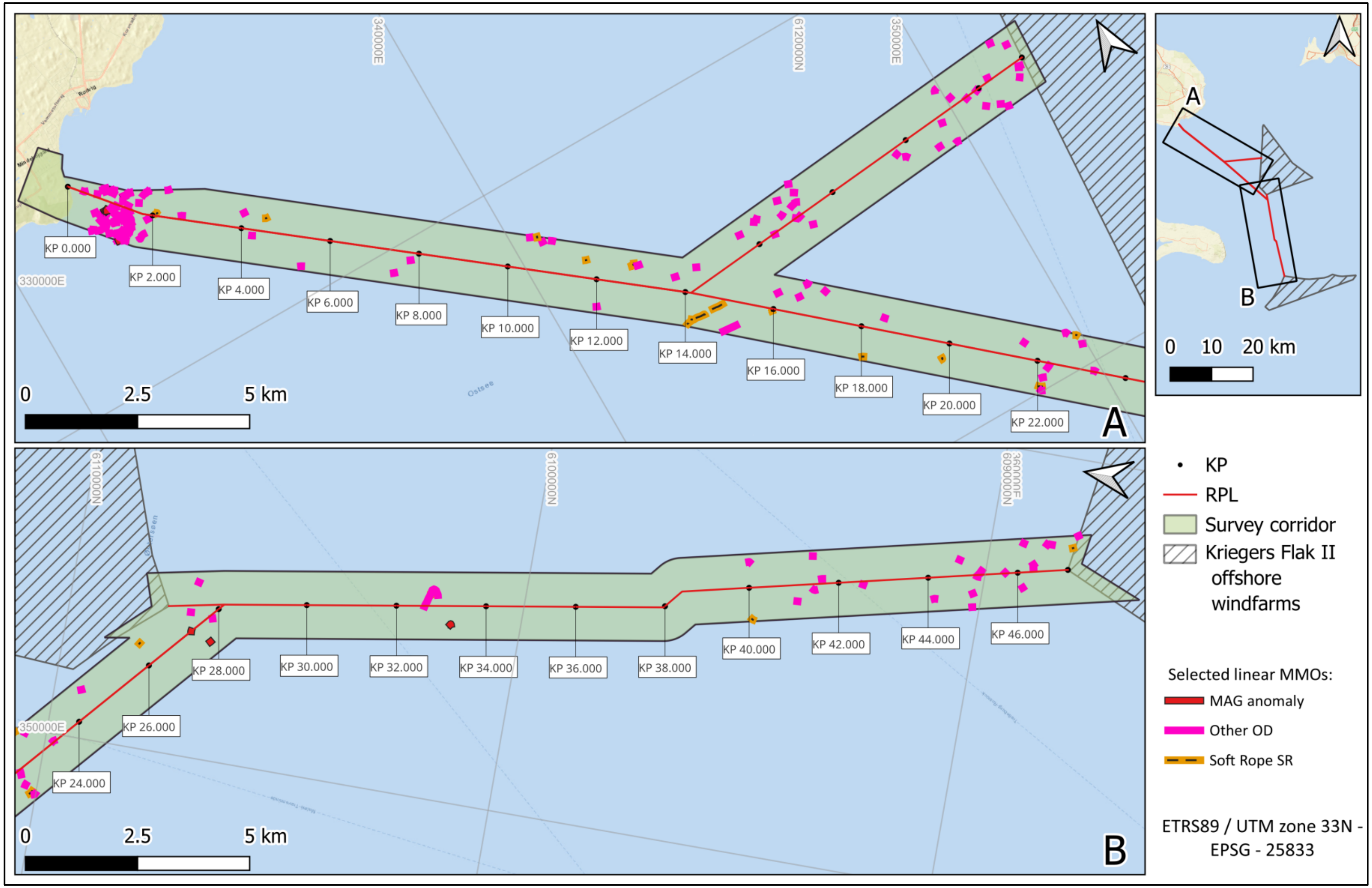


Figure 51: Overview of linear MMO found within the survey site (without cables and pipelines)

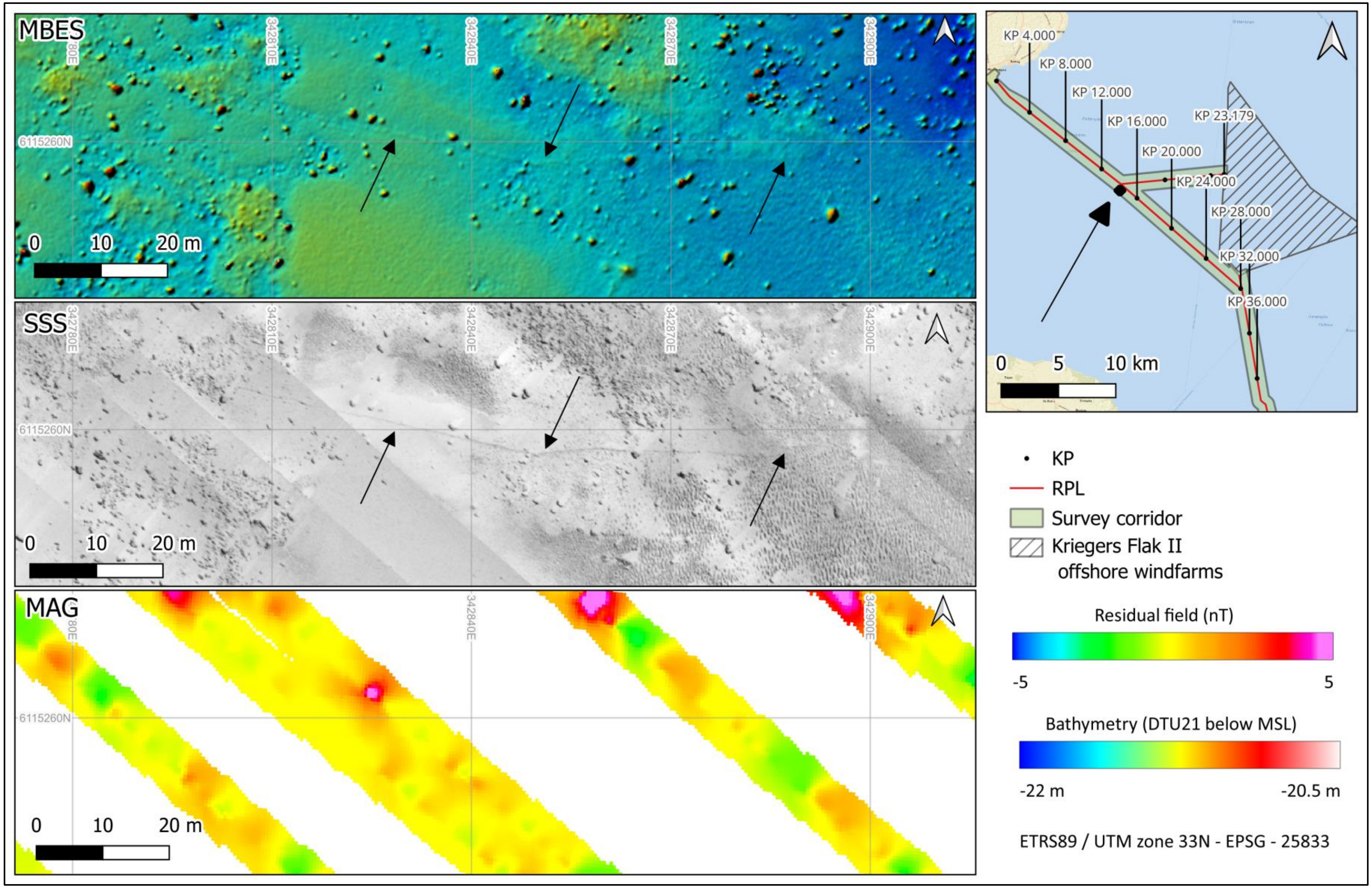


Figure 52: Example of an MMO labelled as "Soft rope" - KFII_ECR_MMO_LIN_0112

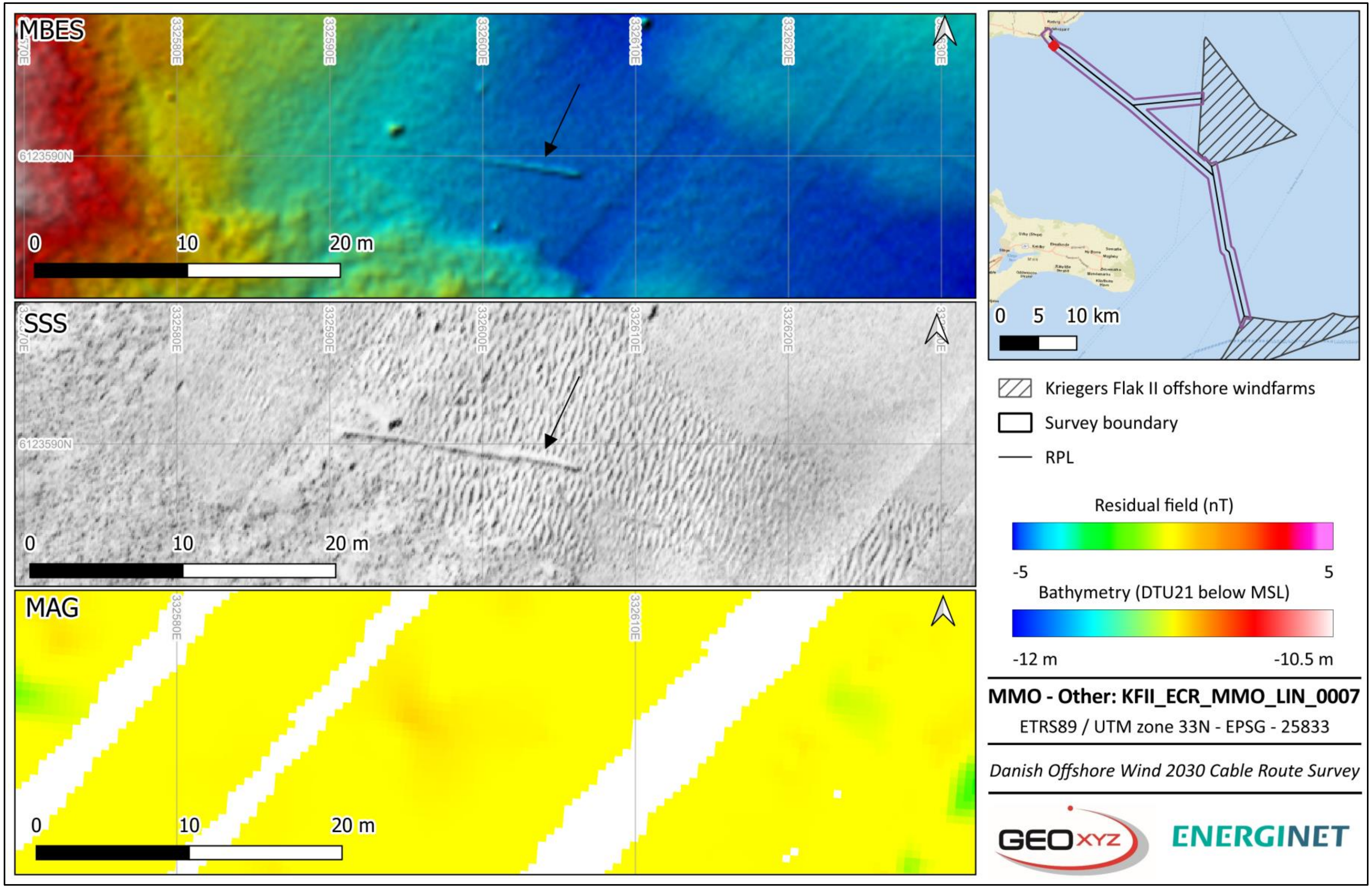


Figure 53: Example of an MMO labelled as "Other" - KFII_ECR_MMO_LIN_0007

6.5.3 Pipelines

Three linear and three point contacts are related to a single pipeline located within the survey corridor. The linear contacts, as well as the location of the cable as provided by the Client, are shown in Figure 49.

6.5.4 Debris

An object confirmed to be within a 5 metre radius of a magnetic anomaly is classified as a metallic object. A total of 1,153 metallic contacts were identified within the Kriegers Flak site, 353 of these point targets have associated SSS anomalies. These objects were either found as single entities or in clusters (Figure 54). The highest density of clusters is located in the initial, nearshore section of the cable route, spanning the entire width of the survey area within this region.

Two anchors were detected within the survey area (Figure 55). They are located between KPs 16 and 18 and both objects can be clearly seen both on MBES and SSS. However, the magnetometer survey does not identify anchor KFII_ECR_MMO_PTS_0387 as a magnetic anomaly. This is likely due to the anchor location being too far off from the survey line. The other anchor, KFII_ECR_MMO_PTS_0397, is clearly seen on the MAG residual grid.

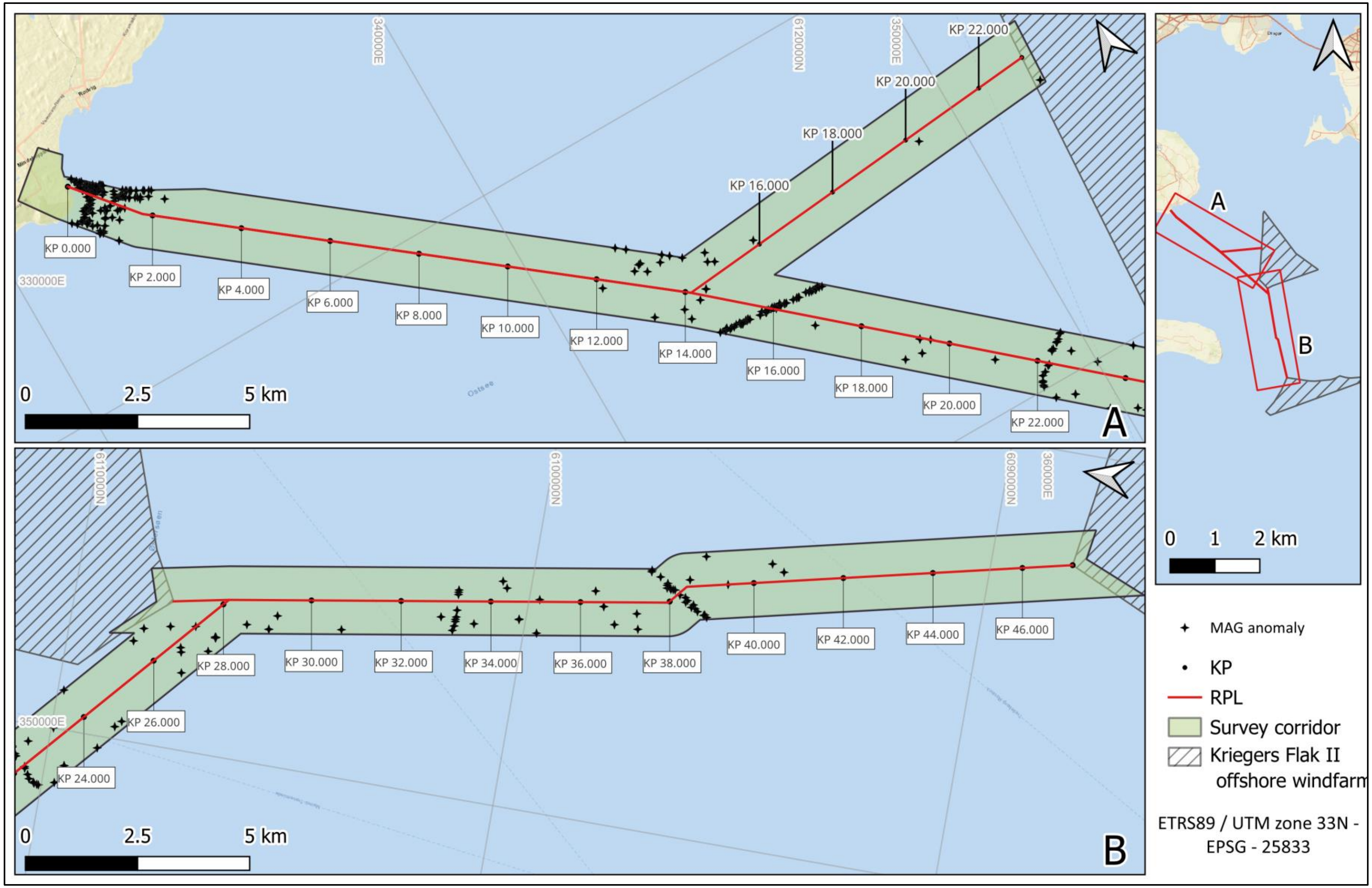


Figure 54: Distribution of MMO contacts with associated MAG anomalies

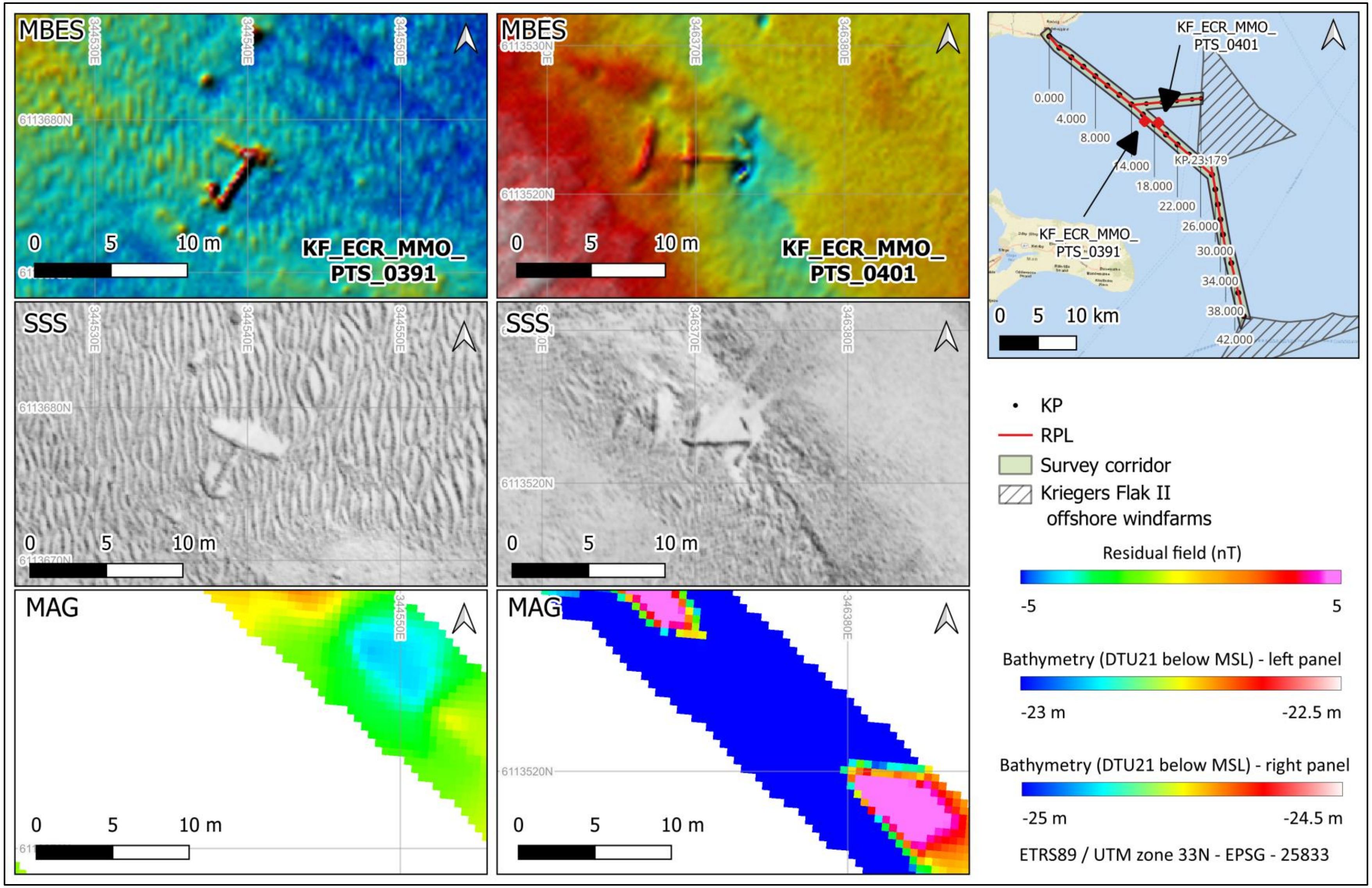


Figure 55: Anchors detected within the survey area

6.5.5 Items related to fishing activities, and seabed disturbances

All trawl marks, ropes and wires identified within the Kriegers Flak II 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 Kriegers Flak II ECR site.

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 Kriegers Flak II North and South routes.

Figure 56 and Figure 57 illustrate the locations of CPT and VC measurements, along with the achieved penetration depth.

Figure 58 to Figure 60 provide the sample analysis results for each vibrocore, including:

- Description of the soil type
- D50 percentile value
- D90 percentile value
- Bulk density
- Water content
- Thermal resistivity (TRT)

Figure 61 presents the cone resistance and friction resistance measurements for each CPT location along the route.

In Figure 62, the percentage of clay and the thermal resistivity values along the route are presented.

Figure 63 and Figure 64 show the correlation between soil type and CPT derived parameters (undrained shear strength and relative density) with the main horizons highlighted from SBP interpretation for North and South routes.

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 as Appendix C (Ref. “DOW 2030 - WPC, KF, Factual Report, Rev. 01, 2024-11-12 REPORT ”).

6.6.1 Particle size distribution and soil type analysis

NORTH ROUTE

Median values from PSD analysis (D50 in Figure 59) indicate that the shallower part of the route is predominantly composed of fine sand from GT-096 to GT-107. Clay is the most represented soil unit only below 5 m at GT-099 and GT-100, and at approximately 1 mbsb from GT-104 to GT-106. D90 values reveal that the coarser grain sizes in this area are primarily coarse sand, with gravel only observed at GT-107.

Further along the route, clay particles dominate the soil type between GT-120 and GT-127 at approximately 1 mbsb. However, in this sector, the top few centimeters of soil consist of fine to coarse sand, with traces of gravel identified at GT-126 (Figure 58).

SOUTH ROUTE

Following the portion of the route shared between the North and South segments (GT-096 to GT-107), PSD analysis reveals a dominance of clay to fine sand particles. Fine-grained sediments, primarily clay and glacial till, are found below 1 mbsb in most geotechnical locations, except between GT-128 and GT-132, where sand is predominant. Sand also dominates the shallower parts of the remaining South route.

Gravel is uncommon along this segment, with D90 values indicating its presence only in the top few centimeters at GT-131 and at approximately 1.5 mbsb at GT-143. However, medium to coarse sand is frequently observed within clay and glacial till intervals, reflecting a low degree of sorting typical of glacially influenced deposits (Figure 59).

6.6.2 Moisture content, bulk density and dry density

NORTH ROUTE

Moisture content ranging from 23% to 26% was recorded within chalk at GT-096, GT-107, GT-120, GT-121, and GT-125. These locations are also characterized by bulk density values exceeding 1.95 g/cm³ (Figure 60).

Clay and glacial till sediments encountered between GT-100 and GT-103, as well as between GT-122 and GT-124, exhibit lower moisture content values (below 20%) and bulk density values reaching or exceeding 2.0 g/cm³. In contrast, the sand-dominated VCs recovered between GT-097 and GT-099, and between GT-104 and GT-106, show moisture content ranging from 23% to 28% and bulk density values generally below 1.90 g/cm³ (Figure 60).

SOUTH ROUTE

In the North Route sector not shared with the South Route (e.g., after GT-107), clay-dominated glacial till sediments between GT-108 and GT-119 exhibit relatively low moisture content (17%–25%) and high bulk density (above 2 g/cm³). Similar moisture content and bulk density values were recorded in clay sediments between GT-128 and GT-137, indicating a high degree of soil consolidation.

For sand-dominated sediments, moisture content was measured between 18% and 25%, while bulk density varied between 1.8 and 2.0 g/cm³, reflecting differences in compaction and grain size distribution. Correlation between derived CPT parameters, soil types and geophysical units

6.6.3 Thermal resistivity from TRT measurements

Thermal resistivity measurements from TRT conducted at 15 geotechnical stations (GT_097, GT_099, GT_100, GT_100a, and GT_103, GT_111, GT_113, GT_117, GT_123, GT_128a, GT_132a, GT_134a, GT_138, GT_142, and GT_144) illustrate the thermal response of different soil types encountered along the RPL, with values ranging from 0.2 to over 1.4 mK/W. Additional resistivity values were taken as discrete samples from selected vibrocore core samples. The lowest thermal resistivity values (<0.3 mK/W) were recorded at GT_103 and GT_117, which showed medium to coarse gravelly SAND, and on GT_123 within TILL composed of sandy gravelly CLAY. The over-consolidated nature of the tills maybe be acting to reduce overall thermal resistivity in conjunctions with the present of coarse material. Unexpectly however, two other locations; GT_132a and GT_142, also showed low thermal resistivity values (<0.3 mK/W), but are logged to be composed of organic rich SAND/CLAY. Organic material has generally been associated with higher resistivities, making these results anomalous. The highest thermal resistivity values (>1 mK/W) were recorded within organic soils, on GT_098a where a thermal resistivity of 1.45 mK/W was recorded within PEAT, GT_129 where a thermal resistivity of 1.25 mK/W was recorded within GYTTJA. High thermal resistivities on GT_134a around 1 mK/W were also recorded, however these results lay within a thickness of CLAY TILL with sand gravel, similar in description to the TILL identified on the low resistivity readings on GT_123, discussed previously. This conflict between sediment descriptions and recorded thermal resistivities within the TILL, indicate high variable soil conditions within the TILL present on the site.

Generally, the near surface (<1 m below seabed) TRT and lab resistivity showed low resistivity (<0.5 mK/W) in the near surface due to the sandy and loose nature of the upper post glacial sediments. Exceptions to this generalization include; GT_096 where CHALK has been penetrated into with a thermal resistivity of 0.7 mK/W recorded at 0.8 m, and the previously discussed GYTTJA present at the seabed on GT_129, and the shallow CLAY TILL identified on GT_134a with a maximum resistivity of 1.03 mK/W. Increases in resistivity then generally occurred at depths >1 m or where post glacial sediments were thin, where clays and more compacted soils were present in the subsurface.

All in-situ and lab thermal testing have been plotted on the 3 km profile panels presented in the route analysis section.

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

NORTH ROUTE

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 (Figure 63).

Cone resistance (Qc) values generally remain below 0.15 MPa within the shallowest meter of the entire North route. However, values exceeding 50 MPa were measured below 3 m at GT-100 and at approximately 1.5 mbsb at GT-103 and GT-104. Regarding friction ratio (Fs), recordings along the geotechnical locations of the entire route are mostly below 0.25 MPa, though localized high friction values were observed at 3 m at GT-105 and below 2 m at GT-123 and GT-124. Comparison of VC data, CPT-derived parameters, and SBP interpretations indicates that high Qc and Fs values recorded below Horizon H20 are associated with glacial Unit III (Figure 63) (see Section 6.7).

The VC collected at GT-096 recovered a thin bed of clay overlying chalk. The mapping of main horizons in the SBP data, combined with the rough seafloor morphology in this area, suggests minimal soil coverage overlying the chalk in this shallower part of the route (Figure 63).

Horizon H05 extends from GT-097 to GT-105 and from GT-121 to GT-126. This horizon typically marks the base of a loose sand layer, up to 2 m thick, composed of fine to coarse sand with low silt content. These sands correspond to post-glacial Unit I (see Section 6.7). The maximum thickness of Unit I is recorded at GT-100, where silty sand with higher silt content was measured in the VC sample. At GT-124, Unit I is capped by a thin bed of clay.

Below H05, Horizon H10 is observed between GT-098 and GT-104, at GT-121, and between GT-123 and GT-124. H10 represents a sub-differentiation within post glacial/periglacial soils (see Section 6.7). Between GT-098 and GT-101, H10 is located within fine to coarse sand and marks a sudden increase in density, transitioning from loose to very dense. However, at GT-102 and GT-103, the clean sand overlying H10 is already very dense, and no significant density change is observed. At GT-123 and GT-124, H10 separates very dense sand (above) from extremely high undrained shear strength clay-dominated till (below).

Horizon H20 represents the lower boundary of Unit II (see Section 6.7) and has been identified between GT-097 and GT-102, as well as between GT-121 and GT-126. At GT-097 and between GT-101 and GT-102, H20 marks the transition from very dense sand of Unit I to extremely high-strength glacial till. Between GT-098 and GT-100, clay was recovered below H20. In the deeper part of the route, from GT-121 to GT-126, H20 is primarily associated with extremely high-strength clayey glacial till, except at GT-125, where chalk was recovered below the horizon.

No main horizons were identified between GT-106 and GT-121, a section characterized by rough seafloor morphology. At GT-106, a medium bed of till was recovered overlying very dense silty sand and capped by a thin bed of clay. VC samples collected at GT-107 and GT-108 revealed chalk, suggesting minimal overlying sediment cover in this area (Figure 63).

SOUTH ROUTE

The Kriegers Flak II South Route diverges from the North Route at GT-108. The remaining portion of the route alternates between areas where glacial till associated with Unit III is exposed at the seafloor—evidenced by irregularities in MBES data—and sections where post-glacial Unit I and periglacial Unit II sediments are present (Figure 64) (see Section 6.7). Areas with exposed glacial till, or topped by a thin bed (<0.5 m) of low-strength clay or loose sand, are observed between GT-108 and GT-110, GT-115 and GT-116, GT-119, GT-133 and GT-137 (where Unit III consists of very dense silty fine sand), GT-139 and GT-141, and from GT-147 to GT-148 (where Unit III comprises very dense fine to medium clean sand).

Between GT-111 and GT-114, a relatively thin (up to 90 cm) coverage of periglacial and post-glacial sediments (Unit I and Unit II) is present as loose silty sand. Similarly, between GT-117 and GT-118, at GT-128, and between GT-129 and GT-131, silty sand alternates with low to medium strength clay. The shallow VC penetration at these geotechnical stations, which never exceeds 1 m, suggests the presence of consolidated glacial soils beneath this soft sediment coverage.

In contrast, at GT-137 and GT-138, VC penetrated nearly 6 m into the seafloor, recovering continuous low- to medium-strength clay and dense silty sand, respectively. SBP interpretations indicate a sharp deepening of Horizon H05 in this area, suggesting the presence of an infilled channel feature.

Between GT-141 and GT-147, Horizons H05, H10, and H20 were all identified. Unit I, marked at its base by H05, consists of a thin loose sand layer, exceeding 1 m in thickness only at GT-146, where a dune-like feature is observed. Below H05, Unit II, bounded at its base by H20, comprises high- to very-high undrained shear strength clay. An exception is noted at GT-146, where a clay layer is bounded at its base by H10, below which silty sand is present (Figure 64).

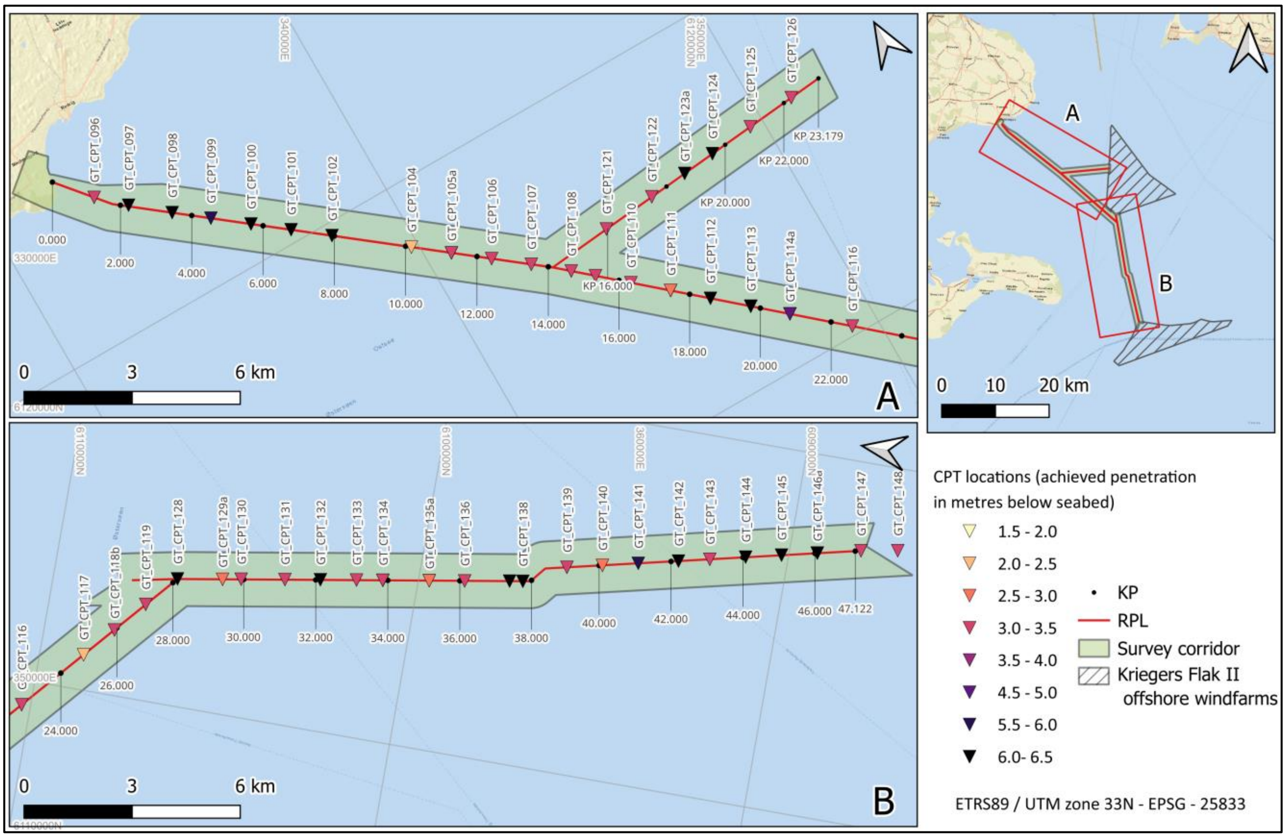


Figure 56: CPT locations overview with achieved depths below seabed

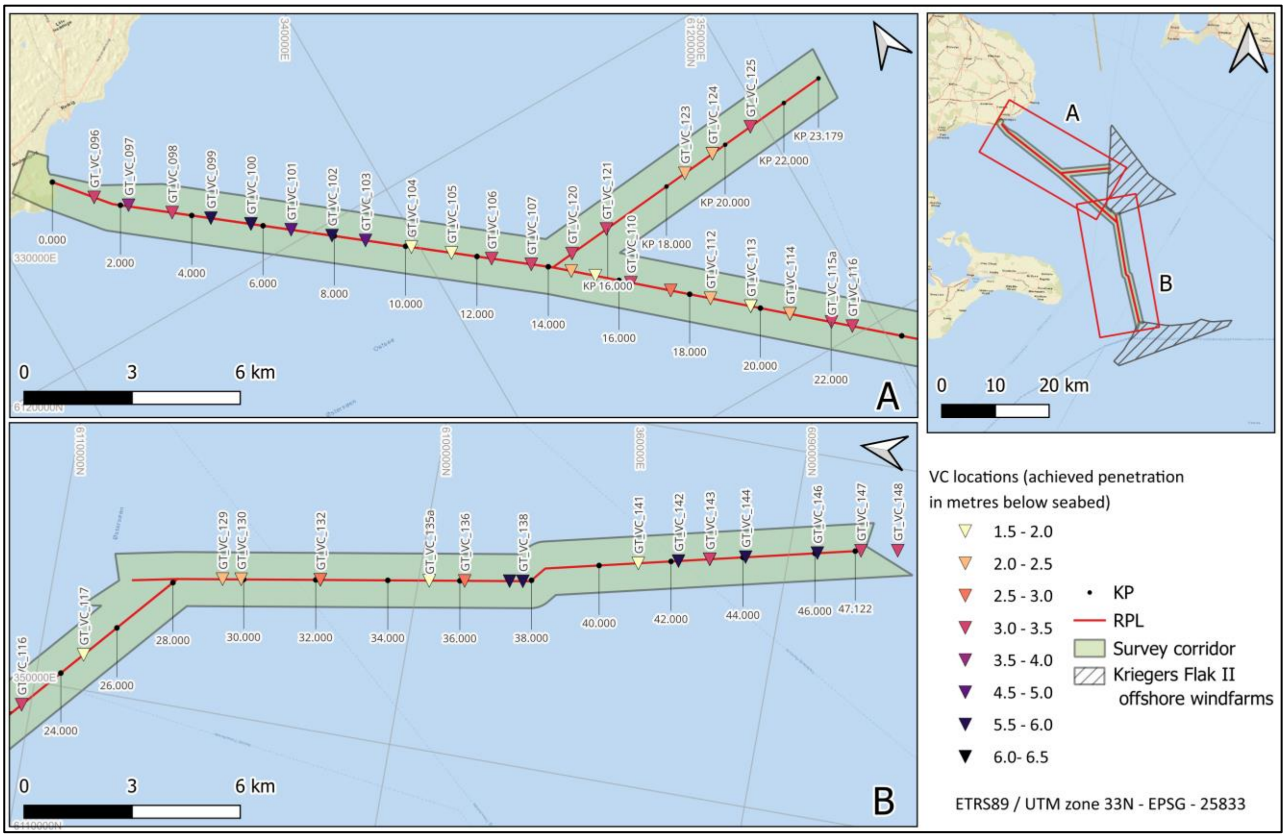


Figure 57: VC locations overview with achieved depths below seabed

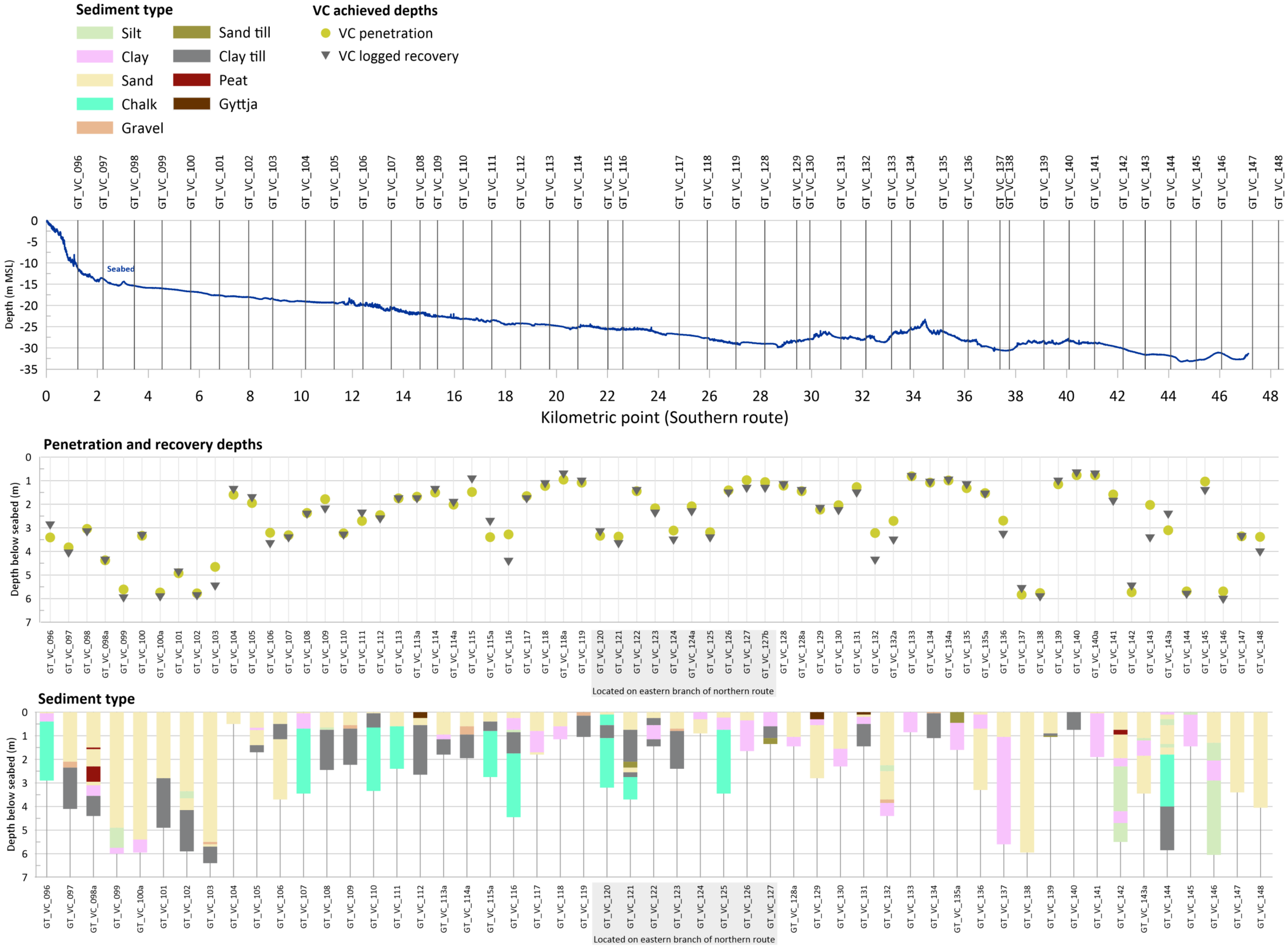


Figure 58: Sample analysis: Achieved depths and soil type distribution

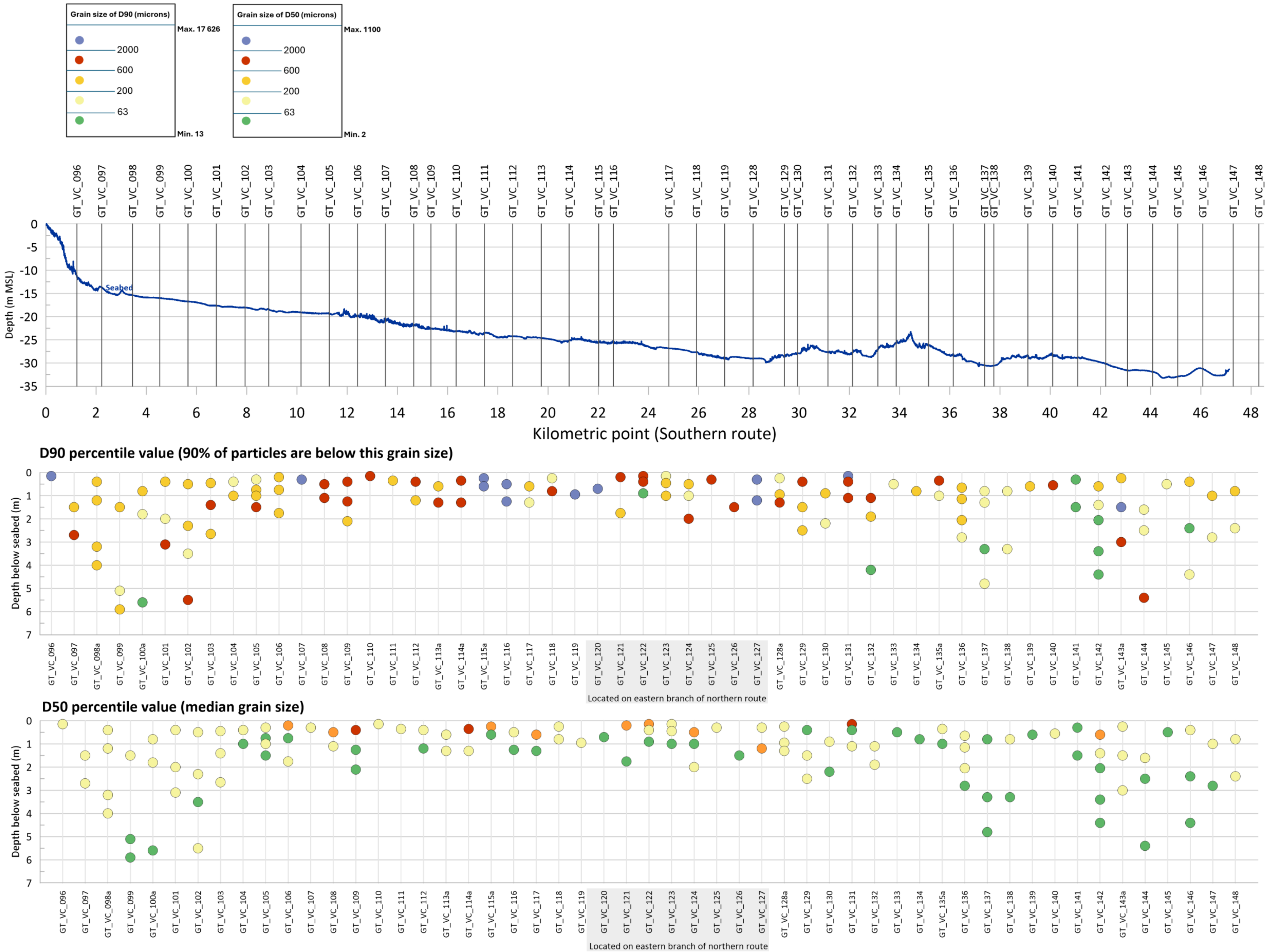


Figure 59: Sample analysis: D50 and D90 grain size diameters

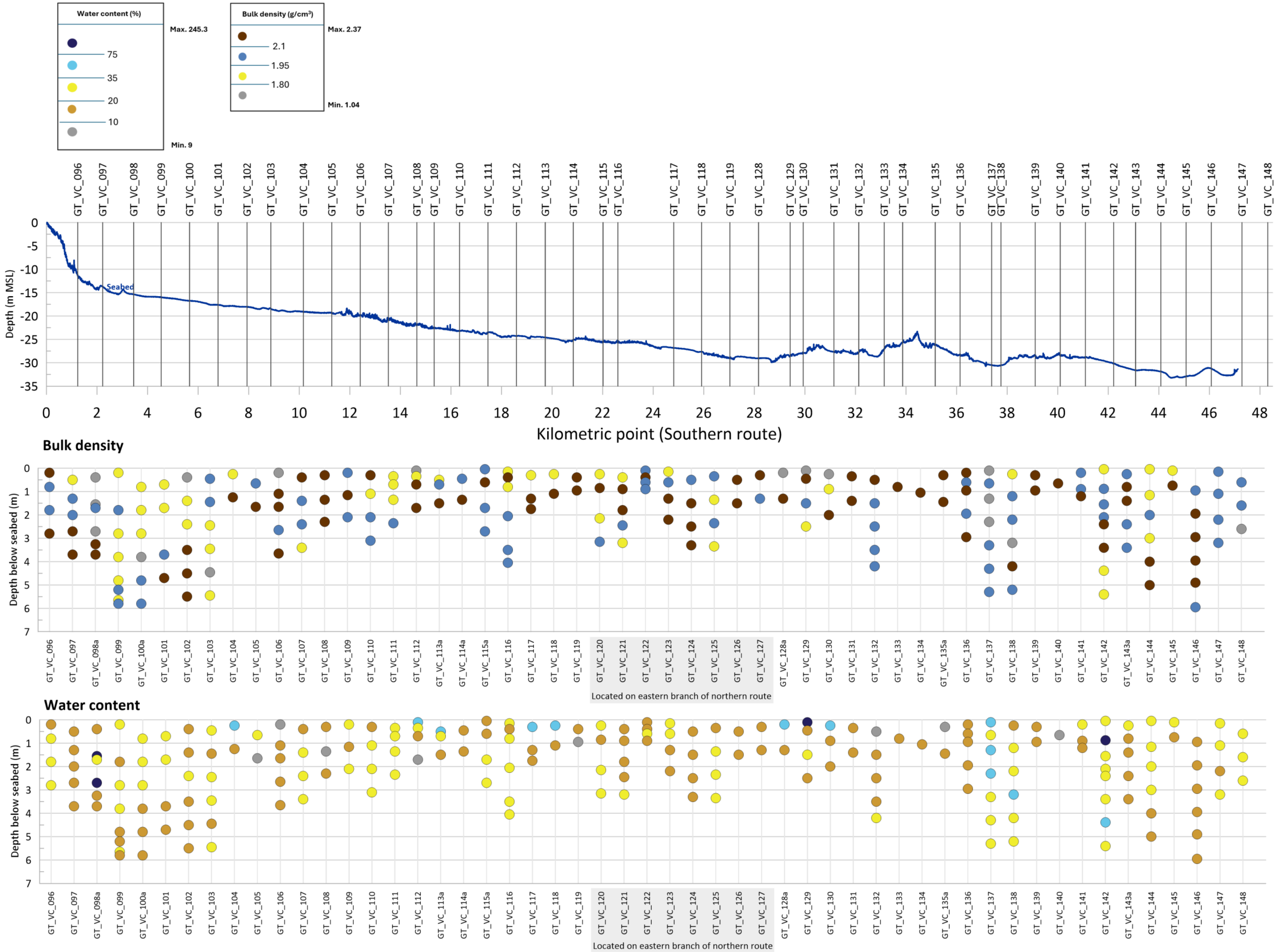


Figure 60: Sample analysis: Bulk density (g/cm³) and water content (%)

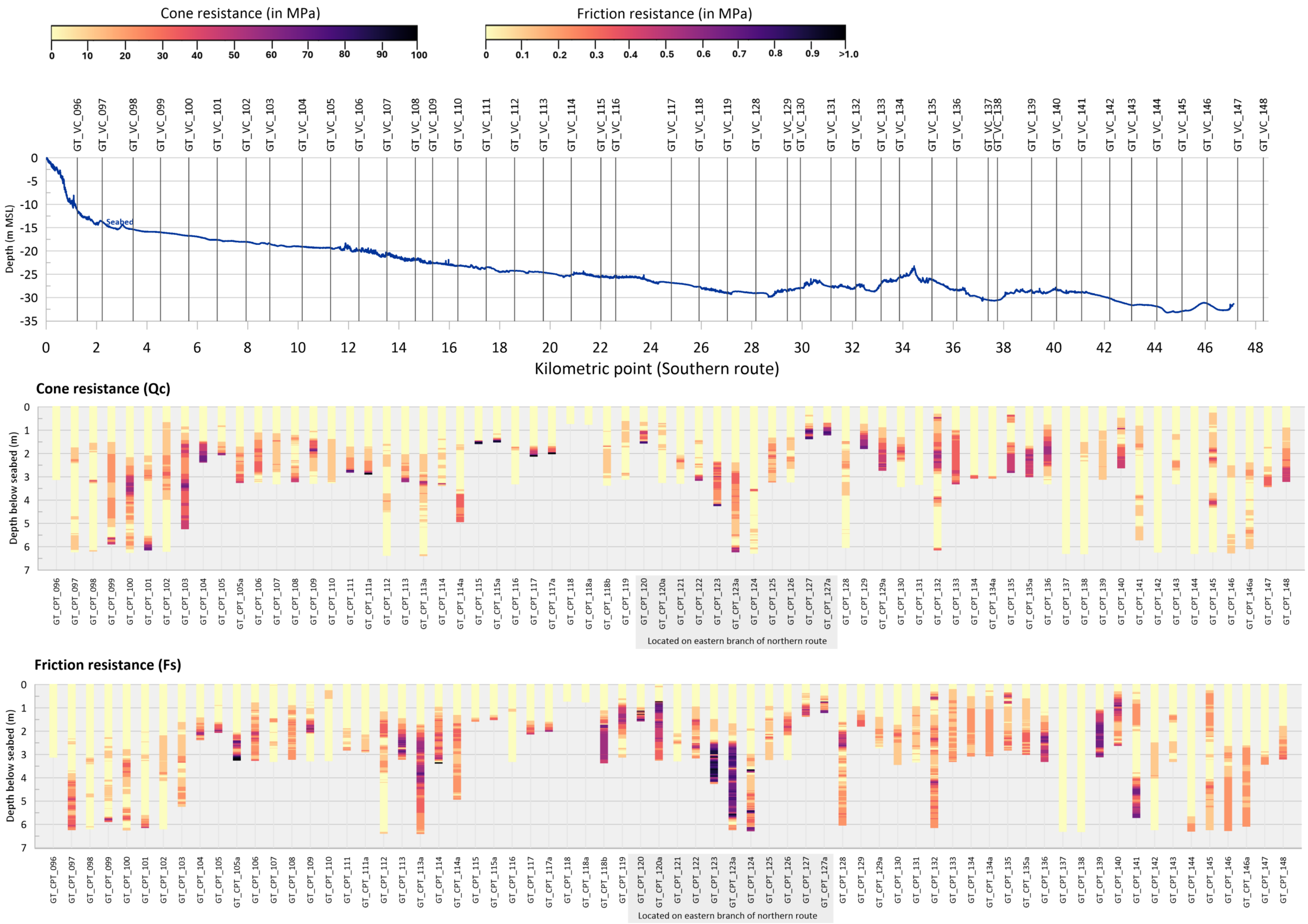


Figure 61: Sample analysis: Cone resistance and friction resistance in MPa

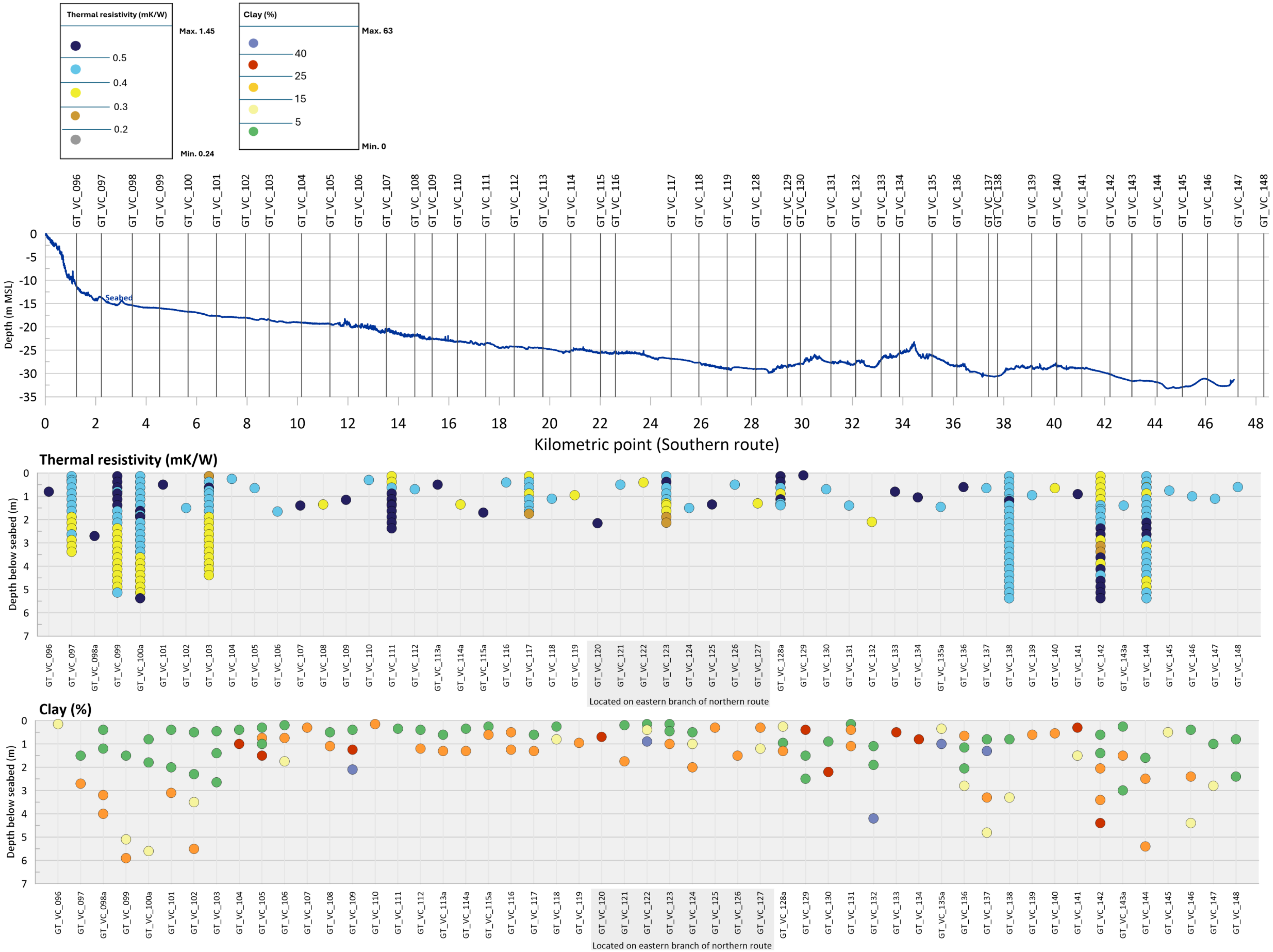


Figure 62: Sample analysis presenting clay (%) and thermal resistivity

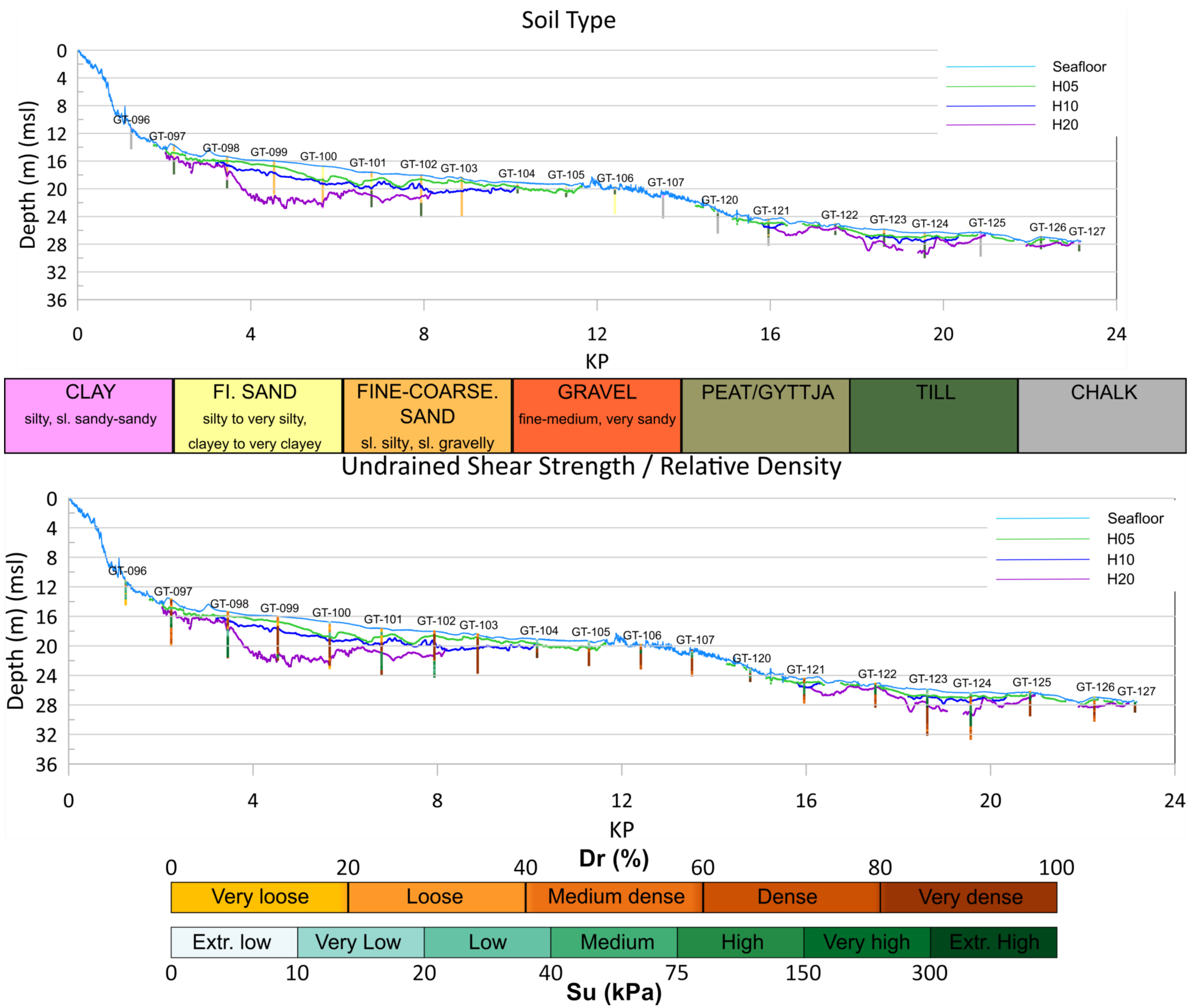


Figure 63: Soil types derived from VC and CPT data (top) and CPT parameters (bottom) compared with key horizons from SBP interpretation along Kriegers Flak II – North Route

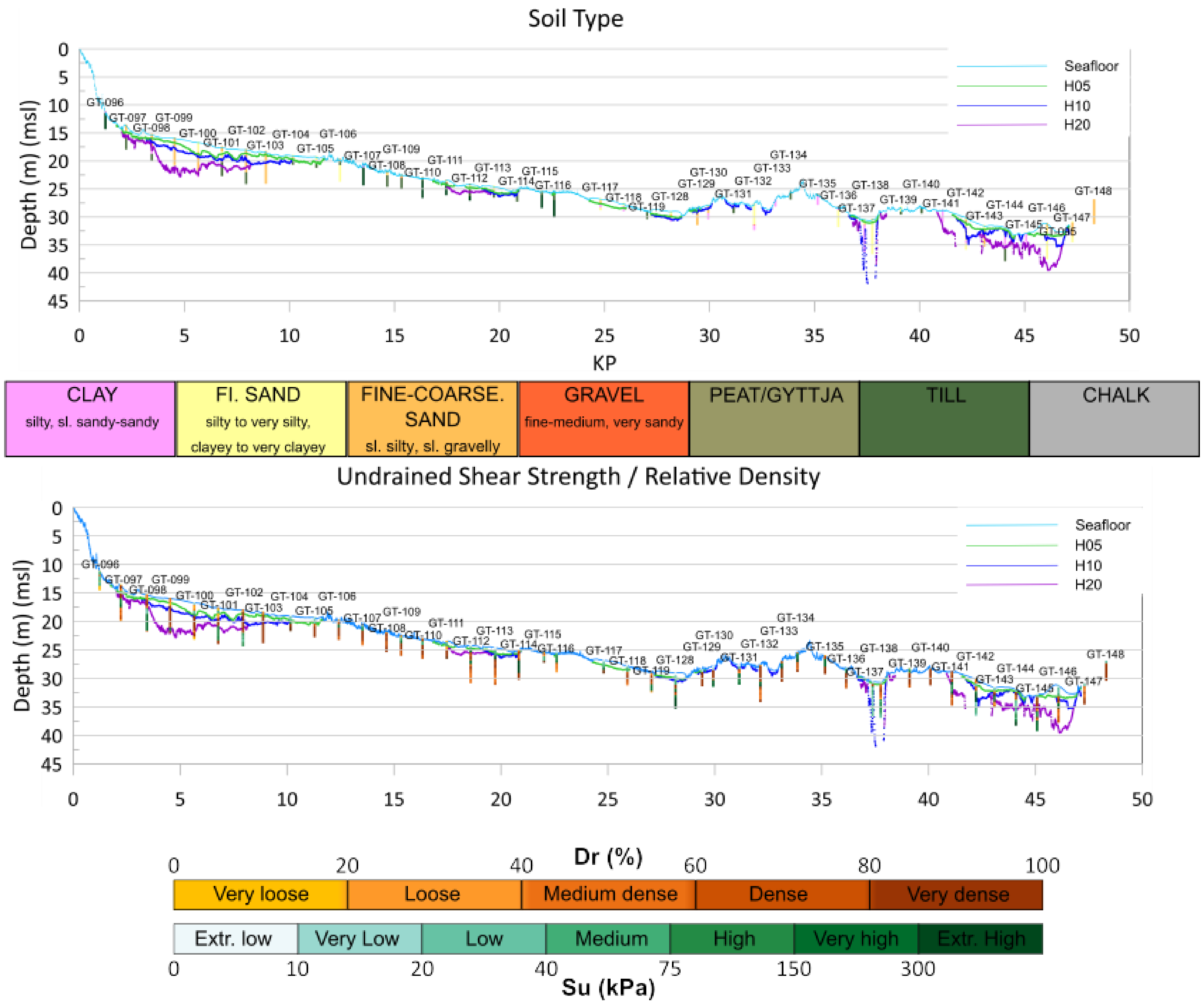


Figure 64: Soil types derived from VC and CPT data (top) and CPT parameters (bottom) compared with key horizons from SBP interpretation along Kriegers Flak II – South Route

6.7 SUB-SURFACE GEOLOGY

6.7.1 Regional geological history

The geological interpretation along the proposed ECR route is based upon the geophysical and geotechnical datasets acquired with reference to the supplied GEUS desk study, and the adjacent windfarm survey results. The desk study applies a stratigraphic model developed by Jensen et al. (2002) in conjunction with archive seismic data and limited ground truth information. In general, there is a good correspondence between shallow geology imaged in this project's sub-seabed data and the desk study. In addition to the DTS, reports for the OWF have been considered (GEOxyz, 2024), to aid interpretation of observed horizons.

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 ECR 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 Kriegers Flak export cable route, the following units have been defined. The interpretation has been done based on both the seismic acoustic nature of the SBP data, the adjoining Kriegers Flak offshore windfarm survey results and report and the GEUS desk study. Geotechnical data, acquired by GeoDK were made available later, and were integrated with the geophysical data. The geotechnical data confirmed the age and depositional environments of the sediments. Table 69 summarises the interpretation, geological units and depositional environments below.

Table 69: Shallow geological units

Unit	Upper surface	Lower surface	Main Soil Description	Depositional Environment
I, Post glacial (PG)	Seabed	H05	Fine to medium SAND	Post-glacial marine
Ia, Post glacial (PG)	Seabed/H05	H10	Coarse to medium SAND, with occasional CLAY beds. Locally organics such as PEAT and GYTTJA present	Post-glacial freshwater
II, Late Glacial (LG)	Seabed/H05/H10	H20	Variable, includes intervals of laminated CLAY and SAND-prone packages	Periglacial, glaciomarine
III, Glacial (GL)	H05/H10/H20		Variable, TILL, CLAY-prone, locally overconsolidated	Glacial with localised direct ice contact

6.7.3 Stratigraphy and general arrangement of units

Figure 65 shows the arrangement of units along the proposed Kriegers Flak II ECR. Table 69 shows the basic characteristics of the stratigraphic units. Key surfaces are bases of Post Glacial - Marine (H05) and Post Glacial

– Freshwater (H10), and the top of Unit III (H20/H05/seabed) which is the top of potentially overconsolidated deposits. Sediments within Units I and II are less well consolidated, with fewer cobbles and boulders present compared to Unit III.

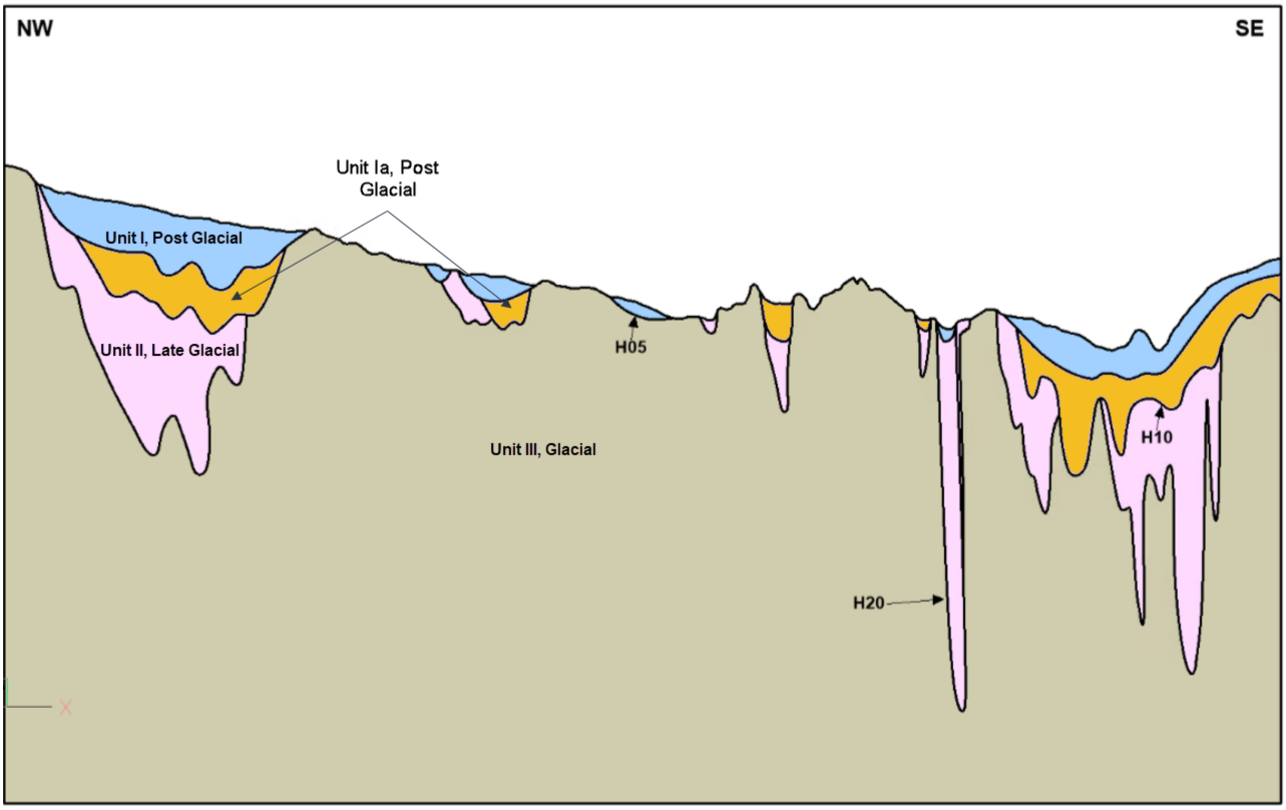


Figure 65: Geological schematic, general arrangement of units

6.7.4 Quaternary 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 evolution to a marine environment.**

a Post Glacial geology

Post glacial geology is interpreted to comprise of two phases; an initial freshwater, likely fluvial, deposition environment, followed by a marine phase, representing the most recent deposits observed.

Unit I is a package of post-glacial fine to medium SAND which is less than 1.5 m thick over large parts of the route, with a maximum thickness of 3 m BSB around KP 46.000 of the southern route. The interval includes a veneer of sandier seabed sediments, though this is interpreted to be very thin and seldom resolved in the SBP data. A veneer may also be present and interpreted from the side scan sonar data where the reflector is within the seabed pulse/ not distinguishable.

These post glacial marine sediments are widely distributed over the cable route corridor (Figure 66). Geotechnical locations 100 and 113, among others, sample this with up to 1 m of finer grained sediments (Figure 68). The post glacial sediments are very thin or absent (unmapped) in much of the nearshore section, from KP 0.000 to KP 1.400, with only small areas with greater than 0.5 m of post-glacial sediments although small pockets may occur in these areas and a < 0.2 m thick seabed veneer may still be present.

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 of the post glacial marine deposits is mapped as H05. Over broad areas, where the unit is thin, it is interpreted to be a mild erosion surface – thickness variations are due to relief at this surface. There are very occasional bright spots which may possibly be organic material, however these are discontinuous and usually very spatially limited.

Unit Ia has been interpreted beneath the marine phase by the reflector H10, which possibly represents the pre-transgressive and transgressive phases of the progression to the overlying marine environment. Within the SBP data this presents as much higher amplitude reflections with well-defined structures including paleochannels and strong internal bedding (Figure 68). This interpreted horizon in SBP data appears to correlate with the presence of organics, including occasional peat layers and plant material.

The interpretation of this unit does produce conflicts with the geotechnical interpretation of soils, as this unit is classified as either deeper deposits of post glacial marine or part of the underlying late glacial units. The unit has been interpreted based on a significant change in acoustic character from the overlying and underlying soils, coupled with the presence of organic material typical of a freshwater or brackish depositional environment. However, it is pertinent to note that some marine shells have been identified in the vibrocoring in layers that have been interpreted as Unit Ia.

This conflict is exacerbated by the presence of numerous strong internal reflectors present with the SBP data where Unit Ia is interpreted, which could possibly mark the boundaries of change from the late glacial phase across the epoch boundary to the post glacial acting as a layer of transition from late glacial to the current marine regime. This complexity was not interpretable on the SBP data and hence the Unit Ia may straddle the epochs and depositional environment.

However, this unit does generally have a similar composition (where interpreted as variable SAND), to the more conformal fine to medium SAND of the overlying marine soils, and the presence of PEAT and GYTTJA, and occasional thin clay and gravel beds. Localised areas also have finer sediments in places. Hence the interpretation of Unit Ia serves as a practical grouping to represent the unit observed, where it has not been possible to subdivide these further.

The thickness and spatial extent of this unit is presented in Figure 67, showing a wide distribution where TILL is not exposed or near the seabed. The largest thickness of interpreted Unit Ia is a channel feature between KP 37.000 and KP 38.000, reaching a thickness of 14 m. This large thickness is classified as post glacial marine on the geotechnical results (VC_138), but contains substantial plant and organic material atypical of a marine environment, an example of this channel is presented in Figure 96.

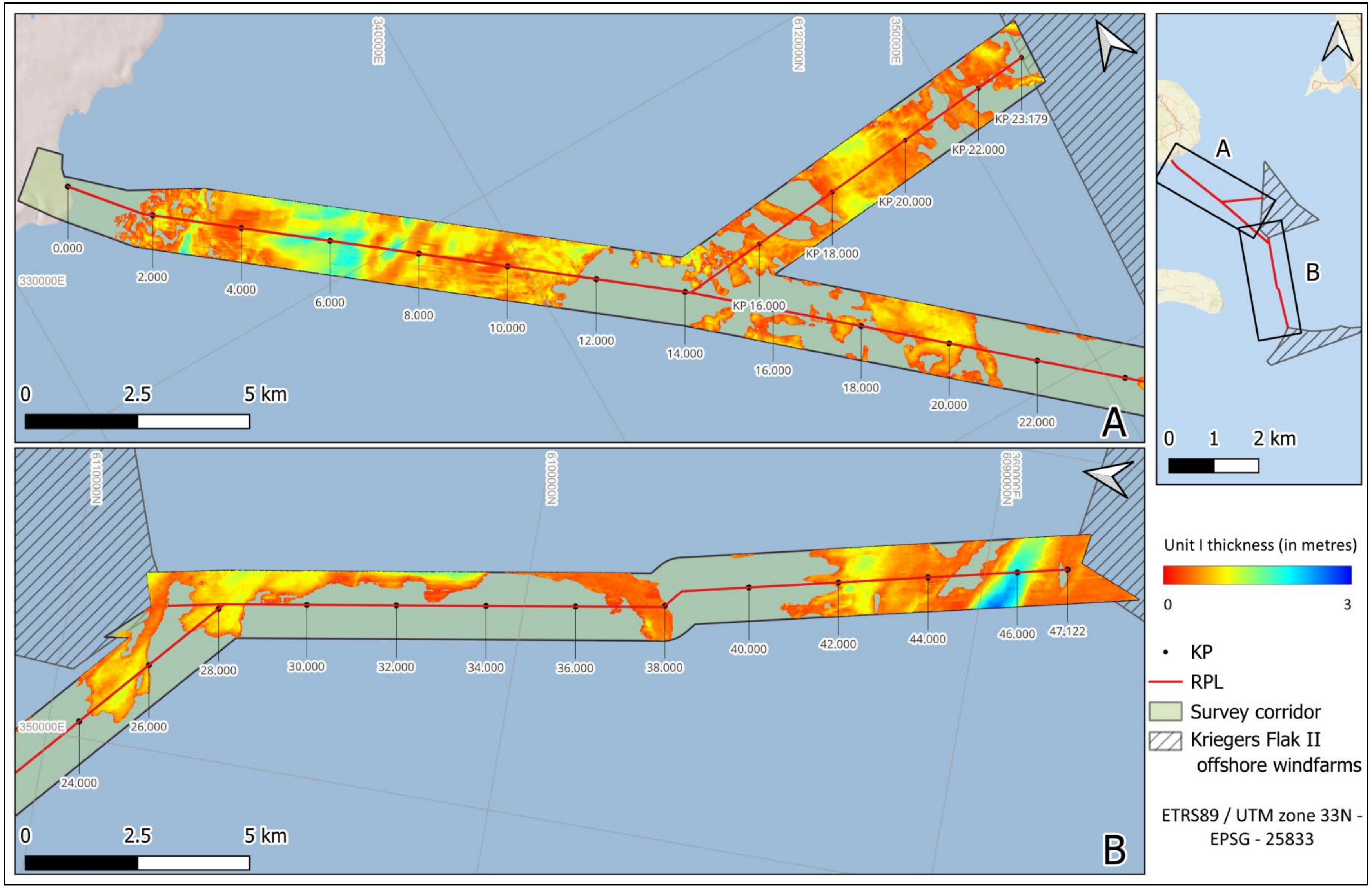


Figure 66: Illustrating extent and thickness of Unit I

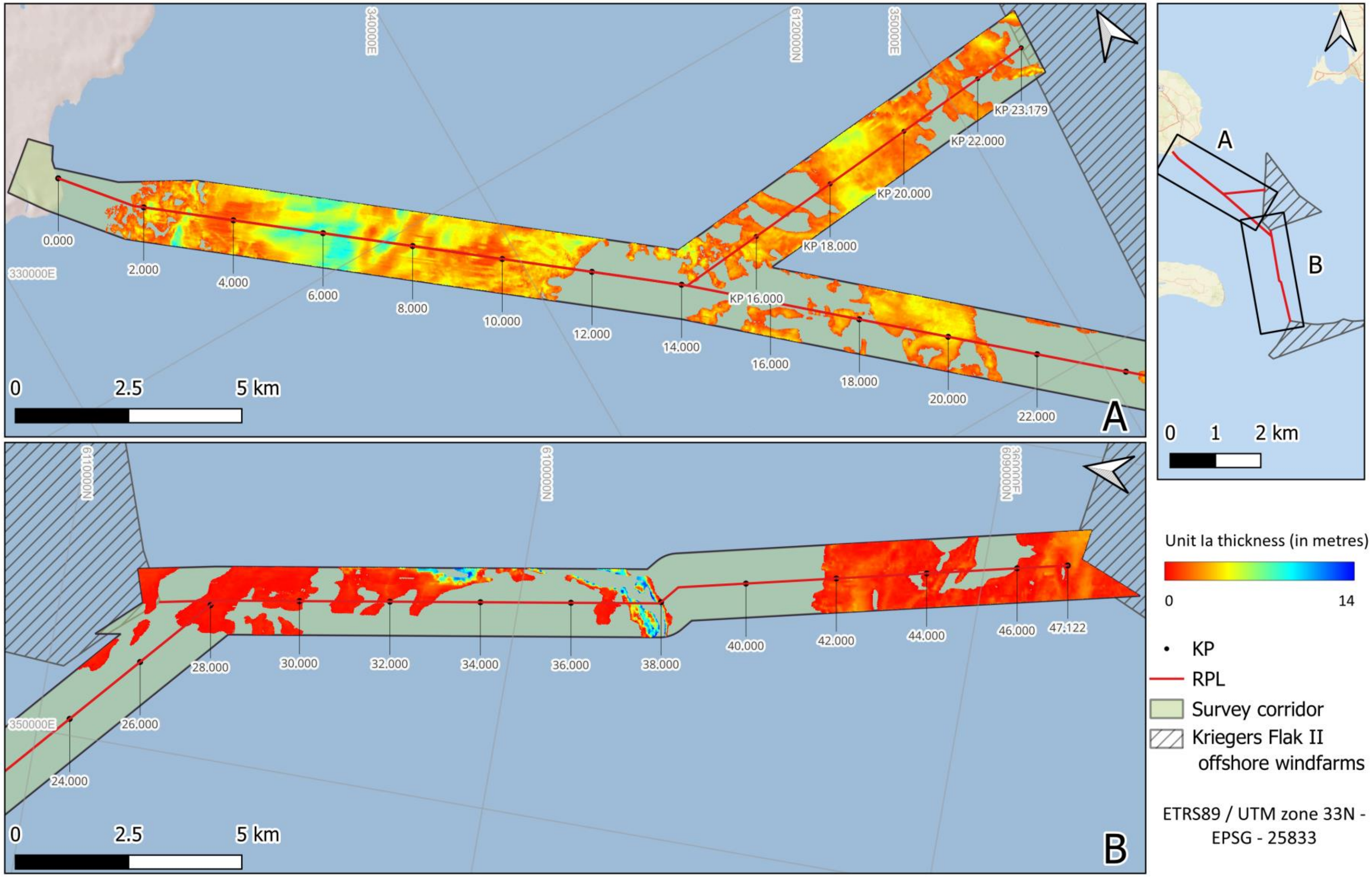


Figure 67: Unit Ia thickness – version 1

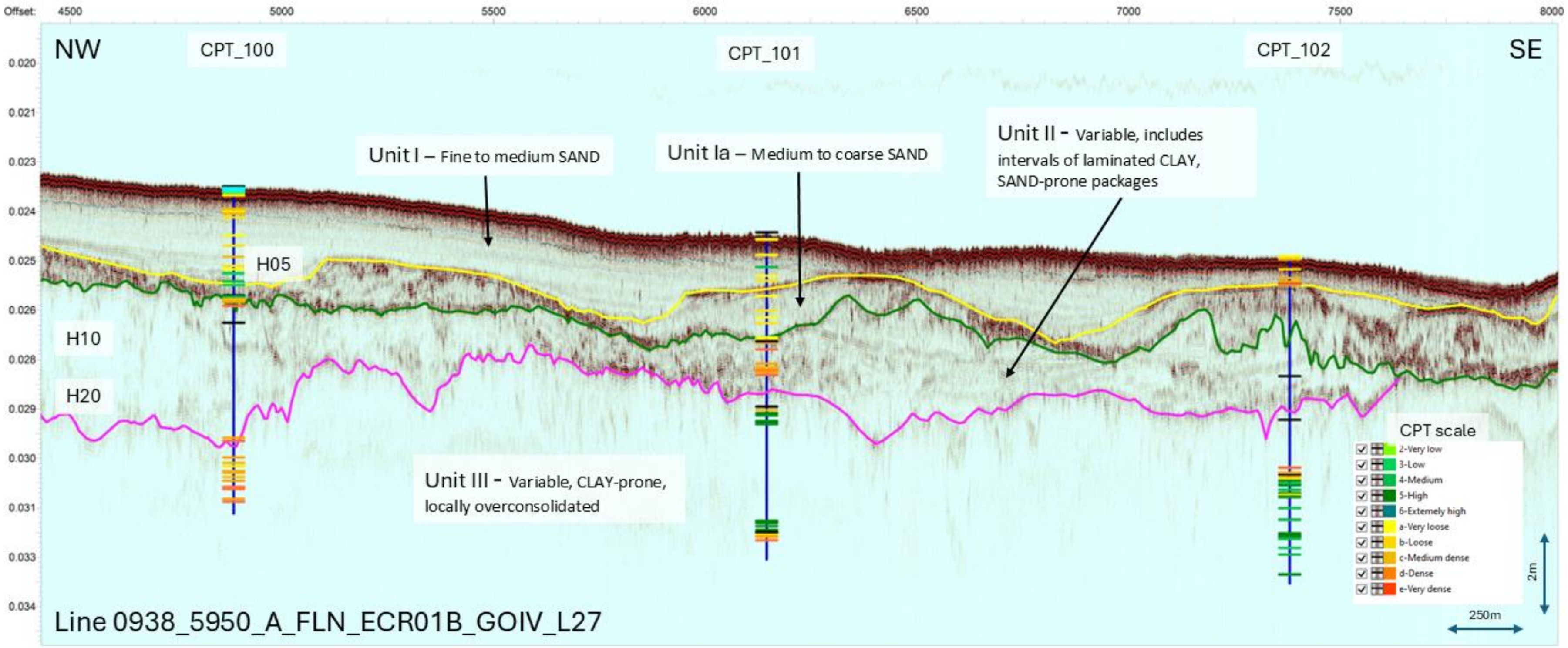


Figure 68: Illustrating Unit I and Unit Ia typical structure and arrangement

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. A layer of coarser materials has also been identified within the geotechnical sampling campaign towards the base of this unit. An internal horizon of H10 has been used to try and differentiate the layer of coarser sediments from the overlying clays and silts to aid with depth of cable burying. 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.

Along the route corridor Unit II, glaciomarine sediments form a blanket deposit on top of the underlying Unit III tills. The extents and depth below seabed to base of Unit II are shown in Figure 70 below. Geotechnical sample locations 123 and 144 are examples of locations where Unit II has been sampled (Figure 71). From these samples, the geotechnical properties of Unit II are expected to predominantly be silty clay and clayey silt.

c Solid geology

CHALK

In total nine vibrocore locations contained CHALK, all of which have been interpreted to be glacially disturbed. It is unlikely that these samples represent the top of actual bedrock in the area, especially given that some of the cores return to glacial material after penetrating through the chalk. It is likely that these are chalk derived sediments formed from glacial processes and have possibly even been transported to this area.

Vibrocore images of the chalk are presented in Figure 69, which show the reworked chalk on GT_VC_096 (left) and GT_VC_107 (right). CPT data at these locations have typically returned low tip pressure (<25 MPa) records when penetrating through the chalks with occasion deviations up to 50 MPa. There are three instances where tip pressure exceeded 50MPa though chalk; over 75 MPa on GT_VC_120, and over 100 MPa on GT_VC_111 and GT_VC_115a.

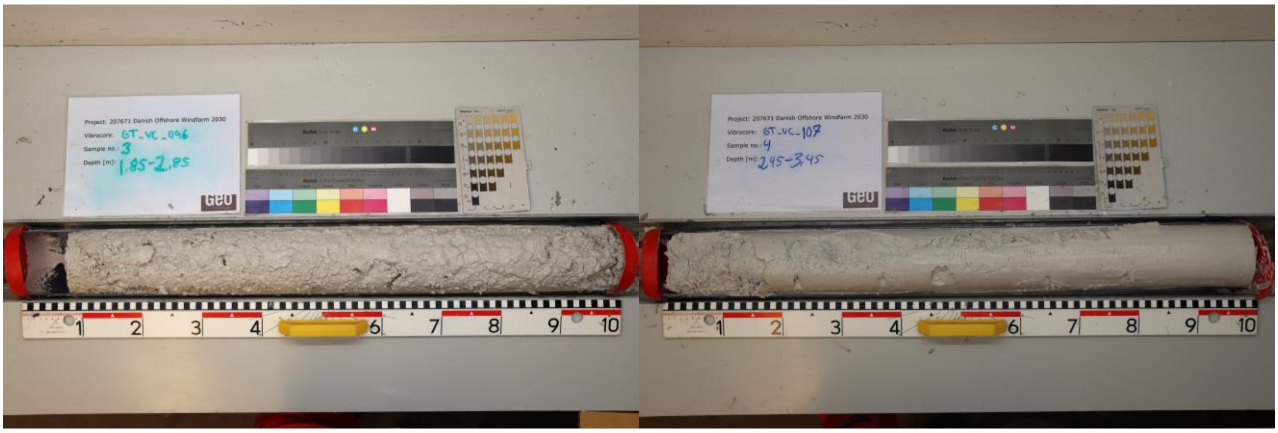


Figure 69: Examples of CHALK in vibrocore samples

The chalk interfaces identified in the vibrocore data have not been well observed in the SBP data and hence the interface could not be mapped spatially, away from the geotechnical data. Therefore there is a risk that the CHALK observed here presents a potential hazard to any installation as the full extent and nature of the chalk cannot be fully determined.

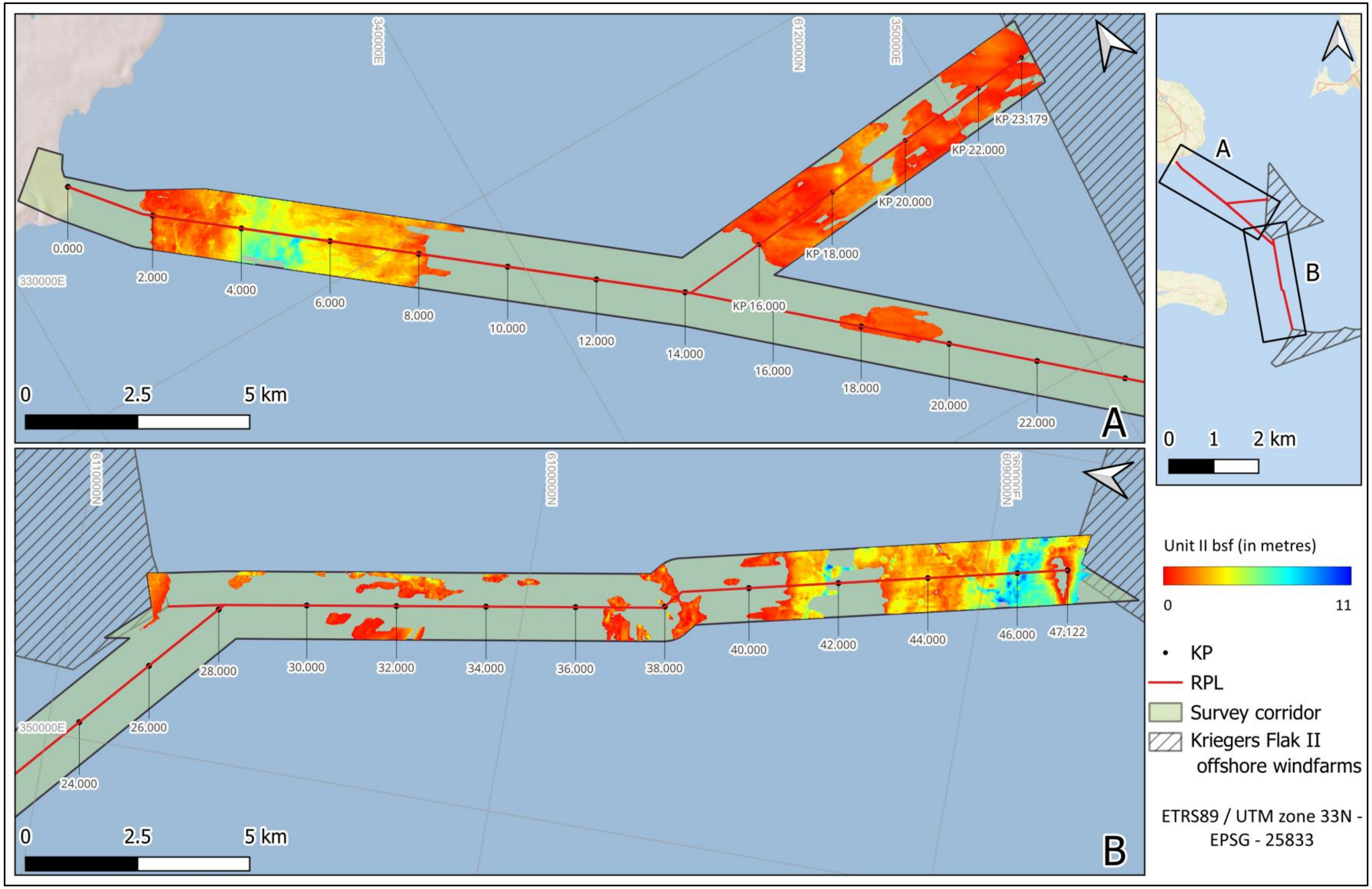


Figure 70: Illustrating Extents and depth BSB to Base Unit II

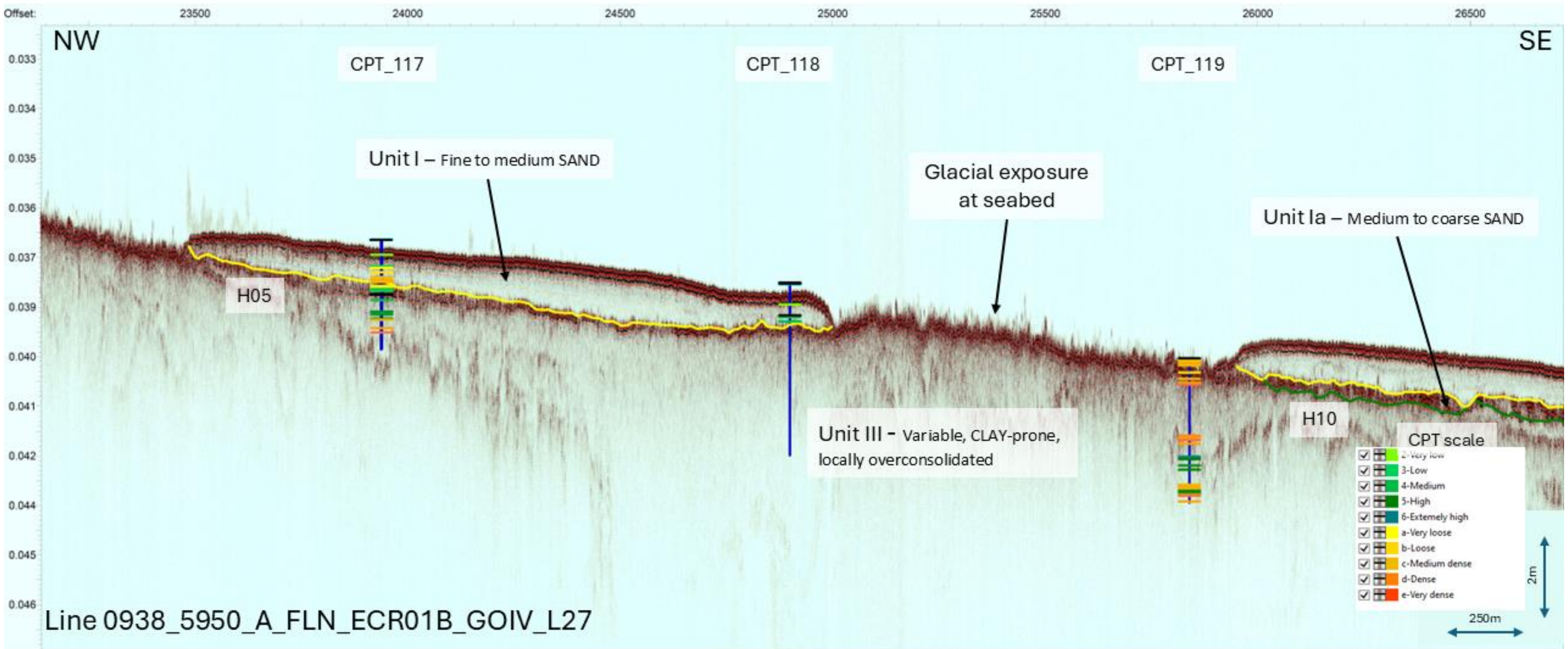


Figure 71: Illustrating Geotechnical sampling into Unit II

Unit III Glacial Deposits

Unit III deposits occur along the route corridor, subcropping at seabed where Units I and II are thin to absent. The areas where there are many cobbles and boulders at seabed suggest Unit III Till is at or close to seabed. 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 on the Innomar data. Within the nearshore section bedrock is noted at seabed on the seabed features, however, due to the acoustic character of the Innomar data in this area and very little penetration being attained it has not been possible to differentiate this change within the sbp dataset.

The till of Unit III is generally within 5 m of seabed along most of the route corridor, apart from between KP 3.000 and KP 7.000 and KP 43.200 and the end of the Kriegers Flak route at KP 47.122.

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 overconsolidated. Consolidation levels may significantly vary over short distances. Seismically, the ice contact facies are structureless with a very irregular upper surface, which probably forms a series of ridges. Geotechnical locations 106-110, 115, 133-135, 138 all sample directly into Unit III.

7 KRIEGERS FLAK II ROUTE ANALYSIS

A summarized route analysis along the Kriegers Flak II ECR South cable route, subdivided into 3 km sections, is displayed in Table 70 below, while the Kriegers Flak II ECR North cable route, also subdivided in 3 km sections, is shown in Table 71. The route analysis is based on correlation between geotechnical and geophysical data.

Grouped soil types, in 3 km sections are presented in Appendix E.

Table 70: Overview per 3 km interval South cable route

From KP	To KP	Seabed geology	Seabed features	Seabed topography	Shallow geology	Environmental and geotechnical	
0	3	Geology predominantly TILL with patches of SAND and gravel and coarse SAND.	KP 0.000 to KP 2.000 a high density boulder field covers the corridor. From KP 2.000 to KP 3.000 featureless seabed, with the exception of boulders which dominate and sediment waveforms which are subordinate.	Seabed slope from KP 0.000 to KP 2.000 gradually declines by 14 meters. The slope from KP 2.000 to KP 3.000 increases by 1 meter at the start, after which it declines by 1 m, and at the end of the KP 3.000 it begins to increase.	H05, H10, H20 present	Geotechnical	VC096 CPT096 VC097 CPT097
						Grab samples	FLN_001_03 FLN_002_03 FLN_003_03 FLN_ECR01B_010 FLN_ECR01B_011
3	6	Predominantly SAND with small patches of gravel and coarse SAND.	Featureless seabed, exception of boulders dominates the corridor. In the middle of the RPL is one small area of sediment waveforms.	At the beginning of KP 3.000, the slope increases by 1 m. From KP 3.500 to KP 6.000 the seabed forms a gentle slope. The slope gradually decreases by 1.5m.	H05, H10, H20 present	Geotechnical	VC098a CPT098 VC099 CPT099 VC100a CPT100
						Grab samples	FLN_ECR01B_012 FLN_ECR01B_013 FLN_ECR01B_014

From KP	To KP	Seabed geology	Seabed features	Seabed topography	Shallow geology	Environmental and geotechnical	
6	9	Gravel and Coarse SAND and SAND dominate the area. Small patches of quaternary clay and silt can be found.	Ripples dominate the area, while featureless seabed, exception of boulders are subordinate.	Slope from KP 6.000 to KP 9.000 slightly decreases by 1.5 m	H05, H10, H20 present	Geotechnical	VC0101 CPT101 VC102 CPT102 VC103 CPT103
						Grab samples	FLN_ECR01B_015 FLN_ECR01B_016
9	12	Predominantly Gravel and Coarse SAND, with patches of Muddy SAND and SAND.	Bedforms, sediment waveforms are dominate and featureless seabed, exception of boulders are subordinate. The high density of boulder field is found from KP 11.500 to KP 12.000	From KP 9.000 to KP 11.500 the seabed forms a gentle slope. The slope gradually decreases by 1 meter. The slope from KP 11.500 starts to increase, with the hills up to 1 m	H05, H10, H12 present	Geotechnical	VC0104 CPT104 VC105 CPT105a
						Grab samples	FLN_ECR01B_017 FLN_ECR01B_018 FLN_ECR01B_019 FLN_ECR01B_020
12	15	Predominantly TILL, with small patches of Muddy SAND and SAND.	High density of boulder fields covers most of the corridor. Featureless seabed, exception of boulders can be found on small area.	The slope from KP 12.000 to KP 15.000 gradually decreases by 3 meters with local elevations – ridges- up to 1 metre in high.		Geotechnical	VC0106 CPT106 VC107 CPT107 VC108 CPT108
						Grab samples	FLN_ECR01B_021 FLN_ECR01B_022 FLN_ECR01B_023 FLN_ECR01C_001

From KP	To KP	Seabed geology	Seabed features	Seabed topography	Shallow geology	Environmental and geotechnical	
15	18	Predominantly TILL with patches of Gravel and Coarse SAND and SAND.	High density boulder field covers the area. There are featureless seabed, exception of boulders, wavelength < 5m and possible biostructures in the small south part of the corridor	The slope from KP 15.000 to KP 18.000 gradually decreases by 1.5 metres with local elevations– ridges- up to 1 meter in high.		Geotechnical	VC0109 CPT109 VC110 CPT110 VC111 CPT111a
						Grab samples	FLN_ECR01B_024 FLN_ECR01B_025
18	21	From KP 18.500 to KP 20.500 predominantly Muddy SAND. On the rest of corridor are patches of Gravel and Coarse SAND, Till and SAND.	Featureless seabed, exception of boulders dominate this part of corridor while boulder fields and sediment waveforms are subordinate.	From KP 18.000 to 19.500: A horizontal valley with ruts up to 0.4 meters deep. Slope from KP 19.500 to KP 20.500 gradually decreases by 1 m. From 20.500 to KP 21.00 slope gradually increases by 0.8 m with few ruts up to 0.3 deep.	H05, H10, H20 present	Geotechnical	VC0112 CPT112 VC113a CPT113a VC114a CPT114a
						Grab samples	FLN_ECR01B_026 FLN_ECR01B_027 FLN_ECR01B_028 FLN_ECR01B_029
21	24	Predominantly TILL with small patches of Gravel and Coarse SAND and SAND.	High density boulder fields cover most of the area, while possible biostructures and wavelength <5 m are on small area.	Slope from KP 21.00 to KP 24.000 slightly decreases by 1 m. Throughout the corridor there are local elevations up to 0.5 m high.		Geotechnical	VC0115a CPT115a VC116 CPT116
						Grab samples	FLN_ECR01B_030 FLN_ECR01B_031 FLN_ECR01B_032
24	27					Geotechnical	VC0117

From KP	To KP	Seabed geology	Seabed features	Seabed topography	Shallow geology	Environmental and geotechnical	
		Predominantly TILL with large patches of Muddy SAND and SAND.	At the beginning and the end of the corridor are high density boulder fields, while in the middle possible biostructures and featureless seabed, exception of boulders can be found.	From KP 24.00 to KP 27.000 the slope decreases by 3 m. Throughout the corridor from KP 24.000 to KP 24.500 and from KP 26.000 to KP 27.000 there are few ruts up to 0.5 m deep.			CPT117a VC118 CPT118b
						Grab samples	FLN_ECR01B_033 FLN_ECR01B_034 FLN_ECR01B_035
27	30	Predominantly TILL with large patches of Muddy SAND.	Featureless seabed, exception of boulders and high density boulder fields dominate the area.	At the beginning of the corridor from KP 27.000 to KP 28.500, there is a groove followed by a horizontal valley. From 28.500 to KP 30 there is a depression of 1 meter, after which the slope gradually increases by 2 meters.		Geotechnical	VC0119 CPT119 VC128a CPT128 VC130 CPT130 VC129 CPT129a
						Grab samples	FLS_ECR01D_036 FLS_ECR01D_037
30	33	Predominantly TILL and Muddy SAND. Small patches of Gravel and Coarse SAND, Quaternary clay and silt, and SAND can also be found.	High density boulder fields dominate the area. Featureless seabed, exception of boulders is subordinate.	Throughout the corridor from KP 30.000 to KP 33.000, there are local elevations—ridges—up to 2 metres high.	H10 present	Geotechnical	VC0131 CPT131 VC132 CPT132
						Grab samples	FLS_ECR01D_038 FLS_ECR01D_039 FLS_ECR01D_040 FLS_ECR01D_041

From KP	To KP	Seabed geology	Seabed features	Seabed topography	Shallow geology	Environmental and geotechnical	
33	36	Predominantly TILL with small patches of Gravel and Coarse SAND, Muddy SAND and SAND.	High density boulder field covers the whole part of the corridor.	From KP 33.000 to KP 34.500 slope increases to 4 m due to elevation hill, and from KP 34.500 to 36.00 decreases by 4.5 m.		Geotechnical	VC0133 CPT133 VC134 CPT134a VC135a CPT135a
						Grab samples	FLS_ECR01D_042 FLS_ECR01D_043 FLS_ECR01D_044
36	39	Predominantly TILL with patches of SAND, Gravel and Coarse SAND, Muddy SAND and Quaternary clay and silt.	Featureless seabed, exception of boulders dominate this part of the corridor, while boulder fields are subordinate.	From KP 36.000 to 37.500 slope decreases by 1.5 m. From KP 37.500 to 38.000 bottom turns into a horizontal valley. From KP 38.000 to 39.000 slope increases with local elevations-ridges- up to 0.5 m.		Geotechnical	VC136 CPT136 VC137 CPT137 VC138 CPT138
						Grab samples	FLS_ECR01D_045 FLS_ECR01D_046 FLS_ECR01D_047
39	42	Predominantly TILL with patches of SAND, Gravel and Coarse SAND in the north of the corridor. Patches of SAND, Muddy SAND and Gravel and Coarse SAND in the south.	Part from KP 39.000 to KP 41.000 is covered in boulder fields. On the south part of the corridor are featureless seabed, exception of boulders and possible biostructures.	From KP 39.000 to 42.000 slope gradually decreases by 0.5 m, with local elevations-ridges- up to 1 m.		Geotechnical	VC139 CPT139 VC140 CPT140 VC141 CPT141
						Grab samples	FLS_ECR01D_048 FLS_ECR01D_049

From KP	To KP	Seabed geology	Seabed features	Seabed topography	Shallow geology	Environmental and geotechnical	
42	45	Predominantly Muddy SAND with patches of SAND and Gravel and Coarse SAND. Small patches of Till and Quaternary clay and silt.	Half part of the seabed is covered with trawl marks, and the other half featureless seabed, exception of boulders.	Slope from KP 42.000 to KP 45.000 gradually decreases by 3 m.		Geotechnical	VC142 CPT142 VC143a CPT143 VC144 CPT144
						Grab samples	FLS_ECR01D_050 FLS_ECR01D_051 FLS_ECR01D_052
45	47.12	Predominantly Muddy SAND and SAND. Small patches of Till and Quaternary clay and silt.	Trawl marks area dominates this part of the corridor. High density boulder field and area of Mytilus edulis can be found on the small part in the south of the route.	From KP 45.000 to KP 47.12 there is horizontal valley with a hill in the middle of the corridor with height 2 m.		Geotechnical	VC145 CPT145 VC146 CPT146 VC147 CPT147
						Grab samples	FLS_ECR01D_053 FLS_ECR01D_054 FLS_ECR01D_055

Table 71: Overview per 3 km interval North cable route

From KP	To KP	Seabed geology	Seabed features	Seabed topography	Shallow geology	Environmental and geotechnical	
0	3	See section of Table 70 above					
3	6	See section of Table 70 above					
6	9	See section of Table 70 above					
9	12	See section of Table 70 above					
12	15	See section of Table 70 above.					
14	17	Predominantly SAND and TILL with patches of Muddy SAND and Gravel and Coarse SAND.	Featureless seabed, exception of boulders and high density dominate the corridor. Possible biostructures and ripples are subordinate.	From KP 14.000 to KP 17.000 slope gradually decreases by 3 m. The corridor contains several depressions up to 0.5 m deep.		Geotechnical	VC120 CPT120 VC121 CPT121
						Grab samples	FLN_ECR01B_022 FLN_ECR01C_001 FLN_ECR01C_002
17	20	Predominantly Muddy SAND with patches of SAND and TILL, and small	Featureless seabed, exception of boulders is dominate, while possible	Slope from KP 17.000 to KP 20.000 gradually decreases by 1.8 m with	H20 present	Geotechnical	VC122 CPT122 VC123 CPT123a

From KP	To KP	Seabed geology	Seabed features	Seabed topography	Shallow geology	Environmental and geotechnical	
		patches of Quaternary clay and silt	biostructures and boulder fields are subordinate.	several small depressions around 0.5 m deep.			VC124 CPT124
						Grab samples	FLN_ECR01C_003 FLN_ECR01C_004 FLN_ECR01C_005 FLN_ECR01C_006
20	23.18	Predominantly TILL with patches of SAND and Muddy SAND.	High density boulder fields and featureless seabed, exception of boulders are dominate, while bedforms are subordinate.	From KP 20.000 to KP 23.17 slope gradually decreases. From KP 22.000 slope increases by 0.5 m after which it decreases by the end of the corridor.	H20 present	Geotechnical	VC125 CPT125 VC126 CPT126 VC127 CPT127
						Grab samples	FLN_ECR01C_007 FLN_ECR01C_008 FLN_ECR01C_009

7.1 KRIEGERS FLAK – 3 KM SECTION SOUTH ROUTE CABLE DESCRIPTIONS

The location of seismic profiles, which are presented throughout the report, are displayed in Figure 72.

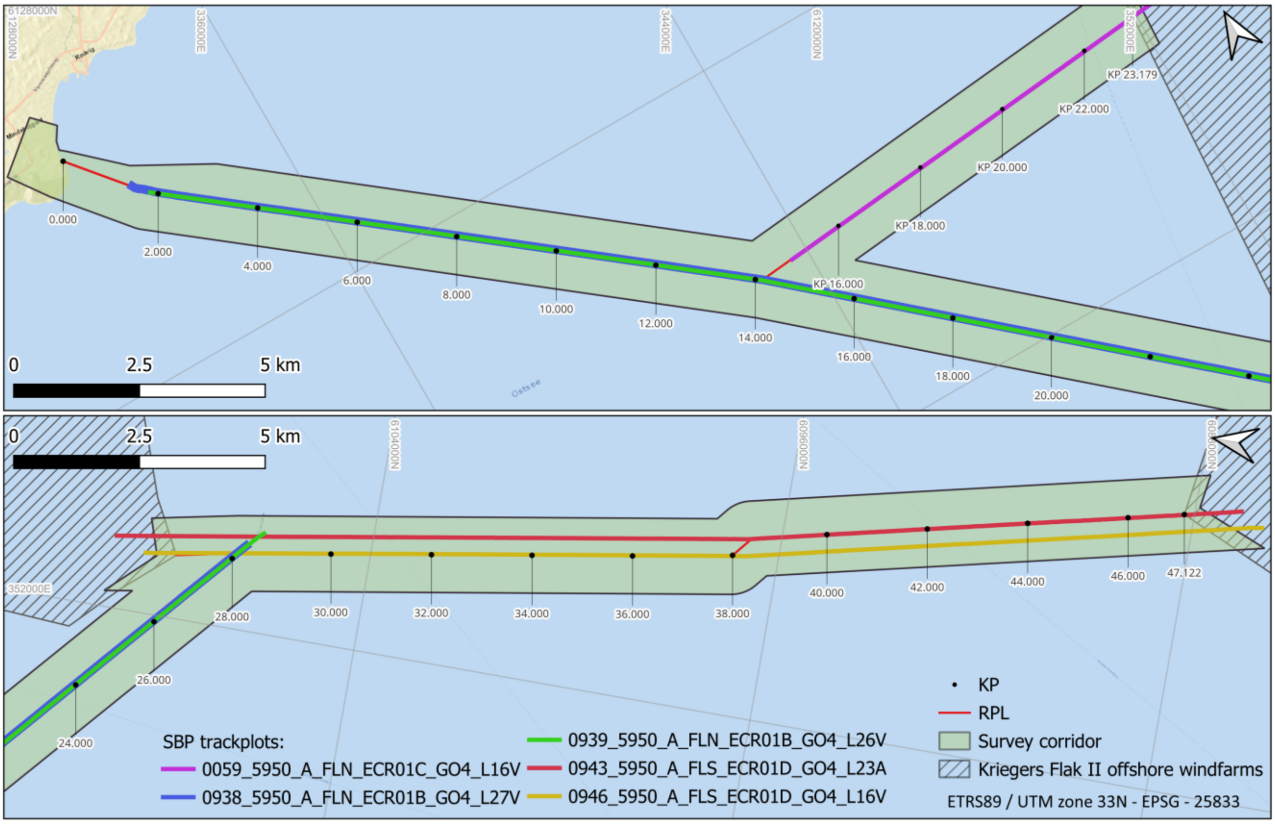


Figure 72: Location of the seismic profiles shown throughout the report

7.1.1 KP 0.000 – KP 3.000

Two VCs, two CPTs and three grab samples were acquired in this section.

From the start of the route to approximately KP 2.0 no horizons have been mapped and bedrock is expected with a veneer of SAND. VC096 showed sandy CHALK to 2.90 m.

Unit I (bounded by H05) is present from around KP 2.0 and varies in thickness from seabed to 1.5 m. Acoustically the interval is almost featureless, with very low amplitude, concordant internal reflections and there are very occasional bright spots which may possibly be organic material. VC097/CPT097 penetrates Unit I and is recorded to comprise fine to medium SAND and H05 corresponds to a relative density contract with underlying Unit II sediments.

Unit I directly overlies Unit II and horizon H10 (an internal marker horizon within Unit II) is mapped in the route corridor but is not seen on the RPL. VC097/CPT097 record Unit II sediments as fine silty gravelly SAND.

H20 is mapped from KP 2.0 and represents the base of Unit II. VC097 shows a layer of GRAVEL at the level of H20 and a sandy CLAY TILL below (Unit III).

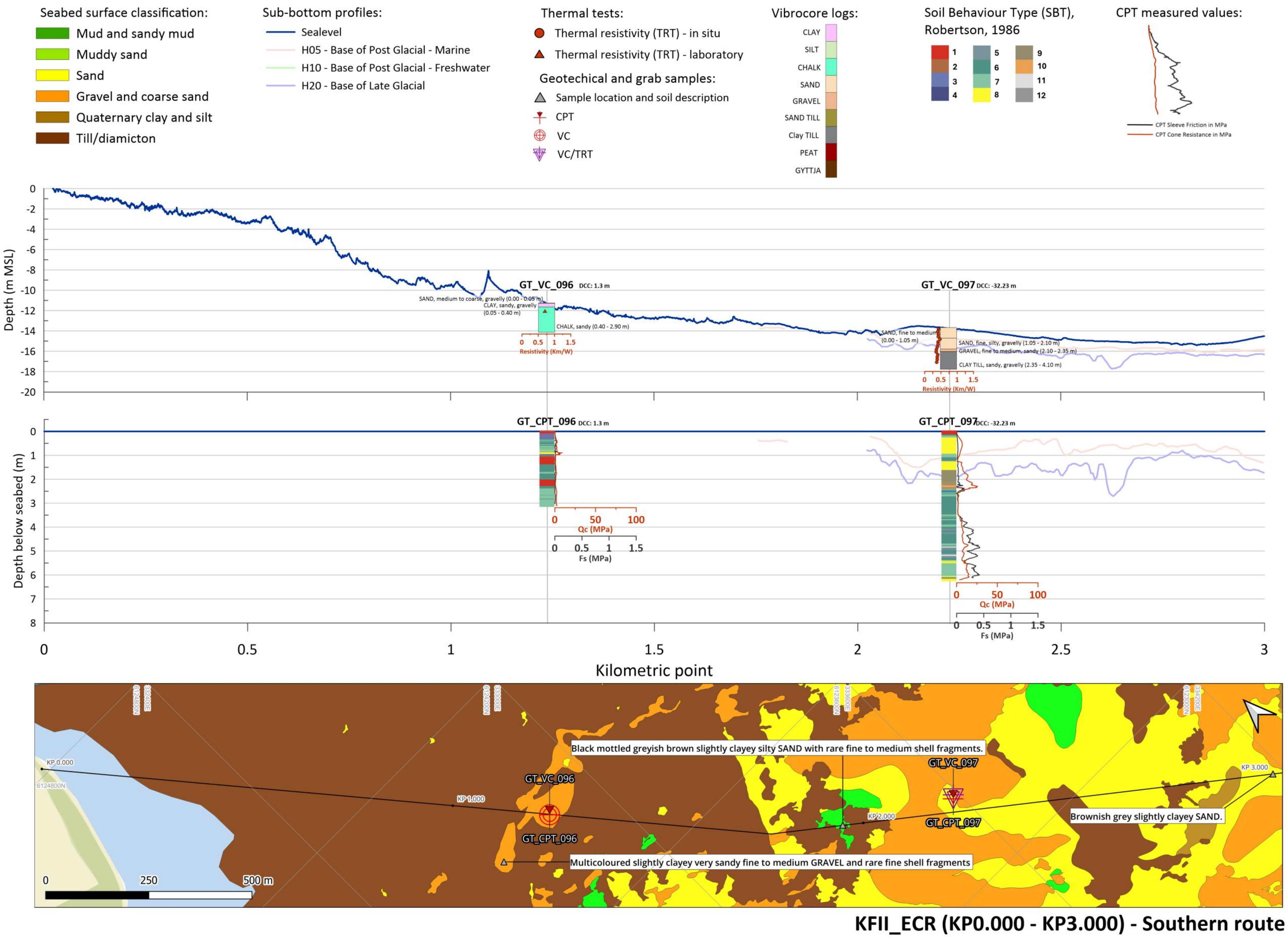


Figure 73: Integrated geotechnical panel KP 0.000 – KP 3.000 – Southern route

7.1.2 KP 3.000 – KP 6.000

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

Unit I (bounded by H05) is present over this whole section and varies in thickness from 0.5 to 2.2 m (within a shallow basin feature around KP 5.7). Acoustically, the interval is almost featureless, with very low amplitude, concordant internal reflections and there are very occasional bright spots which may possibly be organic material or, more likely, dropstones.

VC098a/CPT098, VC099/CPT099 and VC100a/CPT100 all penetrate Unit I and are recorded to comprise fine to medium clayey, silty SAND and H05 corresponds to a relative density contract with underlying Unit Ia sediments in CPT098 and CPT099.

The horizon H10 (basal reflector for Unit Ia) is mapped from KP 3.2 for the remainder of this section. All geotechnical stations penetrate Unit Ia and are recorded as predominantly fine to medium SAND although VC098a records a thin layer of PEAT at 1.5 m BSB.

As discussed in Section 6.6.4, there is uncertainty in the interpretation of H10 between ~KP 3.0 to KP 3.7 where a deeper channel might exist. The channel is inferred by the geotechnical data (VC_098) but it is not well observed on the SBP data and the H10 reflector has been interpreted on a higher reflector. The channel is observed to a depth of 3m below seabed in the results for VC_098a and contains PEAT and SAND.

H20 is mapped over the whole section and represents the base of Unit II, and all geotechnical stations penetrate Unit III recording a mix of sediments from sandy PEAT overlying a CLAY TILL (station 98) to a silty sandy CLAY. It is possible that the H20 horizon could be ~50cm deeper at VC_098 as indicated by the VC results, however low penetration of the acoustic dataset at this location is likely limiting accuracy of interpretation.

Top of Unit III (H20) is within 2 m of seabed at KP 3.0 deepening to the southeast and shoaling from around KP 5.5 where it shallows to less than 4 m BSB at KP 6.0. There is uncertainty in the depth of H20 between KP 4.6 and KP6, as indicated by the C14 result at VC_100 (previously reported on in Section 6.6.4) that indicated that glacial sediments could be as shallow as 2.4m at VC_100. Again, the limited penetration is affecting the ability to interpret the dataset, exacerbated by conflicts between C14 and VC interpreted results.

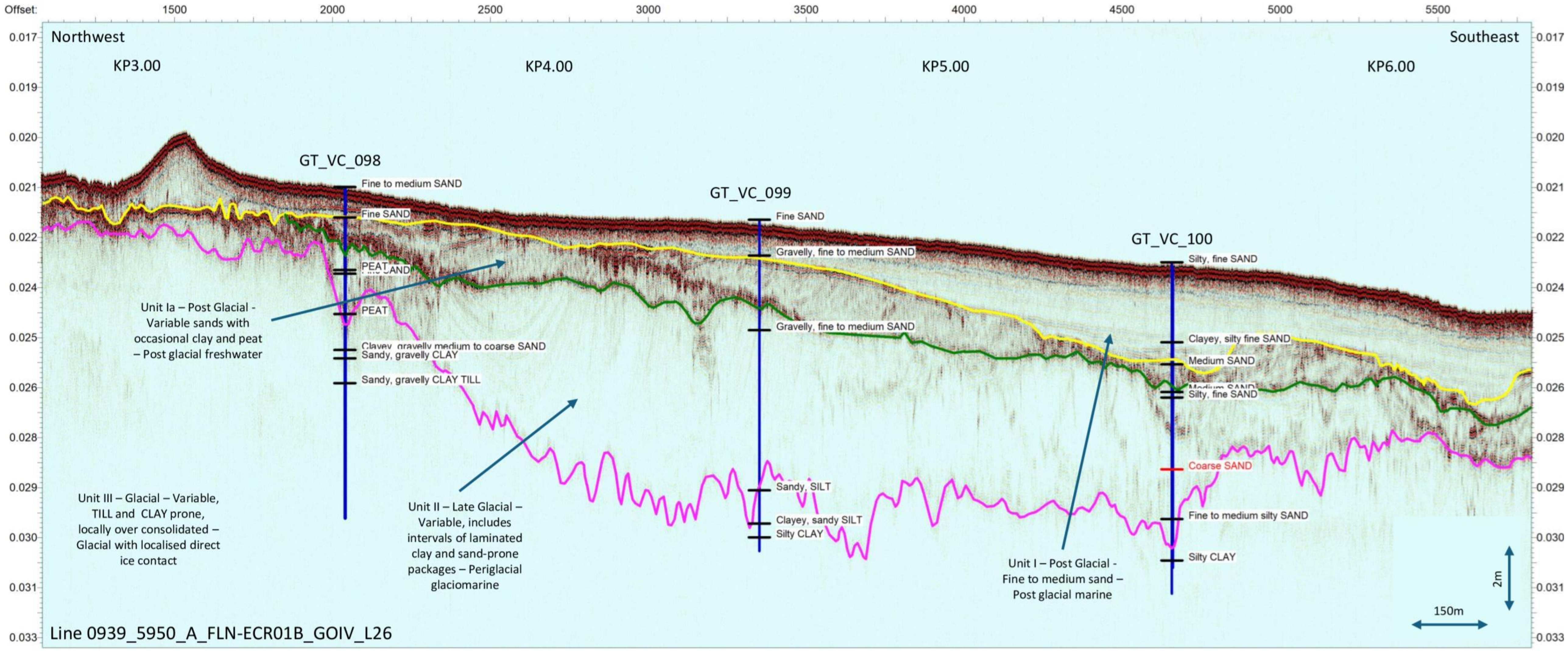


Figure 74: SBP and Geotech, KP 3.000 – KP 6.000 - Southern route

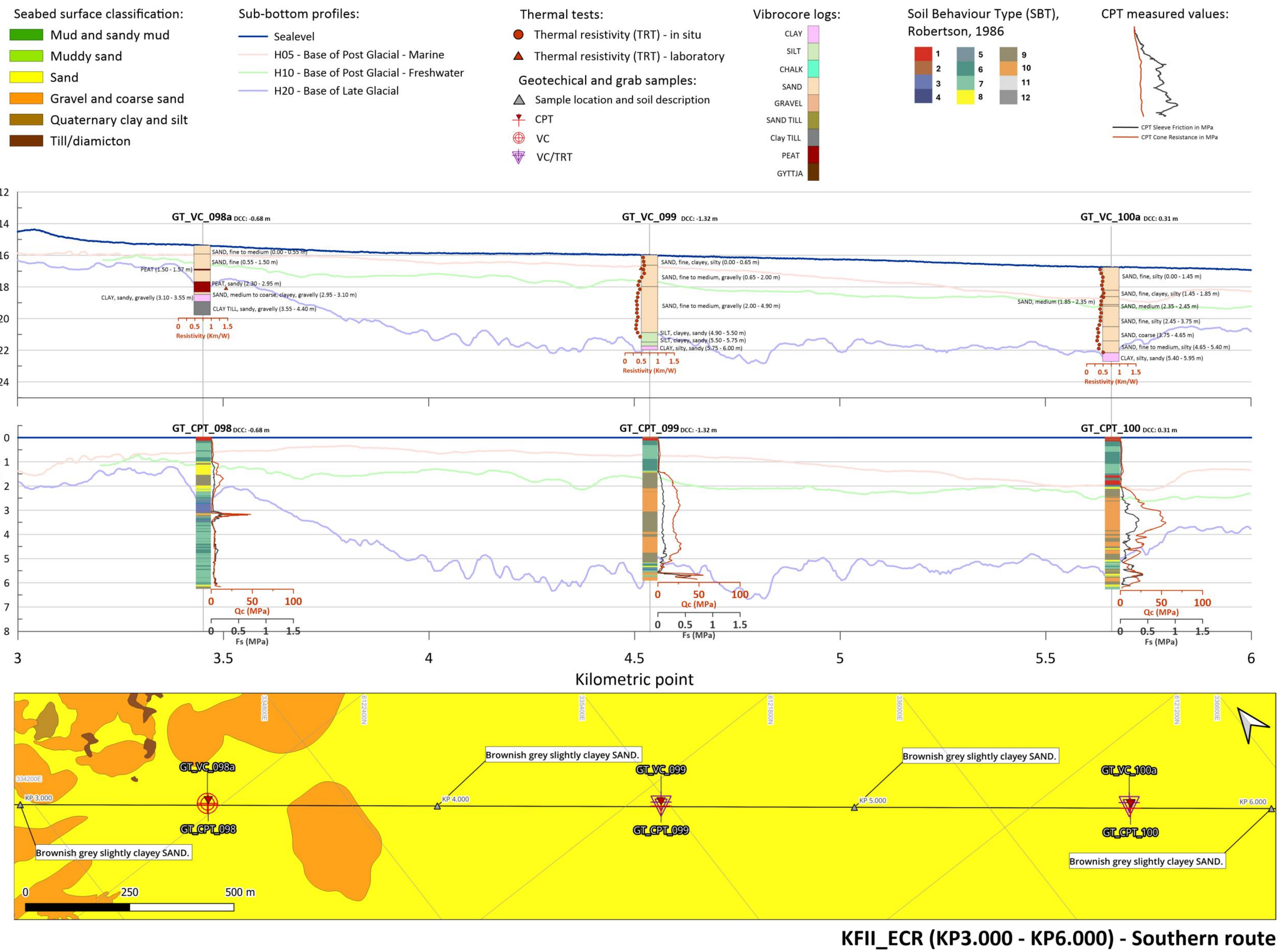


Figure 75: Integrated geotechnical panel KP 3.000 – KP 6.000 – Southern route

7.1.3 KP 6.000 – KP 9.000

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

Unit I (bounded by H05) is present over this whole section and varies in thickness from 0.5 to 2.0 m. Acoustically the interval is almost featureless, with very low amplitude, concordant internal reflections and there are very occasional bright spots which may possibly be organic material or, more likely, dropstones.

VC0101/CPT101, VC102/CPT102 and VC103/CPT103 all penetrate Unit I and are recorded to comprise fine to medium (coarse in VC103) SAND and H05 corresponds to a relative density contract with underlying Unit II sediments in CPT102 and CPT103.

Unit I directly overlies Unit Ia and horizon H10 is mapped from KP 6.0 for the remainder of this section. All geotechnical stations penetrate Unit II and are recorded as predominantly fine silty SAND although records medium to coarse SAND.

H20 is mapped from KP 6.0 to KP 8.2 and represents the base of Unit II. All geotechnical stations penetrate Unit III recording a mix of sediments from gravelly CLAY TILL (station 101) SILT and SAND overlying a CLAY TILL (station 102) to fine gravelly SAND (station 103).

Top of Unit III (H20) shoals to the southeast where it pinches out against overlying H10 at KP 8.2.

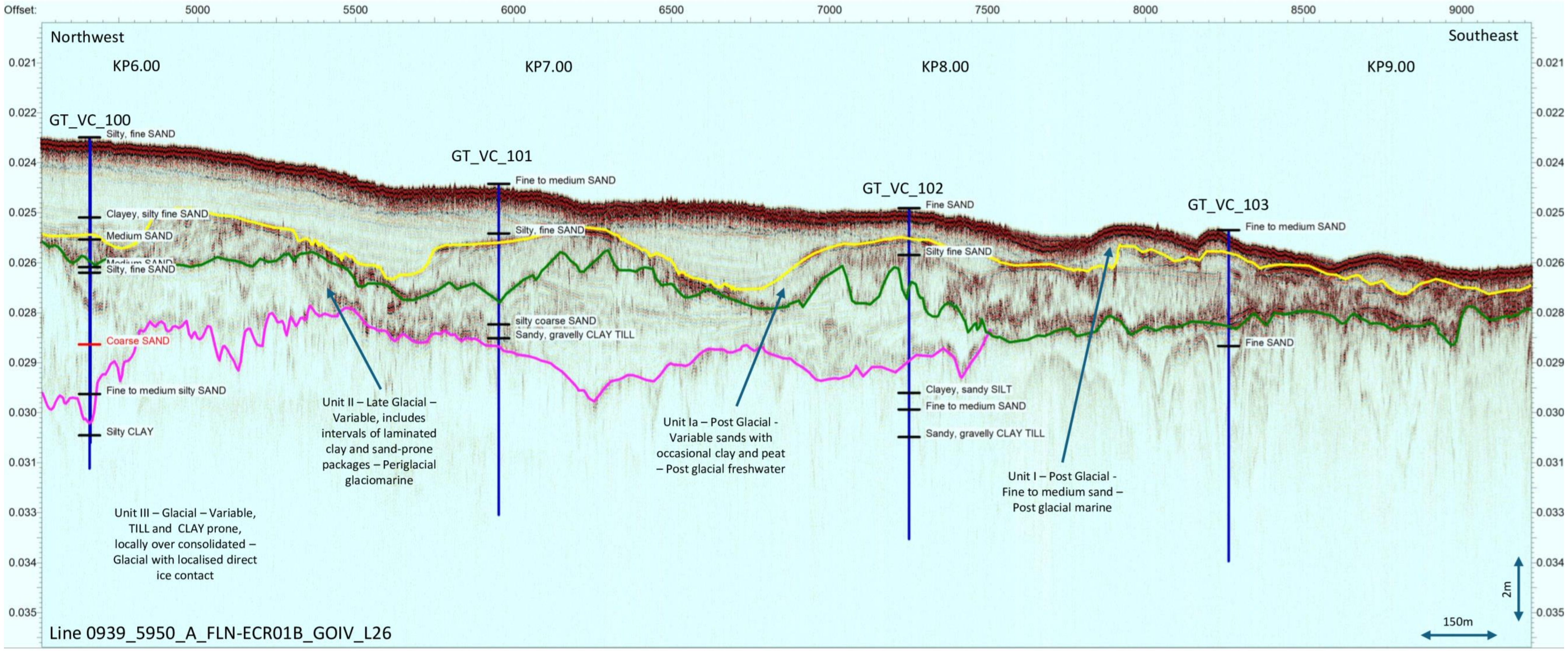


Figure 76: SBP and Geotech, KP 6.000 – KP 9.000 – Southern route

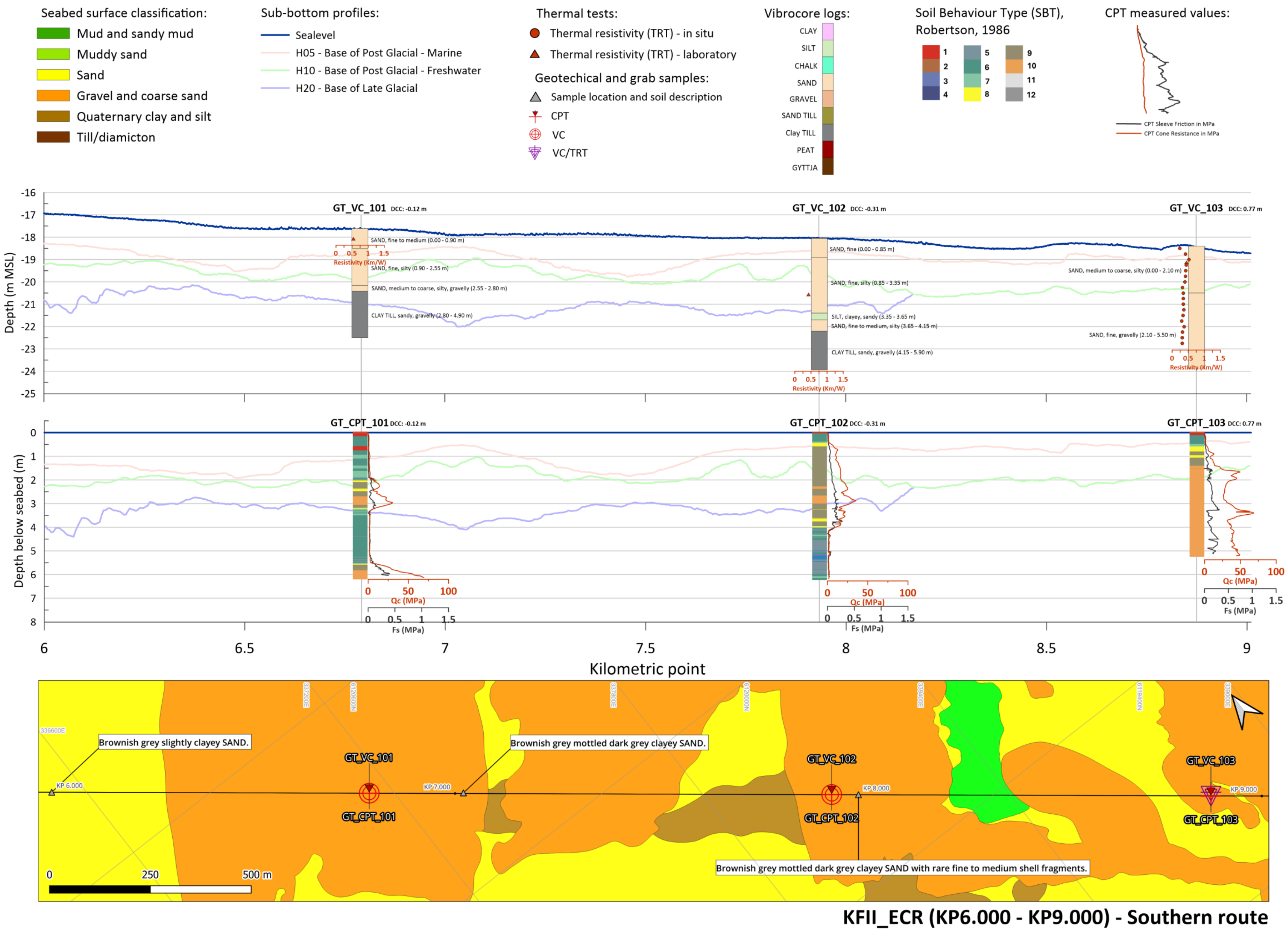


Figure 77: Integrated geotechnical panel KP 6.000 – KP 9.000 – Southern route

7.1.4 KP 9.000 – KP 12.000

Two VCs, two CPTs and four grab samples were acquired in this section.

Unit I (bounded by H05) is present until it pinches out against seabed at KP 11.65 and is generally less than 1 m thick. Acoustically the interval is almost featureless, with very low amplitude, concordant internal reflections and there are very occasional bright spots which may possibly be organic material or, more likely, dropstones.

VC0104/CPT104 and VC105/CPT105a both penetrate Unit I and are recorded to comprise fine silty clayey SAND.

Unit I directly overlies Unit Ia and horizon H10, and in this section pinches out against H05 at KP 10.2 within the acoustic data.

From where H10 pinches out until H05 pinches out Unit III directly underlies Unit I and H05 represents a boundary between SAND above and CLAY TILL below (Unit III).

Southeast of KP 11.65 Unit III (until the end of this section) is at seabed so overconsolidated sediments may be present directly below seabed.

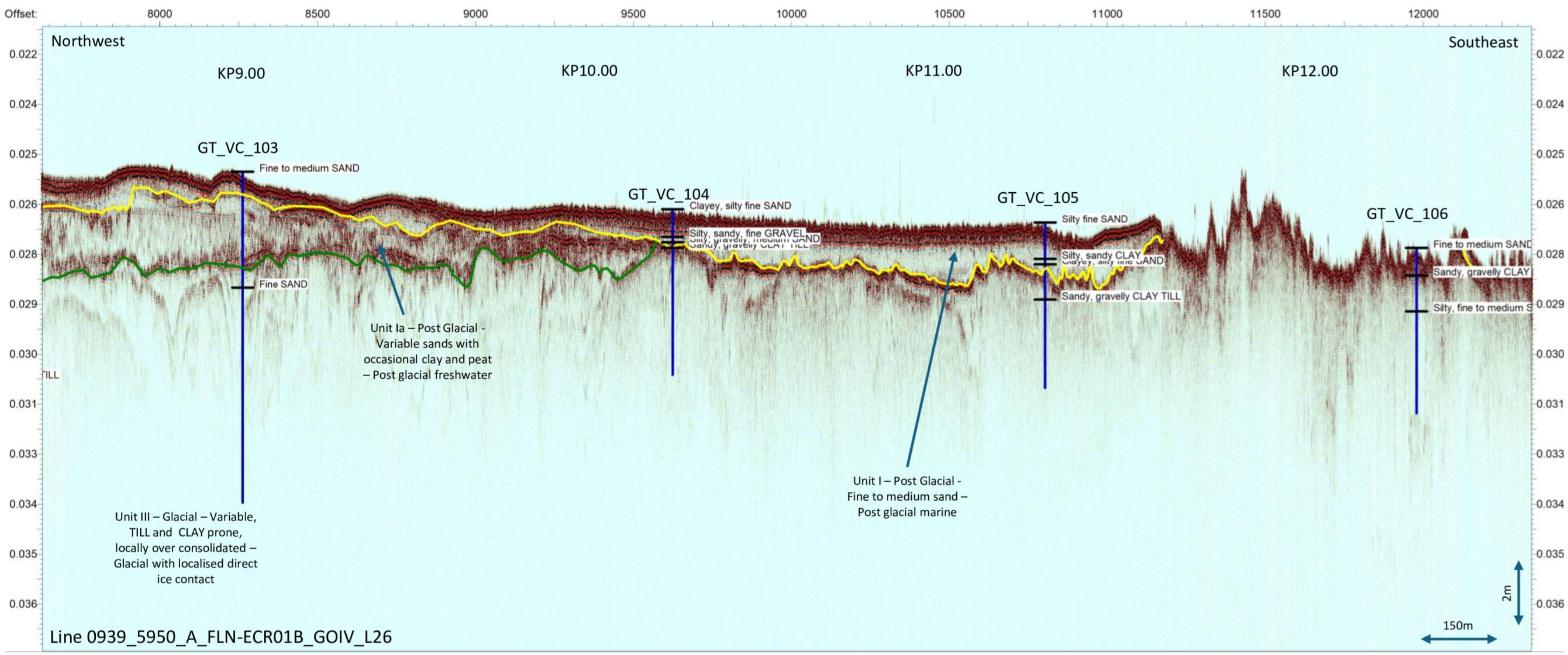


Figure 78: SBP and Geotech, KP 9.000 – KP 12.000 – Southern route

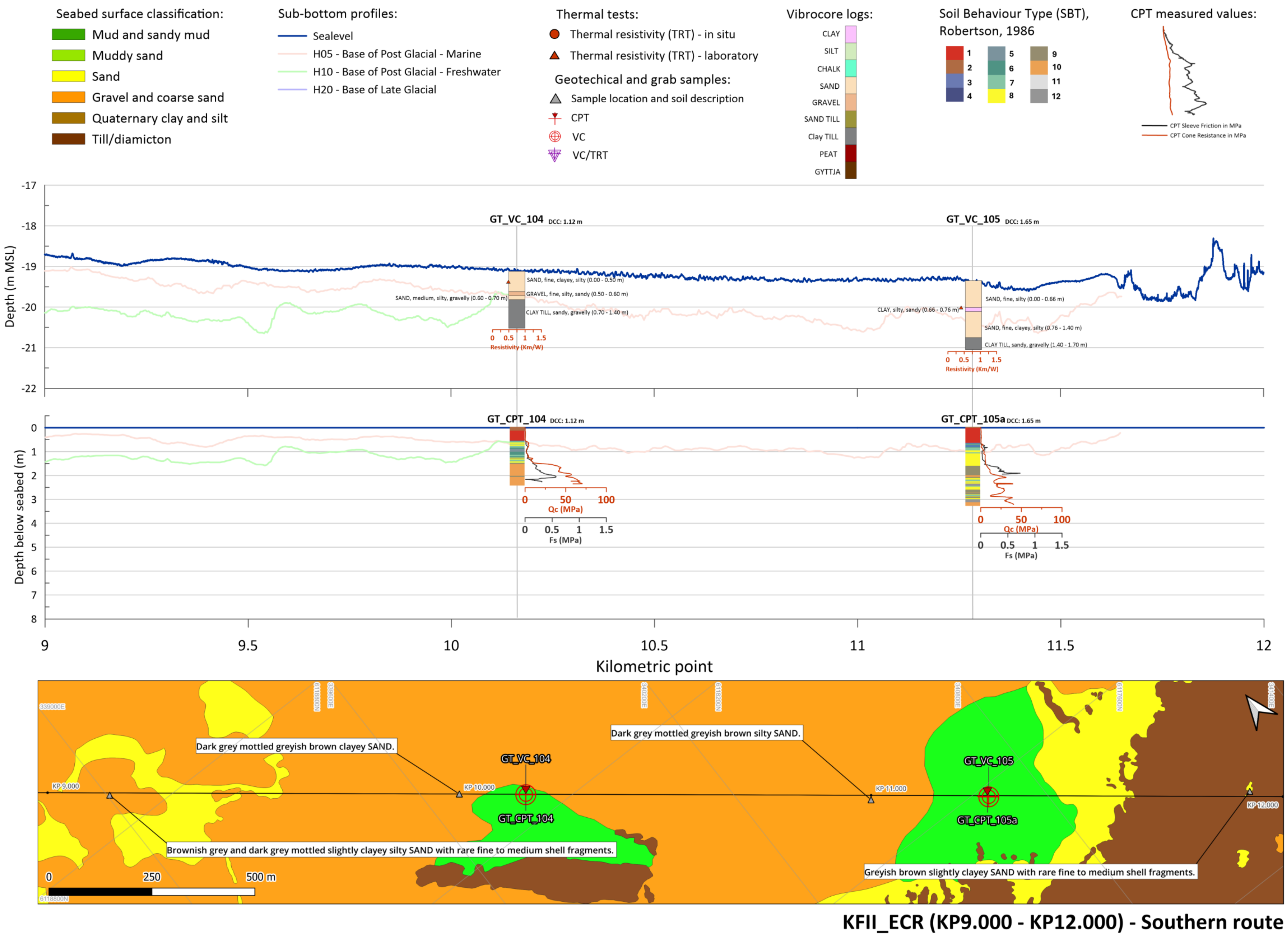


Figure 79: Integrated geotechnical panel KP 9.000 – KP 12.000 – Southern route

7.1.5 KP 12.000 – KP 15.000

Three VCs, 3 CPTs and three grab samples were acquired in this section.

Units I, Ia, and II are absent along this section of the route so Unit III is present directly below the seabed.

VC0106/CPT106, VC107/CPT107 and VC108/CPT108 all penetrate Unit III, and a mix of sediments are recorded illustrating the variability within the makeup of Unit III.

To the northwest geotechnical station 106 records fine to medium SAND over CLAY TILL over fine to medium SAND whereas in the centre of this section geotechnical station 107 records gravelly CLAY over sandy CHALK. Moving southeast station 108 records SAND and gravelly SILT over CLAY TILL.

As Unit III is at/near the seabed, overconsolidated sediments may be present directly below seabed over this whole section.

No correlating reflection in the SBP data is observed or interpreted for the CHALK observed on VC_107. The layer is not detected in the SBP data or corroborated on adjacent geotechnical sites, hence making this observation a possible localised feature, or spurious.

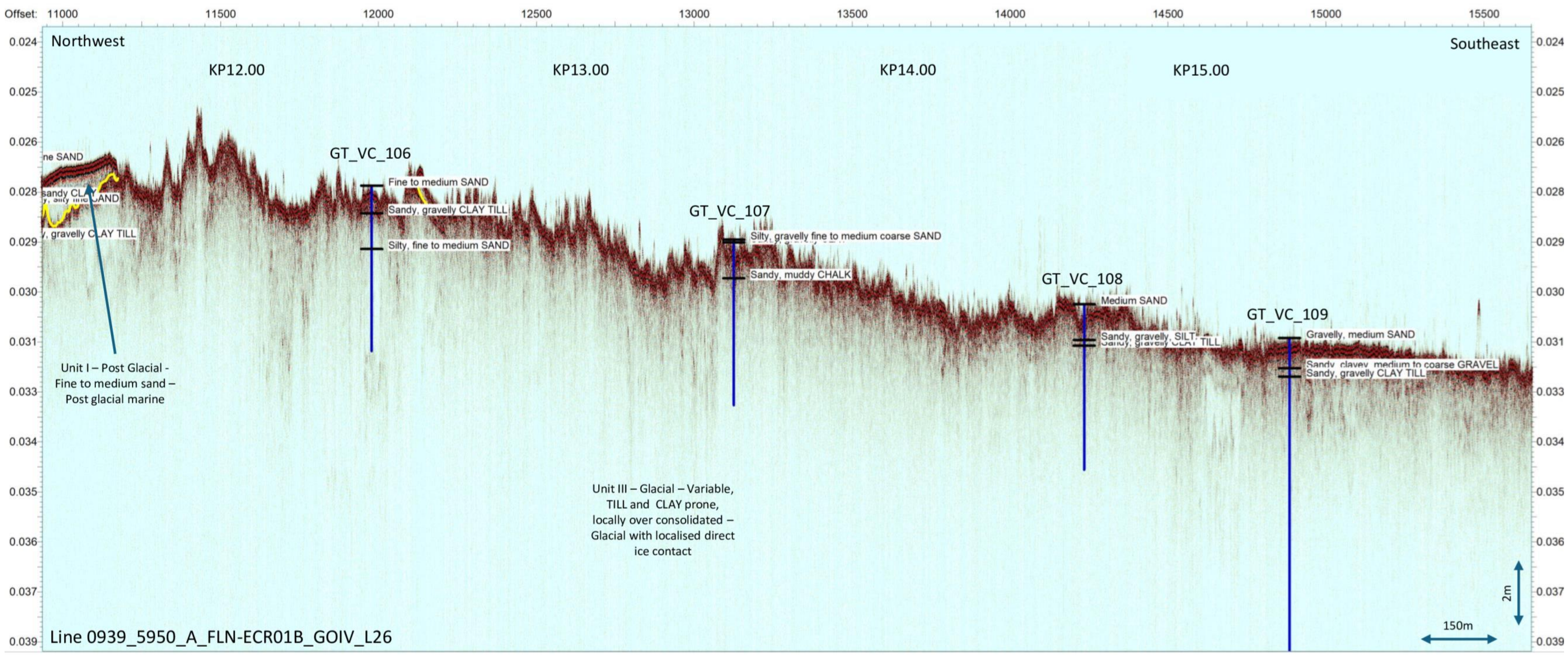
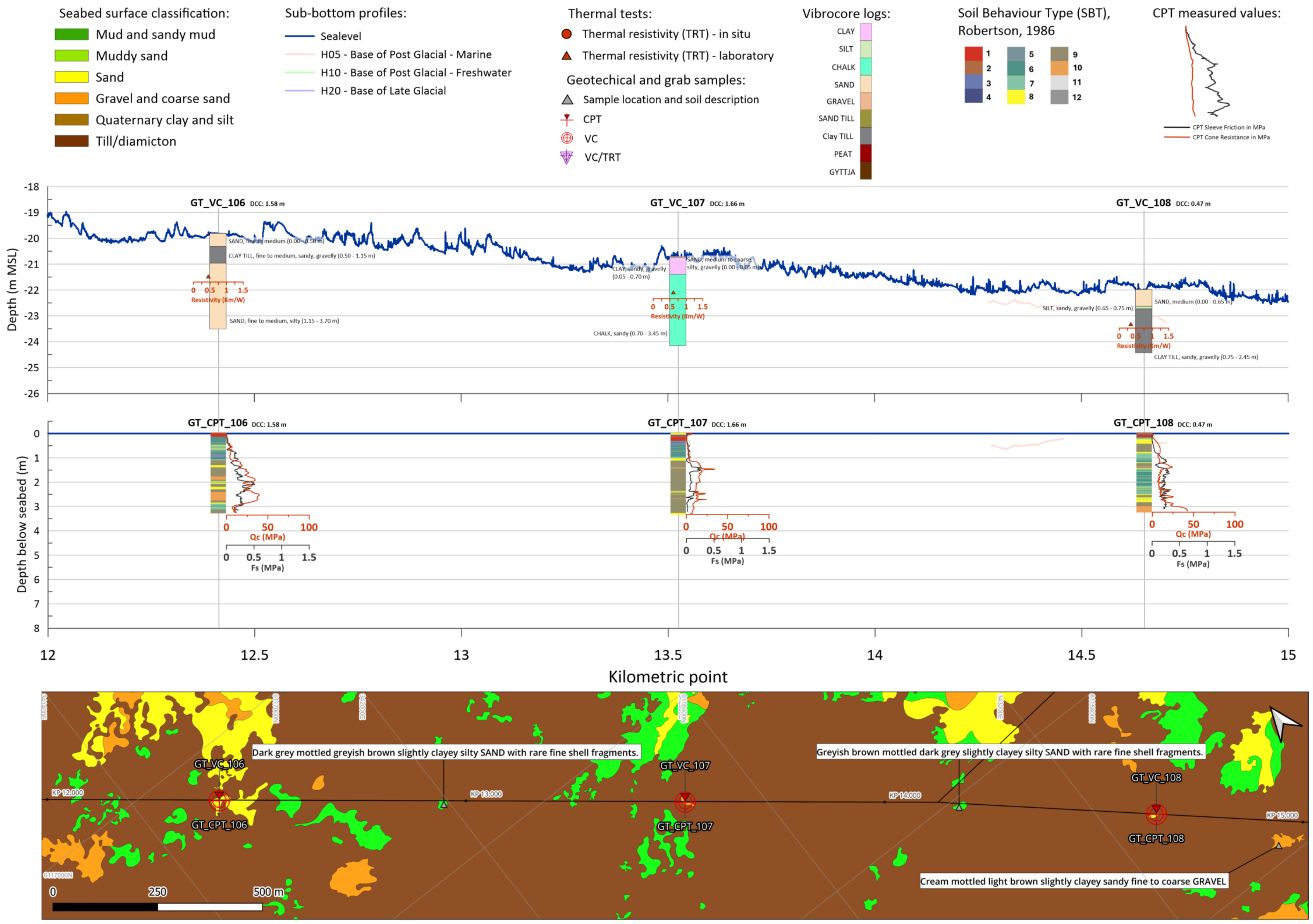


Figure 80: SBP and Geotech, KP 12.000 – KP 15.000 – Southern route



KFII_ECR (KP12.000 - KP15.000) - Northern and Southern route

Figure 81: Integrated geotechnical panel KP 12.000 – KP 15.000 –Southern route

7.1.6 KP 15.000 – KP 18.000

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

Units I and II become present again from around KP 16.8 (Unit I) and KP 17.5 (Unit II) up until then Unit III is present directly below seabed.

The base of Unit I is not well defined here and has been tentatively mapped.

VC0109/CPT109, VC110/CPT110 and VC111/CPT111a all penetrate Unit III (only station 111 penetrates the overlying Unit I) and a mix of sediments are recorded illustrating the variability within the makeup of Unit III.

To the northwest geotechnical station 109 records fine to medium gravelly SAND with a layer of GRAVEL over CLAY TILL whereas in the centre of this section geotechnical station 110 records CLAY TILL over sandy CHALK. Moving southeast station 111 records fine to medium SAND (Unit I) overlying sandy CHALK (Unit III).

As Unit III is at/near at seabed overconsolidated sediments may be present directly below seabed over this whole section.

CHALK is observed on both VC_110 and VC_111, however a clear and continuous reflector rising from depth is not observed. However it is likely that between these two VC locations, CHALK is present near to the seabed.

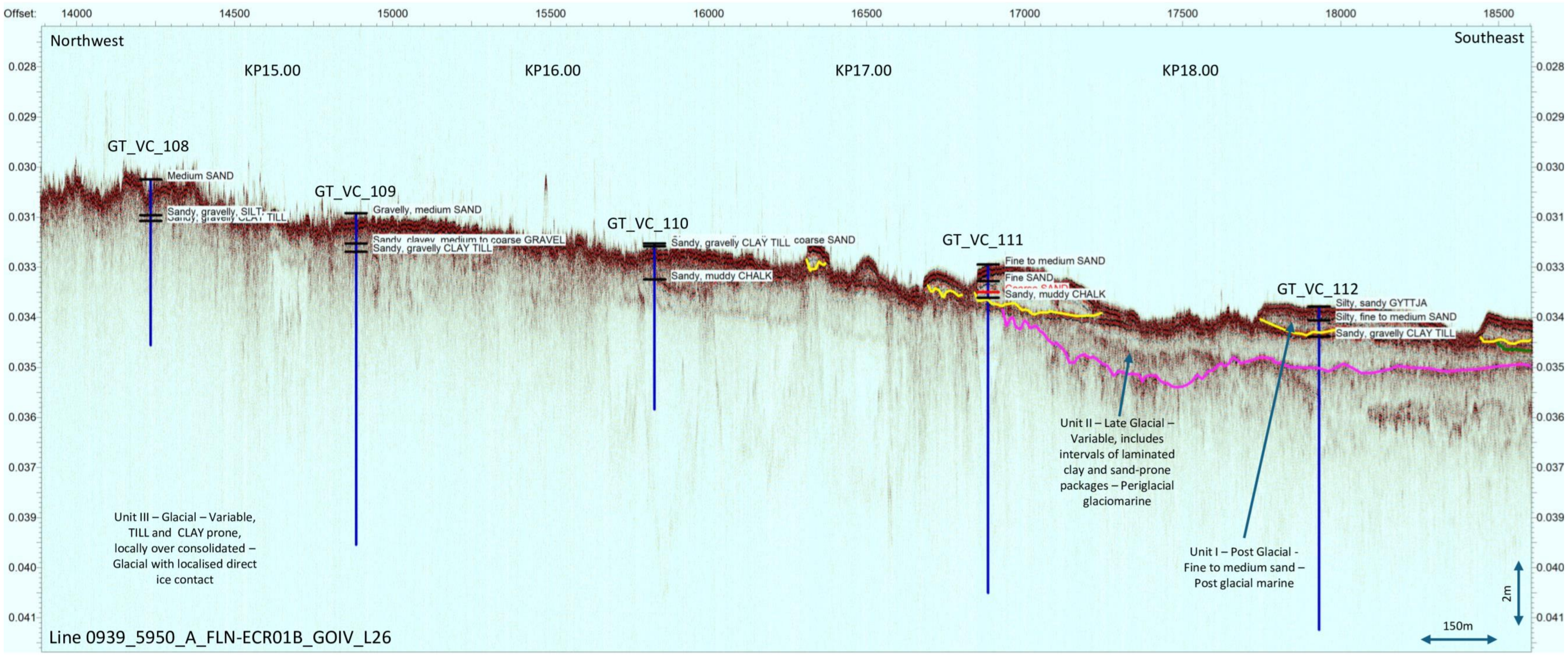


Figure 82: SBP and Geotech, KP 15.000 – KP 18.000 – Southern route

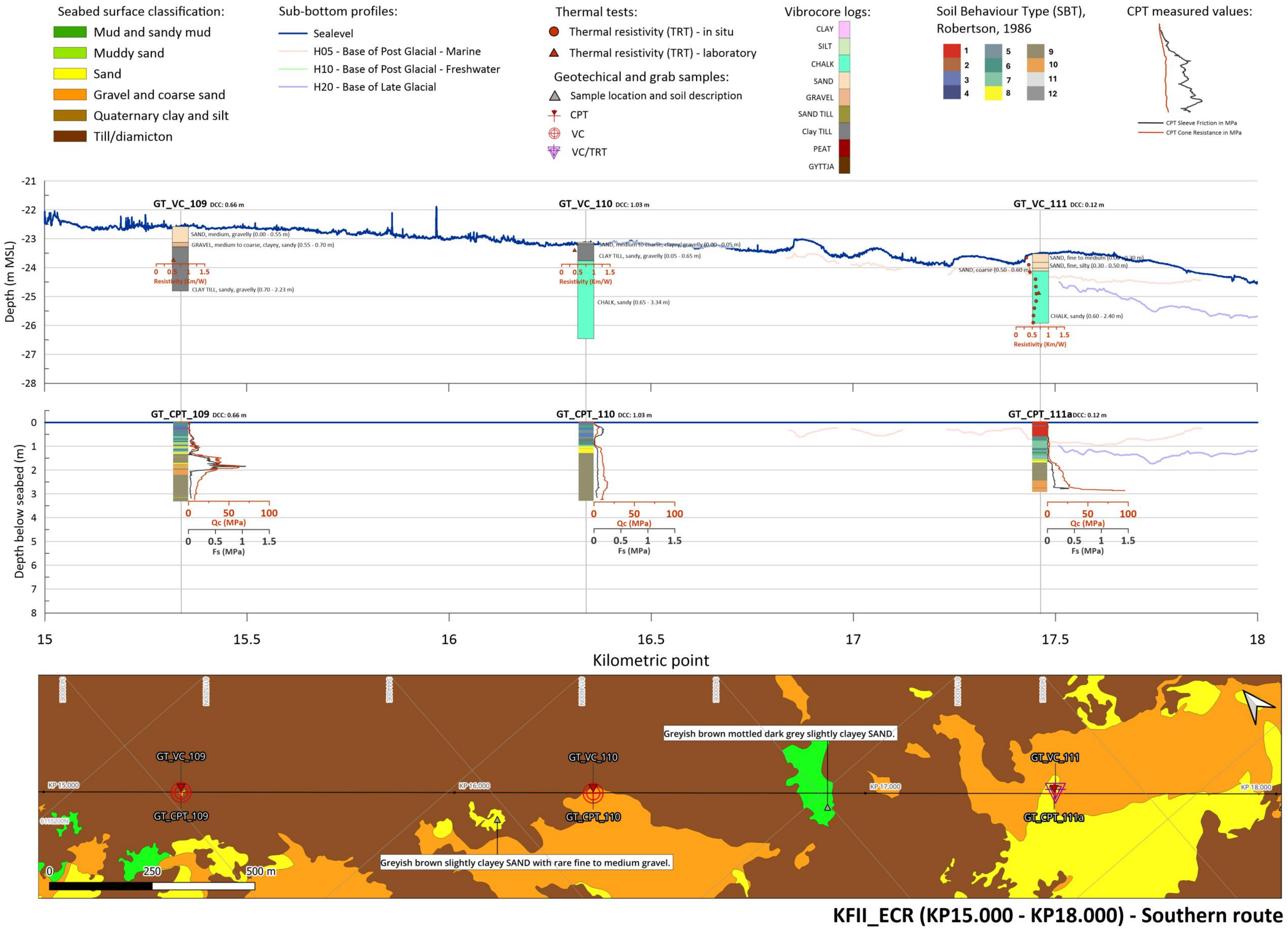


Figure 83: Integrated geotechnical panel KP 15.000 – KP 18.000 –Southern route

7.1.7 KP 18.000 – KP 21.000

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

Unit I (the base marked by H05) has been intermittently traceable within this section and a thin layer of Unit Ia between KP19.3 and KP 20.8, and Unit II between KP 17.6 and KP 19.7; the base of which marked by H20. Unit III is present throughout this section within 3 m of seabed. From approximately KP20.5, Unit III is interpreted to be exposed or very close to the seabed.

VC0112/CPT112, VC113a/CPT113a and VC114a/CPT114a all penetrate Units I, Ia and II (where present) and III and all stations record CLAY TILL as the dominant sediment in Unit III.

Units I and II comprise a predominant SAND however there is variation around the boundary represented by H10 (base of Unit Ia) where sandy, gravelly CLAY and silty sandy GRAVEL have been recorded at stations 113a and 114a. Station 112 has a thin layer of GYTTJA directly below seabed.

As Unit III is within 3 m of seabed over this section so overconsolidated sediments may be present within the cable burial depth over this whole section.

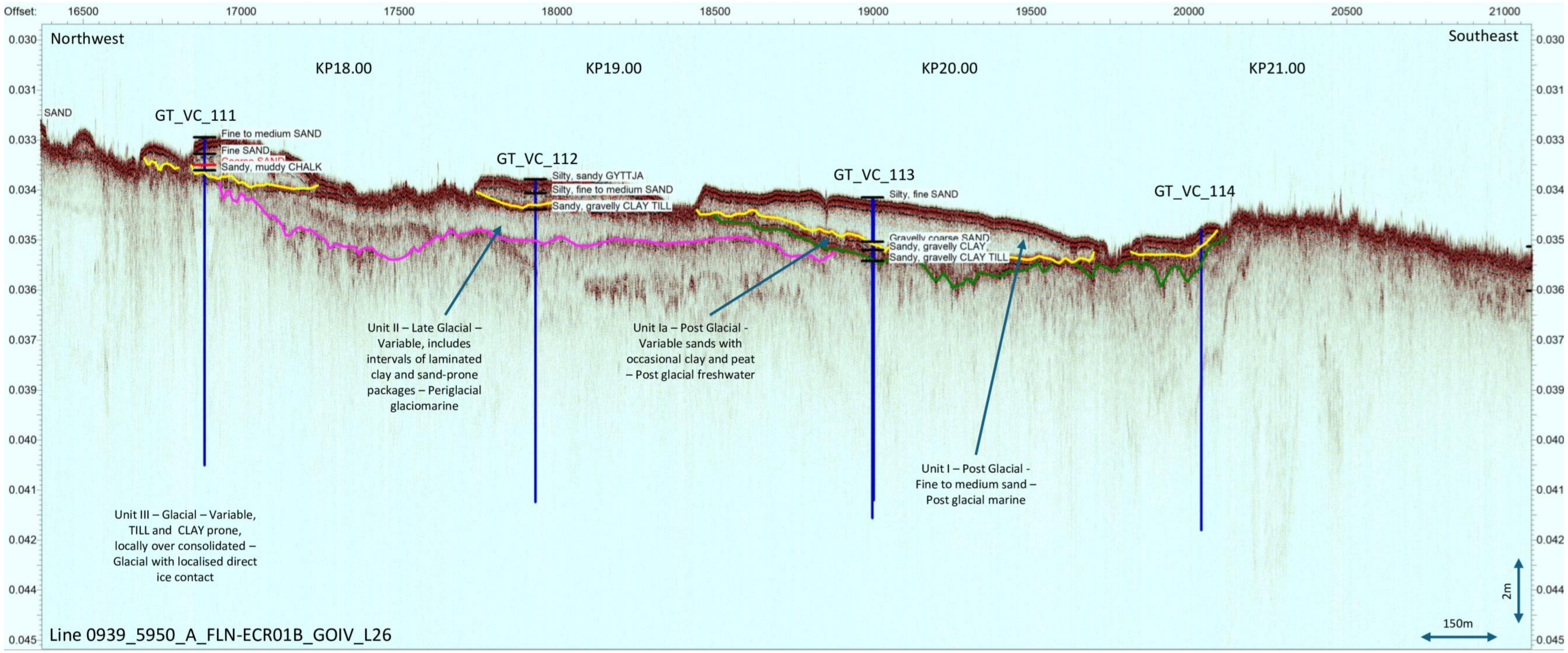


Figure 84: SBP and Geotech, KP 18.000 – KP 21.000 – Southern route

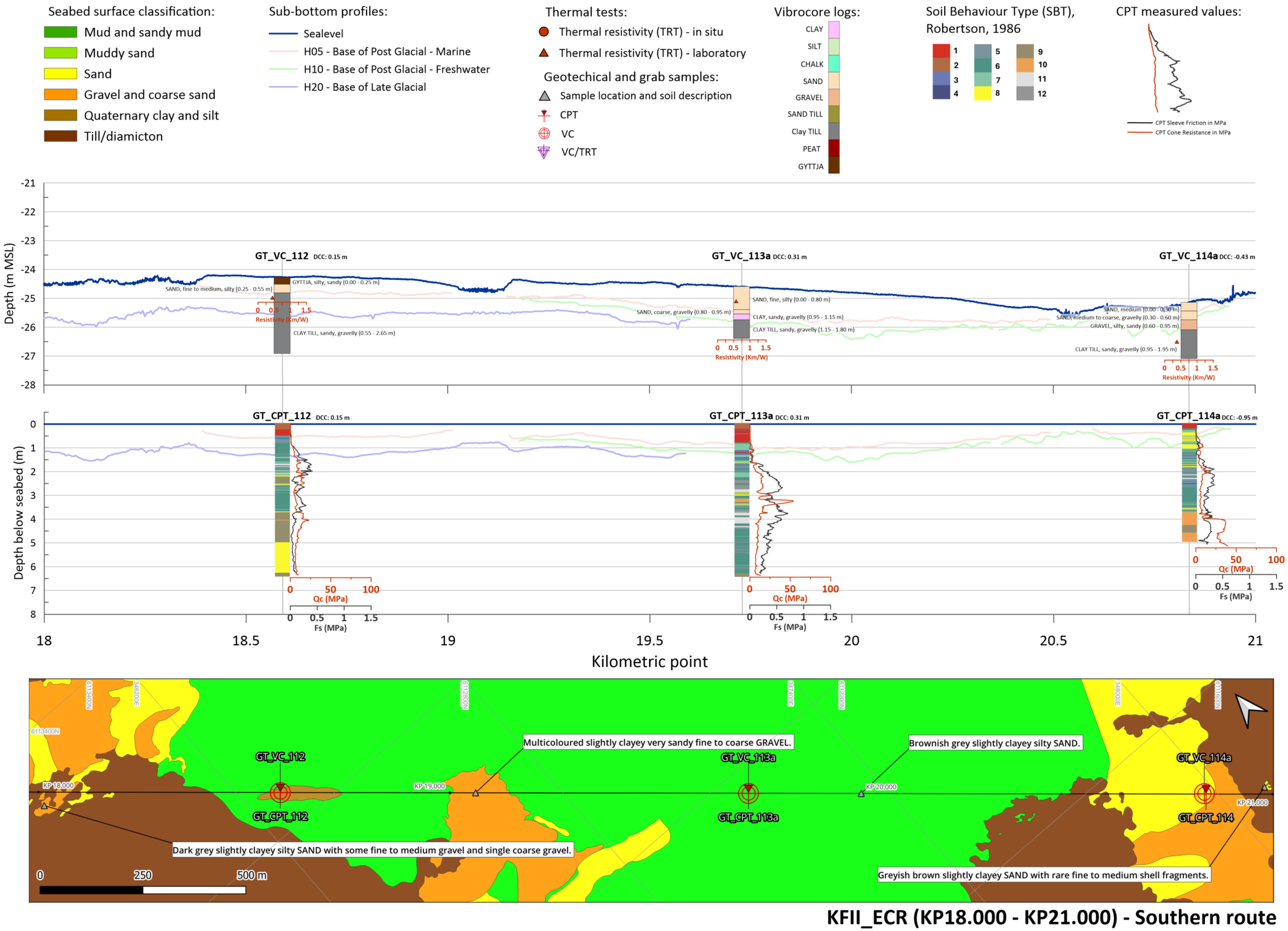


Figure 85: Integrated geotechnical panel KP 18.000 – KP 21.000 –Southern route

7.1.8 KP 21.000 – KP 24.000

Two VCs, two CPTs and three grab samples were acquired in this section.

There is potentially a very small deposit of Unit I sediments around KP 22.6 otherwise Unit III is at or just below seabed throughout this whole section.

VC0115a/CPT115a and VC116/CPT116 both record fine to medium SAND overlying CLAY TILL overlying sandy CHALK; Station 116 shows a sandy CLAY layer about the CLAY TILL). These sediments are part of Unit III and as Unit III is near/at seabed over this section overconsolidated sediments may be present within the cable burial depth over this whole section.

CHALK has been observed on VC_115 and VC_116, however a continuous reflector to represent this change between CLAY TILL and CHALK has not been observed or interpreted, as interpretation has been limited by the acoustic penetration of the dataset.

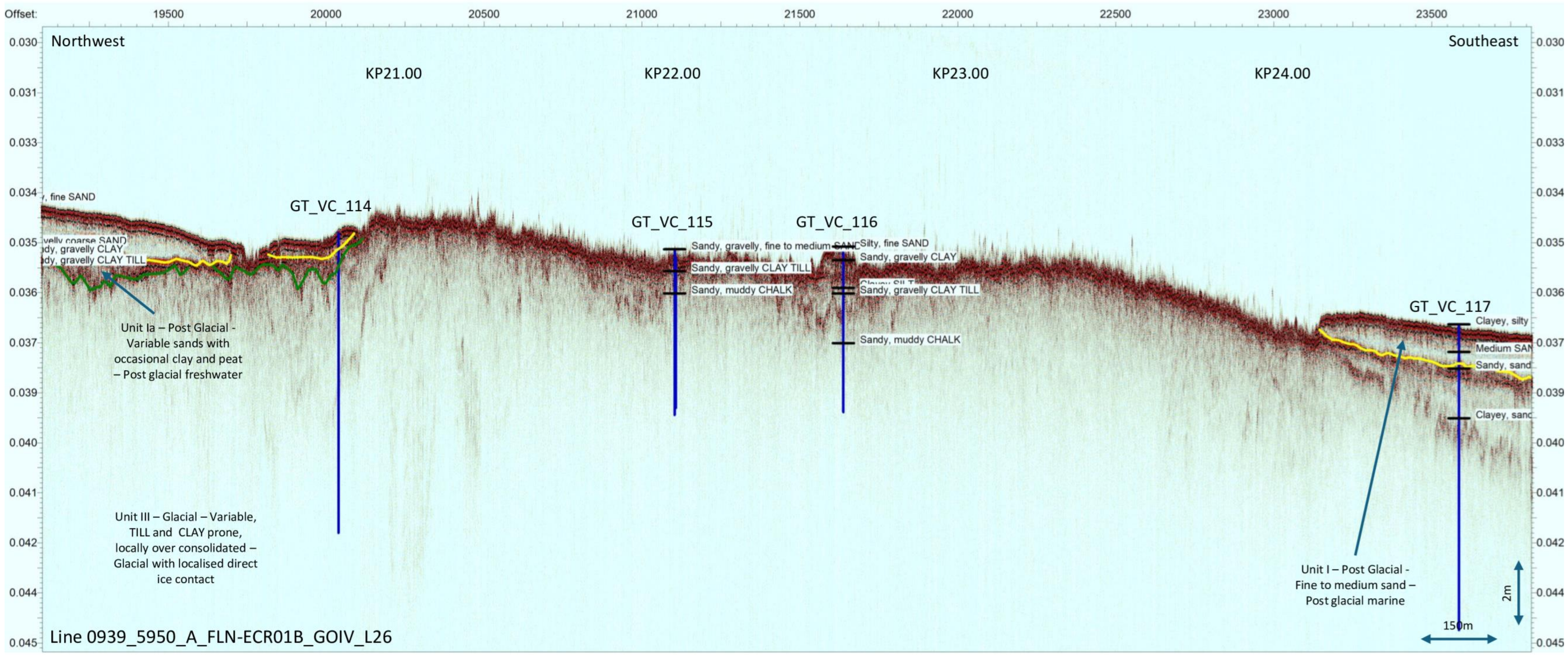


Figure 86: SBP and Geotech, KP 21.000 – KP 24.000 – Southern route

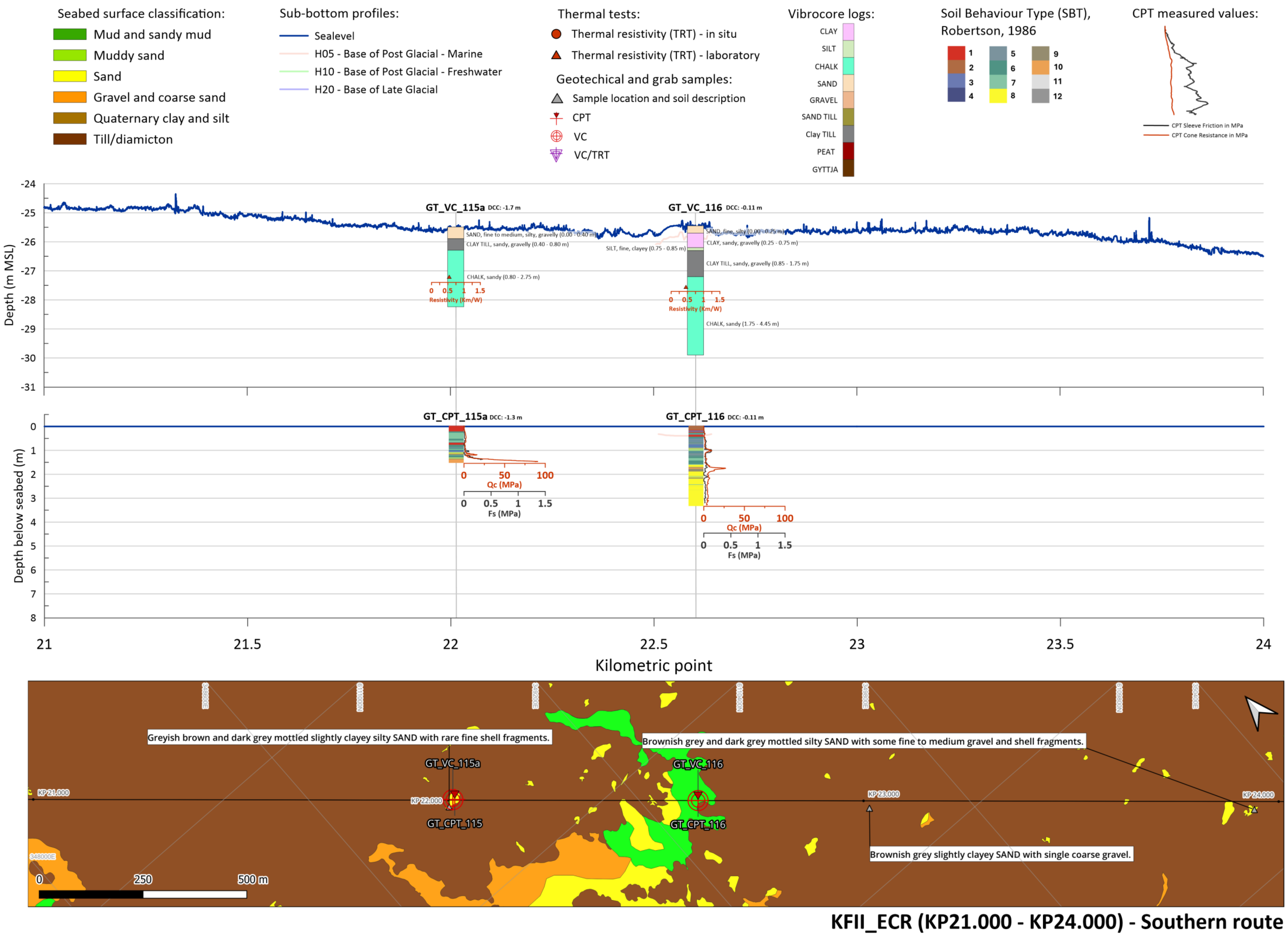


Figure 87: Integrated geotechnical panel KP 21.000 – KP 24.000 –Southern route

7.1.9 KP 24.000 – KP 27.000

Two VCs, two CPTs and three grab samples were acquired in this section.

There is a deposit of Unit I sediments up to 1m thick between KP 24.3 and KP 26.1 otherwise Unit III is at or just below seabed throughout this whole section.

VC0117/CPT117a and VC118/CPT118b both record fine to coarse silty SAND (Unit I) overlying gravelly, sandy CLAY (Unit III sediments). Unit III is near/at seabed over this section so overconsolidated sediments may be present within the cable burial depth over this whole section.

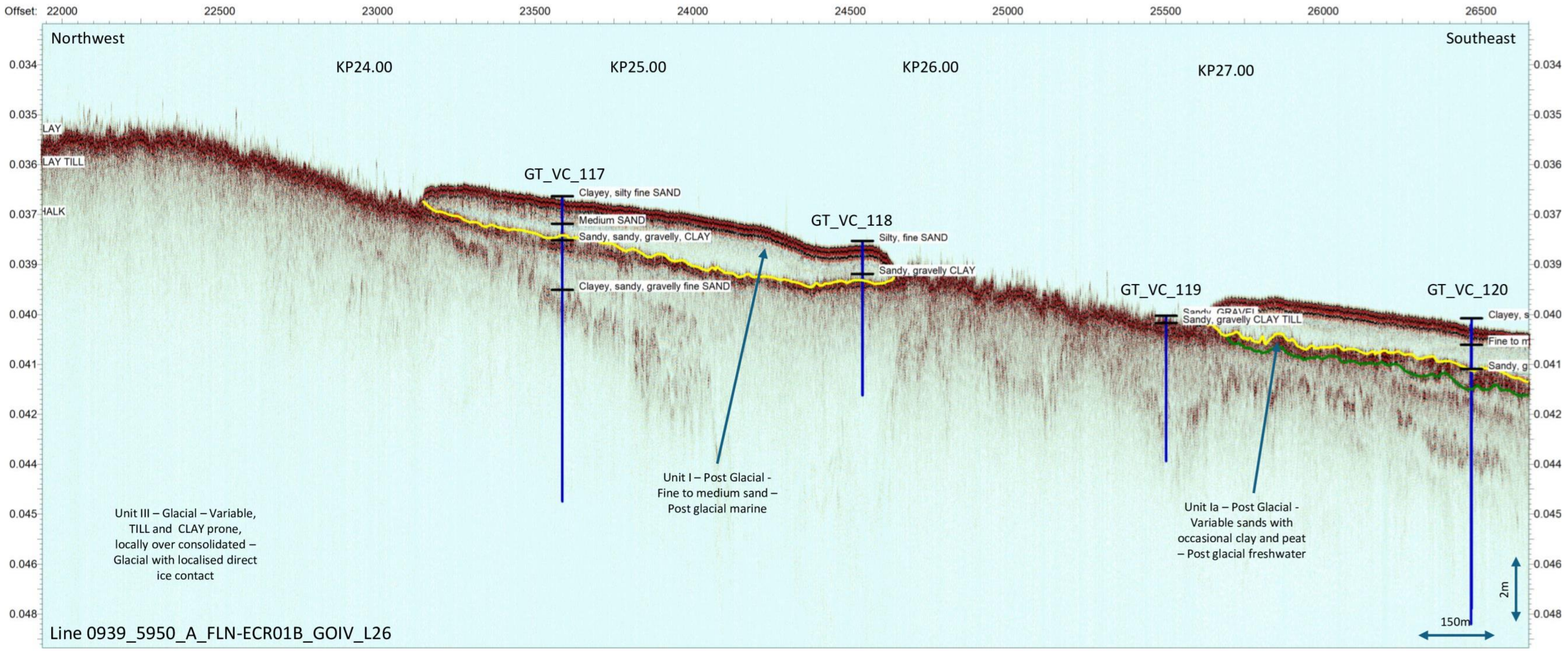


Figure 88: SBP and Geotech, KP 24.000 – KP 27.000 – Southern route

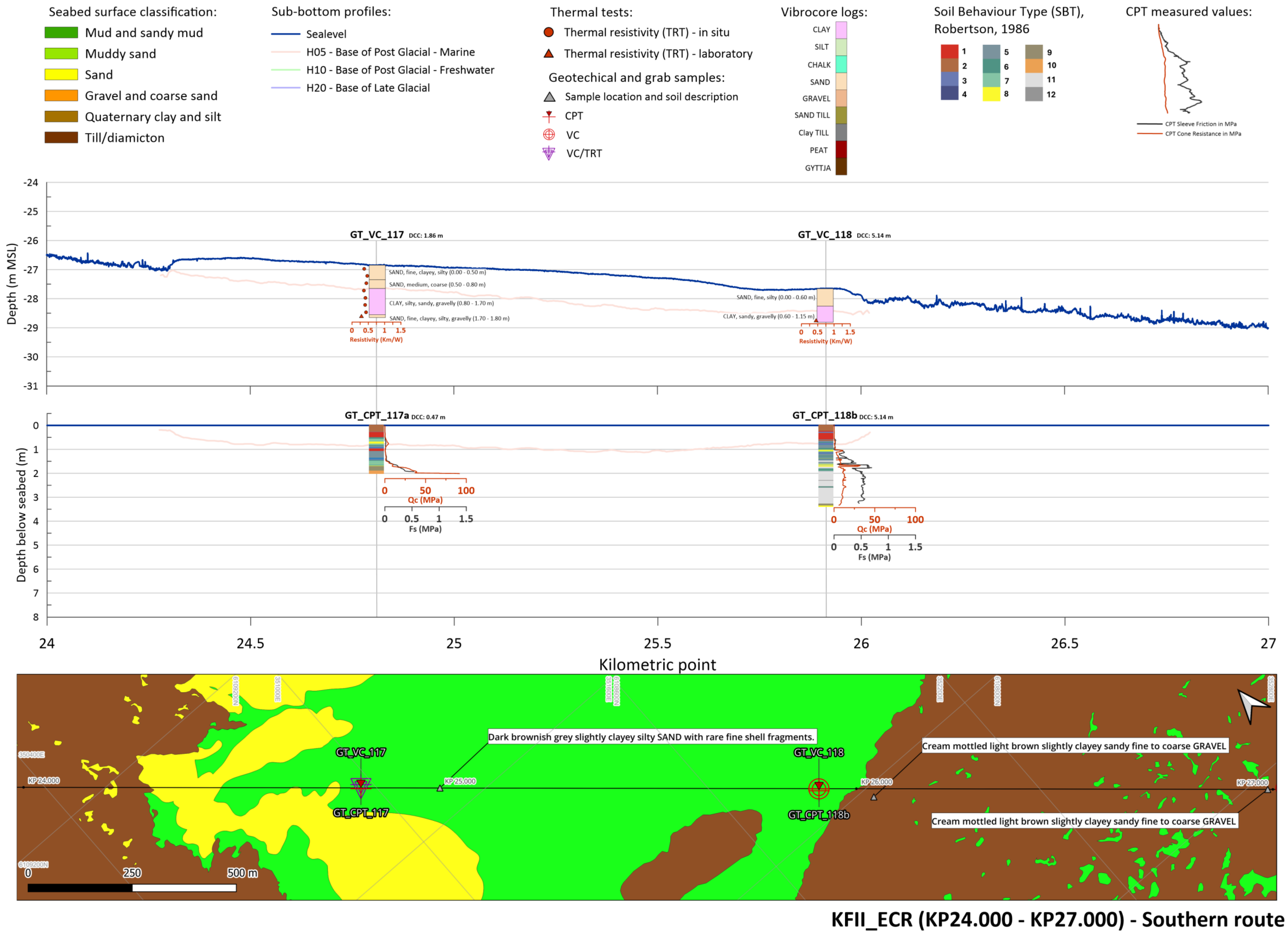


Figure 89: Integrated geotechnical panel KP 24.000 – KP 27.000 –Southern route

7.1.10 KP 27.000 – KP 30.000

Four VCs, four CPTs and two grab samples were acquired in this section.

There is a deposit of Unit I sediments up to 1 m thick between KP 27.3 and KP 28.7 where the seabed has a very different nature to the seabed either side and a very thin layer of potential Unit Ia sediments underlies this deposit. Otherwise, Unit III is at or just below seabed throughout this whole section and is always within 3 m of seabed.

VC0119/CPT119, VC128a/CPT128, and VC130/CPT130 record fine to coarse silty SAND (Unit I and seabed veneer) however VC129/CPT129a records GYTTJA to 0.3 m BSB. This station then records a layers of gravelly CLAY (Unit I) overlying Unit III sediments comprising fine to medium silty SAND.

VC0119/CPT119 records a sandy GRAVEL overlying a sandy, gravelly CLAY TILL (Unit III).

Stations 128 and 130 record Unit III sediments as SAND overlying sandy (gravelly) CLAY.

Unit III is near/at seabed and always within 3 m over this section so overconsolidated sediments may be present within the cable burial depth over this whole section.

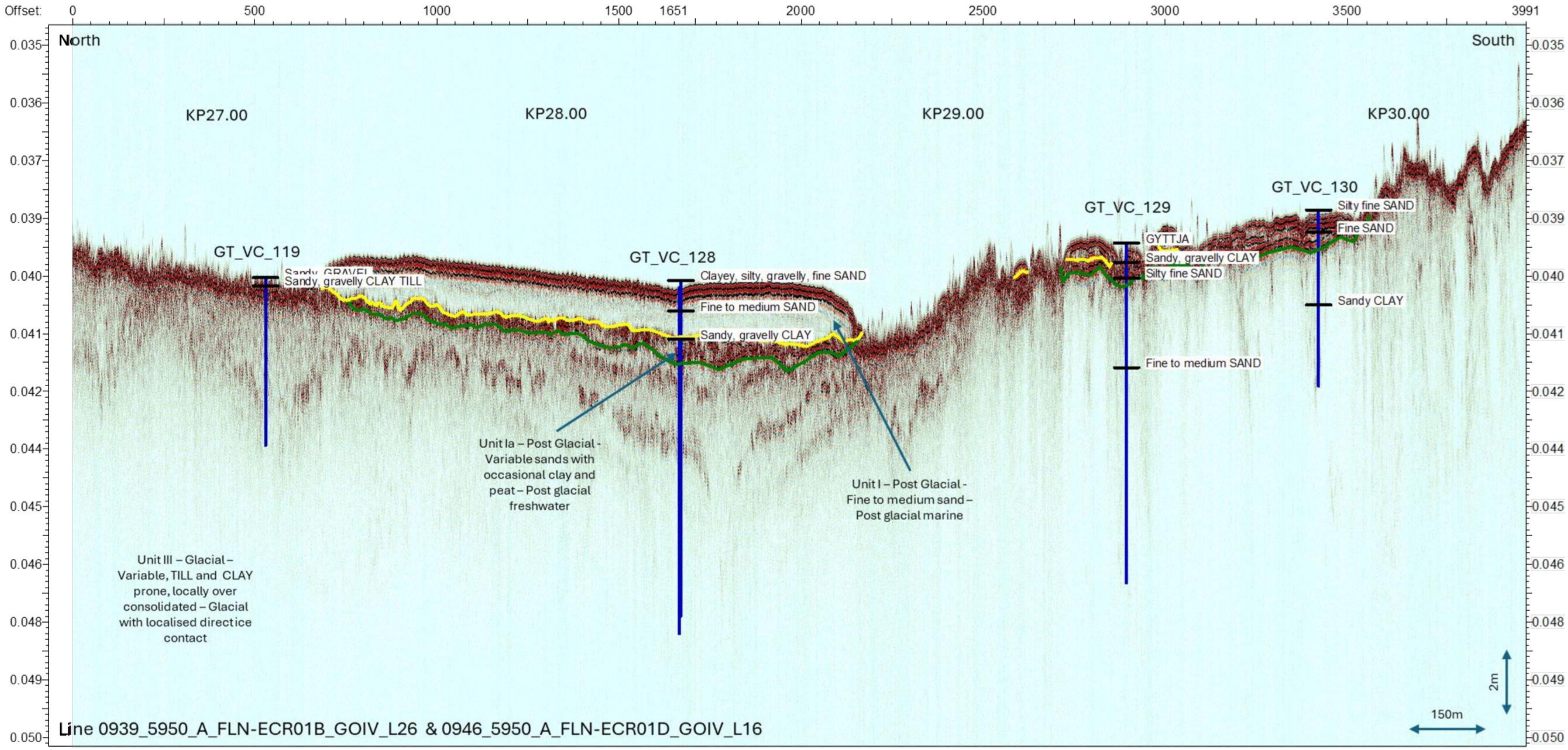


Figure 90: SBP and Geotech, KP 27.000 – KP 30.000 – Southern route

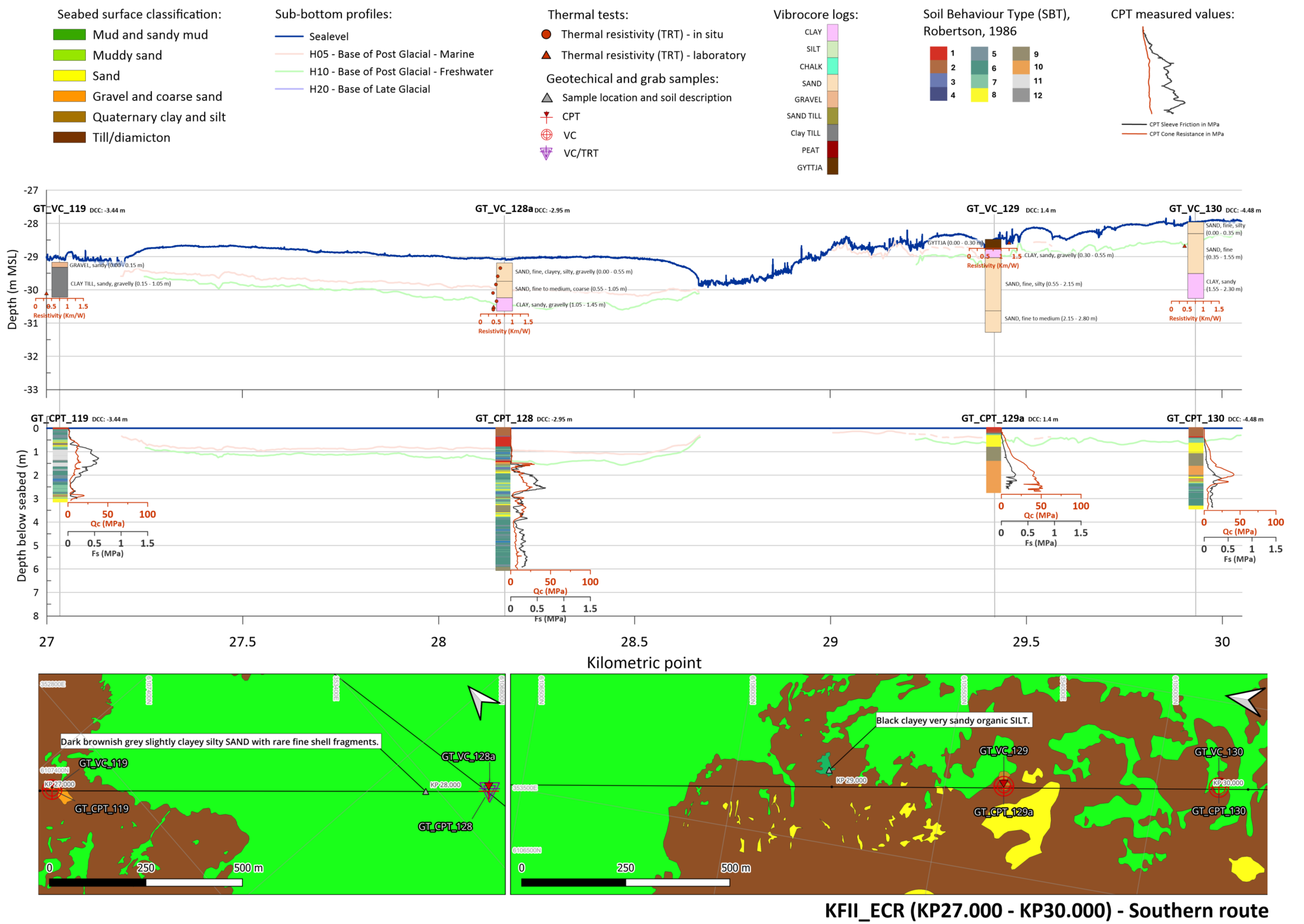


Figure 91: Integrated geotechnical panel KP 27.000 – KP 30.000 –Southern route

7.1.11 KP 30.000 – KP 33.000

Two VCs, two CPTs and four grab samples were acquired in this section.

Unit I sediments are present in this section but have not been acoustically distinguished on the RPL (so H05 has not been mapped here). H10 (less than 1 m BSB) is intermittently present in this section so some shallow deposits of Unit Ia are present in the section. Otherwise, Unit III is at or just below seabed throughout this whole section and is always within 3 m of seabed.

VC0131/CPT131 and VC132/CPT132 record quite different sediments despite their proximity. Station 131 records a layer of GYTTJA at seabed overlying a thin layer of GRAVEL overlying sandy CLAY and CLAY TILL (typical Unit III sediments). Station 132 records a SAND dominant sequence to approximately 2.7 m BSB whereupon a layer of GRAVEL overlying gravelly CLAY are recorded illustrating the mix of sediments within the Units.

Unit III is near/at seabed and always within 3 m over this section so overconsolidated sediments may be present within the cable burial depth over this whole section.

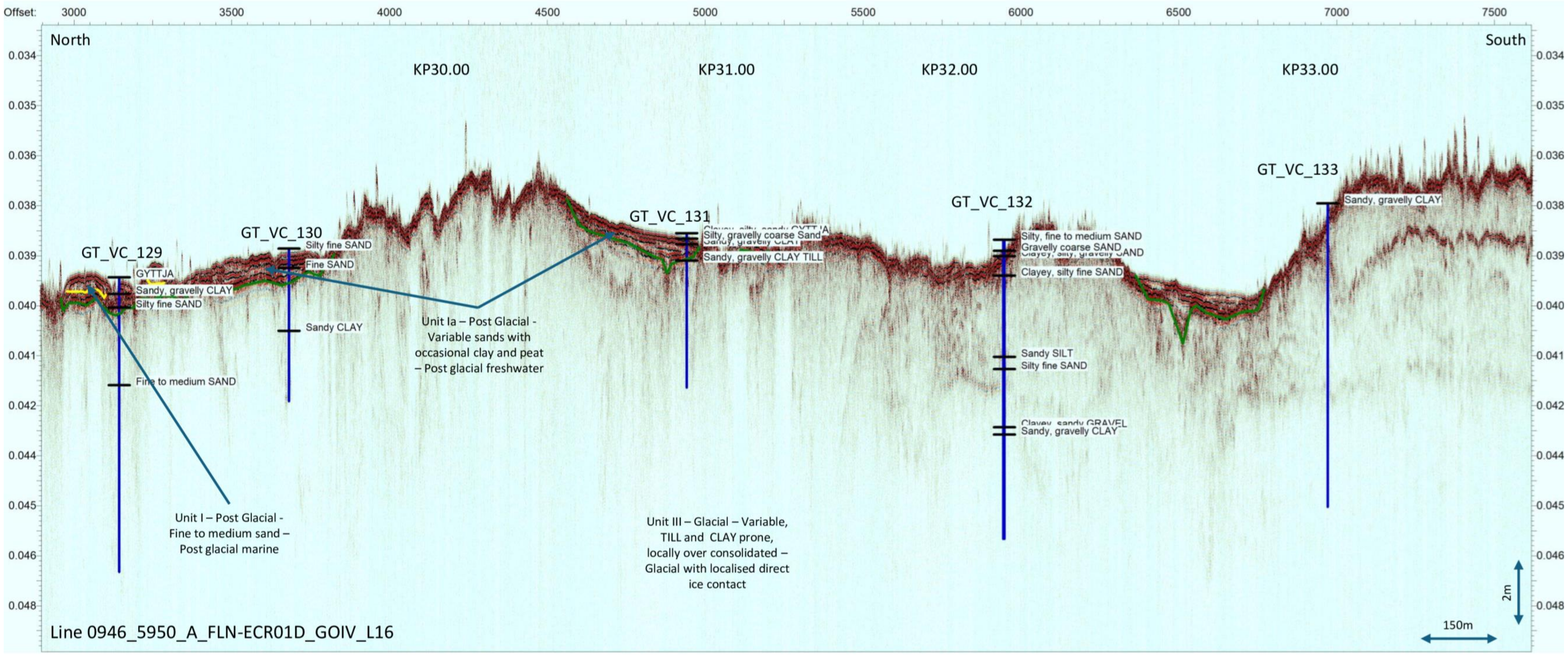


Figure 92: SBP and Geotech, KP 30.000 – KP 33.000 – Southern route

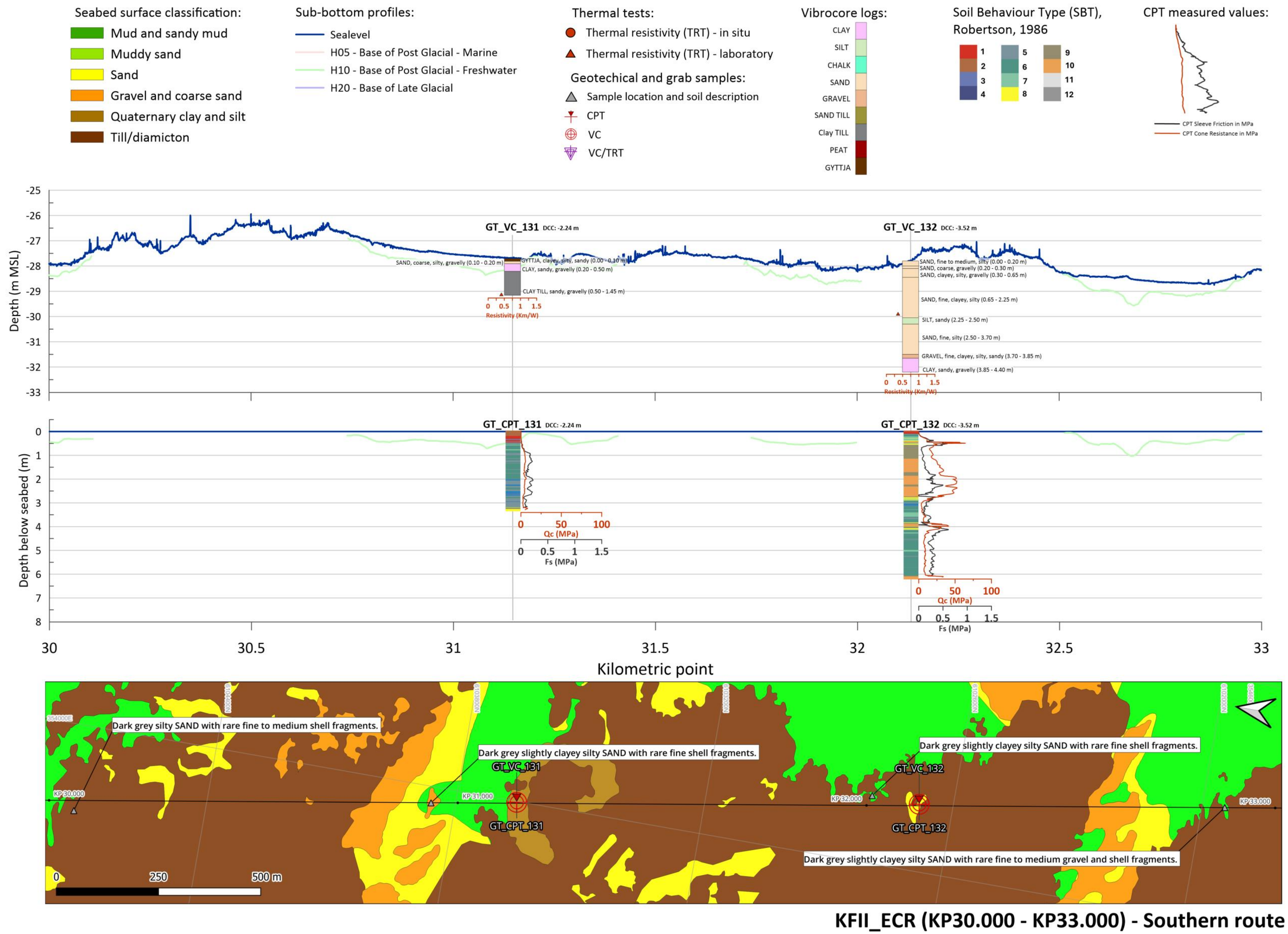


Figure 93: Integrated geotechnical panel KP 30.000 – KP 33.000 –Southern route

7.1.12 KP 33.000 – KP 36.000

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

Unit I and Ia sediments are present in this section but have not been acoustically distinguished on the RPL (so H05, H10 and H20 have not been mapped here however these units are distinguished and mapped within the eastern section of the route corridor within this section). Over the RPL Unit III is at or just below seabed throughout this whole section a more rugose seabed (associated with the presence of Unit III at/near seabed) is evident.

VC0133/CPT133, VC134/CPT134a and VC135a/CPT135a all record typical Unit III sediments. Station 133 records predominantly sandy CLAY, station 134 – gravelly CLAY TILL and station 135a gravelly SAND TILL over sandy CLAY.

Unit III is near/at seabed and always within 3 m over this section so overconsolidated sediments may be present within the cable burial depth over this whole section.

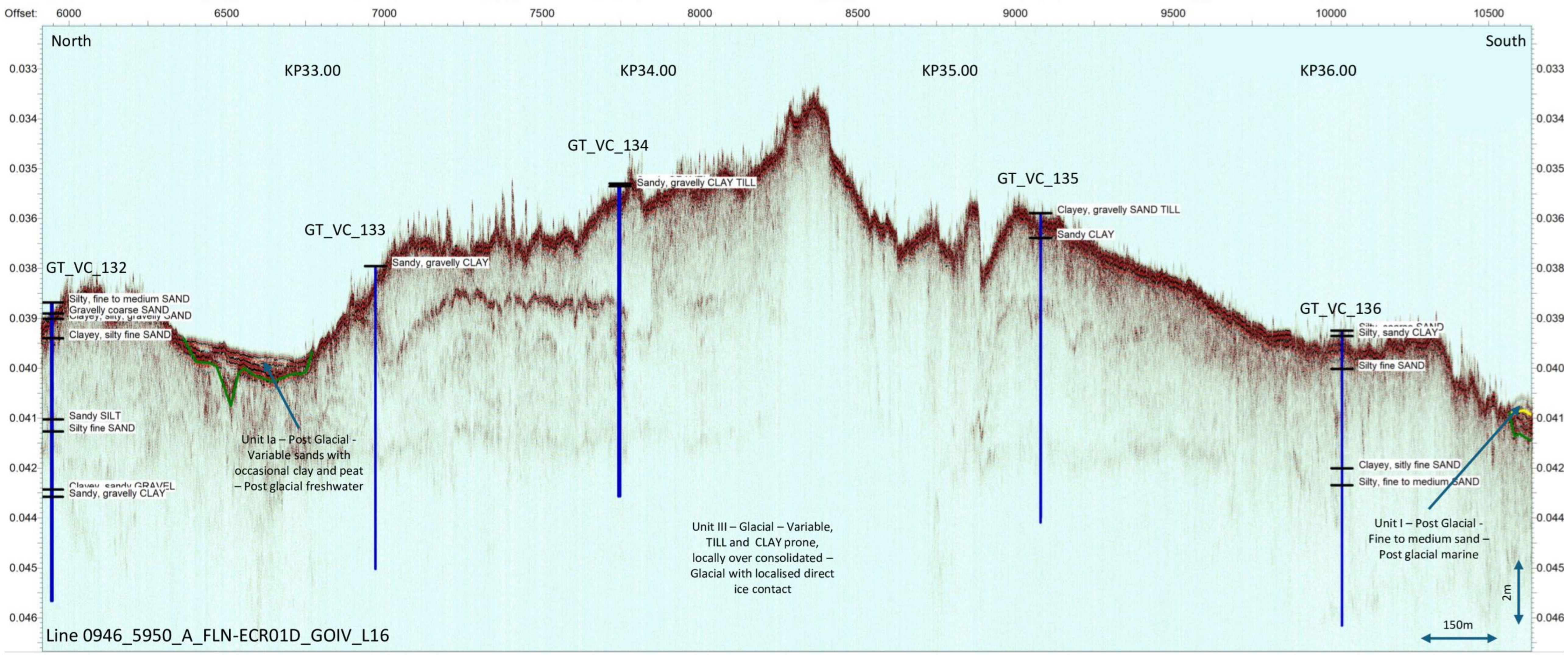
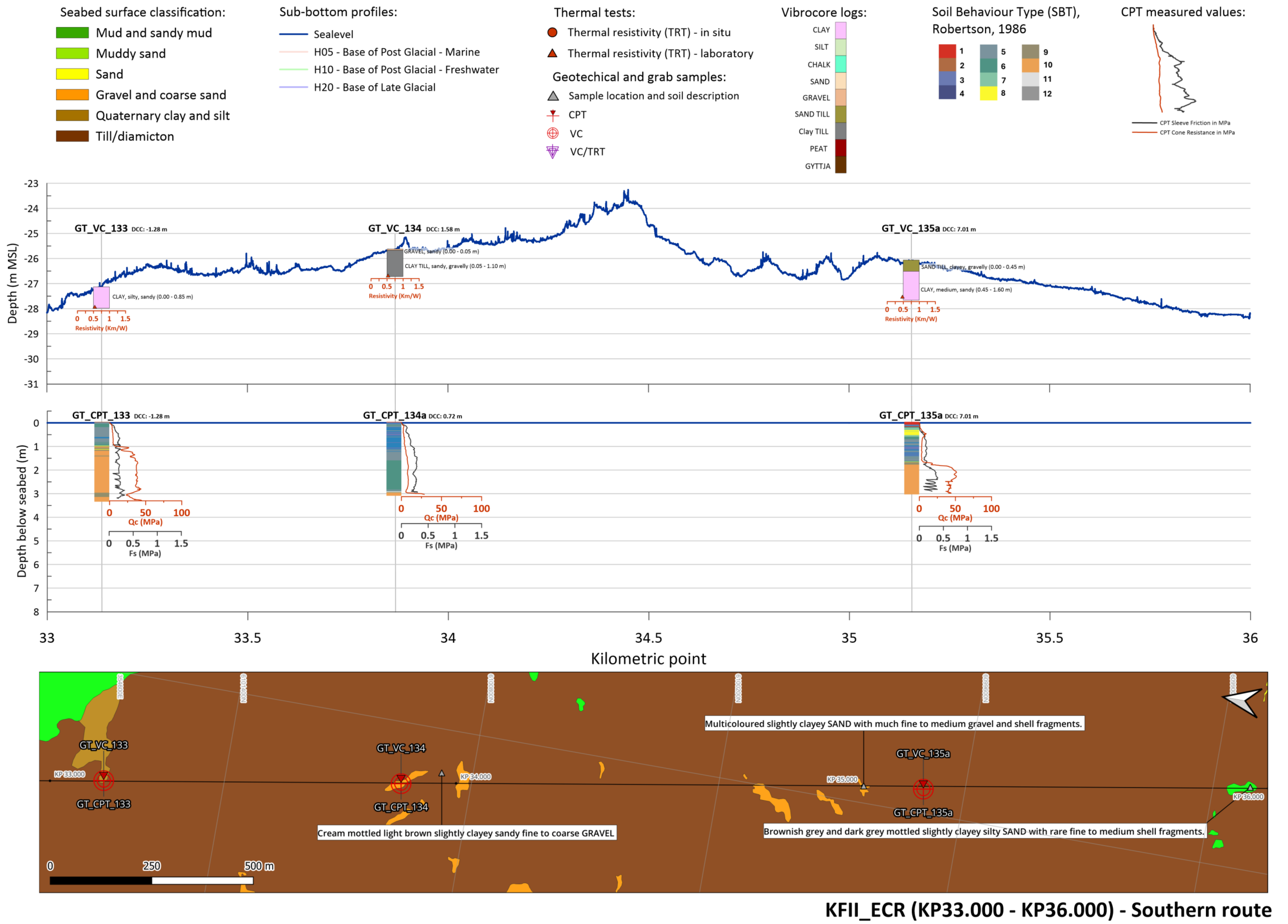


Figure 94: SBP and Geotech, KP 33.000 – KP 36.000 – Southern route



KFII_ECR (KP33.000 - KP36.000) - Southern route

Figure 95: Integrated geotechnical panel KP 33.000 – KP 36.000 –Southern route

7.1.13 KP 36.000 – KP 39.000

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

Unit I, Unit Ia and II sediments are present in this section and have been mapped where distinguishable acoustically – this is mostly within the section between approximately KP 37 and KP 38. Each side of this section Unit III is at or just below seabed and a more rugose seabed (associated with the presence of Unit III at/near seabed) is evident.

VC136/CPT136 and VC137/CPT137 penetrate Unit III sediments, however they do not appear to be as overconsolidated here a station 136 records a mostly SAND sequence and 137 records a sandy CLAY.

Station VC138/CPT138 penetrates Units I and Ia and records a fine silty SAND throughout the sample to almost 6 m.

Unit III is near/at seabed in parts of this section and despite the geotechnical stations results overconsolidated sediments may be present within the cable burial depth where Units I and II are not present.

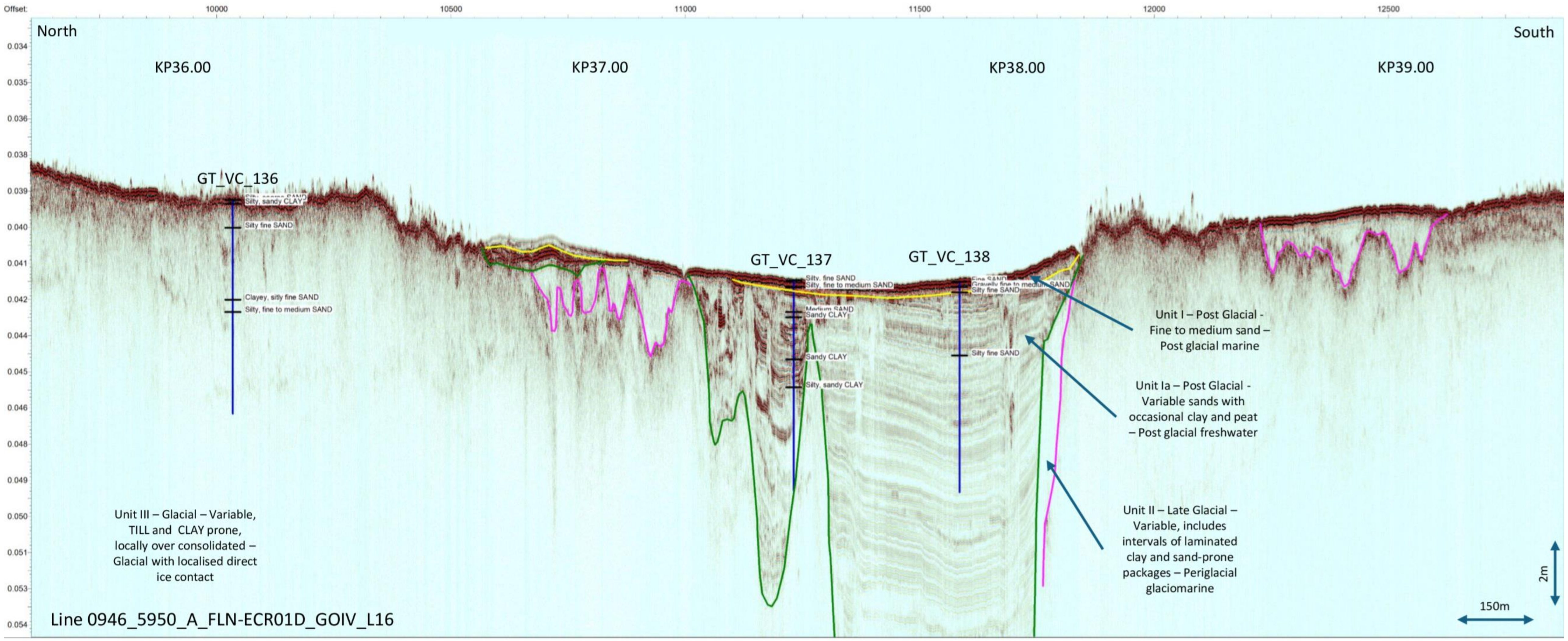


Figure 96: SBP and Geotech, KP 36.000 – KP 39.000 – Southern route

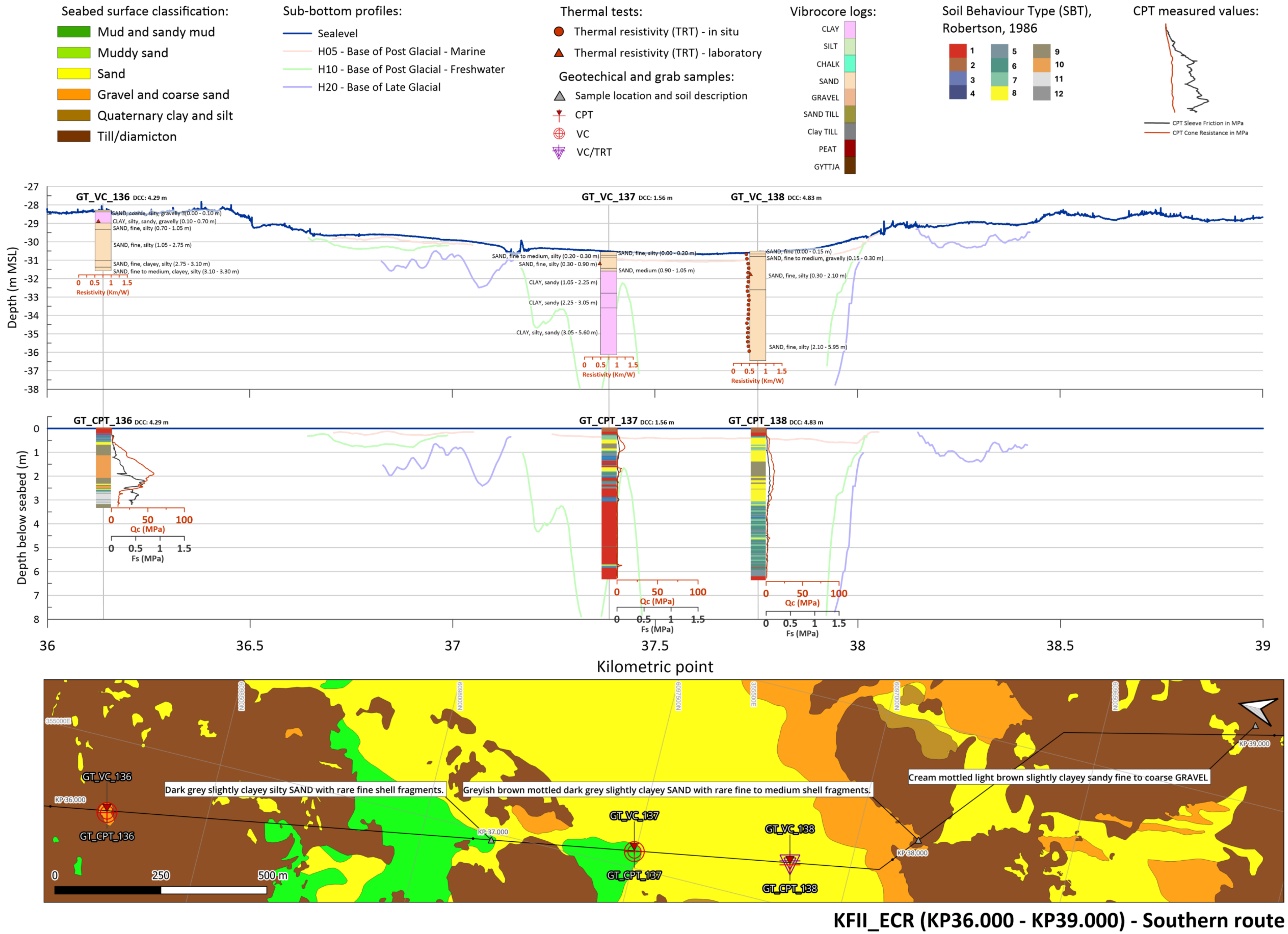


Figure 97: Integrated geotechnical panel KP 36.000 – KP 39.000 –Southern route

7.1.14 KP 39.000 – KP 42.000

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

Unit I, Unit 1a, and II sediments are present in this section from approximately KP 40.8; up until this point Unit III is at or just below seabed and a more rugose seabed (associated with the presence of Unit III at/near seabed) is evident.

VC139/CPT139 and VC140/CPT140 penetrate Unit III sediments and record clayey, silty, gravelly SAND (in VC139) overlying CLAY TILL – Station 140 only records CLAY TILL which is typical of Unit III sediments.

Station VC141/CPT141 penetrates Unit II and records a fine silty, sandy CLAY in the VC however the CPT (which penetrates to almost 6m into Unit III) records a more SAND dominant profile and describes sediments in Unit III as hard CLAY and weak ROCK.

Unit III is near/at seabed in this section to approximately KP 40.8 and so overconsolidated sediments may be present within the cable burial depth where Units I and II are not present.

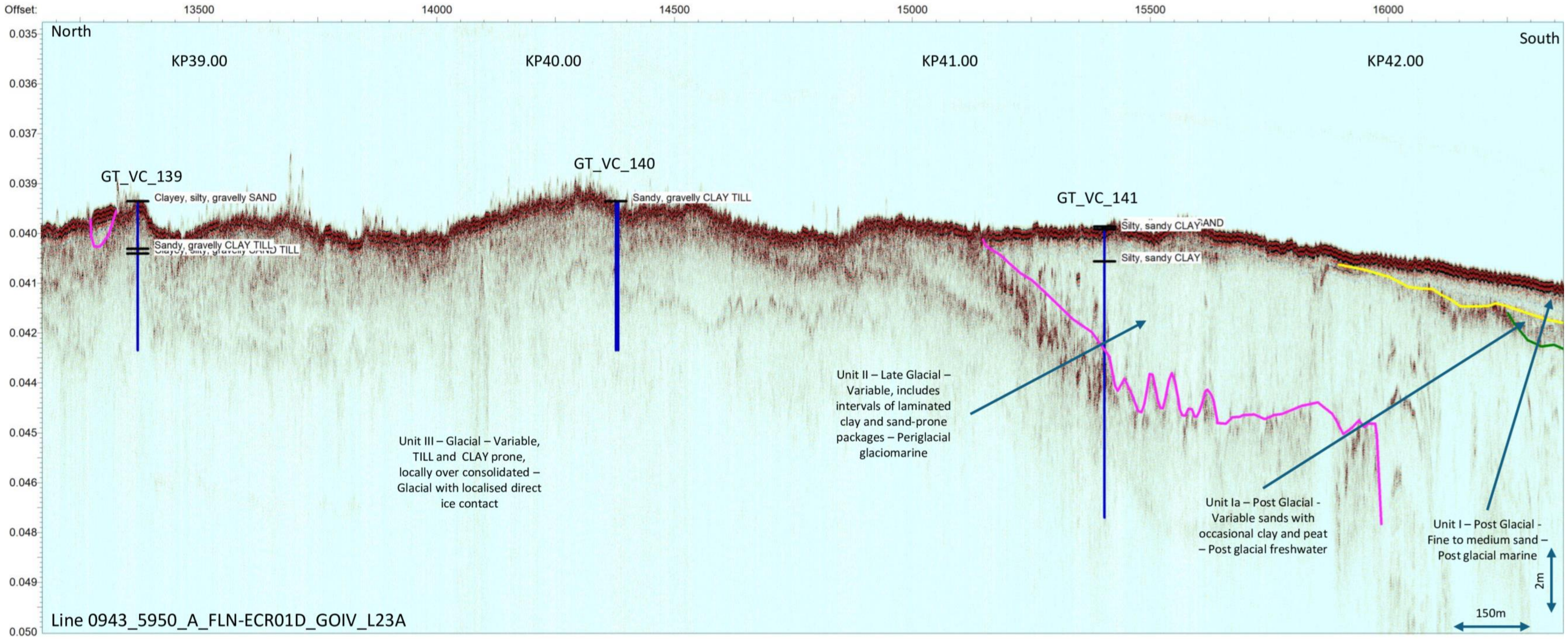


Figure 98: SBP and Geotech, KP 39.000 – KP 42.000 – Southern route

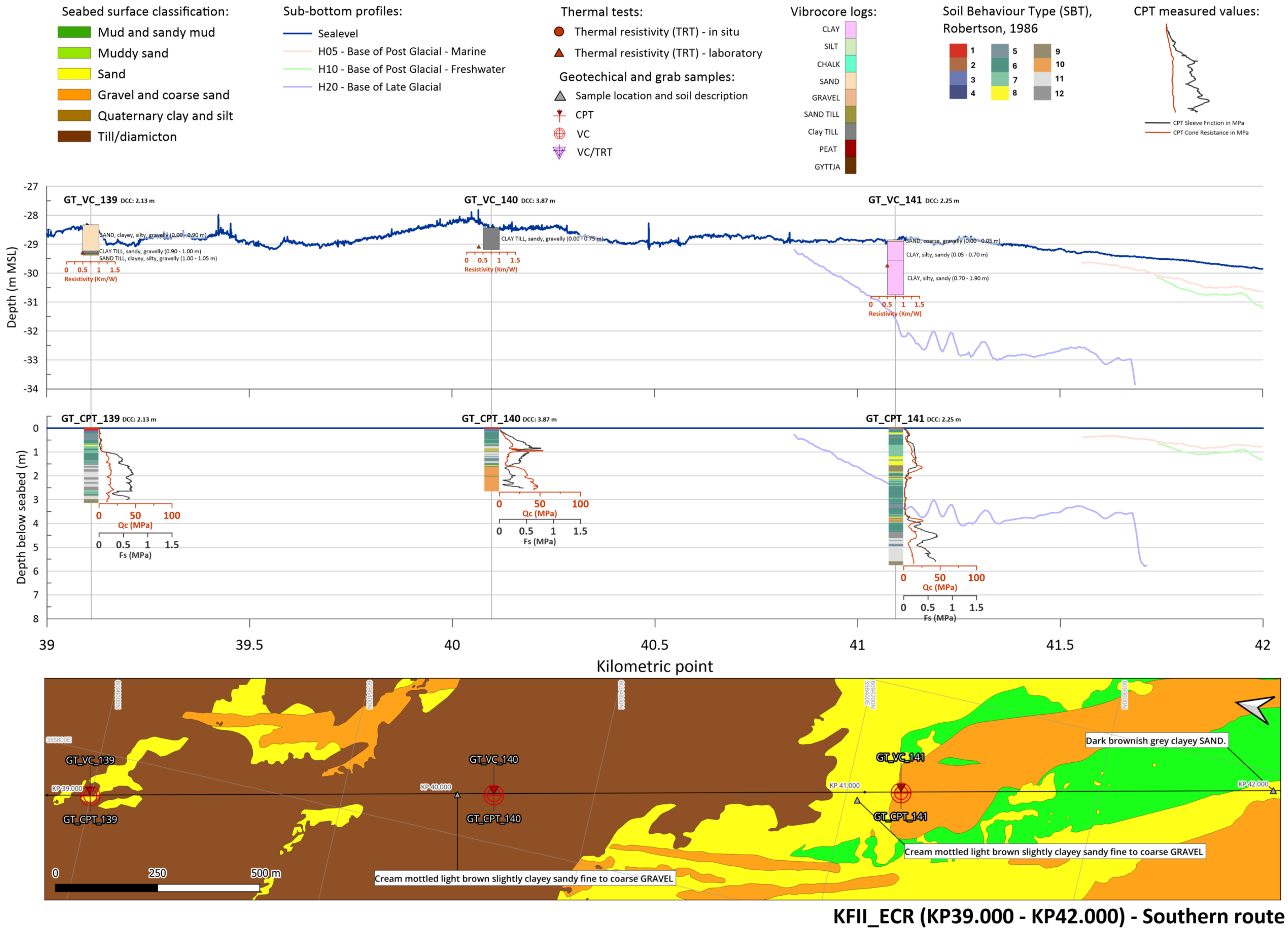


Figure 99: Integrated geotechnical panel KP 39.000 – KP 42.000 –Southern route

7.1.15 KP 42.000 – KP 45.000

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

Unit I, Unit 1a, and Unit II sediments are present in this over this section – Unit I sediments are less than 1 m thick, and Unit Ia and Unit II sediments are both present up to 5m BSB.

VC142/CPT142, VC143a/CPT143 and VC144/CPT144 all penetrate Unit I sediments and record a SAND dominant sediment profile (although note that VC142 records a layer of PEAT at the base of Unit I).

Unit Ia sediments are primarily composed of SAND with occasional SILT.

Unit II sediments are recorded as a mix of SAND, SILT and CLAY over these geotechnical stations.

All stations penetrate Unit III and station 144 records a gravelly CLAY and a CLAY TILL, station 143 records a CLAY TILL overlying a SAND however station 142 presents a continuation of a mix of CLAY, SAND and SILT layers.

Unit III is present within 3 m of seabed around KP 43, and CLAY TILL has been recorded so overconsolidated sediments may be present within the cable burial depth.

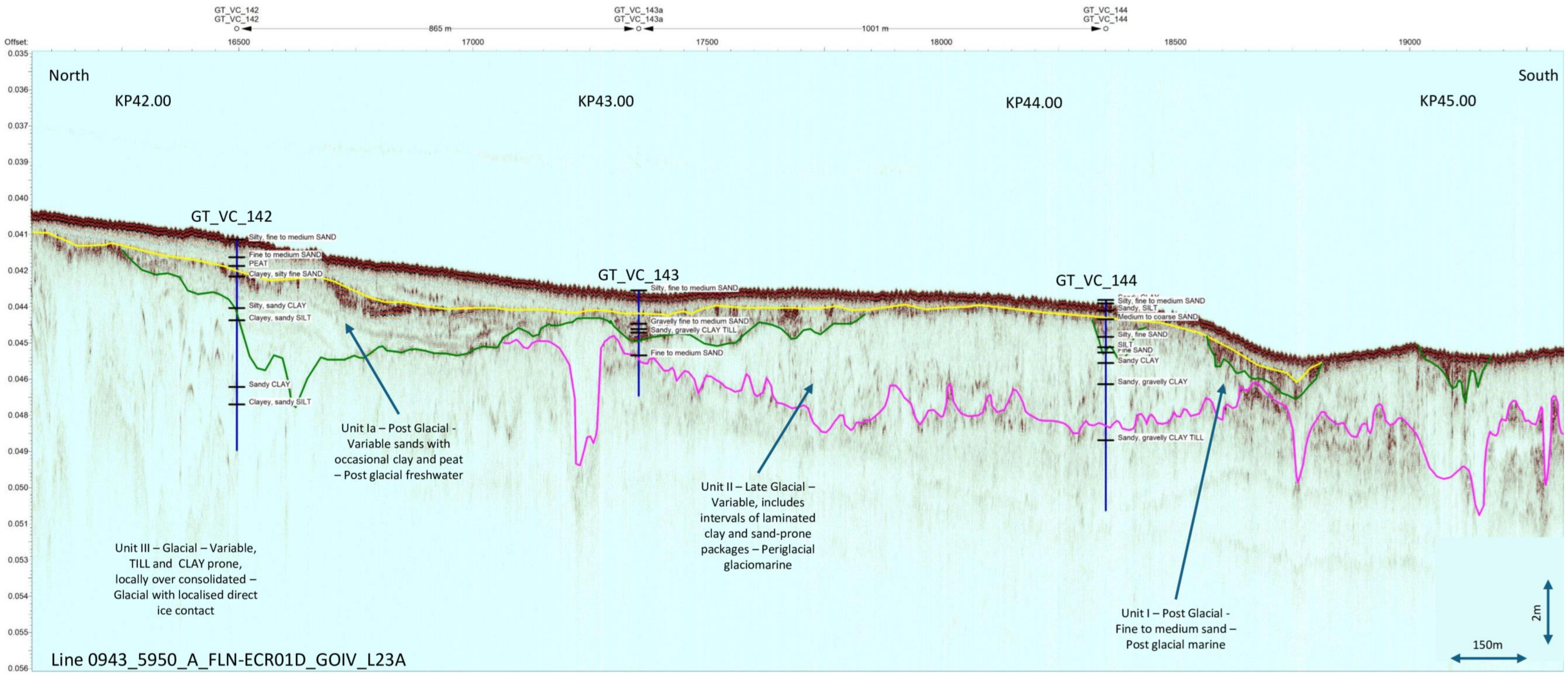


Figure 100: SBP and Geotech, KP 42.000 – KP 45.000 – Southern route

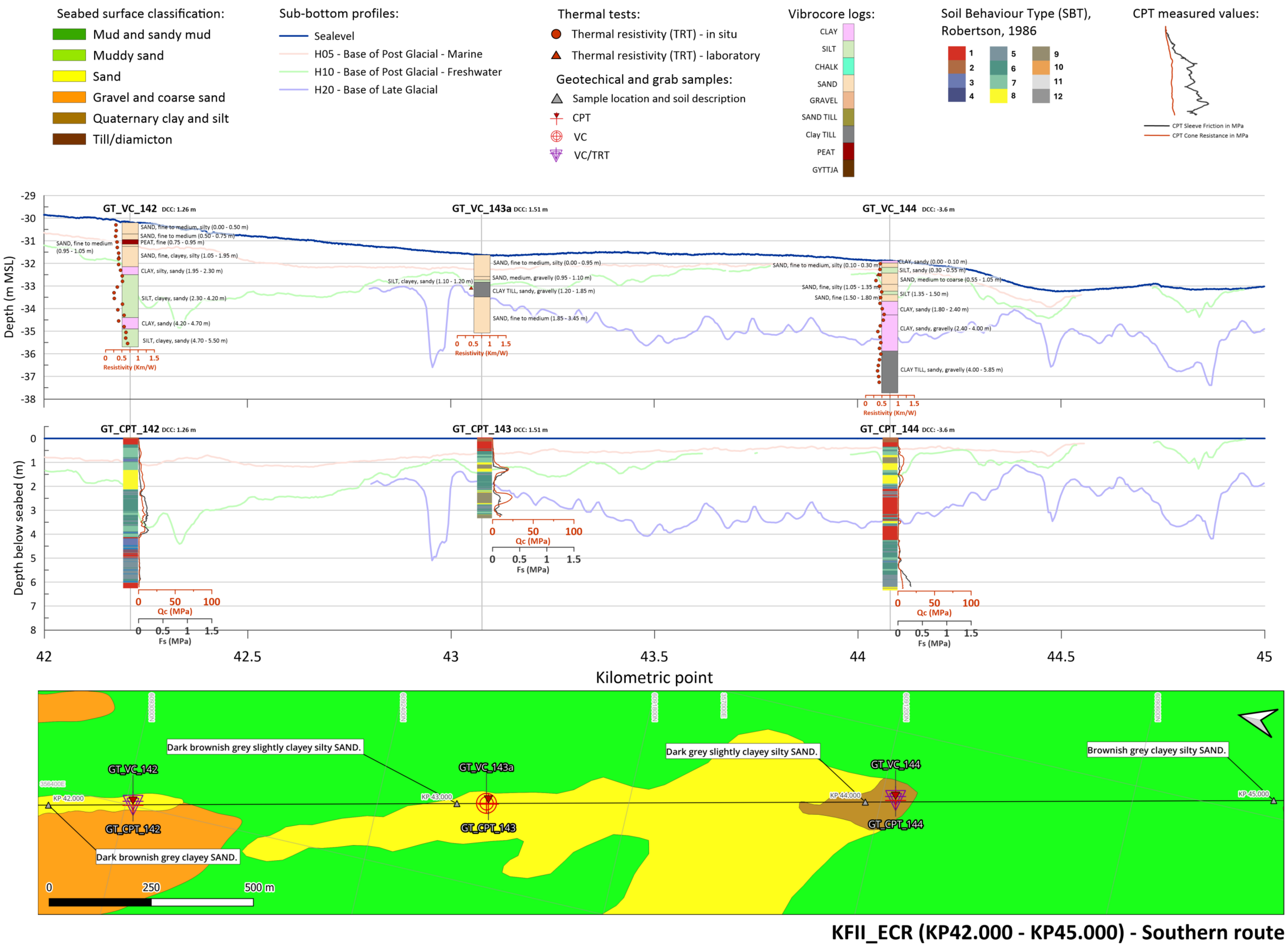


Figure 101: Integrated geotechnical panel KP42.000 – KP 45.000 –Southern route

7.1.16 KP 45.000 – KP 47.122

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

Unit I, Unit 1a and II sediments are present over this section – Unit I sediments reach 2 m in thickness associated with an area of seabed shoaling, Unit Ia sediments are interpreted up to 2.6m BSB, and Unit II sediments reach up to 8 m BSB in this same area.

VC145/CPT145, VC146/CPT146 and VC147/CPT147 all penetrate Unit I sediments and record a SAND dominant sediment profile (although note that VC145 and 146 also record a layer of SILT at the base of Unit I).

Unit Ia sediments are primarily interpreted to be SILT in this area.

Unit II sediments are recorded as a mix of SAND, SILT and CLAY over these geotechnical stations.

CPT145 is the only station to penetrate Unit III and records layers of silty CLAY and sandy SILT.

Unit III is present within 3 m of seabed around KP 45 and whilst CLAY TILL has not been recorded in geotechnical station 145 overconsolidated sediments may be present within the cable burial depth.

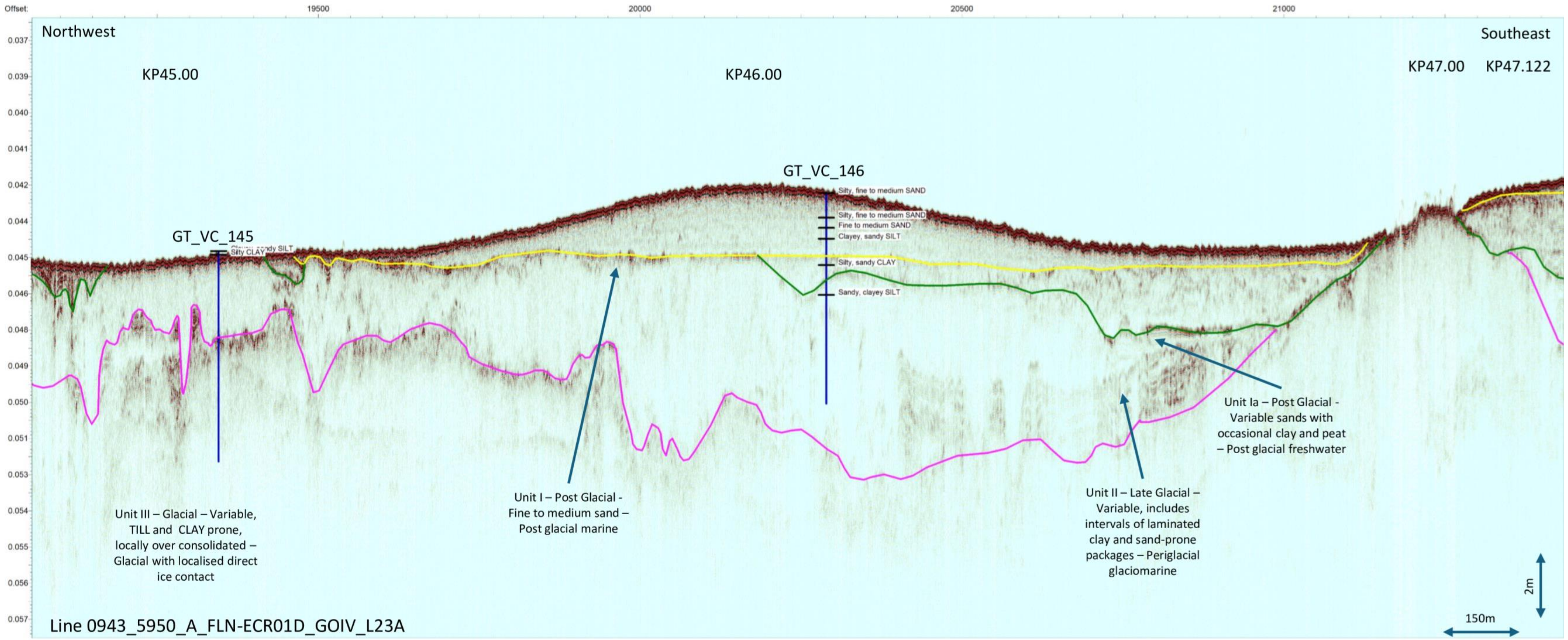


Figure 102: SBP and Geotech, KP 45.000 – KP 47.122 – Southern route

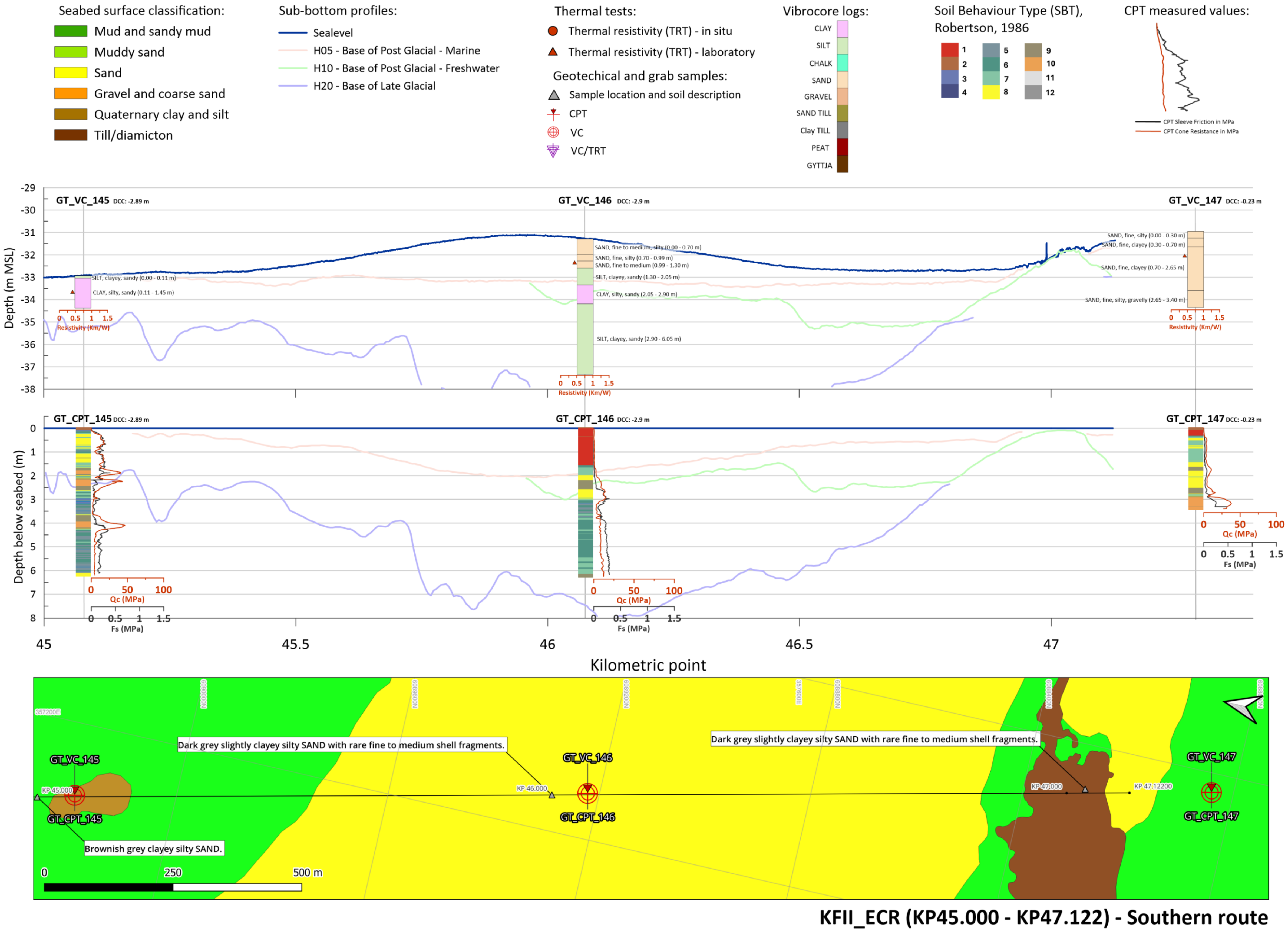


Figure 103: Integrated geotechnical panel KP45.000 – KP 47.122 –Southern route

7.2 KRIEGERS FLAK – 3 KM SECTION NORTH ROUTE CABLE DESCRIPTIONS

7.2.1 KP 0.000 – KP 3.000

See Section 7.1.1 above

7.2.2 KP 3.000 – KP 6.000

See Section 7.1.2 above

7.2.3 KP 6.000 – KP 9.000

See Section 7.1.3 above

7.2.4 KP 9.000 – KP 12.000

See Section 7.1.4 above

7.2.5 KP 12.000 – KP 15.000

See Section 7.1.5 above

7.2.6 KP 14.000 – KP 17.000

Two VCs, two CPTs and four grab samples were acquired in this section.

Unit I, Unit 1a, and Unit II sediments are intermittently present over this section – Unit I sediments are generally less than 1 m thick, Unit Ia shows a maximum depth of 1.5m BSB, and Unit II sediments only reach approximately 2 m BSB.

VC120/CPT120 and VC121/CPT121 penetrate Unit I/Ia/II sediments and record a SAND dominant sediment.

Unit III sediments are recorded as CLAY TILL and CHALK in both stations.

Unit III is present within 3 m of seabed (at/near seabed up to approximately KP 15) so overconsolidated sediments may be present within the cable burial depth (and CHALK has been recorded in the geotechnical samples).

The CHALK interface, indicated from geotechnical data is not observed in SBP data.

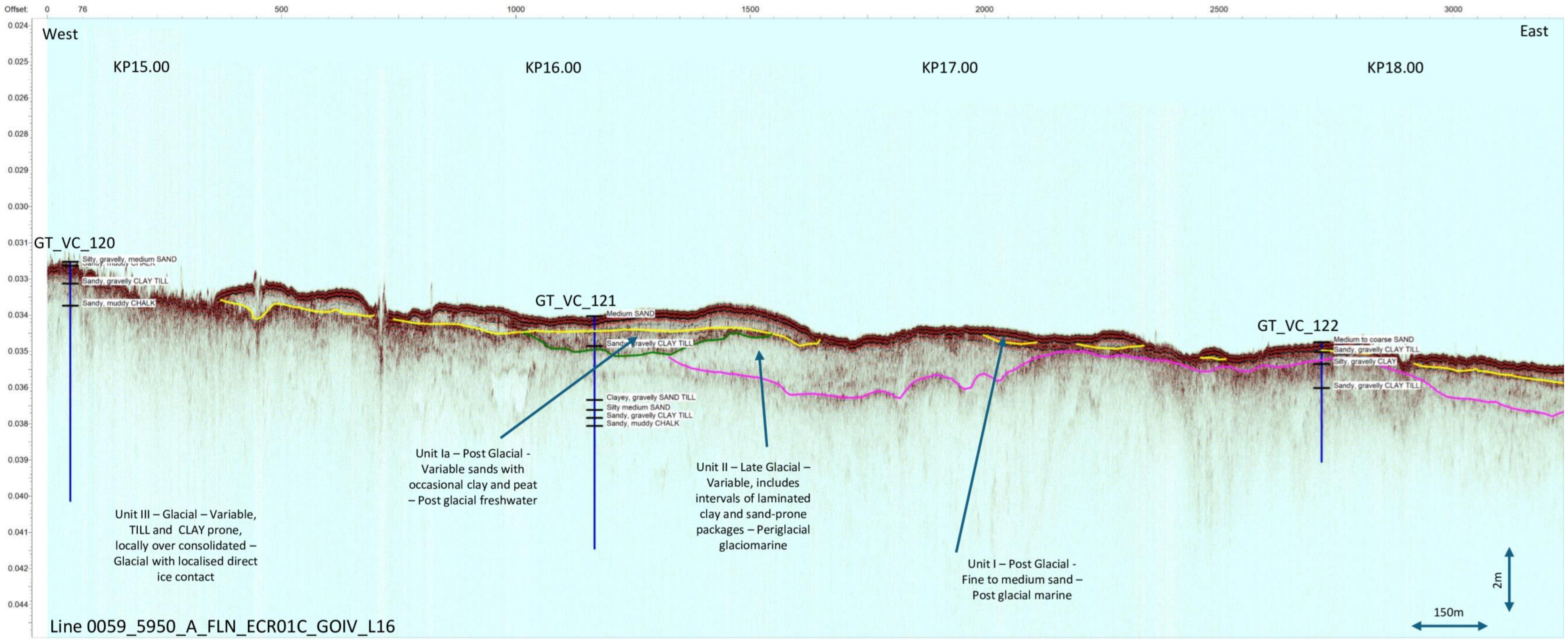


Figure 104: SBP and Geotech, KP 15.000 – KP 18.000 – Northern route

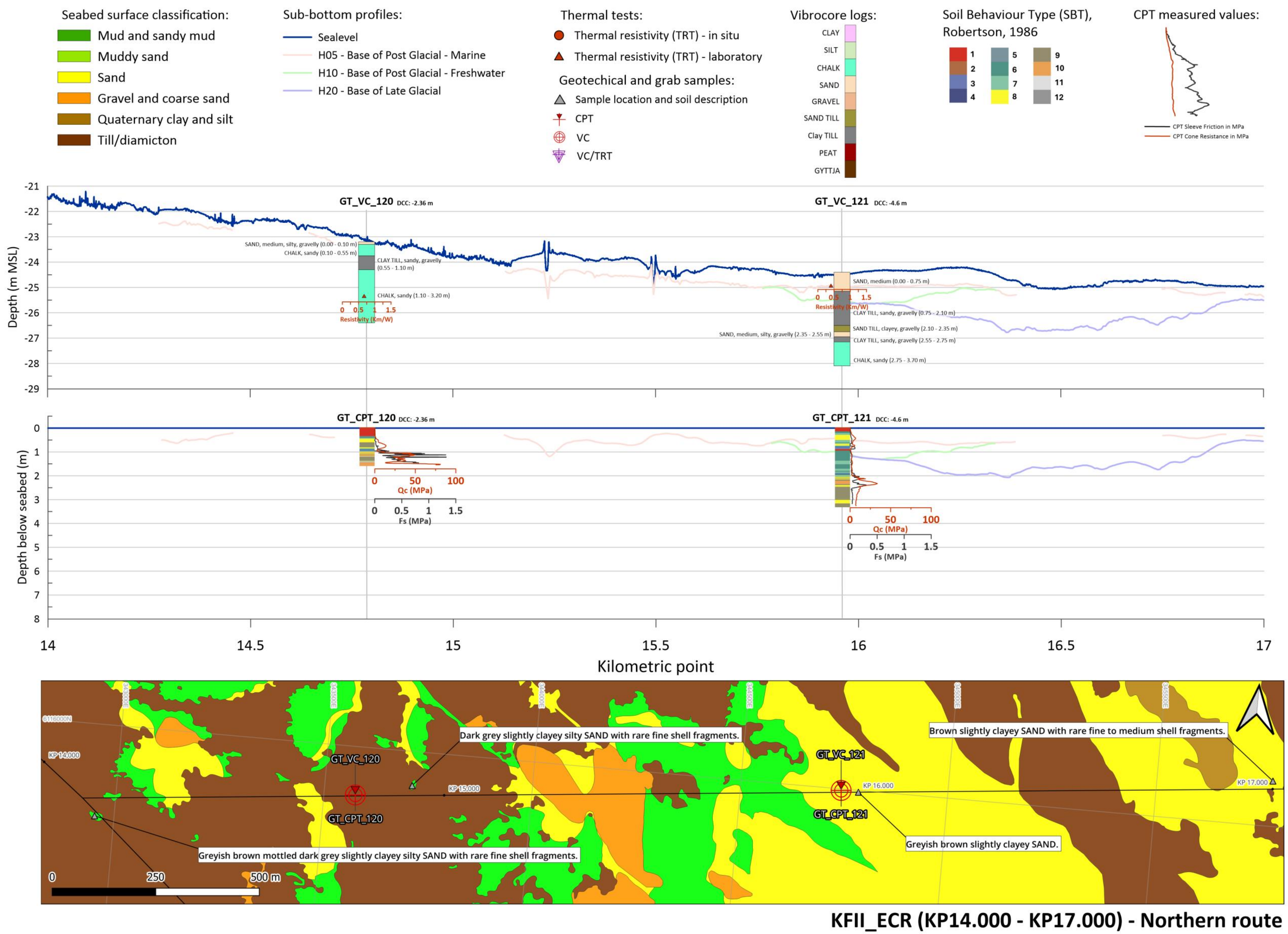


Figure 105: Integrated geotechnical panel KP14.000 – KP 17.000 –Northern route

7.2.7 KP 17.000 – KP 20.000

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

Unit I, Unit Ia, and II sediments are present over most of this section – Unit I sediments are less than 1 m thick, Unit Ia have been interpreted up to 1.5m BSB , and Unit II sediments only reach approximately 3 m BSB within a channel but is mostly thin and H20 (Base Unit II) is mapped at less than 2 m BSB outside the small channel feature.

VC122/CPT122, VC123/CPT123a and VC124/CPT124 penetrate Unit I/Ia/II sediments and record a SAND dominant sediment (although station 124 records a layer of silty CLAY at seabed).

Unit III sediments are recorded as CLAY TILL and SAND TILL in all stations.

Unit III is present within 3 m of seabed so overconsolidated sediments may be present within the cable burial depth (and TILL has been recorded in the geotechnical samples).

Some conflict exists between geotechnical data and the acoustic interpretation across this section with geotechnical cores returning TILL shallower than interpreted on SBP data. The SBP interpretation of H20 appears to follow a similar reflector interpretation on the previous section, however the TILL is observed as shallower from VC_123 towards the end of the route. It is possible that the CLAY TILL observed in both VC_123 and VC_124 are overconsolidated late glacial deposits or that the H20 reflector has been interpreted too deep, but no clear transition to the upper surface is observed in SBP.

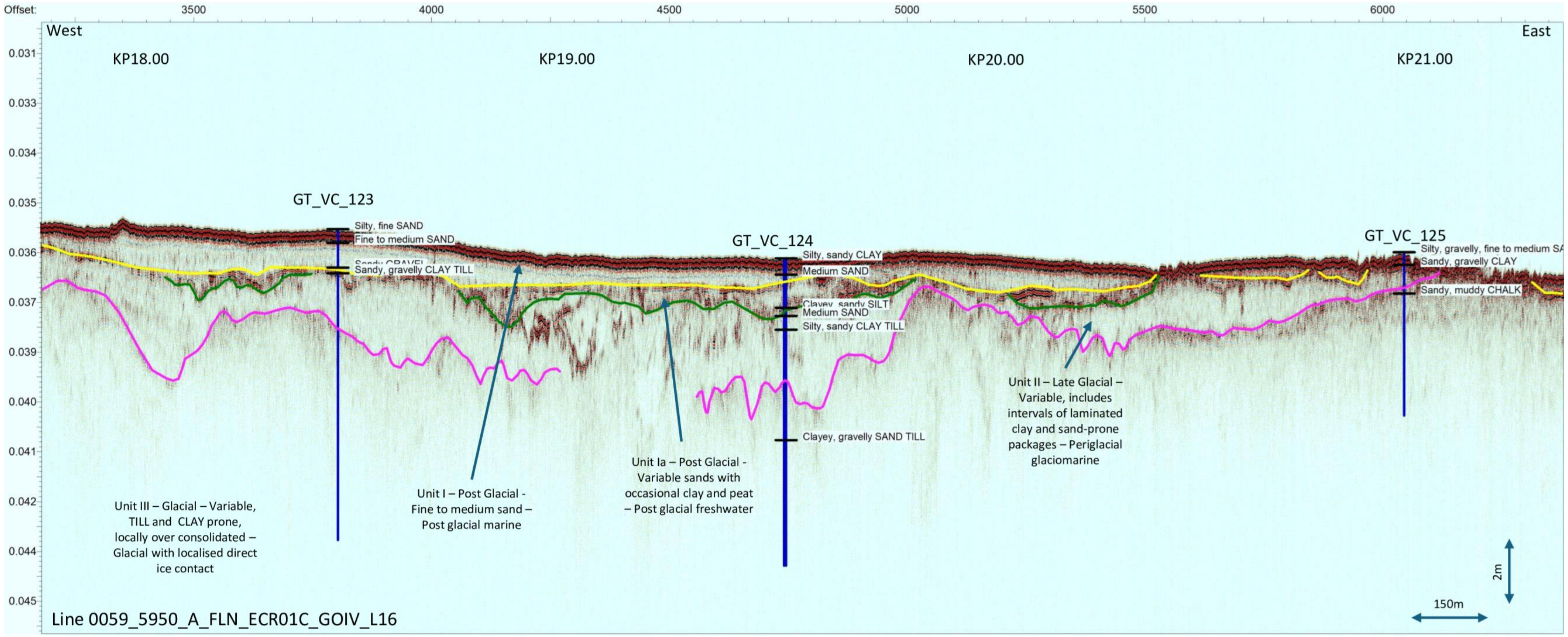


Figure 106: SBP and Geotech, KP 18.000 – KP 21.000 – Northern route

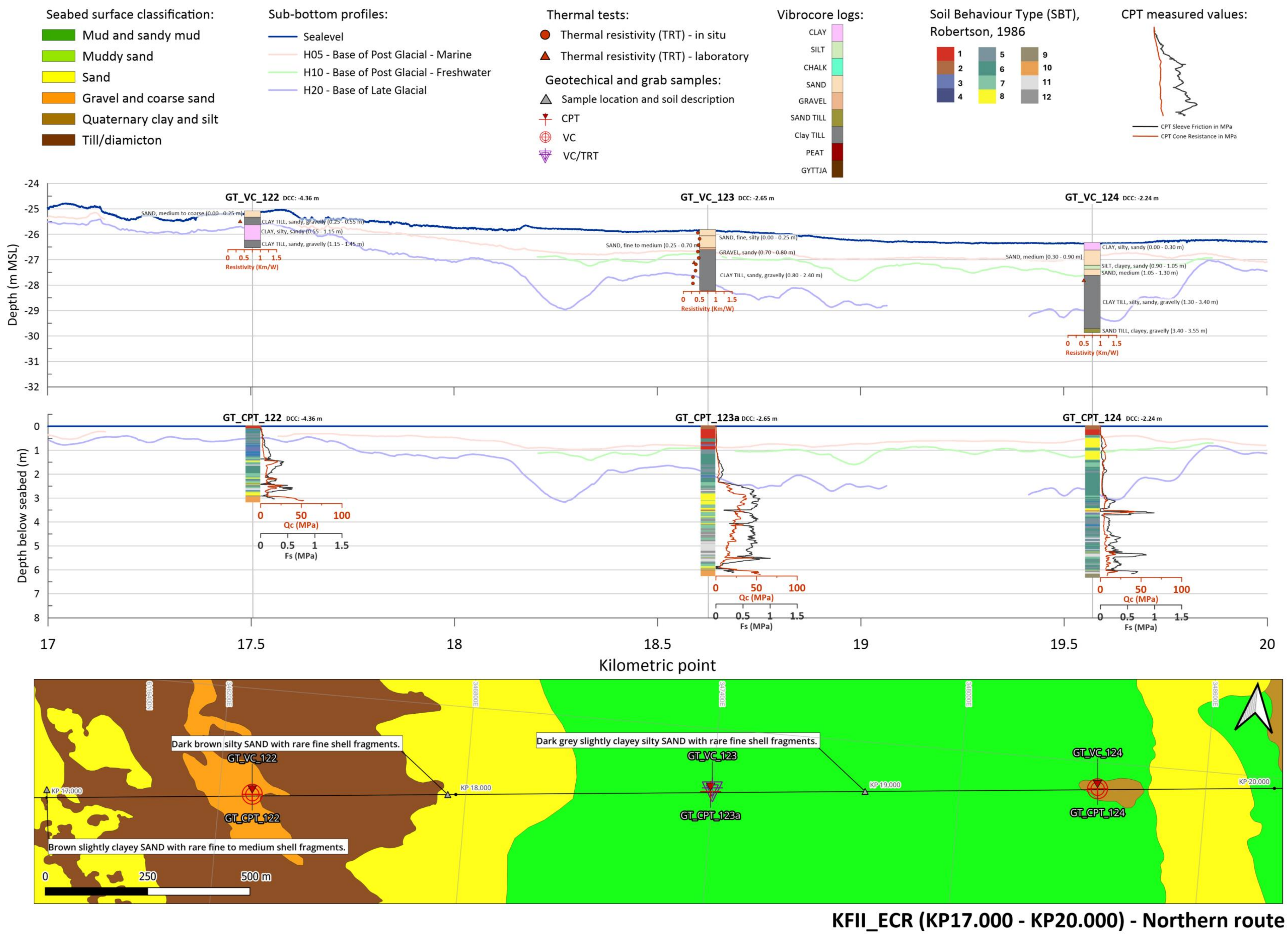


Figure 107: Integrated geotechnical panel KP17.000 – KP 20.000 –Northern route

7.2.8 KP 20.000 – KP 23.180

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

Unit I and II sediments are present over most of this section – and, combined, are thin with H20 (Base Unit II) less than 2 m BSB over the section.

VC125/CPT125, VC126/CPT126 and VC127/CPT127 penetrate Unit I/II sediments and record a SAND dominant sediment (although station 127 records a layer of gravelly CLAY at seabed.

Unit III sediments are recorded as CLAY TILL, SAND TILL or CHALK in all stations.

Unit III is present within 3 m of seabed so overconsolidated sediments may be present within the cable burial depth (and TILL and CHALK have been recorded in the geotechnical samples).

At VC_125 the interpreted H20 correlates to the CHALK observed on the vibrocore. The H20 reflector at the adjacent VC locations (VC_124 and VC_126) do not identify CHALK. Between VC_124 and VC_125 it is possible that the H20 horizon merges with the top of the CHALK, however no such feature is observed in the acoustic data and no separation of the TILL/CHALK interface is observed between VC_125 and VC_126.

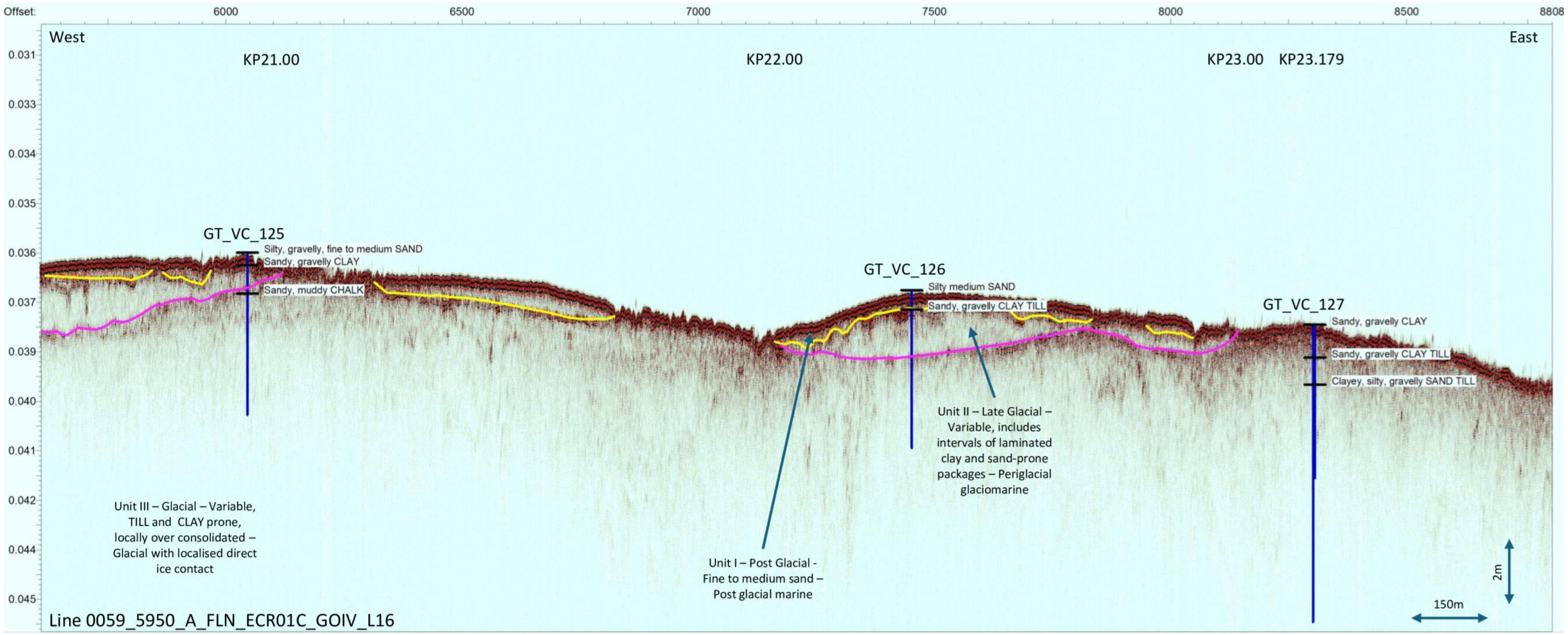


Figure 108: SBP and Geotech, KP 21.000 – KP 23.179 – Northern route

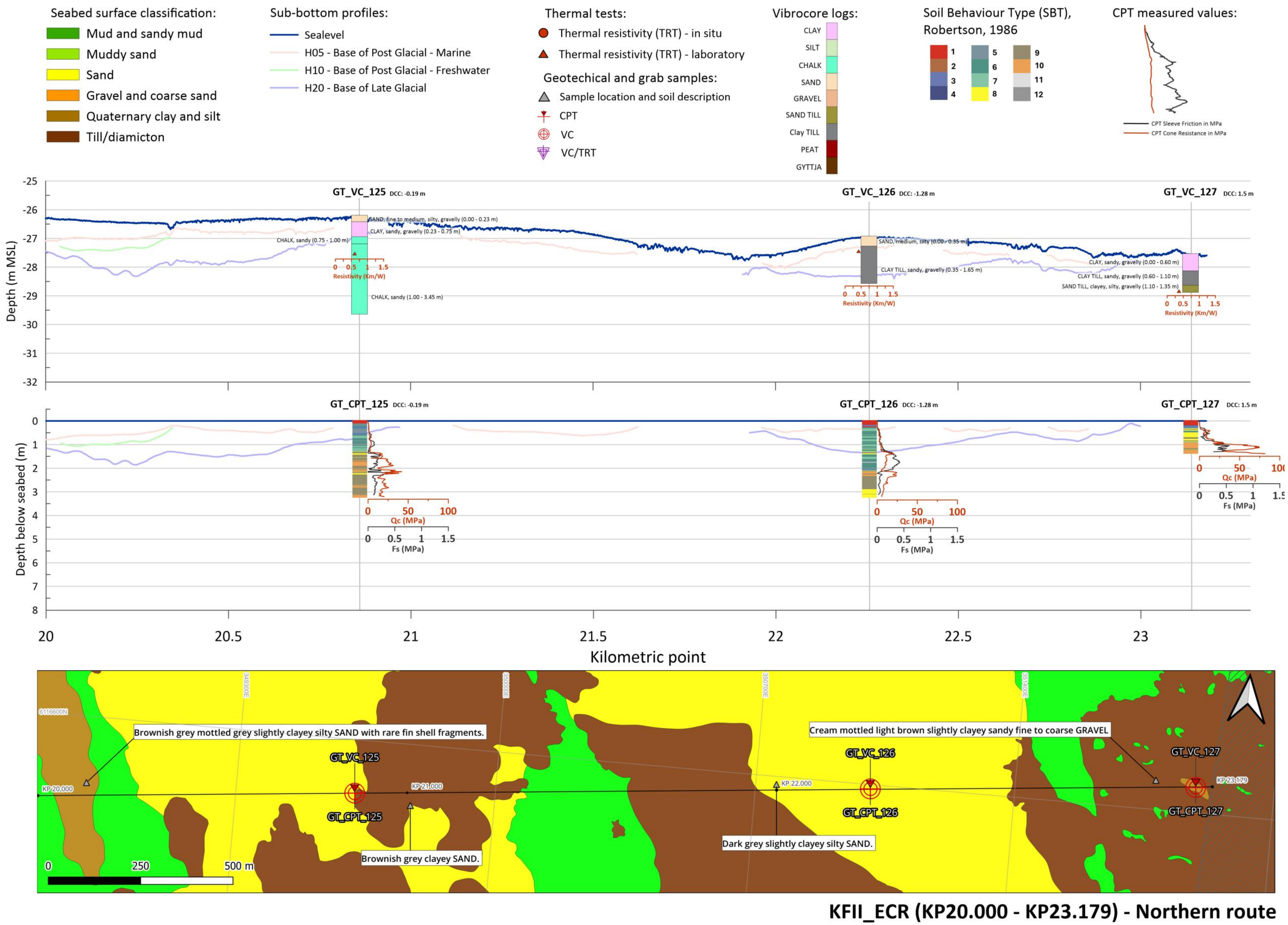


Figure 109: Integrated geotechnical panel KP20.000 – KP 23.179 –Northern route

7.3 SHALLOW GEOLOGICAL INSTALLATION CONSTRAINTS

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 overconsolidation.

Unit III contains numerous cobbles and boulders.

The presence of CHALK on the route, as observed in the geotechnical results, may impose engineering and installation constraints. This is especially pertinent as it has not been possible to derive the spatial extent of this as it cannot be consistently and accurately interpreted in the acoustic dataset. Whilst the CHALK is interpreted to be part of glacially derived deposits of eroded bedrock, the unit has not been observed well enough to confirm that this is the case at all locations.

7.3.1 Cobbles and Boulders

There are occasional indications of boulders within the sub-bottom profiler data. These data have 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.

7.3.2 Organic Material

GYTTJA and PEAT layers have been observed in geotechnical data, which have been presented and described in the route analysis. However, these have not presented as clear or continuous reflectors in SBP data that consistently correlated with the geotechnical data, and hence are not mapped spatially away from GT locations. These present a possible geohazard relating to heat dissipation as well as trenching considerations for PEAT.

7.4 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/H10/H20) identified as a glacial till is at or near the seabed in the nearshore zone, “Till/diamicton” is present at the seabed delineated in the seabed geology (Figure 45). In the nearshore zone the outcropping Glacial Till correlates with an abundance of boulders delineated as “intermediate” boulder fields seabed features (Figure 46). Inversely there is a strong correlation between the presence of sub-seabed Unit I/II (Figure 66/Figure 70) and the “Gravel and Coarse SAND”, “SAND”, “Mud and Sandy Mud”, “Muddy Sand” and “Quaternary clay and silt” surficial substrates. In the nearshore area there is a strong correlation between the occurrence of magnetic anomalies (Figure 51) and the Till/diamicton and intermediate boulder field.

8 CONCLUSIONS

The elevation along the Kriegers Flak II cable route range from 9.36 m MSL (topographic), in landfall area, to -34.36 m MSL towards the southern boundary of the survey area.

The seabed gradient along the route varies significantly, starting from KP 0.000, where it deepens to 10 metres below MSL with an average slope of 5.4 degrees. This section is characterized by a rocky beach with steep slopes due to geological features. The slope becomes gentler south-eastward, with two sand bedforms observed around KP 2.175 to KP 3.000. From KP 3.000 to KP 11.630, the seabed slopes slightly, with a maximum depth of 19.2 metres below MSL. Continuing to KP 29.400, the seabed deepens further, reaching 28.5 metres, with steep slopes near KP 16.000 and a shipwreck site. In the area between KP 14.000 and KP 23.173, the seabed slopes gently at 0.3 degrees, with steep slopes observed near trench areas and till/diamicton outcrops. Beyond KP 29.400, very steep slopes are found within boulder fields, with irregular bathymetry until KP 41.000. The route ends at 31.5 metres below MSL, with the seabed covered mainly in sand and muddy sand, except for steep patches near KP 45.000.

Starting at KP 0 and moving landward, the elevation quickly rises from 0 to 3 metres MSL over a short distance. The terrain in the southern half of the shoreline is more rugged compared to the gentler northern half, where the planned landfall is located. Adjacent to the landfall, the flat agricultural land slopes slightly from 3 to 6–7 metres in the west. West of this field lies low-lying land (1 m MSL) crossed by a creek. The surveyed area also includes slightly inclined residential zones (4 to 8 metres MSL) and flat forested areas (2 to 4 metres MSL), with the elevation peaking just below 10 metres, likely due to a tall building or other man-made structure.

The seabed geology across the Kriegers Flak II ECR area is diverse with no predominant substrate. The area near KP 0 to KP 2 consists of till/diamicton, which becomes sparser moving east as sand and gravel dominate up to KP 11. Beyond this, till and diamicton are predominant in the central southern RPL branch, with patches of muddy sand in the eastern half. In the final kilometres, till/diamicton transitions to muddy sand and sand. The branch near the Kriegers Flak II North windfarm features a mix of till/diamicton, sand, quaternary clay, silt, and predominantly muddy sand in the central part.

The initial stretch of the survey area shows no detectable seabed features. However, till/diamicton regions are marked by intermediate-density boulder fields, with some sediment waveform and ripple areas. Between KP 3 and KP 11, featureless seabed alternates with large ripples and sediment waves. From KP 11 to KP 41, intermediate-density boulder fields dominate, with featureless strips in the eastern half. Beyond KP 41, boulder fields give way to trawl marks, featureless areas, and Mytilus edulis beds at the southern end. The branch near the northern windfarm features a mix of boulder fields, possible biostructures, and featureless patches.

A total of 833 MMO points and 218 MMO linear features MAG anomalies were identified within the survey boundaries. Two anchors were identified, yet one of these features has no associated magnetic anomaly. A total of 19 items, identified as varying lengths of soft rope, were found within the survey area. Two wrecks were found within the survey area. Twelve linear and two point contacts are related to cables located within the survey corridor and correspond to five cables. Three linear and three point contacts are related to a single pipeline (Baltic Pipe) located within the survey corridor. A total of 460 objects were classified as debris and 345 objects classed as metallic debris. A total of 31,965 boulders were identified.

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.

The area generally has a glacial to post-glacial sequence of relatively recent sediments over much older bedrock. Only the upper glacial, late glacial and post glacial deposits are discussed along the ECR as top bedrock is expected to be deeper than the installation zone of interest and not imaged on the SBP data. However, CHALK has been identified and discussed as part of the glacial sediments.

The Post Glacial (marine) unit (Unit I) is a package of post-glacial fine to medium SAND which is less than 1.5 m thick over large parts of the route, with a maximum thickness of 3m. The unit is mapped with H05 as its base. The interval includes veneers of sandier seabed sediments where the unit is very thin and is no resolved in the SBP data. The post glacial sediments are widely distributed over the cable route corridor. However, they are very thin or absent (unmapped) in much of the nearshore section, from KP 0.000 to KP 1.400, with only small areas with a thickness greater than 0.5 m. Small pockets of post glacial sediments may occur in these areas and a <0.2 m thick seabed veneer may still be present.

The Post Glacial (freshwater) unit (Unit Ia) is interpreted as a transition unit and likely includes post glacial and late glacial soils with similar characteristics that could not be discretely interpreted from the SBP data. The unit is mapped with H10 as its base. The unit varies between 0 – 14m in thickness, with the largest thicknesses associated with channel features. The unit is interpreted to consist of variable SAND with minor CLAY and GRAVEL, with occurrences of PEAT and GYTTJA beds.

The Late Glacial Deposits unit (Unit II) 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. A layer of coarser materials has also been identified within the geotechnical sampling campaign towards the base of this unit. 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. Along the route corridor Unit II, glaciomarine sediments form a blanket deposit on top of the underlying Unit III tills. From geotechnical samples, the geotechnical properties of Unit II are expected to predominantly be silty clay and clayey silt.

Glacial Deposits (Unit III) occur along the route corridor, subcropping at seabed where Units I and II are thin to absent. The areas where there are many cobbles and boulders at seabed suggest Unit III till is at or close to seabed. Unit III is interpreted to be 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, deeper than the depth of interest for cable burying. The base of the till/top of bedrock is not imaged within the export route corridor on the Innomar data. Within the nearshore section bedrock is noted at seabed on the seabed features. The top of Unit III is generally within 5 m of the seabed level. Seismically, the ice contact facies are structureless with a very irregular upper surface, which probably forms a series of ridges.

CHALK identified in vibrocore data has been observed, and is interpreted as glacial derived eroded bedrock. However, it is not imaged in the SBP and the depth to bedrock cannot be confirmed from this dataset. The presence of this unit is occasionally at or near the seabed and may present engineering constraints.

In terms of geohazards and installation constraints, 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 overconsolidation and contains numerous cobbles and boulders. There are occasional indications of boulders within the sub-bottom profiler data. These data have 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. There is no evidence of gas within the Kriegers Flak cable route corridor. However, organic sediments including PEAT and GYTTJA have been identified on geotechnical data and are expected to be widely present across the site, however these layers have not appeared a continuous features in SBP data.

9 DIGITAL DATA DELIVERABLES OVERVIEW

9.1 DIGITAL DELIVERABLES SUMMARY

Table 72: 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
SonarWiz project	SonarWiz Project Files

Deliverable	Format
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
SBP profile images	JPGE
Residual grid	Encoded TIF

Deliverable	Format
Reports	
Mob and Cal report	PDF
Operations report	PDF
Geotechnical report	PDF
Environmental report	PDF
Cable crossing 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
Seabed features	PDF
Sub-seabed geology	PDF

Deliverable	Format
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
LIDAR average values gridded surface	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 73: 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											
FLN_001_03	3	332292.87	6123713.50	10.80	Cream mottled light brown slightly clayey sandy fine to coarse GRAVEL	Highly Calcareous	Glacial	Glacial	0.987	537.57	SN2023_027_KP_ROUTE_LIN_UTM33N / Part 6 and Part 7
FLN_002_03	3	332704.80	6123864.20	11.20	Multicoloured slightly clayey very sandy fine to medium GRAVEL and rare fine shell fragments	Slightly Calcareous	Glacial	Glacial	1.136	124.88	SN2023_027_KP_ROUTE_LIN_UTM33N / Part 6 and Part 7
FLN_003_03	3	332693.10	6123639.30	11.30	Dark grey mottled greyish brown slightly clayey SAND with rare fine to medium shell fragments.	Slightly Calcareous	Glacial	Glacial	1.301	278.14	SN2023_027_KP_ROUTE_LIN_UTM33N / Part 6 and Part 7
Offshore											
FLN_ECR01C_009	1	351778.62	6116679.23	27.48	Cream mottled light brown slightly clayey sandy fine to coarse GRAVEL	-	Glacial	Glacial	20.24	-6471.85	SN2023_027_KP_ROUTE_LIN_UTM33N / Part 6 and Part 7
FLN_ECR01B_010	1	333348.54	6123346.34	14.21	Black mottled greyish brown slightly clayey silty SAND with rare fine to medium shell fragments.	Slightly Calcareous	Glacial	Glacial	1.95	-0.54	SN2023_027_KP_ROUTE_LIN_UTM33N / Part 6 and Part 7
FLN_ECR01B_011	1	334173.72	6122696.76	14.51	Brownish grey slightly clayey SAND.	-	Post Glacial	Post-glacial marine	3	0.01	SN2023_027_KP_ROUTE_LIN_UTM33N / Part 6 and Part 7
FLN_ECR01B_012	1	334959.80	6122078.63	15.88	Brownish grey slightly clayey SAND.	Slightly Calcareous	Post Glacial	Post-glacial marine	4	0	SN2023_027_KP_ROUTE_LIN_UTM33N / Part 6 and Part 7
FLN_ECR01B_013	1	335745.87	6121460.50	16.29	Brownish grey slightly clayey SAND.	Slightly Calcareous	Post Glacial	Post-glacial marine	5	0	SN2023_027_KP_ROUTE_LIN_UTM33N / Part 6 and Part 7
FLN_ECR01B_014	1	336531.95	6120842.36	16.94	Brownish grey slightly clayey SAND.	Slightly Calcareous	Post Glacial	Post-glacial marine	6	0	SN2023_027_KP_ROUTE_LIN_UTM33N / Part 6 and Part 7
FLN_ECR01B_015	1	337335.24	6120212.76	17.89	Brownish grey mottled dark grey clayey SAND.	Non-calcareous	Post Glacial	Post-glacial marine	7.021	-1.63	SN2023_027_KP_ROUTE_LIN_UTM33N / Part 6 and Part 7
FLN_ECR01B_016	1	338104.10	6119606.10	18.05	Brownish grey mottled dark grey clayey SAND with rare fine to medium shell fragments.	Slightly Calcareous	Post Glacial	Post-glacial marine	8.001	-0.01	SN2023_027_KP_ROUTE_LIN_UTM33N / Part 6 and Part 7
FLN_ECR01B_017	1	339005.53	6118890.42	18.93	Brownish grey and dark grey mottled slightly clayey silty SAND with rare fine to medium shell fragments.	Slightly Calcareous	Post Glacial	Post-glacial marine	9.152	5.36	SN2023_027_KP_ROUTE_LIN_UTM33N / Part 6 and Part 7
FLN_ECR01B_018	1	339676.25	6118369.84	19.00	Dark grey mottled greyish brown clayey SAND.	Non-calcareous	Post Glacial	Post-glacial marine	10	-0.02	SN2023_027_KP_ROUTE_LIN_UTM33N / Part 6 and Part 7
FLN_ECR01B_019	1	340455.42	6117743.11	19.34	Dark grey mottled greyish brown silty SAND.	Slightly Calcareous	Post Glacial	Post-glacial marine	11	11.01	SN2023_027_KP_ROUTE_LIN_UTM33N / Part 6 and Part 7
FLN_ECR01B_020	1	341192.82	6117193.19	19.39	Greyish brown slightly clayey SAND with rare fine to medium shell fragments.	Calcareous	Glacial	Glacial	11.92	-12.53	SN2023_027_KP_ROUTE_LIN_UTM33N / Part 6 and Part 7

Point ID	Attempt	Easting	Northing	Elevation (m)	Lithology description	Carbonate content	Depositional Age	Depositional Environment	KP	Offset from RPL	KP reference
FLN_ECR01B_021	1	341987.45	6116541.32	20.47	Dark grey mottled greyish brown slightly clayey silty SAND with rare fine shell fragments.	-	Glacial	Glacial	12.95	8.7	SN2023_027_KP_ROUTE_LIN _UTM33N / Part 6 and Part 7
FLN_ECR01B_022	1	342953.16	6115778.28	21.79	Greyish brown mottled dark grey slightly clayey silty SAND with rare fine shell fragments.	Slightly Calcareous	Glacial	Glacial	14.18	8.99	SN2023_027_KP_ROUTE_LIN _UTM33N / Part 6 and Part 7
FLN_ECR01B_023	3	343498.36	6115236.25	21.95	Cream mottled light brown slightly clayey sandy fine to coarse GRAVEL	-	Glacial	Glacial	14.95	59.12	SN2023_027_KP_ROUTE_LIN _UTM33N / Part 6 and Part 7
FLN_ECR01B_024	1	344367.66	6114469.78	23.09	Greyish brown slightly clayey SAND with rare fine to medium gravel.	-	Glacial	Glacial	16.11	65.34	SN2023_027_KP_ROUTE_LIN _UTM33N / Part 6 and Part 7
FLN_ECR01B_025	1	344993.75	6113964.96	23.03	Greyish brown mottled dark grey slightly clayey SAND.	Non-calcareous	Post Glacial	Post-glacial marine	16.91	34.24	SN2023_027_KP_ROUTE_LIN _UTM33N / Part 6 and Part 7
FLN_ECR01B_026	1	345828.41	6113238.97	24.42	Dark grey slightly clayey silty SAND with some fine to medium gravel and single coarse gravel.	Slightly Calcareous	Post Glacial	Post-glacial marine	18.02	32.73	SN2023_027_KP_ROUTE_LIN _UTM33N / Part 6 and Part 7
FLN_ECR01B_027	1	346640.05	6112574.60	24.37	Multicoloured slightly clayey very sandy fine to coarse GRAVEL.	-	Post Glacial	Post-glacial marine	19.06	-0.09	SN2023_027_KP_ROUTE_LIN _UTM33N / Part 6 and Part 7
FLN_ECR01B_028	1	347346.39	6111958.43	24.80	Brownish grey slightly clayey silty SAND.	-	Post Glacial	Post-glacial marine	20	-0.02	SN2023_027_KP_ROUTE_LIN _UTM33N / Part 6 and Part 7
FLN_ECR01B_029	1	348096.55	6111327.13	24.89	Greyish brown slightly clayey SAND with rare fine to medium shell fragments.	Calcareous	Glacial	Glacial	20.98	-17.35	SN2023_027_KP_ROUTE_LIN _UTM33N / Part 6 and Part 7
FLN_ECR01B_030	1	348844.41	6110630.46	25.47	Greyish brown and dark grey mottled slightly clayey silty SAND with rare fine shell fragments.	Slightly Calcareous	Glacial	Glacial	22	16.1	SN2023_027_KP_ROUTE_LIN _UTM33N / Part 6 and Part 7
FLN_ECR01B_031	3	349606.41	6109963.71	25.52	Brownish grey slightly clayey SAND with single coarse gravel.	-	Glacial	Glacial	23.02	17.7	SN2023_027_KP_ROUTE_LIN _UTM33N / Part 6 and Part 7
FLN_ECR01B_032	1	350303.97	6109353.07	26.37	Brownish grey and dark grey mottled silty SAND with some fine to medium gravel and shell fragments.	Slightly Calcareous	Glacial	Glacial	23.94	19.38	SN2023_027_KP_ROUTE_LIN _UTM33N / Part 6 and Part 7
FLN_ECR01B_033	1	351114.47	6108671.86	26.94	Dark brownish grey slightly clayey silty SAND with rare fine shell fragments.	-	Post Glacial	Post-glacial marine	25	0	SN2023_027_KP_ROUTE_LIN _UTM33N / Part 6 and Part 7
FLN_ECR01B_034	1	351886.79	6107972.19	28.10	Cream mottled light brown slightly clayey sandy fine to coarse GRAVEL	-	Glacial	Glacial	26.04	19.63	SN2023_027_KP_ROUTE_LIN _UTM33N / Part 6 and Part 7
FLN_ECR01B_035	3	352612.44	6107365.17	29.10	Cream mottled light brown slightly clayey sandy fine to coarse GRAVEL	-	Glacial	Glacial	26.99	0.11	SN2023_027_KP_ROUTE_LIN _UTM33N / Part 6 and Part 7
FLN_ECR01C_001	1	343710.50	6115917.67	23.42	Dark grey slightly clayey silty SAND with rare fine shell fragments.	Slightly Calcareous	Glacial	Glacial	14.66	-593.92	SN2023_027_KP_ROUTE_LIN _UTM33N / Part 6 and Part 7
FLN_ECR01C_002	2	344784.99	6115995.67	24.34	Greyish brown slightly clayey SAND.	-	Glacial	Glacial	15.42	-1359.06	SN2023_027_KP_ROUTE_LIN _UTM33N / Part 6 and Part 7

Point ID	Attempt	Easting	Northing	Elevation (m)	Lithology description	Carbonate content	Depositional Age	Depositional Environment	KP	Offset from RPL	KP reference
FLN_ECR01C_003	1	345779.44	6116109.65	24.79	Brown slightly clayey SAND with rare fine to medium shell fragments.	Slightly Calcareous	Post Glacial	Post-glacial marine	16.09	-2098.7	SN2023_027_KP_ROUTE_LIN _UTM33N / Part 6 and Part 7
FLN_ECR01C_004	1	346756.41	6116183.08	25.62	Dark brown silty SAND with rare fine shell fragments.	-	Post Glacial	Post-glacial marine	16.78	-2796.3	SN2023_027_KP_ROUTE_LIN _UTM33N / Part 6 and Part 7
FLN_ECR01C_005	1	347771.54	6116279.46	26.22	Dark grey slightly clayey silty SAND with rare fine shell fragments.	Non-calcareous	Post Glacial	Post-glacial marine	17.48	-3536.28	SN2023_027_KP_ROUTE_LIN _UTM33N / Part 6 and Part 7
FLN_ECR01C_006	1	348895.20	6116420.62	26.41	Brownish grey mottled grey slightly clayey silty SAND with rare fin shell fragments.	-	Post Glacial	Post-glacial marine	18.24	-4381.36	SN2023_027_KP_ROUTE_LIN _UTM33N / Part 6 and Part 7
FLN_ECR01C_007	1	349773.92	6116435.07	26.36	Brownish grey clayey SAND.	Slightly Calcareous	Glacial	Glacial	18.89	-4969.93	SN2023_027_KP_ROUTE_LIN _UTM33N / Part 6 and Part 7
FLN-ECR01C_008	1	350756.30	6116578.28	20.32	Dark grey slightly clayey silty SAND.	-	Post Glacial	Post-glacial marine	19.54	-5723.68	SN2023_027_KP_ROUTE_LIN _UTM33N / Part 6 and Part 7
FLS_ECR01D_036	1	353375.32	6106699.92	29.02	Dark brownish grey slightly clayey silty SAND with rare fine shell fragments.	Non-calcareous	Post Glacial	Post-glacial marine	28	0	SN2023_027_KP_ROUTE_LIN _UTM33N / Part 6 and Part 7
FLS_ECR01D_037	1	353674.81	6105779.54	29.16	Black clayey very sandy organic SILT.	-	Glacial	Glacial	29	-40.2	SN2023_027_KP_ROUTE_LIN _UTM33N / Part 6 and Part 7
FLS_ECR01D_038	1	353789.44	6104716.59	27.90	Dark grey silty SAND with rare fine to medium shell fragments.	-	Post Glacial	Post-glacial marine	30.06	24.81	SN2023_027_KP_ROUTE_LIN _UTM33N / Part 6 and Part 7
FLS_ECR01D_039	1	353959.85	6103859.18	27.42	Dark grey slightly clayey silty SAND with rare fine shell fragments.	-	Post Glacial	Post-glacial marine	30.94	0.39	SN2023_027_KP_ROUTE_LIN _UTM33N / Part 6 and Part 7
FLS_ECR01D_040	1	354164.84	6102799.16	28.17	Dark grey slightly clayey silty SAND with rare fine shell fragments.	Slightly Calcareous	Glacial	Glacial	32.02	-24.18	SN2023_027_KP_ROUTE_LIN _UTM33N / Part 6 and Part 7
FLS_ECR01D_041	1	354285.69	6101944.71	28.67	Dark grey slightly clayey silty SAND with rare fine to medium gravel and shell fragments.	Slightly Calcareous	Post Glacial	Post-glacial marine	32.88	-0.23	SN2023_027_KP_ROUTE_LIN _UTM33N / Part 6 and Part 7
FLS_ECR01D_042	3	354492.82	6100876.23	28.94	Cream mottled light brown slightly clayey sandy fine to coarse GRAVEL	-	Glacial	Glacial	33.97	-25.5	SN2023_027_KP_ROUTE_LIN _UTM33N / Part 6 and Part 7
FLS_ECR01D_043	1	354641.75	6099847.31	22.34	Multicoloured slightly clayey SAND with much fine to medium gravel and shell fragments.	Slightly Calcareous	Glacial	Glacial	35.01	-0.01	SN2023_027_KP_ROUTE_LIN _UTM33N / Part 6 and Part 7
FLS_ECR01D_044	1	354803.67	6098909.13	28.23	Brownish grey and dark grey mottled slightly clayey silty SAND with rare fine to medium shell fragments.	-	Glacial	Glacial	35.96	-2.52	SN2023_027_KP_ROUTE_LIN _UTM33N / Part 6 and Part 7
FLS_ECR01D_045	1	354983.39	6097836.83	30.00	Dark grey slightly clayey silty SAND with rare fine shell fragments.	Non-calcareous	Post Glacial	Post-glacial marine	37.05	-0.13	SN2023_027_KP_ROUTE_LIN _UTM33N / Part 6 and Part 7
FLS_ECR01D_046	1	355226.68	6096859.18	29.21	Greyish brown mottled dark grey slightly clayey SAND with rare fine to medium shell fragments.	-	Glacial	Glacial	38.08	-0.46	SN2023_027_KP_ROUTE_LIN _UTM33N / Part 6 and Part 7

Point ID	Attempt	Easting	Northing	Elevation (m)	Lithology description	Carbonate content	Depositional Age	Depositional Environment	KP	Offset from RPL	KP reference
FLS_ECR01D_047	1	355681.29	6096153.09	28.70	Cream mottled light brown slightly clayey sandy fine to coarse GRAVEL	-	Glacial	Glacial	38.96	-22.6	SN2023_027_KP_ROUTE_LIN _UTM33N / Part 6 and Part 7
FLS_ECR01D_048	3	355896.65	6095126.53	28.22	Cream mottled light brown slightly clayey sandy fine to coarse GRAVEL	-	Glacial	Glacial	40.01	2.38	SN2023_027_KP_ROUTE_LIN _UTM33N / Part 6 and Part 7
FLS_ECR01D_049	1	356103.62	6094170.35	28.90	Cream mottled light brown slightly clayey sandy fine to coarse GRAVEL	-	Post Glacial	Post-glacial marine	40.99	19.44	SN2023_027_KP_ROUTE_LIN _UTM33N / Part 6 and Part 7
FLS_ECR01D_050	1	356355.27	6093183.53	29.86	Dark brownish grey clayey SAND.	-	Post Glacial	Post-glacial marine	42.01	0	SN2023_027_KP_ROUTE_LIN _UTM33N / Part 6 and Part 7
FLS_ECR01D_051	1	356583.84	6092210.00	31.59	Dark brownish grey slightly clayey silty SAND.	Slightly Calcareous	Post Glacial	Post-glacial marine	43.01	-0.01	SN2023_027_KP_ROUTE_LIN _UTM33N / Part 6 and Part 7
FLS_ECR01D_052	1	356812.41	6091236.47	31.82	Dark grey slightly clayey silty SAND.	-	Post Glacial	Post-glacial marine	44.01	-0.01	SN2023_027_KP_ROUTE_LIN _UTM33N / Part 6 and Part 7
FLS_ECR01D_053	1	357040.98	6090262.94	33.02	Brownish grey clayey silty SAND.	Slightly Calcareous	Post Glacial	Post-glacial marine	45.01	-0.02	SN2023_027_KP_ROUTE_LIN _UTM33N / Part 6 and Part 7
FLS_ECR01D_054	1	357269.55	6089289.42	31.16	Dark grey slightly clayey silty SAND with rare fine to medium shell fragments.	Slightly Calcareous	Post Glacial	Post-glacial marine	46.01	-0.03	SN2023_027_KP_ROUTE_LIN _UTM33N / Part 6 and Part 7
FLS_ECR01D_055	1	357513.78	6088282.45	31.72	Dark grey slightly clayey silty SAND with rare fine to medium shell fragments.	Calcareous	Glacial	Glacial	47.04	-7.64	SN2023_027_KP_ROUTE_LIN _UTM33N / Part 6 and Part 7

APPENDIX B. GEOTECHNICAL RESULTS OVERVIEW TABLES

Point ID	TRT analysis	Easting	Northing	Elevation surface (m)	Elevation top (m)	Elevation bottom (m)	KP	Offset from RPL(m)	Penetration (m)	Recovery (m)
Vibrocore										
GT_VC_096	No	332863.8	6123867	11.24	0	3	1.236	1.3	3.41	2.9
GT_VC_097	Yes	333583.5	6123203	13.67	0	6	2.224	-32.23	3.83	4.1
GT_VC_098	No	334528.5	6122419	15.37	0	6	3.451	-0.68	3.04	3.2
GT_VC_098a	No	334528.5	6122419	15.37	0	6	3.449	-4.45	4.37	4.4
GT_VC_099	Yes	335382.4	6121747	15.98	0	6	4.537	-1.32	5.61	6
GT_VC_100	Yes	336266.3	6121052	16.76	0	6	5.662	0.31	3.34	3.35
GT_VC_100a	Yes	336266.3	6121052	16.76	0	6	5.659	-3.57	5.74	5.95
GT_VC_101	No	337150.5	6120356	17.61	0	6	6.788	-0.12	4.92	4.9
GT_VC_102	No	338054	6119645	18.05	0	6	7.934	-0.31	5.78	5.9
GT_VC_103	Yes	338790.5	6119066	18.4	0	6	8.875	0.77	4.65	5.5
GT_VC_104	No	339802.4	6118269	19.12	0	3	10.162	1.12	1.59	1.4
GT_VC_105	No	340686.6	6117574	19.35	0	3	11.286	2.83	1.95	1.75
GT_VC_106	No	341571.3	6116878	19.81	0	3	12.412	1.58	3.20	3.7
GT_VC_107	No	342441.9	6116193	20.7	0	3	13.524	1.66	3.31	3.45
GT_VC_108	No	343314.2	6115476	21.98	0	3	14.651	0.47	2.37	2.45
GT_VC_109	No	343829.4	6115025	22.58	0	3	15.336	0.66	1.78	2.23

Point ID	TRT analysis	Easting	Northing	Elevation surface (m)	Elevation top (m)	Elevation bottom (m)	KP	Offset from RPL(m)	Penetration (m)	Recovery (m)
Vibrocore										
GT_VC_110	No	344586	6114365	23.12	0	3	16.339	1.03	3.23	3.34
GT_VC_111	Yes	345434.7	6113626	23.52	0	6	17.464	-0.55	2.70	2.4
GT_VC_112	No	346282.1	6112887	24.26	0	6	18.59	0.15	2.47	2.65
GT_VC_113	Yes	347142.7	6112135	24.59	0	6	19.732	0.8	1.75	1.8
GT_VC_113a	No	347142.7	6112135	24.59	0	6	19.728	0.31	1.68	1.8
GT_VC_114	No	347977.9	6111408	25.14	0	6	20.84	-0.43	1.50	1.4
GT_VC_114a	No	347977.9	6111408	25.14	0	6	20.836	-0.96	2.02	1.95
GT_VC_115	No	348865.5	6110635	25.49	0	3	22.017	-1.7	1.48	0.95
GT_VC_115a	No	348865.5	6110635	25.49	0	3	22.013	-1.27	3.40	2.75
GT_VC_116	No	349306.8	6110249	25.45	0	3	22.603	-0.11	3.26	4.45
GT_VC_117	Yes	350970.8	6108796	26.85	0	6	24.812	1.86	1.66	1.8
GT_VC_118	No	351799.9	6108074	27.66	0	3	25.912	0.53	1.22	1.15
GT_VC_118a	No	351799.9	6108074	27.66	0	3	25.913	5.14	0.95	0.75
GT_VC_119	No	352647.9	6107335	29.17	0	3	27.034	-3.44	1.08	1.05
GT_VC_120	No	343579.5	6115883	23.2	0	3	14.58	-479.31	3.33	3.2
GT_VC_121	No	344743.4	6115997	24.4	0	3	15.385	-1332.01	3.37	3.7
GT_VC_122	No	346280.1	6116142	25.08	0	3	16.448	-2452.53	1.45	1.45

Point ID	TRT analysis	Easting	Northing	Elevation surface (m)	Elevation top (m)	Elevation bottom (m)	KP	Offset from RPL(m)	Penetration (m)	Recovery (m)
Vibrocore										
GT_VC_123	Yes	347399.9	6116246	25.81	0	6	17.223	-3266.56	2.17	2.4
GT_VC_124	No	348336.7	6116335	26.32	0	6	17.871	-3949.97	3.11	3.55
GT_VC_124a	No	348336.7	6116335	26.32	0	6	17.868	-3946.68	2.09	2.35
GT_VC_125	No	349621.5	6116456	26.19	0	3	18.76	-4884.8	3.18	3.45
GT_VC_126	No	351009.8	6116589	26.92	0	3	19.72	-5898.56	1.41	1.55
GT_VC_127	No	351887.7	6116669	27.53	0	3	20.328	-6535.87	0.98	1.35
GT_VC_127b	No	351887.7	6116669	27.53	0	3	20.324	-6532.6	1.06	1.35
GT_VC_128	No	353498.7	6106593	29.19	0	6	28.164	-2.95	1.21	1.2
GT_VC_128a	Yes	353498.7	6106593	29.19	0	6	28.169	-1.67	1.45	1.45
GT_VC_129	No	353708.5	6105359	28.48	0	3	29.416	-4.09	2.23	2.2
GT_VC_130	No	353795.8	6104850	27.96	0	3	29.933	-4.48	2.044	2.3
GT_VC_131	No	353997.7	6103653	27.71	0	3	31.147	-2.24	1.27	1.55
GT_VC_132	No	354163.2	6102682	27.8	0	6	32.132	-3.52	3.22	4.4
GT_VC_132a	Yes	354163.2	6102682	27.8	0	6	32.128	-4.06	2.71	3.55
GT_VC_133	No	354329.4	6101692	27.13	0	6	33.136	-1.28	0.82	0.85
GT_VC_134	No	354449.4	6100970	25.62	0	6	33.868	1.58	1.08	1.1
GT_VC_134a	Yes	354449.4	6100970	25.62	0	6	33.864	0.71	1	1

Point ID	TRT analysis	Easting	Northing	Elevation surface (m)	Elevation top (m)	Elevation bottom (m)	KP	Offset from RPL(m)	Penetration (m)	Recovery (m)
Vibrocore										
GT_VC_135	No	354664.2	6099702	26.06	0	6	35.155	2.22	1.32	1.2
GT_VC_135a	No	354664.2	6099702	26.06	0	6	35.155	7.01	1.53	1.6
GT_VC_136	No	354827.1	6098732	28.28	0	3	36.138	4.29	2.69	3.3
GT_VC_137	No	355037.3	6097498	30.54	0	6	37.386	1.56	5.84	5.6
GT_VC_138	Yes	355097.3	6097139	30.51	0	6	37.754	4.83	5.77	5.95
GT_VC_139	No	355691	6096002	28.33	0	3	39.109	2.13	1.15	1.05
GT_VC_140	No	355915	6095037	28.43	0	3	40.097	3.87	0.77	0.7
GT_VC_140a	No	355915	6095037	28.43	0	3	40.101	5.58	0.77	0.75
GT_VC_141	No	356146.6	6094065	28.85	0	6	41.094	2.25	1.58	1.9
GT_VC_142	Yes	356401.1	6092982	30.2	0	6	42.212	1.26	5.73	5.5
GT_VC_143	No	356600	6092135	31.63	0	3	43.082	1.51	2.02	3.45
GT_VC_143a	No	356600	6092135	31.63	0	3	43.077	-0.37	3.11	2.45
GT_VC_144	Yes	356832.6	6091165	31.88	0	6	44.079	-3.6	5.69	5.85
GT_VC_145	No	357061.1	6090193	32.93	0	6	45.078	-2.89	1.04	1.45
GT_VC_146	No	357288.5	6089223	31.29	0	6	46.075	-2.9	5.70	6.05
GT_VC_147	No	357562.6	6088042	30.95	0	3	47.287	-0.23	3.36	3.4
GT_VC_148	No	357741	6087037	27.03	0	3	48.307	56.08	3.38	4.05

Point ID	Comment	Easting	Northing	Elevation surface	Elevation top	Elevation bottom	KP	Offset from RPL (m)	Penetration	Est_sett
Cone penetration tests										
GT_CPT_096	Cone ID: GG60433. Cone size: 10	332863.8	6123867	11.24	0	3	1.236	1.3	3.11	0
GT_CPT_097	Cone ID: GG60433. Cone size: 10	333583.5	6123203	13.67	0	6	2.224	-32.23	6.21	0.06
GT_CPT_098	Cone ID: GG60433. Cone size: 10	334528.5	6122419	15.37	0	6	3.451	-0.68	6.18	0.06
GT_CPT_099	Cone ID: GG60433. Cone size: 10	335382.4	6121747	15.98	0	6	4.537	-1.32	5.87	0.08
GT_CPT_100	Cone ID: GG60433. Cone size: 10	336266.3	6121052	16.76	0	6	5.662	0.31	6.23	0.08
GT_CPT_101	Cone ID: GG60433. Cone size: 10	337150.5	6120356	17.61	0	6	6.788	-0.12	6.13	0.07
GT_CPT_102	Cone ID: GG60443. Cone size: 10	338054	6119645	18.05	0	6	7.934	-0.31	6.19	0.04
GT_CPT_103	Cone ID: GG60443. Cone size: 10	338790.5	6119066	18.4	0	6	8.875	0.77	5.22	0.06
GT_CPT_104	Cone ID: GG60443. Cone size: 10	339802.4	6118269	19.12	0	3	10.162	1.12	2.36	0.1
GT_CPT_105	Cone ID: GG60443. Cone size: 10	340686.6	6117574	19.35	0	3	11.286	2.83	2.05	0.08

Point ID	Comment	Easting	Northing	Elevation surface	Elevation top	Elevation bottom	KP	Offset from RPL (m)	Penetration	Est_sett
Cone penetration tests										
GT_CPT_105a	Cone ID: GG60443. Cone size: 10	340686.6	6117574	19.35	0	3	11.283	1.65	3.23	0.06
GT_CPT_106	Cone ID: GG60443. Cone size: 10	341571.3	6116878	19.81	0	3	12.412	1.58	3.19	0
GT_CPT_107	Cone ID: GG60443. Cone size: 10	342441.9	6116193	20.7	0	3	13.524	1.66	3.30	0.09
GT_CPT_108	Cone ID: GG60450. Cone size: 10	343314.2	6115476	21.98	0	3	14.651	0.47	3.20	0
GT_CPT_109	Cone ID: GG60433. Cone size: 10	343829.4	6115025	22.58	0	3	15.336	0.66	3.27	0.01
GT_CPT_110	Cone ID: GG60450. Cone size: 10	344586	6114365	23.12	0	3	16.339	1.03	3.25	0.01
GT_CPT_111	Cone ID: GG60450. Cone size: 10	345434.7	6113626	23.52	0	6	17.464	-0.55	2.80	0.06
GT_CPT_111a	Cone ID: GG60450. Cone size: 10	345434.7	6113626	23.52	0	6	17.461	0.12	2.88	0.05
GT_CPT_112	Cone ID: GG60450. Cone size: 10	346282.1	6112887	24.26	0	6	18.59	0.15	6.37	0.22
GT_CPT_113	Cone ID: GG60450. Cone size: 10	347142.7	6112135	24.59	0	6	19.732	0.8	3.20	0.25

Point ID	Comment	Easting	Northing	Elevation surface	Elevation top	Elevation bottom	KP	Offset from RPL (m)	Penetration	Est_sett
Cone penetration tests										
GT_CPT_113a	Cone ID: GG60450. Cone size: 10	347142.7	6112135	24.59	0	6	19.728	0.31	6.38	0.24
GT_CPT_114	Cone ID: GG60451. Cone size: 10	347977.9	6111408	25.14	0	6	20.84	-0.43	3.36	0.05
GT_CPT_114a	Cone ID: GG60450. Cone size: 10	347977.9	6111408	25.14	0	6	20.836	-0.96	4.91	0.05
GT_CPT_115	Cone ID: GG60451. Cone size: 10	348865.5	6110635	25.49	0	3	22.017	-1.7	1.57	0.03
GT_CPT_115a	Cone ID: GG60451. Cone size: 10	348865.5	6110635	25.49	0	3	22.013	-1.27	1.50	0.01
GT_CPT_116	Cone ID: GG60451. Cone size: 10	349306.8	6110249	25.45	0	3	22.603	-0.11	3.30	0.13
GT_CPT_117	Cone ID: GG60433. Cone size: 10	350970.8	6108796	26.85	0	6	24.812	1.86	2.11	0.19
GT_CPT_117a	Cone ID: GG60451. Cone size: 10	350970.8	6108796	26.85	0	6	24.809	0.46	2	0.17
GT_CPT_118	Cone ID: GG60433. Cone size: 10	351799.9	6108074	27.66	0	3	25.912	0.53	0.71	0.2
GT_CPT_118a	Cone ID: GG60433. Cone size: 10	351799.9	6108074	27.66	0	3	25.913	-2.93	0.74	0.22

Point ID	Comment	Easting	Northing	Elevation surface	Elevation top	Elevation bottom	KP	Offset from RPL (m)	Penetration	Est_sett
Cone penetration tests										
GT_CPT_118b	Cone ID: GG60433. Cone size: 10	351799.9	6108074	27.66	0	3	25.913	5.14	3.36	0.19
GT_CPT_119	Cone ID: GG60433. Cone size: 10	352647.9	6107335	29.17	0	3	27.034	-3.44	3.10	0
GT_CPT_120	Cone ID: GG60450. Cone size: 10	343579.5	6115883	23.2	0	3	14.58	-479.31	1.55	0.02
GT_CPT_120a	Cone ID: GG60450. Cone size: 10	343579.5	6115883	23.2	0	3	14.587	-481.51	0.8	0.04
GT_CPT_121	Cone ID: GG60442. Cone size: 10	344743.4	6115997	24.4	0	3	15.385	-1332.01	3.27	0.02
GT_CPT_122	Cone ID: GG60442. Cone size: 10	346280.1	6116142	25.08	0	3	16.448	-2452.53	3.14	0.04
GT_CPT_123	Cone ID: GG60442. Cone size: 10	347399.9	6116246	25.81	0	6	17.223	-3266.56	4.24	0.17
GT_CPT_123a	Cone ID: GG60433. Cone size: 10	347399.9	6116246	25.81	0	6	17.22	-3264.09	6.22	0.14
GT_CPT_124	Cone ID: GG60433. Cone size: 10	348336.7	6116335	26.32	0	6	17.871	-3949.97	6.27	0.13
GT_CPT_125	Cone ID: GG60433. Cone size: 10	349621.5	6116456	26.19	0	3	18.76	-4884.8	3.21	0.05

Point ID	Comment	Easting	Northing	Elevation surface	Elevation top	Elevation bottom	KP	Offset from RPL (m)	Penetration	Est_sett
Cone penetration tests										
GT_CPT_126	Cone ID: GG60433. Cone size: 10	351009.8	6116589	26.92	0	3	19.72	-5898.56	3.22	0.05
GT_CPT_127	Cone ID: GG60433. Cone size: 10	351887.7	6116669	27.53	0	3	20.328	-6535.87	1.36	0.05
GT_CPT_127a	Cone ID: GG60433. Cone size: 10	351887.7	6116669	27.53	0	3	20.325	-6539.04	1.19	0
GT_CPT_128	Cone ID: GG60433. Cone size: 10	353498.7	6106593	29.19	0	6	28.164	-2.95	6.02	0.26
GT_CPT_129	Cone ID: GG60442. Cone size: 10	353708.5	6105359	28.48	0	3	29.416	-4.09	1.78	0.04
GT_CPT_129a	Cone ID: GG60442. Cone size: 10	353708.5	6105359	28.48	0	3	29.416	1.4	2.71	0.12
GT_CPT_130	Cone ID: GG60442. Cone size: 10	353795.8	6104850	27.96	0	3	29.933	-4.48	3.42	0.25
GT_CPT_131	Cone ID: GG60442. Cone size: 10	353997.7	6103653	27.71	0	3	31.147	-2.24	3.32	0.15
GT_CPT_132	Cone ID: GG60450. Cone size: 10	354163.2	6102682	27.8	0	6	32.132	-3.52	6.13	0.06
GT_CPT_133	Cone ID: GG60450. Cone size: 10	354329.4	6101692	27.13	0	6	33.136	-1.28	3.30	0.02

Point ID	Comment	Easting	Northing	Elevation surface	Elevation top	Elevation bottom	KP	Offset from RPL (m)	Penetration	Est_sett
Cone penetration tests										
GT_CPT_134	Cone ID: GG60450. Cone size: 10	354449.4	6100970	25.62	0	6	33.868	1.58	3.06	0
GT_CPT_134a	Cone ID: GG60450. Cone size: 10	354449.4	6100970	25.62	0	6	33.864	0.71	3.05	0.01
GT_CPT_135	Cone ID: GG60433. Cone size: 10	354664.2	6099702	26.06	0	6	35.155	2.22	2.81	0
GT_CPT_135a	Cone ID: GG60433. Cone size: 10	354664.2	6099702	26.06	0	6	35.155	7.01	2.99	0.02
GT_CPT_136	Cone ID: GG60433. Cone size: 10	354827.1	6098732	28.28	0	3	36.138	4.29	3.29	0.05
GT_CPT_137	Cone ID: GG60433. Cone size: 10	355037.3	6097498	30.54	0	6	37.386	1.56	6.28	0.13
GT_CPT_138	Cone ID: GG60451. Cone size: 10	355097.3	6097139	30.51	0	6	37.754	4.83	6.30	0.15
GT_CPT_139	Cone ID: GG60451. Cone size: 10	355691	6096002	28.33	0	3	39.109	2.13	3.10	0
GT_CPT_140	Cone ID: GG60451. Cone size: 10	355915	6095037	28.43	0	3	40.097	3.87	2.61	0
GT_CPT_141	Cone ID: GG60451. Cone size: 10	356146.6	6094065	28.85	0	6	41.094	2.25	5.70	0.05

Point ID	Comment	Easting	Northing	Elevation surface	Elevation top	Elevation bottom	KP	Offset from RPL (m)	Penetration	Est_sett
Cone penetration tests										
GT_CPT_142	Cone ID: GG60451. Cone size: 10	356401.1	6092982	30.2	0	6	42.212	1.26	6.22	0.07
GT_CPT_143	Cone ID: GG60442. Cone size: 10	356600	6092135	31.63	0	3	43.082	1.51	3.30	0.13
GT_CPT_144	Cone ID: GG60442. Cone size: 10	356832.6	6091165	31.88	0	6	44.079	-3.6	6.28	0.14
GT_CPT_145	Cone ID: GG60442. Cone size: 10	357061.1	6090193	32.93	0	6	45.078	-2.89	6.22	0.09
GT_CPT_146	Cone ID: GG60484. Cone size: 10	357288.5	6089223	31.29	0	6	46.075	-2.9	6.26	0.11
GT_CPT_146a	Cone ID: GG60442. Cone size: 10	357288.5	6089223	31.29	0	6	46.07	-4.83	6.07	0.1
GT_CPT_147	Cone ID: GG60442. Cone size: 10	357562.6	6088042	30.95	0	3	47.287	-0.23	3.41	0.11
GT_CPT_148	Cone ID: GG60442. Cone size: 10	357741	6087037	27.03	0	3	48.307	56.08	3.19	0.08