DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2009/47

Anholt Offshore Wind Farm
Marine Geophysical Investigations

The Cable Corridors

Jørgen O. Leth, Zyad K. Al-Hamdani, Bernhard Novak,
Sabah M. Barzani & Christian Hindrichsen

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MINISTRY OF CLIMATE AND ENERGY

GEUS

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Client: Rambøll Oil & Gas

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1. Introduction

1.1 Aims and objectives of the geophysical survey

The establishment of the Anholt Wind Farm was agreed by the Danish Government in February 2008. The development of the wind farm between Djursland and Anholt governed by Energinet.dk will be based on series of preliminary investigation including environmental assessments studies and geotechnical evaluations of a gross area and two cable corridors. Within this framework geophysical surveys have been performed by The Geological Survey of Denmark and Greenland (GEUS) in the period April to May 2009. The installed capacity of the wind farm of approximately 400 MW will be stored in a transformer platform within the wind farm area before exporting to a connection point onshore at Djursland north of Grenå via a submarine cable. The gross area delimited for the wind farm was surveyed during the latter period but has been reported separately.

The brief objectives of the survey include for the wind farm investigation area and the transformer platform:

- To provide data for the ongoing environmental statement and the subsequent technical development on a various number of different subjects.
- To provide an accurate hydrographical chart of the two potential cable routes
- To map seabed features within the two potential cable routes including natural features and artefacts, obstructions and ship wrecks.
- To provide broad scale seabed classification of surface sediments for a baseline benthic survey.
- To provide information on the shallow geology i.e. mapping the distribution and thickness of the main geological formations.
- To provide information for the marine archaeological assessments of the area.

1.2 The survey area

The survey reported here is related to the cable corridors connecting the wind farm area in Kattegat between Grenå and the island Anholt with Djursland. In the planning phase two alternative routes are in play, a northern and a southern (figure 1).

Table 1 defines the cable routes by start and end point by sets of UTM 32N coordinates and geographical coordinates within the Euref89 datum.

Datum Euref89	UTM Easting	UTM Northing
Alternative 1-north		
ID1.1	632160.4	6274418.0
ID1.2	615265.6	6262516.3
Alternative 2-south		
ID2.1	632160.4	6274418.0
ID2.2	621025.7	6255382.7
ID2.3	618956.7	6255169.9

Tabel 1: Coordinates for the two cable route alternatives

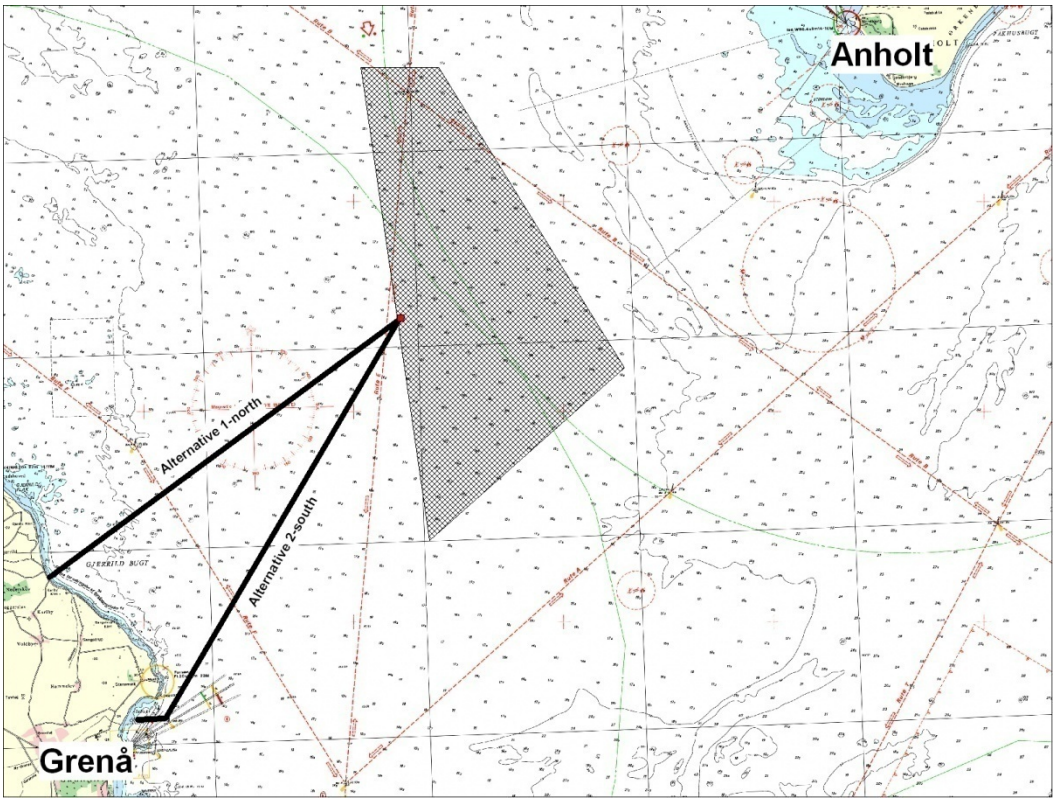


Figure 1. The cable route alternatives connecting the transformer station (red box) onshore. The Anholt Windfarm investigation area indicated as the hatched area.

1.3 Scope of work

This report presents the final results of the data acquisition programme within the two cable route alternatives connecting Anholt Windfarm area with land.

The geophysical survey was carried in the period from 2009-04-18 to 2009-05-03 acquiring data for geotechnical purposes and the environmental and archaeological assessment studies using the following instruments: multibeam echosounder, side scan sonar, chirp sonar, marine caesium magnetometer and sparker system. Two parallel survey lines were run in each of the two corri-

dors with spacing of 25m. The survey lines were extended into the windpark area crossing the area for the planned transformer station. To the west the survey lines ended at the nearest point to land limited by the water depth of approximately 5m, which was the depth limit for the survey vessel.

The location of the corridor survey lines appear from the side scan mosaic, Chart E1.

The combination of the two seismic equipments (chirp and sparker systems) was chosen to ensure a proper penetration together with a high resolution seismic record. The sparker system provides data from depths more than 25m below the seabed with a vertical seismic resolution in the order of less than 50cm. On the other hand the chirp system provides high resolution seismic data from the upper 5 – 10m below the seabed with a vertical seismic resolution in the decimetre scale.

During all the survey activities, a long-range RTK navigation system was used as the primary system. The base station was established in the Fornæs Lighthouse at a distance of 35 km to the far end of the survey area with a satisfying accuracy for the job.

The mobilisation and operation responsibility for the RTK-system was done by the GEUS sub-contractor, Dansurvey.

The geophysical data acquisition was performed by GEUS, while the sub-contractor Scansurvey assisted GEUS with the multibeam bathymetry survey. The QINSy acquisition system has been used for the survey planning and the bathymetric survey. The NaviPac software system was used for acquisition of navigation data and for the distribution of offset values for the instruments.

1.3.1 Data acquisition for marine archaeology

Data has been acquired for the purpose of mapping the eventual presence of marine archaeological objects and munitions. A catalogue of the side scan sonar targets and observed magnetic anomalies has been produced highlighting positions that might need further examination with ROV/video or diver inspection.

The magnetic survey was a part of the geophysical survey conducted by GEUS at 25m spacing of the survey lines. The magnetometer was always kept at less than 5m above the seabed. The dense survey lines and the height of the instrument ensure a full coverage to the corridors. The MagLog dedicated software was used to log the magnetic data. The survey was conducted at a speed of about 4.5knots which is very adequate for such kind of work where survey equipment is towed behind the ship.

1.3.2 Raw materials

The geophysical mapping yield information on the presence of potential raw materials. Hence an evaluation of the uppermost part of the seabed sediments (the Holocene deposits) has been evaluated, mainly based on the high resolution chirp data.

1.3.3 Permission

The survey programme has been performed in accordance with the special permission from the Danish Maritime Safety Administration reference number 2009-002301.

1.4 Geodesy

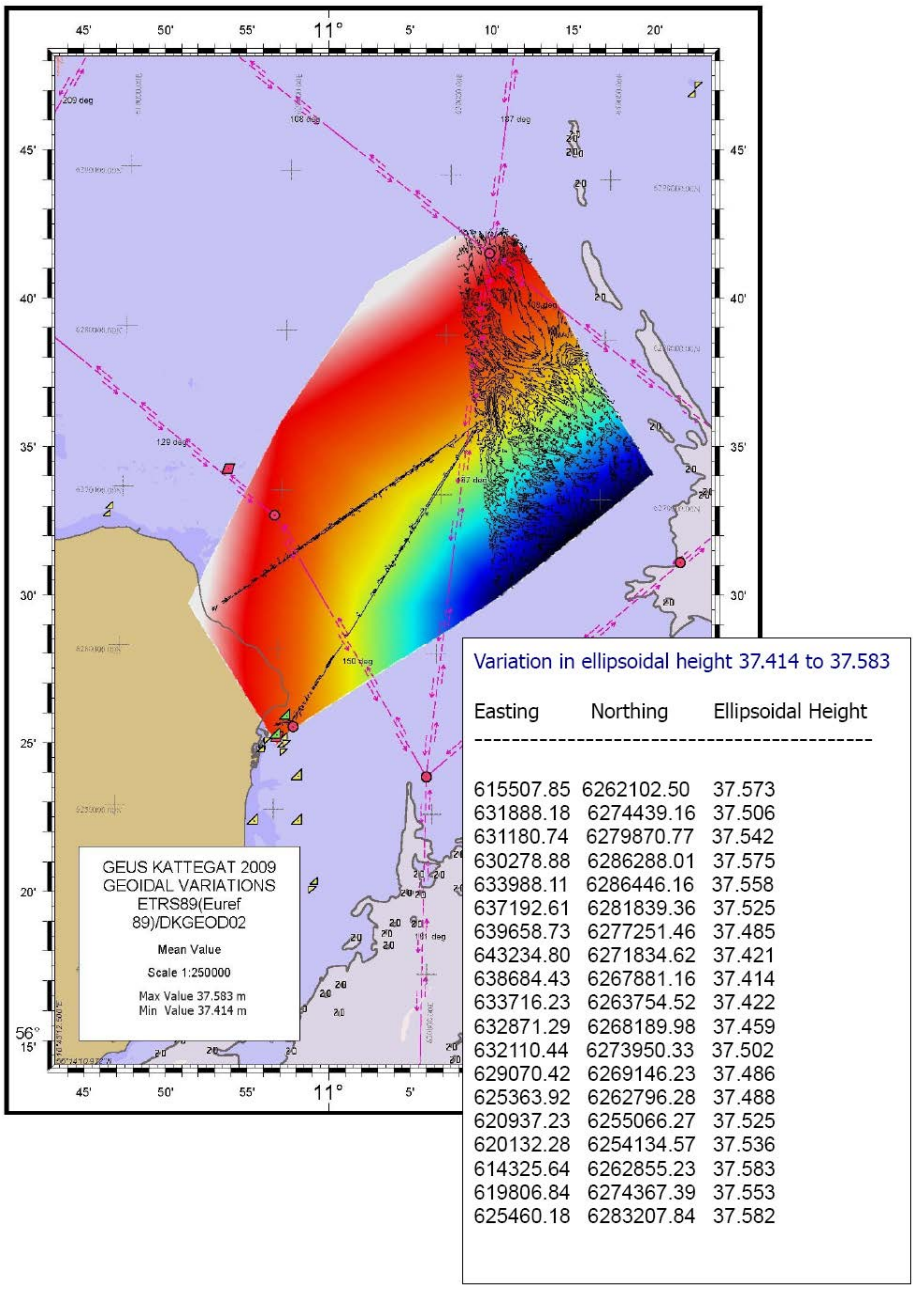
The survey results are mapped in terms of the local geodetic reference system. The general survey definitions are listed below. A statement of the geodetic parameters and other survey definitions used is included in appendix 8.

Geodetic Definitions		
Magnetic Variation Information		
Undefined		
Datum Definitions		
Survey Datum	:	ETRS89 (EUREF89)
Spheroid name	:	GRS 1980
Semi-major axis (a)	:	6378137.000 m
Semi-minor axis (b)	:	6356752.314 m
Conversion factor to meters	:	1.000000
Inverse flattening (1/f)	:	298.25722210
First eccentricity (e**2)	:	0.00669438
Second eccentricity (e'**2)	:	0.00673950
Datum Shift Definitions		
Undefined		
Height Datum Definition		
Vertical datum	:	DKGEOID02 (Denmark)
Height file	:	DKGEOID02.BIN
Height level	:	No Level Correction
Height file	:	N/A
Height offset	:	0.000 m
MSL model	:	DKGEOID02 (Denmark)
MSL file	:	DKGEOID02.BIN
MSL level	:	No Level Correction
MSL file	:	N/A
MSL offset	:	0.000 m
MSL st.dev.	:	0.002 m
DTM mode	:	Absolute DTM's
DTM datum	:	DKGEOID02 (Denmark)
DTM file	:	DKGEOID02.BIN
DTM level	:	No Level Correction
DTM file	:	N/A
DTM offset	:	0.000 m
Projection Definition		
Projection type	:	001
Projection name	:	Universal Transverse Mercator (North Oriented)
Conversion factor to meters	:	1.000000
UTM zone number	:	32
Latitude of grid origin	:	0;00;00.000 N
Longitude of grid origin	:	9;00;00.000 E
Grid Easting at grid origin	:	500000.000 E
Grid Northing at grid origin	:	0.000 N
Scale factor at longitude of origin	:	0.999600
Local Construction Grid Definition		
Not Applicable		
Offset Convention		
Offset mode	:	Rectangular
Offset distances units	:	Meters
Offset angles units	:	Degrees

1.4.1 Geoide model correction

To correct the values obtained by the GPS system from the initial online settings WGS 84 to the required reference datum and geoide all data were ETRS89 (Euref 89)/DKGEOID02. All data were recalculated to the required parameters by using the QINSy multibeam software with implementation of the Danish official geoide DKGEOID02. The ellipsoidal height varied from 37.414 metres in the south-eastern part to 37.583metres in the north-western part of the area (figure 2).

Software used for Ellipsoidal height calculation: KMSTRANS2009.



Variation in ellipsoidal height 37.414 to 37.583

Easting	Northing	Ellipsoidal Height
615507.85	6262102.50	37.573
631888.18	6274439.16	37.506
631180.74	6279870.77	37.542
630278.88	6286288.01	37.575
633988.11	6286446.16	37.558
637192.61	6281839.36	37.525
639658.73	6277251.46	37.485
643234.80	6271834.62	37.421
638684.43	6267881.16	37.414
633716.23	6263754.52	37.422
632871.29	6268189.98	37.459
632110.44	6273950.33	37.502
629070.42	6269146.23	37.486
625363.92	6262796.28	37.488
620937.23	6255066.27	37.525
620132.28	6254134.57	37.536
614325.64	6262855.23	37.583
619806.84	6274367.39	37.553
625460.18	6283207.84	37.582

Figure 2. Map showing the variations of the ellipsoidal height in the survey area.

2. Acquisition equipment and parameters

Equipment	Type	Details	Acquisition parameters
Multibeam echo sounder	Kongsberg EM3002D	Dual Head sonar system. 1.5 ° beam spacing.	Frequencies 293 and 307 kHz.
Chirp	Teledyne Benthos SIS 1625 TTV-290 Tow fish	1-10 kHz	Depth of fish 6m. TVG: custom setting
Side scan sonar	Teledyne Benthos SIS 1625 / TTV-290 Tow fish	100/400 kHz Range 50m /75m	Depth of fish 6m. TVG: custom setting
Sparker	Geo Spark 200	Input energy 300 J	Recording length = 200ms Sampling rate = 10000
Magnetometer	Geometrics G-882	Depth sensor	
Motion sensor (HPR)	Seatex MRU5		
Sound velocity Sensor	Sound Velocity Smart Sensor	Cont. sound velocity measurements at sonar head	
Sound velocity profiler	Applied Microsystems SV Plus	Sound velocity profiling tests	
Navigation software	NaviPac	Helmsman-display	
RTK navigation	AD-Navigation DC 201 and Triumph-1		
Data acquisition software, sparker	Delph Seismic		Band-pass filtering: 200– 2500 Hz
Data acquisition software, side scan sonar	ISIS		
Data acquisition software, magnetometer	MagLogLite		
Data acquisition/processing software, multibeam echo sounder	QINSy		
Survey vessel	M/S Madog		

Table 2. Equipment list and acquisition parameters used for the geophysical survey. Technical specifications of each instrument are described below and in details in appendix 7.

2.1 Sparker

The Geo-Spark series is a new generation of very high-resolution multi-tip sparkers and HV pulsed power supplies developed and manufactured by Geo-Resources Instruments. It has been designed for operation with the Geo-Spark 1000 Pulsed Power Supply using the Preserving Electrode Mode. In this patented mode the electrodes are negative with respect to the frame (ground referenced), reducing the electrode wear to practically zero.

The Geo-Spark 200 source system (figure 3) is capable to acquire very high-resolution seismic profiles of the "shallow" sub-bottom strata. Depending on the energy level, the geology and water depth, the effective penetration can exceed 300 - 400 ms below seabed. The standard Geo-Spark 200 very high-resolution seismic spread typically consists of:

- Geo-Spark 200 Sparker source c/w cable and patch panel
- Geo-Sense dedicated high resolution single channel streamer
- Geo-Spark 1 kJ solid state pulsed power supply

Figure 3. The Geo-Sparker 200 source.

2.2 Combined Chirp/Side Scan Sonar system

The combined seafloor imaging system from Teledyne Benthos SIS has been used for acquiring high resolution chirp side scan /sub-bottom data. The DSP based side scan sonar operates at 100/400 kHz simultaneously. The chirp DSP/CW based sub-bottom profiling system operates in the 1 to 10 kHz region allowing a maximum sediment penetration with a high resolution.

The TTV-290 tow vehicle (figure 4) is a fully digital platform with standard chirp side scan/sub-bottom transducer arrays, digital multiplexor, subsea electronics and RS-232 ports for optional sensors. The vehicle is hydrodynamically stable including pitch, roll and heading sensors, optional position responder/transponder. It provides a 0.5° side scan horizontal pattern, combined with broad band Chirp DSP match filter processing. It provides optimal cross-track and along track resolution.

Figure 4. The SIS-1625 Seafloor Imaging system tow vehicle TTV-290.

2.3 Marine Ceasium magnetometer

The Geometrics high resolution marine Caesium magnetometer system (figure 5) has been used for mapping of the magnetic anomalies. It has simultaneous readings may be obtained from up to 6 individual sensors through cable lengths to 2500 ft. System features include very high sensitivity measurements of total field and gradient combined with rapid sampling.

The G-882 is flexible for operation in small boat, shallow water surveys as well as deep tow applications (4,000 psi rating, telemetry over steel coax available to 10Km). Being small and lightweight (40 lbs net, no extra weights) it is easily deployed and operated by one person. One streamlined weight collar was mounted prior to the survey. The tow cable employs high strength Kevlar with a standard length of 200 ft (61 m) and optional cable length up to 500m (no telemetry required). A rugged fibre-wound fibreglass housing provided selectable orientation of the sensor (45°). The shipboard end of the tow cable was attached to an included junction box or optional on-board cable for quick and simple hook up to power and output of data into the computer via a RS-232 serial port including a built-in echo sounder and altimeter showing the height above sea bottom and depth in water column in real time.

Figure 5. The Geometrics G-882 Magnetometer.

The G-882 Caesium magnetometer provides the same operating sensitivity and sample rates as the larger deep tow model G-880. MagLogLite™ Logging Software is offered with each magnetometer and allows recording and display of data and position with Automatic Anomaly Detection.

The G-882 system is particularly well suited for the detection and mapping of all sizes of ferrous objects. This includes anchors, chains, cables, pipelines, ballast stone and other scattered shipwreck debris, munitions of all sizes (UXO), aircraft, engines and any other object with magnetic expression. Objects as small as a 5 inch screwdriver is readily detected provided that the sensor is close to the seafloor and within practical detection range.

2.4 Multibeam Echosounder

The used system is a high resolution Kongsberg EM3002D dual head seabed mapping system. Each head delivers a 1.5° beam for transmission and reception, where the swath coverage of the dual head system can reach up to 10 times the water depth. In the high density mode of operation each head acquires up to 254 soundings per ping. The operating frequencies are 293 and 307 kHz to avoid interference between the two heads. The operation range of the system is from 1m to 150m, which is also a function of salinity and temperature. The depth resolution is very high (~1cm), the across track measurement accuracy is a function of depth and the distance from nadir position, a nominal range resolution of 5cm is reported. The schematic diagram in figure 6 illustrates the principle of the multibeam system.

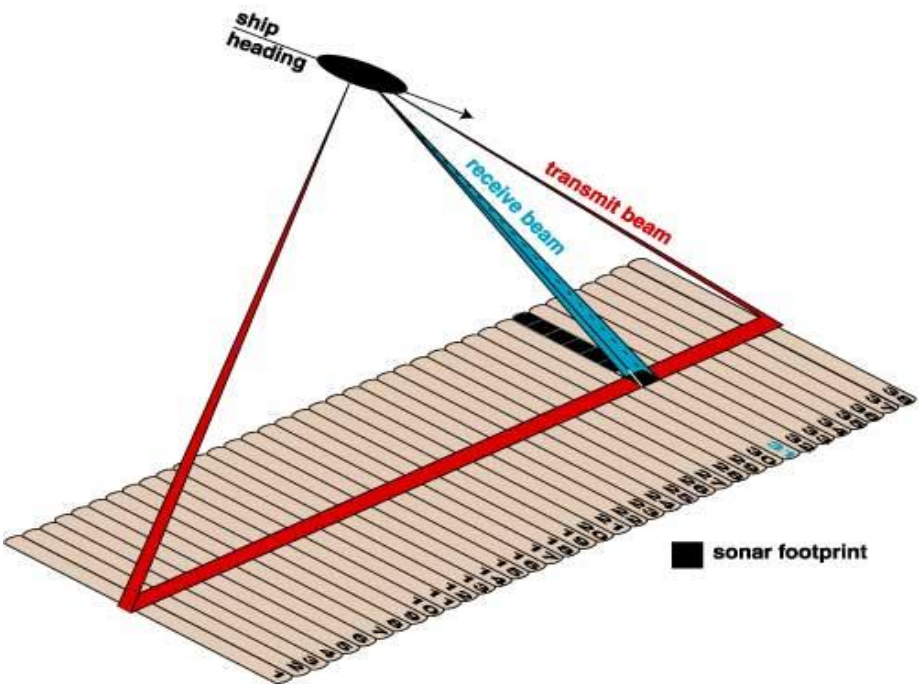


Figure 6. Schematic diagram of multibeam system operation.

2.5 Motion Sensor

For measurements of heave, roll and pitch a Seatex MRU-5 has provided motion data for compensation of the multibeam bathymetry echo sounder data.

2.6 QINSy system

The QINSy system has been used for the survey planning and for the acquisition and processing of the multibeam bathymetry data (i.e. survey planning, data collection, data cleaning, and chart production).

QINSy Console

Gathering and organizing the various QINSy 7 programs in a single desktop application, called the Console (figure 7), makes navigation through the program suite at each phase of the project. Guided through the various program modules designed specifically for survey planning, data collection, data processing and chart production. Program Managers provide a complete overview of project status at each phase. The main program modules are:

- Planning
- On-line
- Replay and SSS Processing
- Processing and Data Cleaning

Figure 7. Screen dump of the QINSy Console.

Survey Lines

The Line Database Manager (figure 8) works interactively in real-time with the Online Navigation Display where points, lines and routes can be generated right in the Navigation Display during data acquisition Survey Configuration.

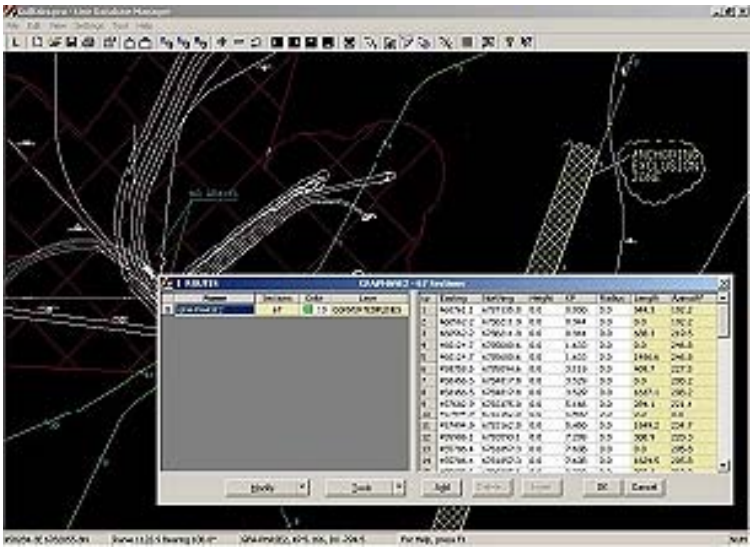


Figure 8. Screen dump of the QINSy Line Database Manager.

Real-Time Final Results - Data Collection and Output Raw Sensor Data

All raw sensor data is logged and permanently stored in a fast relational database (*.db) to which the entire survey configuration is copied from the template. Raw data were analysed and edited using the Analyse program, making it ready for the Replay program and generation of new results. Results data (X,Y,Z and attributes) is stored to one of several formats, primarily the QPS internal format (*.qpd), but also to ASCII, FAU or Helical SDS format.

QINSy uses a very sophisticated timing routine based on the PPS option (Pulse Per Second). All incoming and outgoing data is accurately time stamped with a UTC time label. Internally, QINSy uses so-called "observation ring buffers", so that data values may be interpolated for the exact moment of the event or ping.

All computations of position are performed in 3D. In combination with RTK all depth observations are immediately available in absolute survey datum coordinates. This unique technique is called "on-the-fly DTM production".

In QINSy there are two gridding methods, namely:

- An irregular gridding method in which the size of cells created in real-time is directly related to variation of the seafloor. In general, large cells, more appropriately called tiles, are created in flat seabed conditions and small tiles created in feature rich areas with slopes, wrecks, rocks, and sand ripples. This on-the-fly method effectively reduces the volume of data without loss of resolution.

- A regular multi-level gridding method. Based on the minimum cell size, 5 additional grids are generated on-the-fly. Grid file size is no longer an issue, since there is no limit to the number of grid cells. If the minimum cell size is selected to be 1 x 1 meter, then automatically the following grid levels are being generated: 2 x 2, 4 x 4, 8 x 8, 16 x 16, and 64 x 64 being the overview level.

Reduced point data output to tiles is accompanied in parallel with output of all soundings to a second file (*.qpd, *.sds, *.fau, *.pts or other).
Either reduced or full datasets are available for further DTM processing.

2.7 Processing procedures (de-spiking and data editing)

The processing procedure falls into three distinct sections:

A:
On-line data collection: Replay/recalculation data with final setting of geodetic parameters and instrument offset/calibration values. This is a function of the data acquisition software QINSy main module. All raw data values are collected, time tagged and stored during the on-line session. For the Anholt Windfarm project the data was replayed/recalculated in order to apply all data points with a calculation based on adjusted patch-test/MB calibration values established by the patch-test runs carried out on the 5th of May 2009. In the same process the geodetic base settings were changed from WGS 84/EGG97 (Europe) to ETRS89(Euref 89)/DKGEOID02.

The recalculated semi-raw data were transferred to the line editing tool QINSy Processing Manager for further individual processing, editing and quality evaluation (Proprietary QPD format).

B:
Single line segment Processing, editing and validation using the QPS Data Processing Manager.
Manual editing using cursor to remove obvious spikes and erroneous data. Quality Control by visual inspection of each individual data segment (figure 9a).

All data points were a posterior recalculated for refraction effect by means of the QINSy Sound Velocity Manager by use of a model with all SVP profiles activated in order to obtain the optimum correction result.

The visually inspected and coarse edited data (in QPD format) were then transferred to the QPS software QLOUD for area evaluation and final editing.

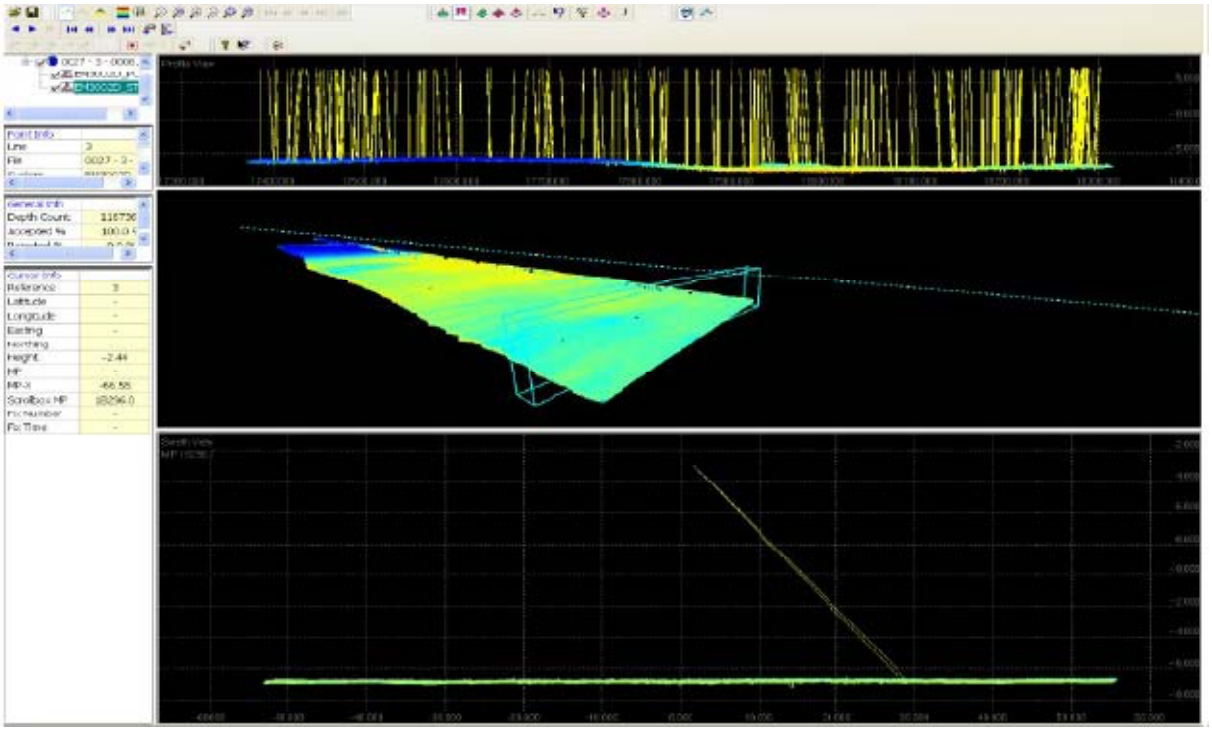


Figure 9a. Screen dump illustrating the Quality Control procedure by visual inspection of each individual data segment.

C:

Area data evaluation and cleaning software QLOUD was used for the final stage of the data preparation. In QLOUD all data are statistically compared. A number of automatic filters are available.

For the Anholt Windfarm project following criteria were used:

1. De-selection of 7 beams on either side in order to improve the general base set by avoiding the outer beams.

2. All data points shallower than 5m to be deselected in order to avoid noise and erroneous data from the area near the vessel hull and the sea surface. See figure 9b.

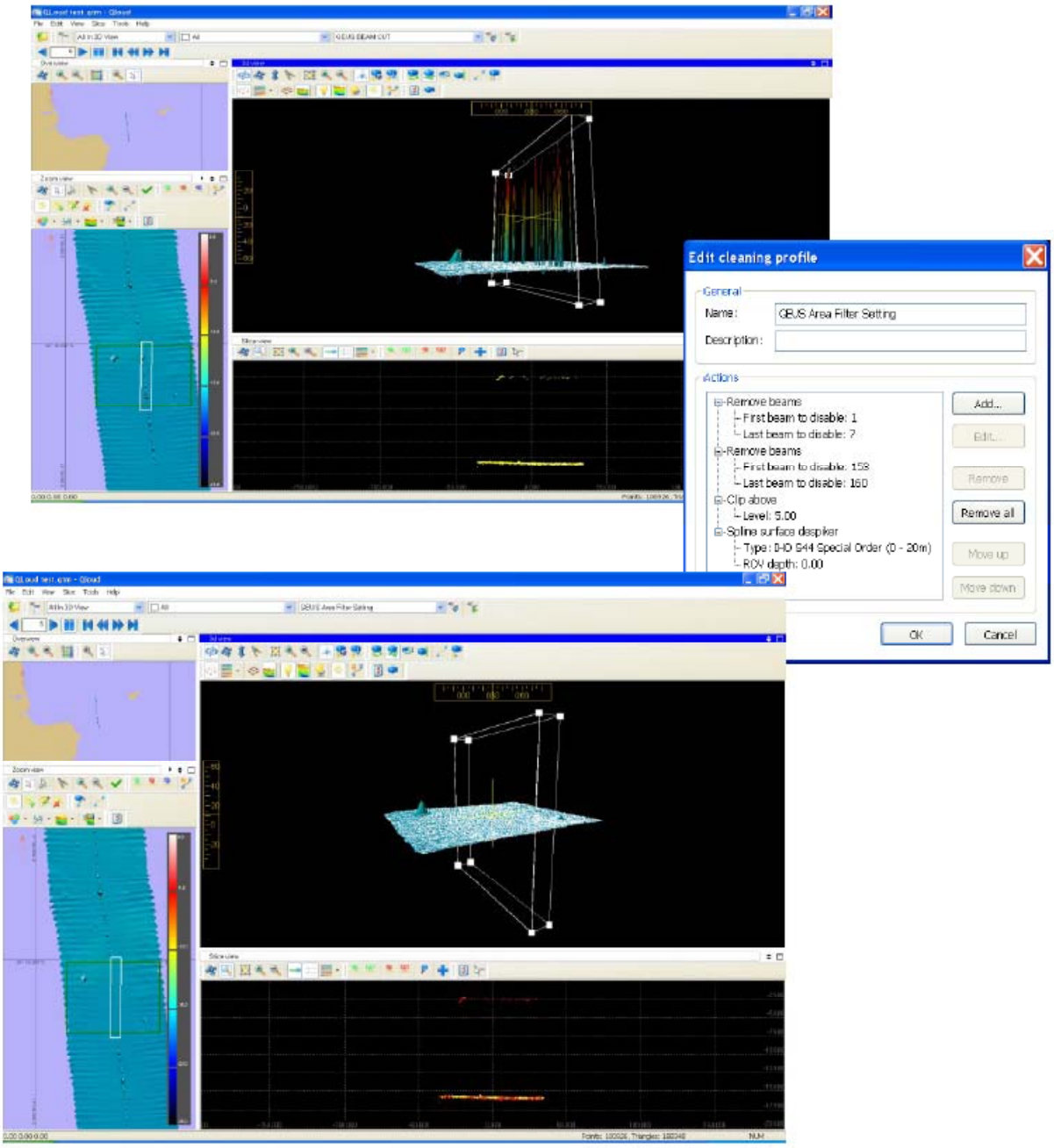


Figure 9b. Screen dumps illustrating the data editing and cleaning process deselecting the 7 outer beams and data points shallower than 5m.

The vertical accuracy at that distance is theoretical about 6.5cm (in reality +/- 10cm) and for the positioning the accuracy was in the range of 5cm. The position accuracy of the secondary DGPS system was about 1m.

3. Area Splining de-spiking using the neighbour comparison using $X = \pm \sqrt{a2 + (b * d)2}$ where a = 0.25 m. b = 0.0075. See figure 9c.

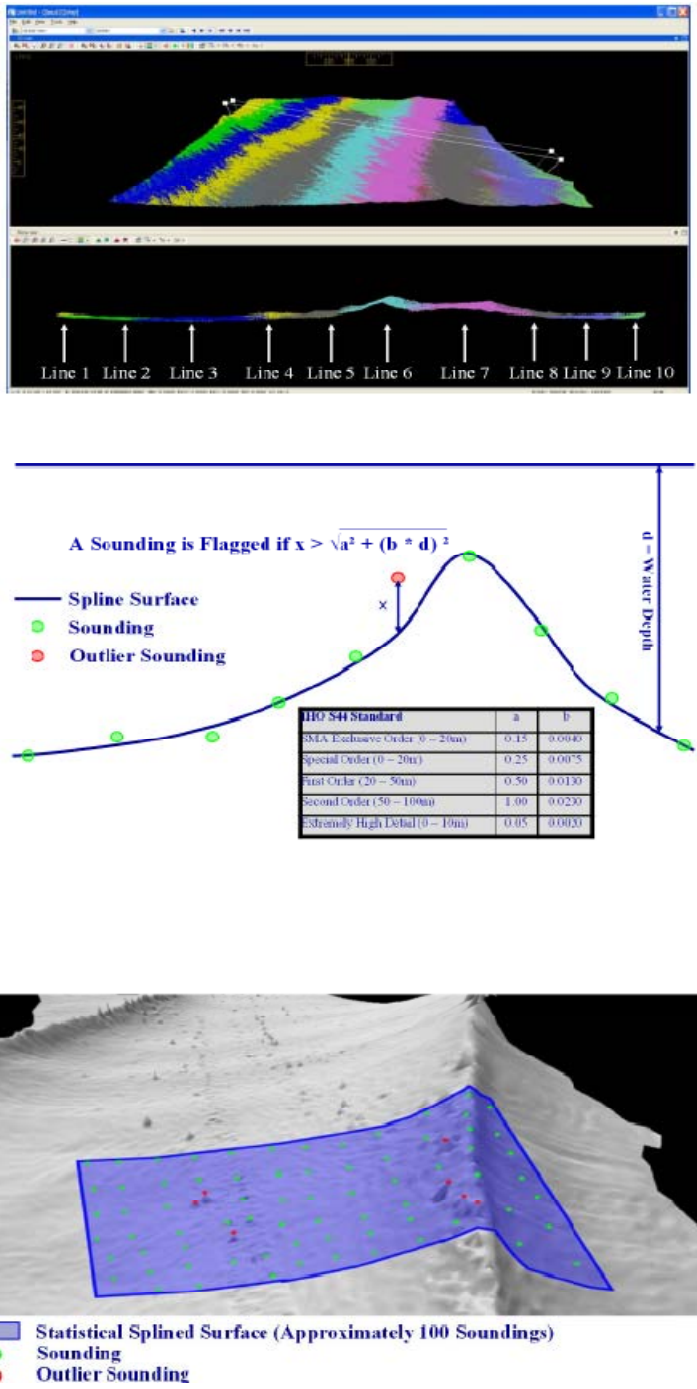


Figure 9c. Screen dump illustrating the area splining de-spiking procedure.

Edited and approved data are subsequently exported into ASCII XYZ format and other required formats after completion of the above mentioned procedures.

Further details on the multibeam QC are attached in appendix 10 (documentation on the multi-beam line spacing), appendix 11 (Cross over tests), and appendix 12 (binning statistics).

2.8 Navigation systems

2.8.1 NaviPac

The NaviPac software is integrated navigation and data acquisition software specifically suited for general navigation and geophysical and seismic surveying.

The NaviPac software system was used for acquisition of navigation data and for the distribution of offset values for the instruments. NaviPac was exported to the QINSy system from which the survey lines were conducted during the survey to ensure the satisfying coverage of the multibeam system.

2.8.2 RTK Navigation system

An AD Navigation DC201 GPS/GLONASS L1/L2 RTK Long Range Receiver was used for the survey. The RTK receivers provide real time positioning data at the 1 cm level while attaining the highest reliability and stability possible. Seamless Combination GPS and GLONASS is the heart of the AD Navigation DC-201 RTK receiver. By seamlessly combining the GPS and GLONASS system, the RTK receivers access the total of 40 positioning satellites. During normal operation, the receiver track 30-50% more satellites than does a GPS-only system. Using diversity receiver techniques (dual antenna system), reception of the UHF signal is significantly improved compared to normal systems, even under difficult radio conditions.

The base station sends CMR corrections at up to 5Hz. The diversity receiver technique, in combination with high update rate of CMR correction broadcasts, results in operational RTK up to 80 kilometres from the RTK base station. With two GPS/GLONASS antennas installed, accuracies of 0.01 deg are achieved at 10 times per second. The unit contains no moving parts, and neither calibration nor maintenance is needed.

According to the specifications the accuracy of DC201 is 1.5cm +1.5ppm equal to 6.5cm at the most distant part of the wind farm area, approximately 35km. The resulting depth accuracy for the wind farm area, taking all the errors into account, is better than approximately +/- 13cm documented by the cross over test (appendix 11). However, for the cable corridors specifically the accuracy is even better because of the shorter distance to the base station.

2.8.3 Positioning receiver systems

RTK Navigation Receiver system

On-board the survey ship a Triumph-1 integrated GPS receiver. The details of the system are presented in appendix 7.

Sagitta DGPS navigation back-up system

As a back-up navigation system to the RTK system the Sagitta DGPS system was set up. The DGPS system gives a navigational accuracy within 1m, and it uses 16-channel GNSS differential signal. The Sagitta™ receiver from Thales is developed for small and medium-scale marine surveys. Sagitta has real-time precision ranging from the meter to the centimetre level, depending on how it is operated (Operating modes available include: WAAS/EGNOS, DGPS, EDGPS, KART or LRK®). It is used for many types of kinematics applications such as bathymetry or coastal works, sea trials or trajectory. Sagitta has dual-frequency.

3. Health, Safety and Security

GEUS undertakes full responsibility to provide for the safety, security and health of GEUS' personnel and to observe the respective laws and regulations of the area of operations. GEUS tries continuously to improve the safety management skills of its personnel both ashore and aboard ships, including preparing for emergencies related both to safety and environmental protection. The target is zero level for injury, accidents, and lost time. The target is further to eliminate or control hazards by risk management at all workplaces. GEUS covenants, warrants, and represents that its personnel and the personnel of its sub-contractors are suitably trained to safely perform the service. The objectives of GEUS' Safety Management Manual are achieved by:

- Senior Management ownership of a Health & Safety Culture achieved by visible investment in GEUS' personnel.
- Maintaining high standards of safety consciousness, personal discipline and individual accountability by adherence to a comprehensive and documented system of training.
- Actively promoting employee participation in measures aimed at improving safety and protecting the environment including the right to stop work should the operational risk be found unacceptable.
- Communications to personnel of known or potential hazards that may affect themselves, their colleagues, the ships equipment or the environment.
- Continuously reviewing all Health, Safety & Environmental mandatory rules, regulations, industry codes and guidelines that are relevant to our work sites, and business.
- Providing operational and health risk assessment.
- Maintaining a schedule of workplace auditing

All employees are required to comply with Safety and Pollution Prevention Regulations and Procedures at all times and to take the necessary precautions to protect themselves, their colleagues, the ship, the equipment, and the environment.

GEUS provides external assessed comprehensive safety training for its marine personnel as follows:

- Personnel Survival Techniques
- Fire prevention and fire fighting
- Elementary first aid
- Personal Safety and social responsibilities

3.1 Safety overview

A Safety Instruction meeting was held on board the ship before leaving Grenaa for the equipment tests. The survey crew was instructed on the safety rules on board the ship. With crew change, new instructions were performed.

3.2 Accidents, near miss and unsafe Acts

Accidents
No accidents have been reported during the survey.

Near miss
There were no equipment miss reports during the survey.

Unsafe Acts
No unsafe acts have been reported during the survey.

Minor incidents
There were neither equipment minor incidents reported nor personal minor incident.

3.3 Environmental incidents

No environmental incidents have been reported during the survey.

4. Survey Vessel

4.1 Ship configuration

The survey ship RV Madog was used for the entire geophysical data acquisition including the combined shallow seismic, side scan sonar, magnetometer and multibeam survey. RV Madog owned by the company NordMarine can be seen on figure 10.

Figure 10. The survey ship RV Madog.

Navigation was carried out by RTK DGPS connected to the NaviPac distributing navigation data corrected for offset to the Side scan data acquisition computer, the seismic data acquisition computer and through QINSy, the multibeam acquisition system. The mentioned data acquisition computers are connected to the sound sources in the water, via the individual power transmitters.

The sketch in figure 11 illustrates the configuration of the equipment onboard RV MADOG. The multibeam dual head sonar head was hull mounted on the front side of the ships keel with the RTK DGPS reference antenna and the MRU5 motion sensor mounted vertically on the sonar head. The multibeam sonar refers directly to the RTK antenna position and MRU (X, Y, Z) = (0, 0, 0). The combined SIS 1625 chirp fish was mounted side off the ships starboard side, held by the ships crane with offsets of X= 6.60m, Y= -21.2m (3m behind the winch point). The depth of the fish was approximately 6 m below sea surface.

The combined SIS 1625 chirp fish was mounted side off the ships starboard side, held by the ships crane with offsets of X= 6.60m, Y= -21.2m (3m behind the winch point). The depth of the fish was approximately 6 m below sea surface.

The sparker catamaran and streamer and the magnetometer was towed behind the ship. The sparker system was towed at the port side, with the catamaran offsets of X= -2,35m Y= -53.75m and the streamer offset of X= 5.35m Y= -53.75m. The magnetometer is towed behind the ship with offsets X= 2.35m and Y= -68.75m.

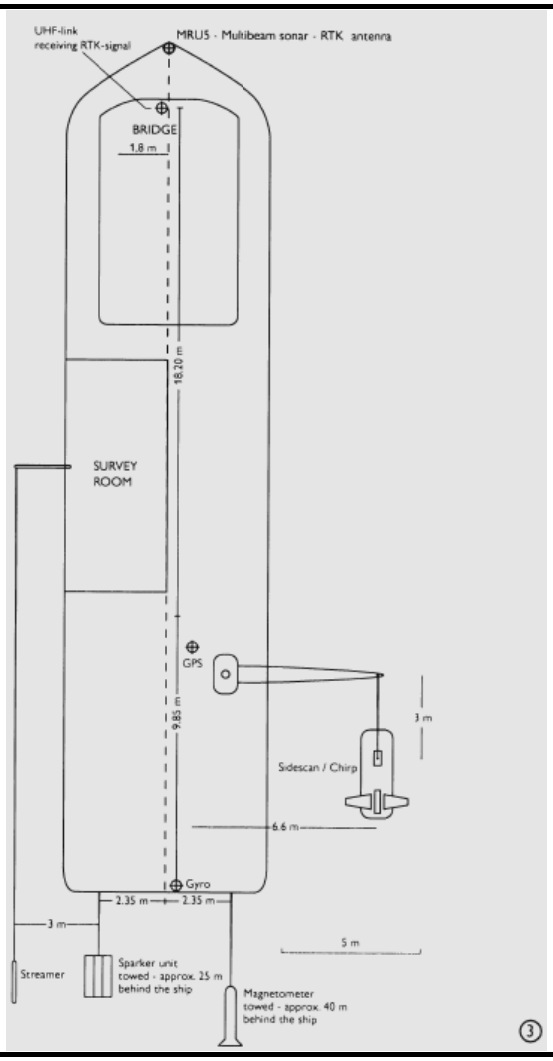


Figure 11. The location and offsets of the acoustical and navigational equipment onboard M/S MADOG.

5. Survey preparation

5.1 Mobilization trials

Checks were performed on each instrument before survey commencement to ensure that all the sensors and processing equipment specified are functioning correctly and performing within the manufacturer's specifications.

All checks were performed with supervision of the Employer's Representative, in order to establish any requirements for additional calibrations and any corrections that shall be applied to the acquired data.

Calibration of the multibeam system was conducted in presence of the Employer's Representative on the 5th of May 2009. (See the attached “Patch test, appendix 2)

The surface positioning system was available during all phases of the survey and it provided an absolute accuracy of better than 1m. The system is an AD Navigation DC202 GPS/GLONASS L1/L2 RTK long range system, and it is based upon the differential Global Positioning System (DGPS). The positioning system was displayed onboard and real time quality control was maintained. Before the mobilization, the master station at Fornæs Lighthouse was checked against two new established calibrated reference control points in Grenå Harbour. The control points 1001 and 1002 were established by the registered Land Surveyor Company Kjær from Grenå the 23th of April 2006 on the pier in Grenå. The maximum deviation of the measured control points were < 0.01m during. For the master station the maximum deviation was 0.02m. (See report “Control measurements of master station, Grenå”, see Appendix 5).

Subsequently the RTK antenna onboard was checked against the newly established control point by demounting the antenna from the ship, placing it upon the control point. The results from the NaviPac navigation log file in figure 12. Compare these values with the measured values in appendix 5.

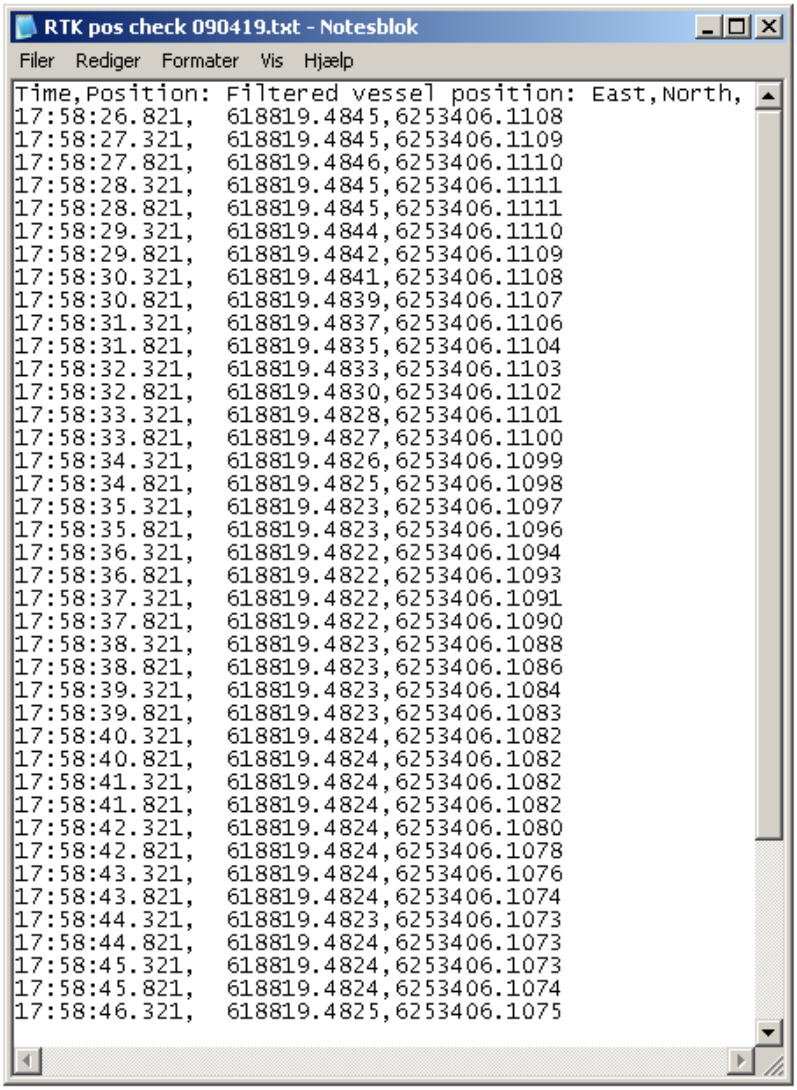


Figure 12. Log file from NaviPac of the RTK position check procedure, showing a extremely constant x,y values at the newly established reference point in Grenå harbour.

5.2 Magnetometer

The marine magnetometer used was a Geometrics Caesium Vapour type capable of recording variations in magnetic field strength during survey to an accuracy of better than 0.1nT (nanno Tesla). All measurements are recorded in MagLog Lite™ Software installed on a separate laptop. The system has repetition rate selectable between 0.5 and 10 seconds including sensor offset and tow depth. Prior to commencing the data acquisition, sea trials ware conducted to establish the optimum deployment location for the magnetometer, such that vessel heading errors are less than 10 nT. The marine magnetometer readings are presented as a data listing of anomalies determined side-by-side with a screen-dump of the side scan sonar picture at the same position.

The built-in echo sounder and altimeter showing the height above sea bottom and depth in water column in real time was tested in harbour by lowering the fish to two different fixed depths (2m and 4m below sea surface). The readings were registered in the MagLog software and compared to the actual water depth. The results are presented in the figures 13 and 14 below.

During the survey the magnetometer was towed 40m behind the ship approximately 4m above the seabed dependant of the water depth. The actual fish depth is registered continuously with the magnetic readings. During the survey the fish depth has been controlled continuously on-line by the surveyor in charge.

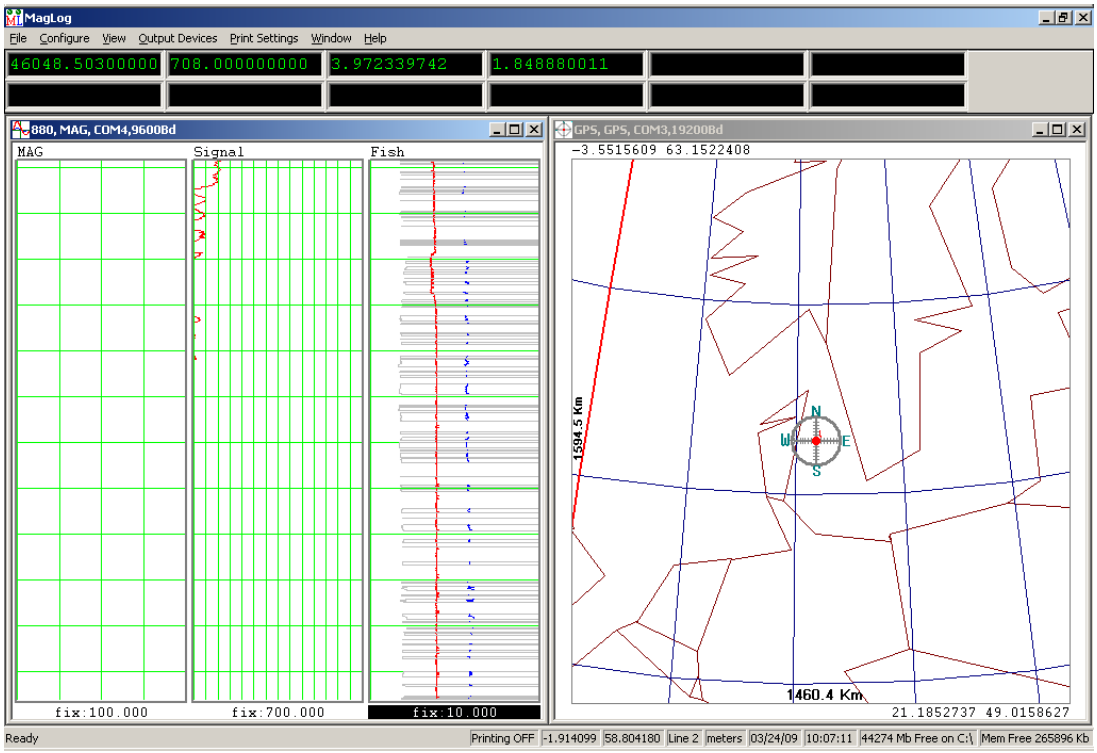


Figure 13. Test results of the magnetometer fish depth from the 4m depth. The red line in the “fish” field shows the fish depth with accuracy within 3cm.

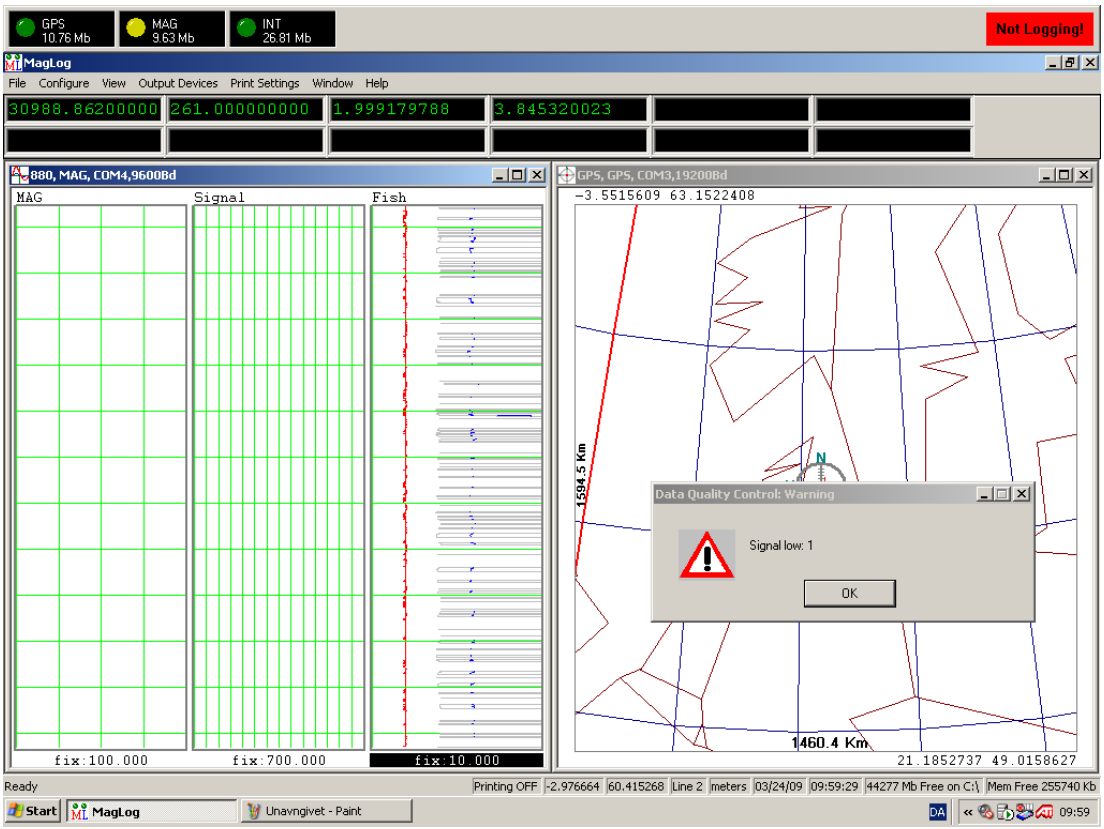


Figure 14. Test results of the magnetometer fish depth from the 2m depth. The red line in the “fish” field shows the fish depth with accuracy within 0.0001m.

5.3 Multibeam Bathymetry

The multibeam transducer was mounted at front point of the ship’s keel. The multibeam echo sounder was compensated for heave via the MRU motion sensor in order to obtain heave corrected echo sounder records. Data was digitally recorded and displayed on-line in analogue form for QC purposes. A comprehensive report on patch test procedures is attached in appendix 2.

5.4 SVP - sound velocity profiling tests

During the phase 2 survey, SVP tests have been carried out at 93 times and the results have been used for calibration of the echo sounder. Whenever data in the QINSy Processing Manager indicate changes of sound velocity supplementary SVP’s were carried out (figure 15). During the survey period strong variations in the hydrographic conditions have been registered due to a strongly developed pycnocline at the depth interval of 15 – 20m (Rasmussen, 1994). Due to salt and temperature differences the surface layer above the pycnocline is usually stratified in the southern Kattegat with vertical density differences of 1 – 5 kg/m^3. Advection of low-saline Baltic Sea water gives the major contribution to this stratification. The reduction of vertical exchange is illustrated by the persistence of temperature inhomogenities above the pycnocline during several days. The physical properties of the water have been measured in two ways, by the SVP probe and continuously by the online probe at the sonar head.

Figure 15. The SVP probe is made ready for a sound velocity profile.

5.5 Side scan sonar

5.5.1 Isis Side Scan Acquisition Software

The ISIS side scan software allowed acquiring; process and playback data for presentation partly as individual survey lines and partly as side scan mosaic (see Chart E1). Incoming side scan sonar and ancillary sensor data are time-stamped to millisecond accuracy, thereby ensuring the final data products can be properly corrected during processing. Both the 100 kHz as well as the 400 kHz data sets were acquired. In the northern corridor a side scan range of 75m was used, in the southern a 50m range ensuring seabed coverage of 50m and 75m on both sides of the ship, respectively.

All data are stored in TEI's open XTF (eXtended Triton Format), an industry-standard, non-proprietary format.

Bottom-tracking, time-varying gain, and slant range correction have been applied to the imagery during processing as part of the mosaicing procedure.

5.6 Chirp survey

The chirp data was acquired by use of the SIS-1625 sub-bottom profiling system operating in the 1 to 10 kHz frequency region. The purpose and effectiveness of the system is expressed in terms of good penetration on the one hand and vertical/horizontal accuracy and resolution on the other. For this survey, the performance of the chirp sonar is estimated as follows: Max. penetration 10m; vertical resolution/layer detectability 0.25m. This allows a maximum sediment penetration with a fairly high resolution. The fish was mounted in the ships crane while dragged in the starboard side of the ship at a water depth of 6m. Data was recorded as the 5th channel of the acquisition system in XTF-format. Prior to the loading into the Geographics interpretation software the raw data were converted from XTF to SEG-Y.

5.7 Sparker survey

The Sparker instrument was chosen as the best suited equipment because the low frequency band allowed acceptable deep penetration at fairly high resolution. The system is described in detail above. The system is capable of delineating hard and soft layers in the first 25m sub-seabed with a definition of 0.5 - 1m near the seabed and 1.5m at depth. It is understood that penetration may be less where sub-seabed is dense. The sparker system has a reliable performance record, with sharp signature at input energy at 300 Joules, and capable of operating at the maximum firing rates specified by the manufacturer. All data was recorded digitally for subsequent processing and interpretation in SEGY format and was automatically referenced for position and event data. Signal processing on board the survey vessel was provided, including (but not limited to) time varying gain, band-pass filtering, stacking and heave or swell compensation, still not affecting the raw data. The sparker and hydrophone was surface towed in such a configuration as to minimize the effects of propeller wash, ship's noise and vessel motion. The hydrophone shall be balanced to maximise data quality. The Employer's Representative agreed on the selected configuration. A test was prepared during the start up of the survey and supervised by the Employer's Representative.

6. Interpretation and gridding procedures

The aim of the seismic interpretation in the project has been the mapping of significant geological horizons and formations with a potential influence on the planning of the wind farm project. At an early stage after the completion of the data acquisition GEUS and the client decided to focus on the shape and distribution of four geological units: The Pre-Quaternary, the glacial deposits, the late-glacial deposits and the Holocene/post glacial deposits.

The interpretation of the seismic sparker and chirp data were performed using the Landmark interpretation software Geographics. The seismic SEG-Y files were in general in a satisfactory data form so no filtering or AGC-gaining was actually added.

The interpretation of the seismic data is based on recognizing style in seismic texture, facies and continuous reflectors in the seismic image. On this basis the observations and descriptions of the individual seismic sections are followed by an interpretation into sedimentary environment and geological relationship (stratigraphy). Nine boreholes constitute the stratigraphic control of the seismic units.

Layer	Instrument	Description	Velocity	MapInfo file name	Interpolation radius	Draw radius	Cell Radius	Maks points
Seabed C	Chirp	Depth in positive numbers	1500	seabed chirp IDW Grid.grd	500	500	10	1000
Seabed S	Sparker	Depth in positive numbers	1500	seabed sparker IDW Grid.grd	500	500	10	1000
Seabed B	Basemetri	Depth in negative numbers, cell size = 10m	-	seabed ecko2 IDW Grid.grd	50	50	10	25
Correction Grid C	Chirp	Correction Grid C = Seabed C + Seabed B	-	Correction Grid.grd				
Correction Grid S	Sparker	Correction Grid S = Seabed S + Seabed B	-	Correction Grid S.grd				
TT C	Chirp	Depth in positive numbers	1600	CHIRP TT IDW Grid.grd	500	500	10	1000
TT S	Sparker	Depth in positive numbers	1600	sparker TT IDW Grid.grd	500	500	10	1000
TT C corrected	Chirp	TT C corrected = TT C - Correction Grid C	-	CHIRP TT IDW Grid corrected.grd				
TT S corrected	Sparker	TT S corrected = TT S - Correction Grid S	-	sparker TT IDW Grid corrected.grd				
TT C 20m cut corrected	Chirp	Chirp data larger than 20 m are cuttet	-	CHIRP TT IDW Grid corrected 20.grd				
TT S 20m cut corrected	Sparker	Sparker data smaller than 20 are cuttet	-	sparker TT IDW Grid corrected 20.grd				
Top Q	Sparker	Depth in positive numbers	1700	Top PQ IDW Grid.grd	500	500	10	1000
Top Q corrected	Sparker	Top Q corrected = Top Q - Correction Grid S	-	Top PQ IDW Grid corrected.grd				
Hol	Chirp	Depth in positive numbers	1500	Base Hole 2.grd	1000	500	20	2000
Hol corrected	Chirp	Base Hol Corrected = Base Hol - Correction Grid C	-	Base Hole 2 IDW Grid corrected.grd				
Hol Vol	Chirp	Base Hol Vol = Base Hol - Seabed C	-	Base Hole 2 IDW Grid corrected VOL.grd				
TT Volume S	Sparker	TT Volume = TT S corrected - Base Hol corrected		TT Vol Grid.grd				
TT Volume C	Chrirp	TT Volume = TT C corrected - Base Hol corrected		TT Vol Grid C.grd				

Figure 16. Settings used for the time-to-depth conversion and the interpolation and gridding parameters.

The defined geological interfaces as well as the seabed were traced and digitized on each seismic profile, generating (x,y,z) ASCII-files where the z-value is TWT/Two-Way Time (ms). These ASCII files were subsequently extracted for gridding. Before gridding the digitized data were im-

ported to Excel for filtering of out-layers and for time-to-depth conversion using specific seismic velocities depending on the geological properties and depth below the seabed (see figure 16).
To reference the geological interfaces of the chirp and sparker data to the vertical reference level the seabed and the geological interfaces have been digitised. Subsequently the differences in time have been transformed by multiplying an average seismic velocity (figure 16) to the time and finally subtracted the difference from the seabed level determined by the processed multibeam bathymetric data (DVR90). As the SIS 1625 fish has been towed 6m below the sea surface the chirp data beforehand were compensated for the depth of the fish.

By that, all the output data sets used for gridding are related to the same vertical reference level. The maps presenting the geological horizons in this report therefore are comparable, independent what the origin the background data is.

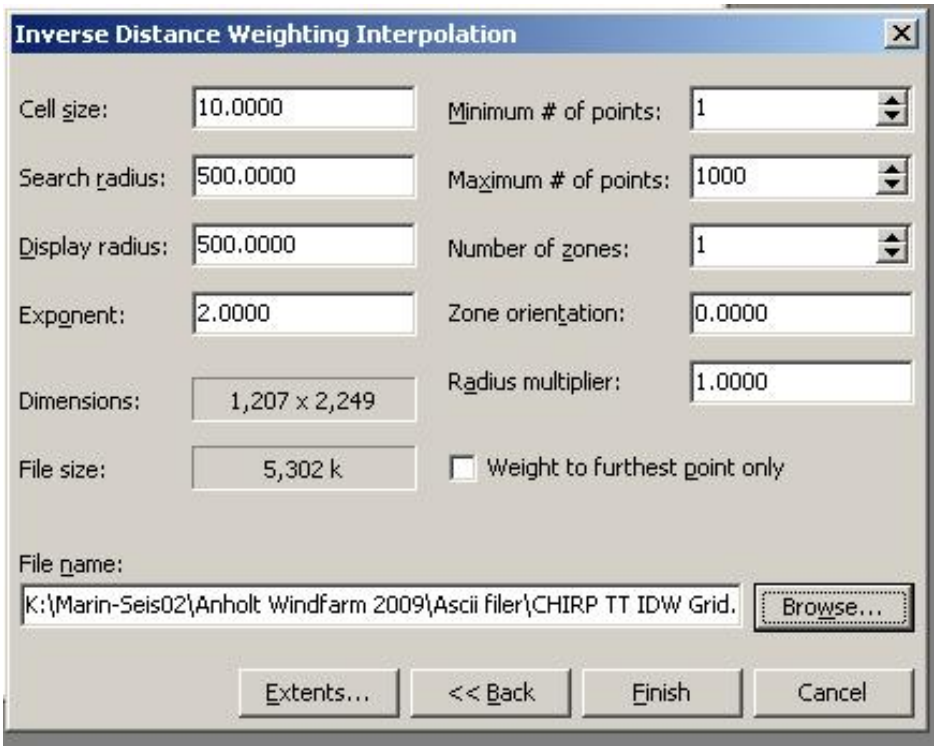


Figure 17: Screen dump of the Vertical Mapper gridding settings.

For gridding the MapInfo software Vertical Mapper has been used. The chosen interpolation method is “Inverse Distance Weighting Interpolation”, where grid cell values are calculated from data points within a specified search radius. Points are weighted so that those found closer to the cell have more influence than ones farther away. The settings used appear from figure 17.

7. Seabed sampling

7.1 Vibrocoring

After the preliminary interpretation of the geophysical data GEUS pointed out 21 positions for 3m vibrocorings: 9 cores in the northern corridor and 12 in the southern. The results of the geological descriptions have been set at the disposal from GEO (GEO, 2009), who were the responsible consultant for this part of the work. The sedimentological logs of the vibrocores are attached in appendix 1.

7.2 Ground truthing

In relation to the mapping of the seabed sediments GEUS performed a sediment classification on the basis of the side scan images (Chart E2). The preliminary classification ended up in 6 side scan sonar classes based on the variations of reflectivity. These classes were the basis for the ground truthing positions selected by GEUS with the purpose of verifying the variability of the seabed. Subsequently a series of visual inspections were performed by Orbicon A/S. The results are published in Rambøll (2009).

8. General geology of the southern Kattegat area

8.1 Geological framework

The Kattegat region is located in the transition zone between the Fennoscandian Shield and the Danish Basin. Tectonically the Fennoscandian Border Zone is a zone which repeatedly has been subject to wrench faulting (i.e. Lykke-Andersen et al., 1993, Gyldenholm et al., 1993). From figure 18a showing the overall structural elements of the Danish area, it appears that the study area is located between two major north-west/south-east striking fault zones: the Anholt – Kullen fault and the Grenå – Helsingborg fault. The studies of the Pre-Quaternary surface topography in the Kattegat shows, that elongated NW-SE trending anticlinorium follows the general dextral wrench fault pattern of the Fennoscandian Border Zone. The map in figure 18b is based on the seismic stratigraphic studies in the area.

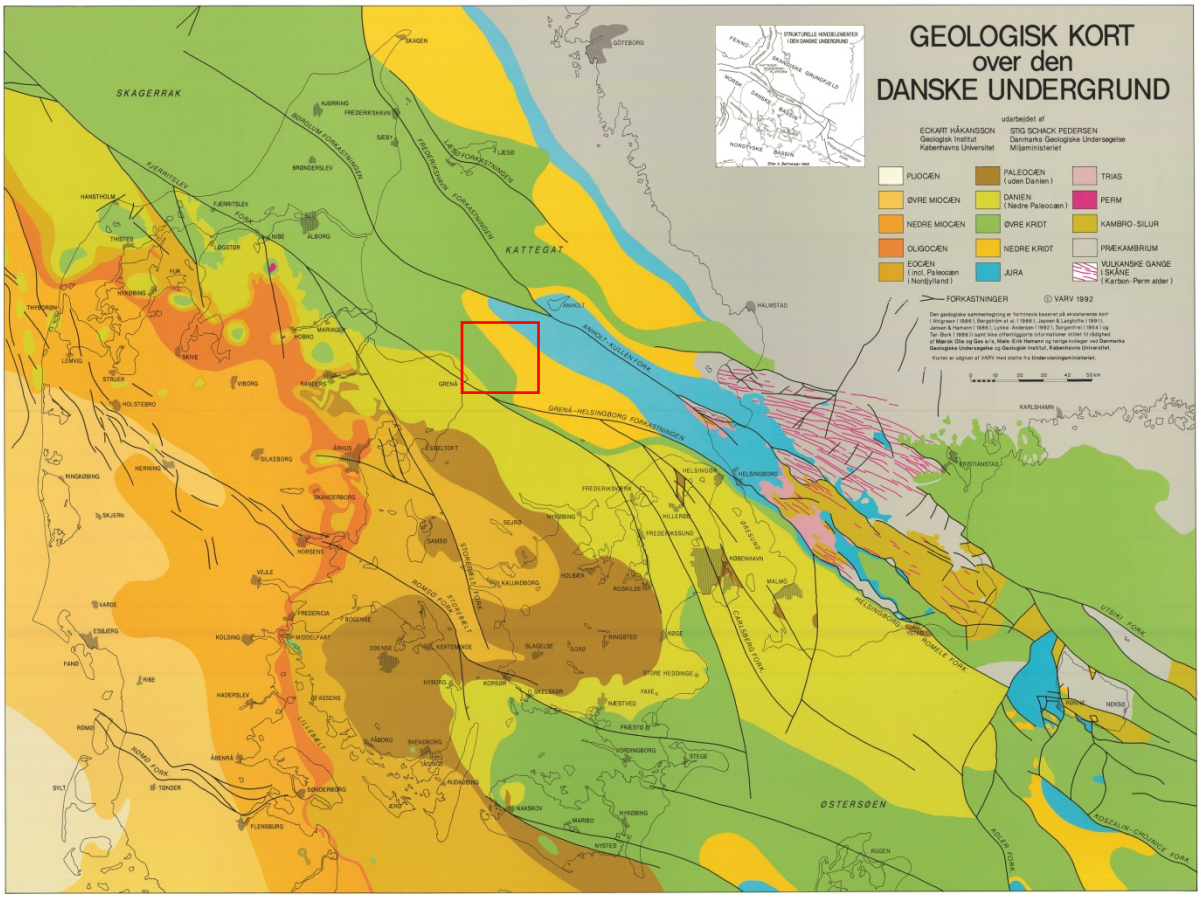
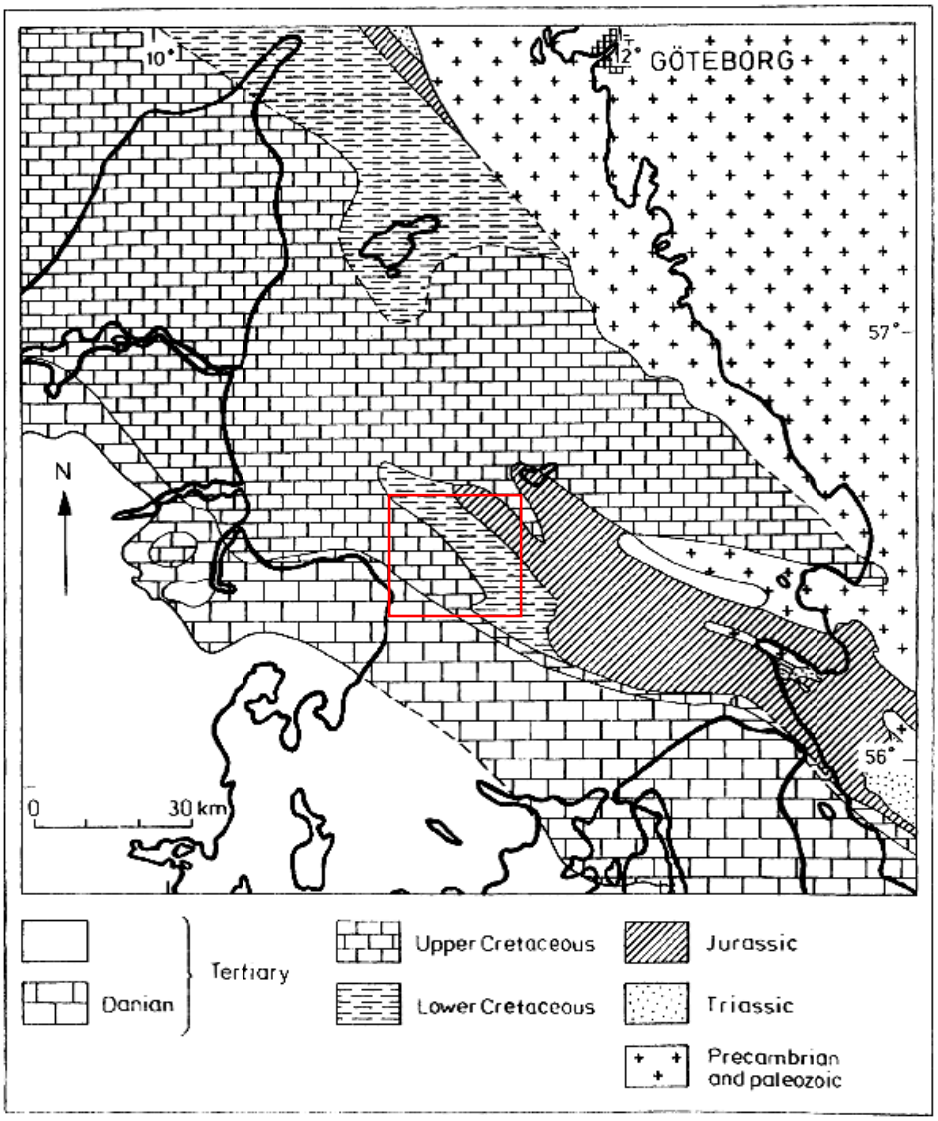


Figure 18a. Map showing the subsurface geology and the main structural elements of the Danish area. Red box indicates the wind farm area. From Håkansson & Pedersen, 1992.

For the importance of the Quaternary development the latest major tectonic event was the inversion episode, starting Early Cretaceous and the subsequent uplift during the Neogene. After this episode the Kattegat became an area of non-deposition and net-erosion until the sedimentation was resumed in the late Middle Pleistocene. At this time the basin floor of Kattegat was charac-

terised by at strong undulating relief, controlled by large and small-scale structures in the Pre-Quaternary basement



Figur 18b. Formations at the base of the Quaternary in the Kattegat. Red box indicates the wind farm area. From Lykke-Andersen et al. 1993.

The Quaternary sediments of the Kattegat basin is restricted to relatively young sediments representing the following main periods: Eemian to Early Middle Weichselian (marine sediments grading upwards into non-marine/fluvial sediments), Late Weichselian/Late glacial (marine and lacustrine deposits and Holocene (marine sediments) (e.g. Knudsen, 1991). Sediments older than Saalian Glacial period have hitherto only been registered in coastal exposures at the southwestern and western margins of the Kattegat.

The Kattegat region is characterised by relatively thick sequences of both marine and non-marine sediments from the Middle Weichselian.

According to Lykke-Andersen et al. (1993) there seems to be no convincing evidences for the assumption of a widely extended Weichselian ice cover in the Kattegat. However, a consensus in previously published papers on the Weichselian in the Kattegat assumes that the area was totally covered by ice in a period around the time corresponding to the Main Stationary Line in Jutland. On the other hand, numerous suggestions on the subsequent ice advances and recessions seem to be available from different authors e.g. Houmark-Nielsen (1995 and 1999) extrapolating the onshore information from northern Sjælland (the Kattegat Till/Norwegian Till) into the offshore areas. The lithology of the latter till unit indicates ice flow from northerly direction. On the basis of shallow seismic investigations Nielsen (1985) suggested that the Norwegian till is present over large areas of the sea floor in the southern part of Kattegat. To conclude, the sparse information on the distribution of glacial deposits in the Kattegat makes it difficult to correlate the newly acquired data to previous published information.

In the Kattegat southeast of Anholt the late glacial composite seismic unit has been recognized by Jensen et al. (2002) with a lower sub-unit with a thickness of 60m characterized with a semi-transparent internal reflection pattern and parallel reflectors conformably draping the underlying unit of glacial deposits. The overlying sub-unit fills in depressions with a thickness of up to 50m. The boundary between these sub-units is sharp and erosional down to about 40m below sea level and conformity below this level. The basal part of this late glacial succession is dominated by interlayered clay and fine sand, indicating a deposition shortly after the de-glaciation (ice proximal sediments).

Gyldenholm et al. (1993) describe a similar, nearly *transparent seismic unit*, occasionally with many continuous, sub-horizontal internal reflections often with laterally varying amplitude. The reflections often drape or onlap older buried units. The unit is widespread in the south-eastern Kattegat. It is overlain by Holocene deposits. The unit is identical with a sequence of clay on the SGU map Stora Middelgrund-Halmstad. These water-lain sediments are derived from glaciers and deposited in either marine or limnic environment. Based on a series of evidences Gyldenholm et al. conclude that the *transparent sequence* represents Late Weichselian water-lain sediments deposited during and immediately after the recession of the ice in south-eastern Kattegat. Similar observations are made by Nielsen & Konradi (1990) and Bergsten & Nordberg (1992) in the southern part of Kattegat.

Marine Holocene sedimentation in the Kattegat region seems to have been characterized by changing periods of deposition and non-deposition. Holocene sandy deposits are typically the result of reworking of glacio-genetic sediments. E.g. Novak & Petersen (2000) have recognized a Holocene spit platform depositional system at Lysegrund south of the present study area with at least 8m of Holocene sandy deposits.

9. Survey results: Bathymetry and surface geology

9.1 Bathymetry

A multibeam echo sounder survey of the seafloor was preformed. The resulting bathymetry after processing is presented in Chart E4 and figure 19. All depths refer to the DVR90 reference level.

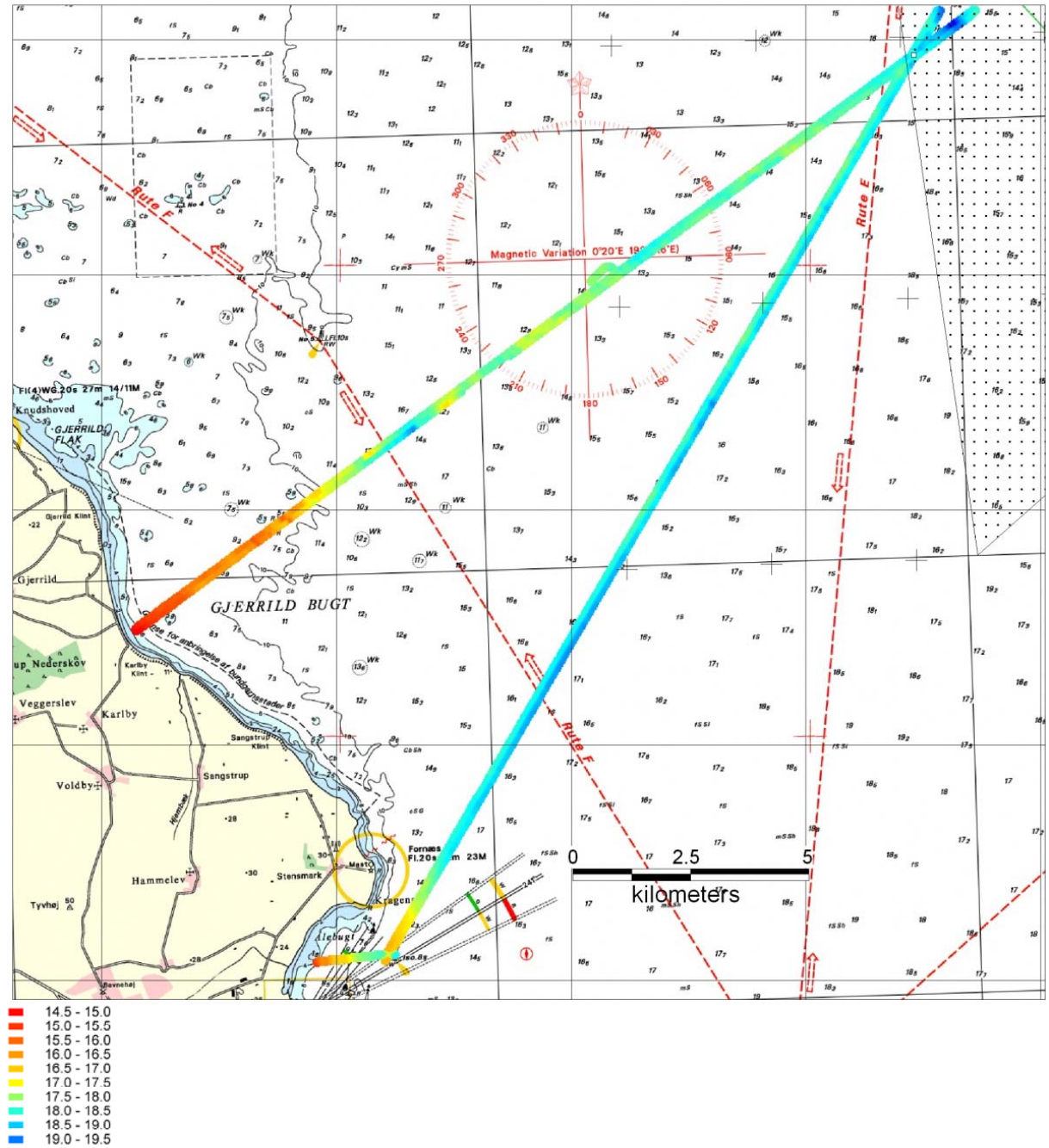


Figure 19. Bathymetry map of the corridors. Depth scale in metres. Reference level DVR90.

The depth variation is self explaining from the map. However, a few striking differences between the two corridors will be highlighted. The southern corridor depths are very level except close to

the coastline where a relatively steep shore face appears from 5m to 12m depth in the Ålebugt area. This steepness coincides with the presence of limestone outcropping at the seabed (see also the seabed descriptions below). Contrarily, shore face in the northern corridor is very gentle from the shore to about 12m depth. Outside this zone the water depths in the northern corridor varies between 12 and 16m, generally shallower than the southern corridor.

Geo-referenced shaded relief images and colour plots of the bathymetric data area are attached in appendix 13 and 14.

9.2 Seabed sediments classification

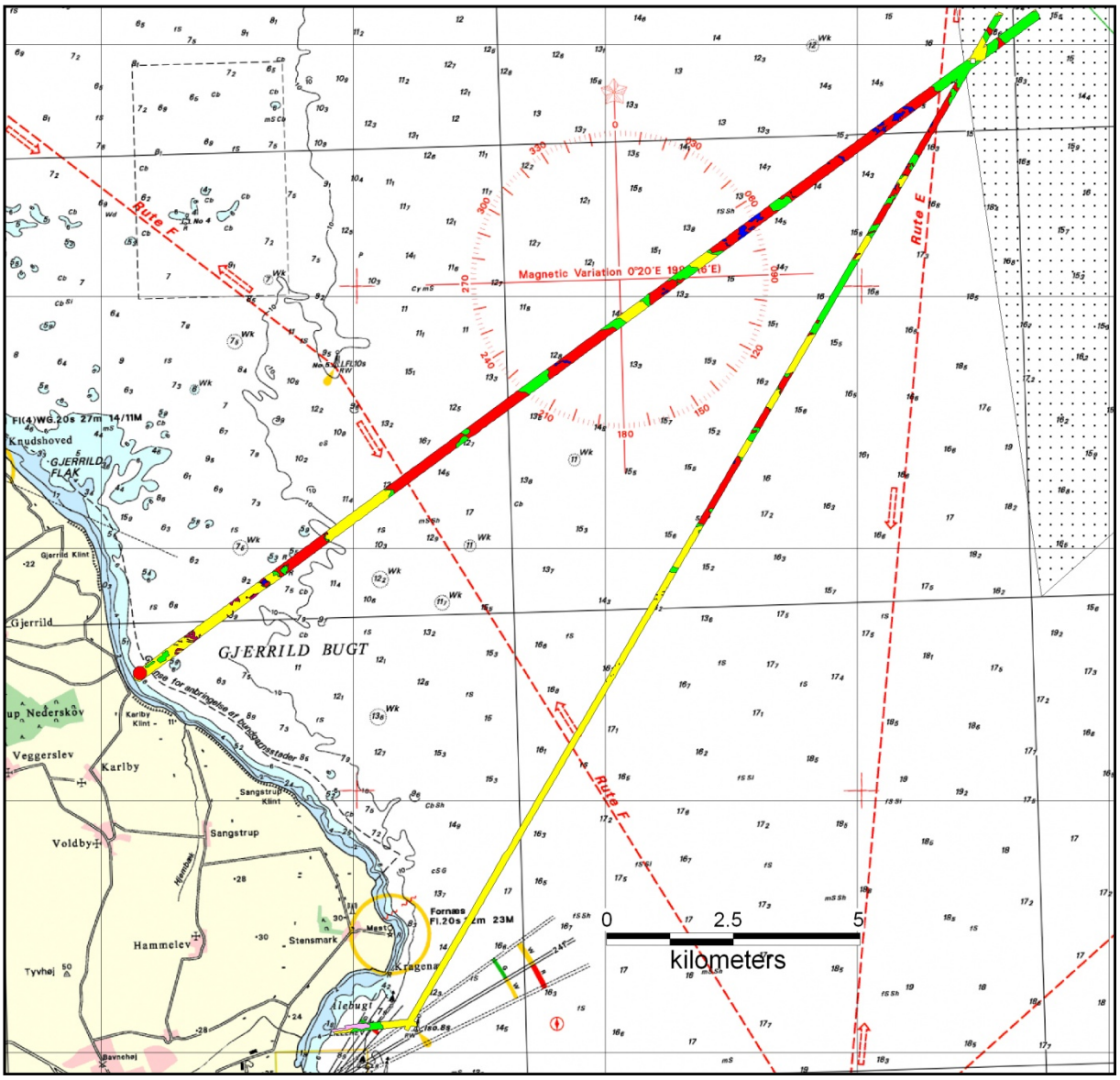


Figure 20. Seabed sediment distribution map of the two corridors. For legend see Chart E2.

Side scan sonar data acquired in April - May 2009 make up the base for the mosaic. The line spacing was 25 meters. In the northern corridor a side scan range of 75m was used, in the southern a 50m range. The 100 kHz channel provided the data used for producing the side scan mosaic. Side scan sonar data were processed using Delph-ISIS mosaicing software producing geo-referenced geo-tiff images. The geo-tiff files were subsequently imported to the MapInfo GIS software and compiled into the final mosaic shown in Chart E1.

Sediment classes were evaluated from the results of classifying side scan sonar mosaic. These classes were combined with the result of the diver's visual verification. The focus of the verification was on the distribution of cobbles and boulder size clasts (> 0.10m diameter) of the seafloor sediment. The results of the diver's survey are reported in the Rambøll (2009) report.

The seabed sediments of the corridors are subdivided into six sediment classes:

- GRAVEL with sand. Cobbles and boulder coverage 25 to 100%: The sediment is classified as boulder reefs – occasionally clast supported. They are associated with high percentage of gravel and pebbles and appear in an elongated but confined area in the central part of the survey area.
- SAND with gravel and pebbles. Cobbles and boulder coverage from 1 to 25%. The sediment is characterized as areas of scattered patches of cobble to boulder size clasts resting on mainly sand to pebble size sediment. The seafloor type is mainly located in the central and southern survey area. It appears in elongated patches.
- SAND with silt, gravel, and pebbles. Solitary clasts of cobbles and boulder coverage < 1%. The sediment is classified as sand with patches of gravel to pebbles and with scattered solitary cobble to boulder clasts. This sediment class is mainly located surrounding the boulder areas in wider continuous areas throughout the most of the survey area.
- SAND with silt, gravel, and pebbles: The sediment is classified as areas with silty to gravelly, occasionally pebbly sand. These areas are characteristic by showing very few or any cobbles to boulder size clasts. The sediment class infill between all the other classes and can be found in wider continuous areas all over the survey area.
- BEDROCK. Limestone outcrops with no or a thin cover of loose sediments.
- UNASSIGNED seabed structures. Probably bedrock/limestone covered by a thin layer of fine sediments.

9.2.1 Seabed sediments distribution

Distribution of sediments on the seabed (figure 20 and Chart E2) in the two corridors has a common pattern. Inshore sorted sand dominates and further offshore sand pebbles and boulder size material is common. In general, coarse sediment covers significant larger parts of the northern corridor than the southern corridor.

Inshore a few exceptions from the sand cover are seen close to the coast in the southern corridor. The seabed here shows outcrops of bedrock/limestone. This observation is confirmed in the vibrocore Syd_VIB01 containing solid limestone. Further offshore in the sand cover unassigned spots appear in two clusters. In the northern corridor the same unassigned spots observed in the inshore sand cover. The spots are not sampled, but it is believed that they could be associated with gas seepages or bedrock covered by a thin veneer of fine sediments. Also in the north corridor approximately 3.5km offshore two spots with a high percentage boulder is believed to be associated with bedrock outcrops.

In the offshore end of both corridors the seafloor consists of coarse sediments. A high percentage of cobble and boulders cover is common and sand is only observed in patches. Two pronounced boulder reefs are found in this area of the northern corridor. This is consistent with diver's observations.

10. Survey results: Sub-surface geology

10.1 Pre-Quaternary deposits

In the shallow part of the southern corridor the bedrock outcrops at the seabed. The surface is evident from the sparker and the chirp data (see appendix 3). The seismic response of the top of the bedrock has a high intensity reflection.

The vibrocore Syd_VIB01 contains solid limestone. The outcrops at the seabed are closely linked to the well-known limestone outcrops in the cliffs onshore (Karlby Klint).

10.2 Quaternary deposits

10.2.1 Holocene deposits

The chart E3 and figure 21 present the thickness of the Holocene deposits (isopach) inside the two corridors. In general, the thickness of Holocene cover in both corridors is thin and often less than 1.5m – thinnest in the north corridor. However, the first 5km inshore in both the northern and southern corridor shows that thickness of more than 3m with a maximum in the range of 5-7m. The thickness here is due to accumulation of loose sand. In the southern corridor “channel like” down cuttings is found all along the route shown by an increased Holocene thickness. These areas are less than 500m wide along line. On the rims of these areas the thickness often is between 1 and 3m. In contrast to the high thickness in the near shore zone the increasing Holocene along the southern corridor reflects lows/basins/channels in the Holocene sub-surface. These lows most likely contain sediments deposited in freshwater environments i.e. deposits of plant material can be expected here.

In the offshore and eastern end where the transformer station is planned the Holocene thickness is in the range of 2-3m.

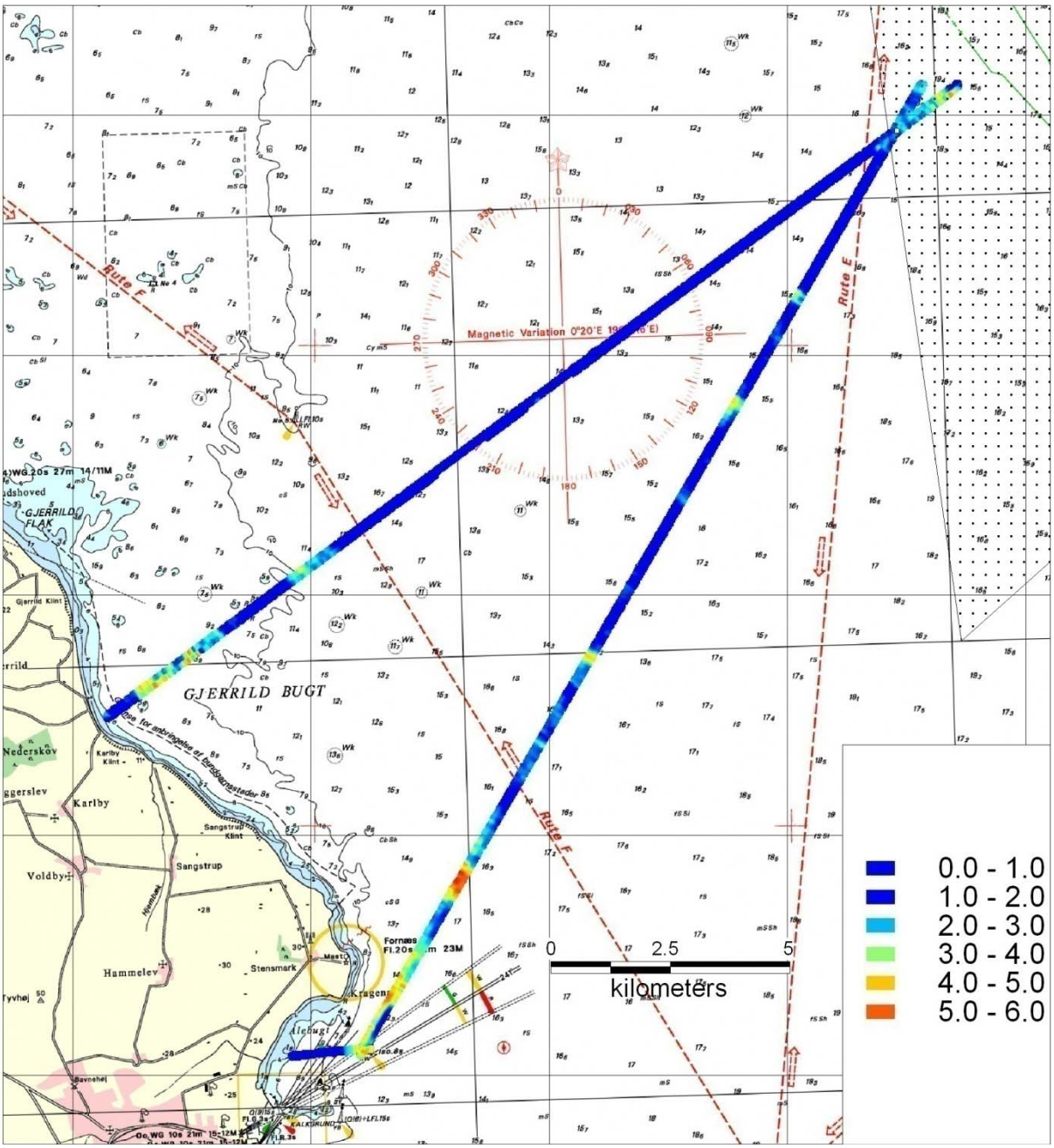


Figure 21. Thickness of the Holocene deposits. Scale in metres.

10.2.2 Raw material aspects

The main purpose of mapping the Holocene sand deposits was to designate any potential raw materials within the wind farm area. Although the Holocene consist of a thin veneer of fine - coarse sand in the coastal zone it is concluded to be beyond any interest from an extraction point of view. Where the thickness of the Holocene increases offshore is it not because of thickening of the sandy deposits, rather a thickening due to the presence of lows with infill of layered sand with clay, silt and organic material as described earlier.

10.3 Glacial deposits

The glacial surface in the corridors has been mapped mainly based on the interpretation of the chirp data (Chart E5 and figure 22). The glacial surface is in the most cases equivalent to the top of the glacial till, but other glacial sediments as meltwater deposits and unconsolidated diamicton can be expected.

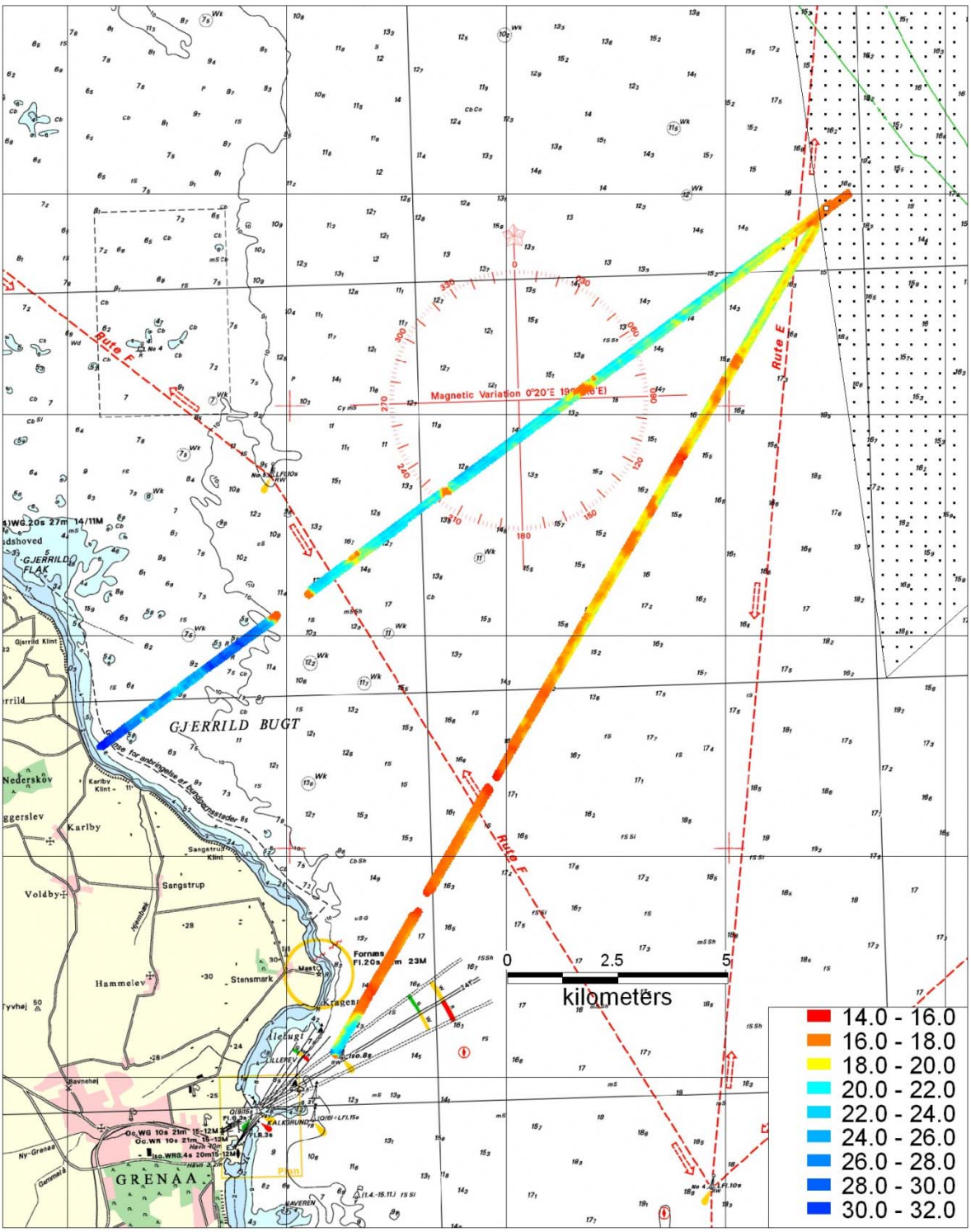


Figure 22. Map showing the depths of the glacial surface. (Reference level DVR90). Scale in meters.

The interpreted glacial surface is presented in cross sections along the seismic lines (appendix 3).

10.4 Magnetic anomalies

The magnetic data was processed and cleaned first from noise and spikes and the resulting magnetic data was tested for anomalies. The MagMap2000 and the *GeoSoft Oasis Montaj* software were used for processing and interpretation.

The magnetic anomalies were then picked up from each survey line with respect to the surrounding or “background” magnetic value. These anomalies were refined and the result is presented in figure 23.

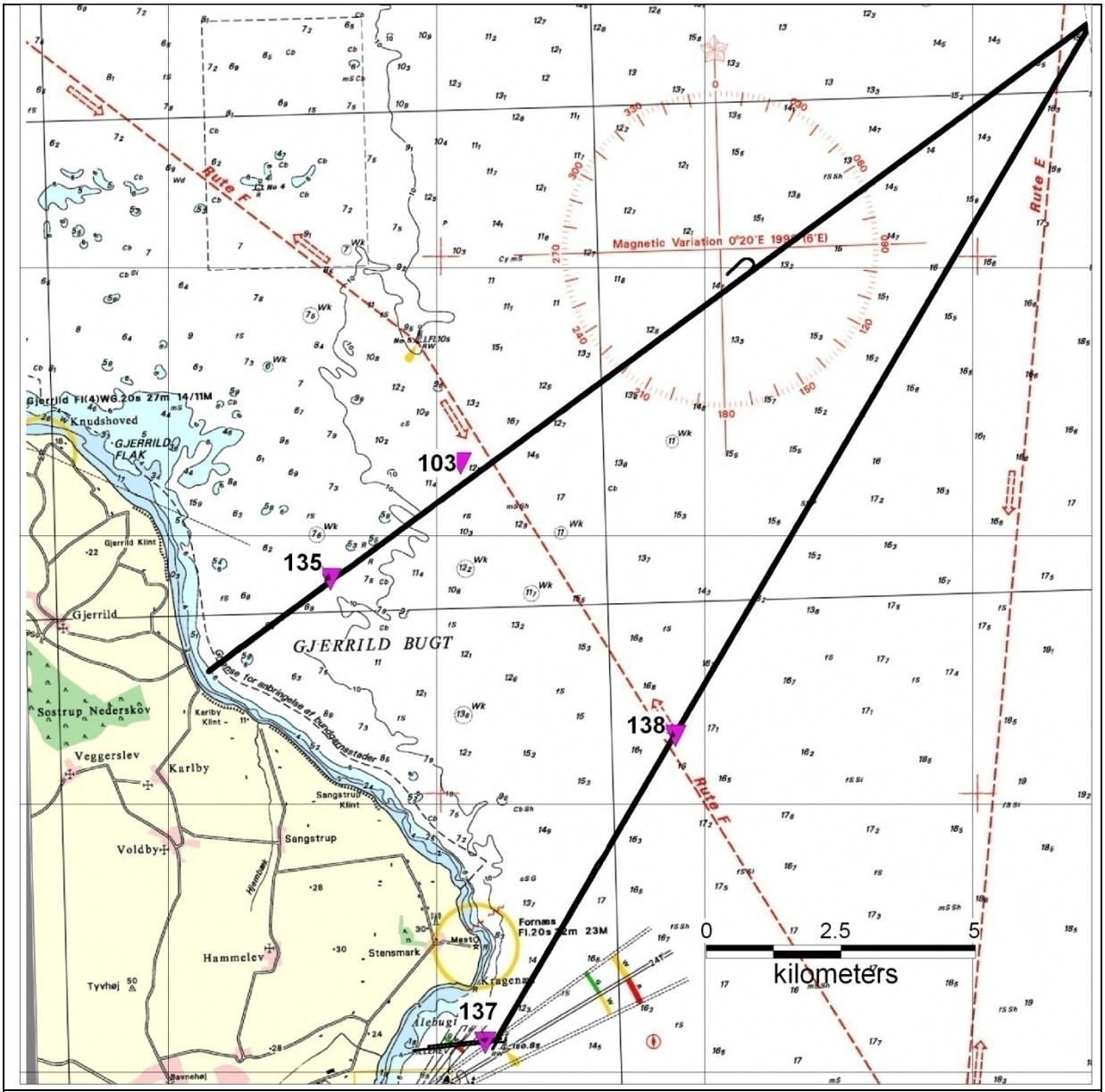


Figure 23. Local magnetic anomalies (purple triangle) distribution in the two corridors. The numbers refer to the list, graphs and the side scan image in appendix 6.

The magnetic anomalies were then picked up from each survey line. The criterion for picking an anomaly is related to the general magnetic background values in the vicinity of the anomaly. The anomaly itself can be positive, negative or bipolar (figure 24). The size of an anomaly is dependant of how the object has been approached as well as the shape of the anomaly is dependent on the type of object.

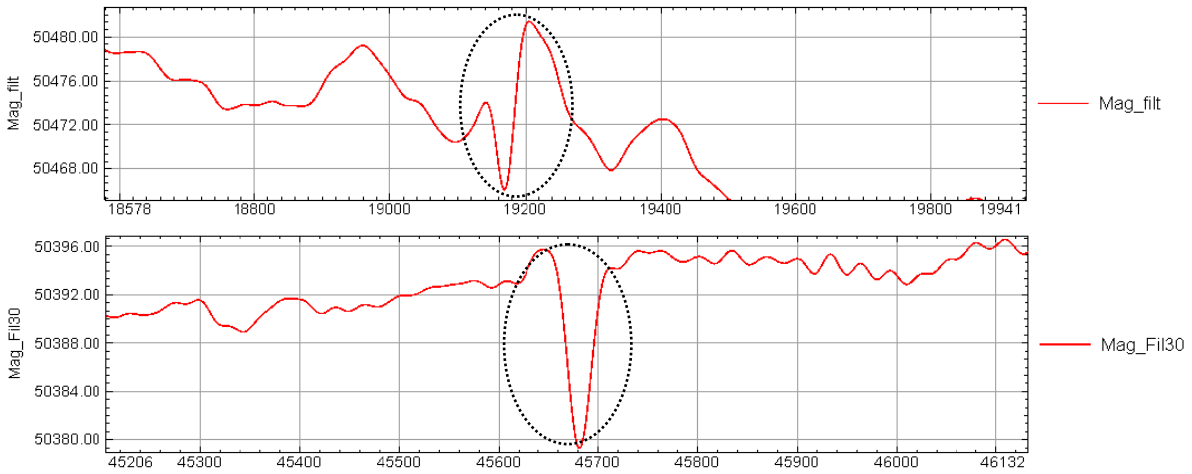


Figure 24. Examples of magnetic anomalies: The upper showing a bipolar type and the lower showing a negative type of anomaly.

According to the specifications of the detection range specified in the G-882 magnetometer instrument specifications the detection range for objects are as follows:

- Pipelines (6 inch) 1 to 2 nT at 30m distance
- 100 kg of iron 1 to 2 nT at 15m distance
- 500 lb bomb 0.5 to 5 nT at 16m distance
- 10 lbs of iron 0.5 to 1 nT at 6m distance

It can be concluded that any of the specified objects i.e. mines and munitions, pipelines, anchors, shipwreck debris with a magnetic expression has been detected in this magnetic survey. Each anomaly was plotted on a separate graph. The corresponding side scan images of the seabed at the anomaly position were produced for each magnetic anomaly.

Four anomalies have been registered: 103, 135, 137 and 138. These are all described in detail in the spreadsheet in appendix 6. The anomaly no. 103, however, is outside the corridor and can be neglected.

10.5 Unidentified objects from the side scan sonar

The 400 kHz side scan sonar data has been checked for the presence of any unidentified objects. Only one object was found. The side scan picture and position is shown in the figure 25 below. From the divers inspection it is known that the object is a broken fishery wire.

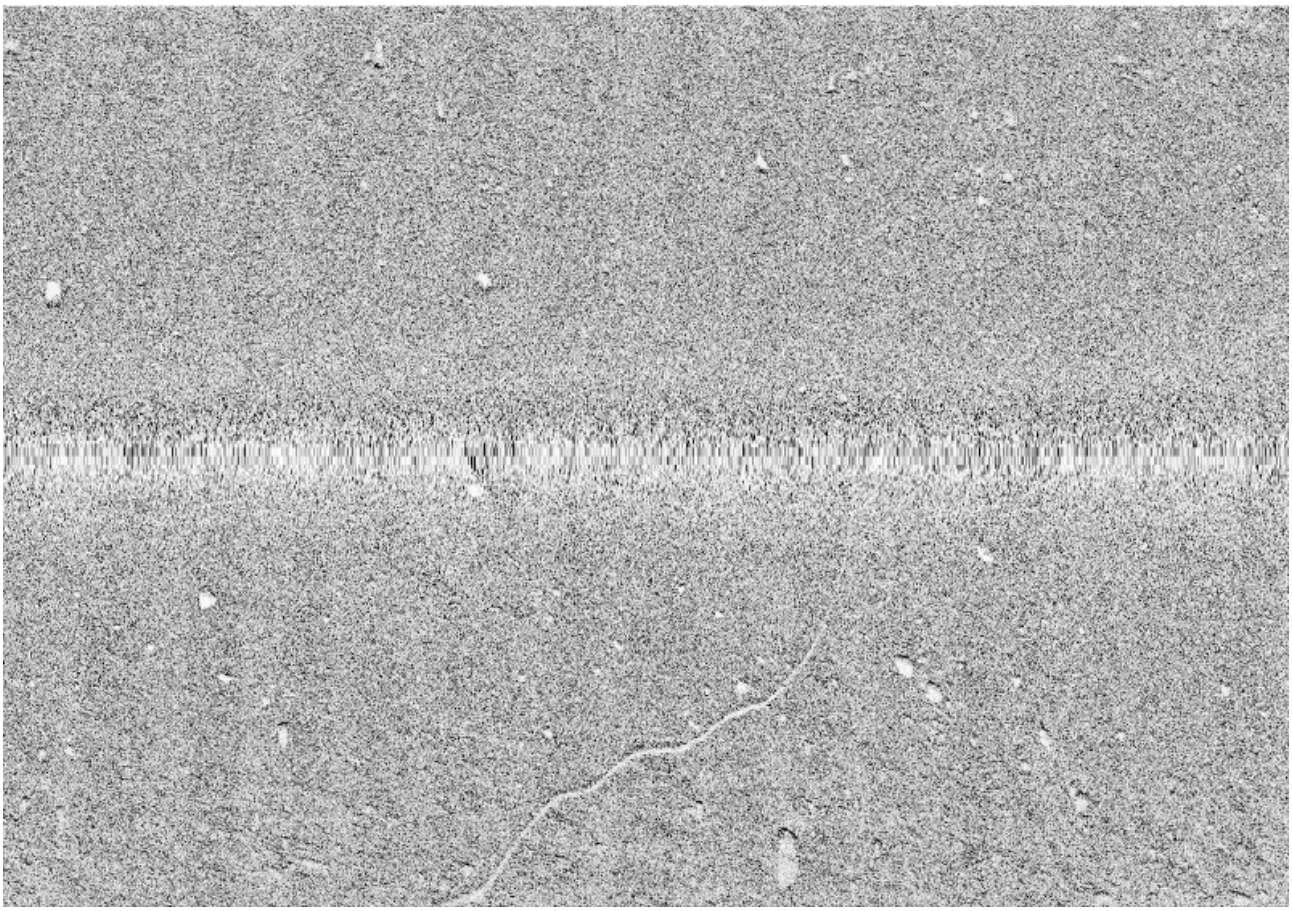


Figure 25. Line debris from the southern corridor at the position: 630529E, 6271612N (UTM32-EUREF89).

11. Geological profiles of the cable corridors

To illustrate the geological interpretations along the corridor lines profiles along the seismic lines including the interpreted horizons have been produced based on chirp data (appendix 3). The location of the vibrocores can be seen from the profiles.

Each corridor consists of two line segments:

The north corridor: AW-COR-06A and AW-COR-06B

The south corridor: AW-COR-03A and AW-COR-03B

12. Conclusion

The geophysical survey of two alternative cable corridors has been performed in April - May 2009. The resulting thematic maps are presented and described in this report. Similar results for the wind farm area have been reported separately (GEUS Report 2009/45).

The seabed sediment map shows the generally coarser seabed types along the northern corridor with a high frequency of sand with pebbles and boulders specifically in the eastern part. From the southern corridor the presence of outcropping bedrock/limestone in the coastal area should be highlighted.

From the bathymetric mapping based on multibeam data set it appears that the seabed in the latter corridors in general is level apart from the coastal zone where a relatively steep southern and a more gentle northern shore face is seen.

The distribution of the Holocene deposits indicates a thin cover layer of a few metres thickness. However, along the corridors a thickening of the Holocene appears due to the presence of underlying basins with fine grained deposit with a possible content of organic material. The same feature is illustrated from the map of the depth to the glacial surface. Here the lows in the glacial surface correspond to the areas with Holocene fine grained/organic infill.

The analysis related to the marine archaeological – the magnetometer and the side scan mapping – has shown the presence of 3 magnetic anomalies.

13. References

Bergsten, H. & Nordberg, K., 1992: Late Weichselian marine stratigraphy of the southern Kattegat, Scandinavia: evidence for drainage of the Baltic Ice Lake between 12,700 and 10,300 years BP. Boreas, Vol. 21, pp. 223-252.

GEO: Anholt/Djursland Offshore Wind Farm. Geotechnical Investigations. Wind Farm Area. Project no. 32490, Report 1, 2009-07-15.

Gyldenholm, K.G., Lykke-Andersen, H. & Lind, G., 1993: Seismic stratigraphy of tehe Quaternary and its substratum in southeastern Kattegat, Scandinavia. Boreas, Vol. 22, pp. 319-327.

Houmark-Nielsen, M., 1987: Pleistocene stratigraphy and glacial history of the central part of Denmark. Bull. of the Geol. Soc. of Denmark, Vol. 36, pp. 1-189.

Houmark-Nielsen, M., 1999: A lithostratigraphy of Weichselian glacial and interstadial deposits in Denmark. Bull. of the Geol. Soc. of Denmark, Vol. 46, pp. 101-114.

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.

Knudsen, K.L., 1991: Marine Eemian and Early Weichselian deposits in northern Denmark – a review of the foraminiferal stratigraphy. Quaternary International 10-12, pp. 167-171.

Nielsen, P.E. & Konradi, P., 1990: Seismic stratigraphy and foraminifera in Late Quaternary deposits, Southern Kattegat. Striae Vol. 29, pp. 105-110.

Nielsen, P.E., 1985: Hvad skjuler Kattegat? VARV 1, 3-7.

Novak, B. & Pedersen, G.K., 2000: Sedimentology, seismic facies and stratigraphy of Holocene – spit platform complex interpreted from high-resolution shallow seismic, Lysegrund, Southern Kattegat, Denmark. Marine Geology 162, pp. 317-335.

Lykke-Andersen, H., Knudsen, K.L. & Christiansen, C. 1993: The Quaternary of the Kattegat area. A review. Boreas, Vol. 22, pp. 269-281.

Rambøll: Anholt Offshore Wind Farm. Mapping of Substrates and Benthic Community Types. Background Memo June 2009.

Rasmussen, Bjarke: Blandingsmekanismer i kystnære farvande. Havforskning fra Miljøstyrelsen. Report no. 32, 1994.

Vangkilde- Pedersen, T., Lykke-Andersen, H. & Lind, G., 1993: Dislocated Quaternary deposits in southeastern Kattegat – a glacial gravitational phenomenon? Boreas, Vol. 22, pp. 329-336.

Håkansson, E. & Pedersen, S.S., 1992: Geologisk kort over den danske undergrund. Published by VARV, 1992.

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Appendix 2 Patch test
Appendix 3 Geological profiles of the cable corridors
Appendix 4 Reference point control
Appendix 5 Unidentified objects from the side scan sonar
Appendix 6 Magnetic anomaly graphs and the matching side scan images
Appendix 7 Technical specifications of the equipment
Appendix 8 Geodetic definitions
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Appendix 10 Documentation of survey line spacing
Appendix 11 Cross over tests
Appendix 11 Cross over tests
Appendix 12 Binning statistics
Appendix 13 Geo-referenced shaded relief images
Appendix 14 Colour plots of the bathymetric data

Charts overview

E1 Side scan sonar mosaic
E2 Seabed sediments
E3 Holocene Isopach map
E4 Bathymetry
E5 Top Glacial contour map

Appendices and Charts

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Charts overview

E1 Side scan sonar mosaic
E2 Seabed sediments
E3 Holocene Isopach map
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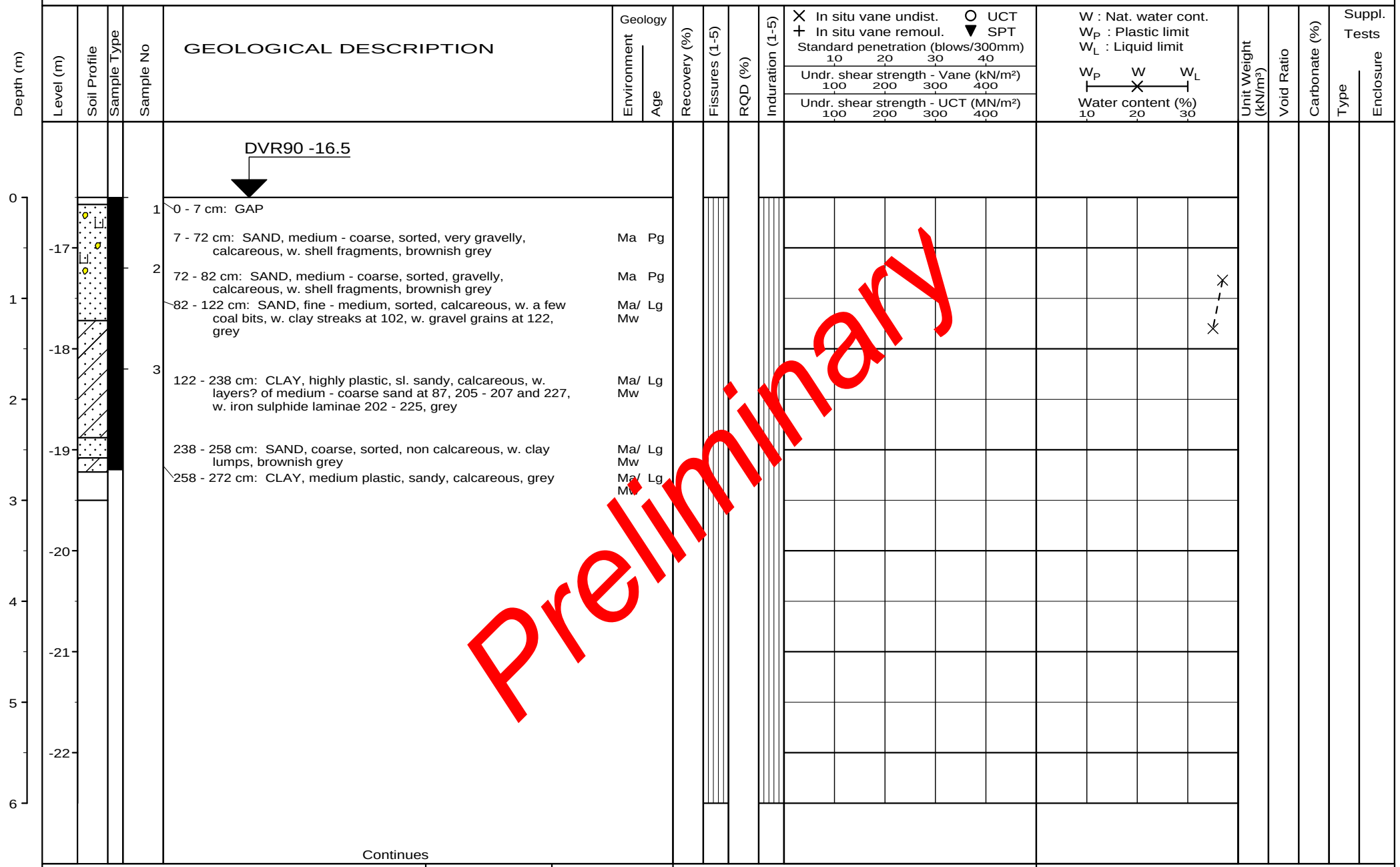
E5 Top Glacial contour map

Appendix 1
Geological descriptions of vibrocores

BORING NO. NORD_VIB01 Anholt. Djursland Wind Farm



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Comments :	Checked :	Date :	Borehole No.: NORD_VIB01 Date : 2009-05-30
	Approved :	Date :	Report No.: 2 Encl.No.: 2D.01

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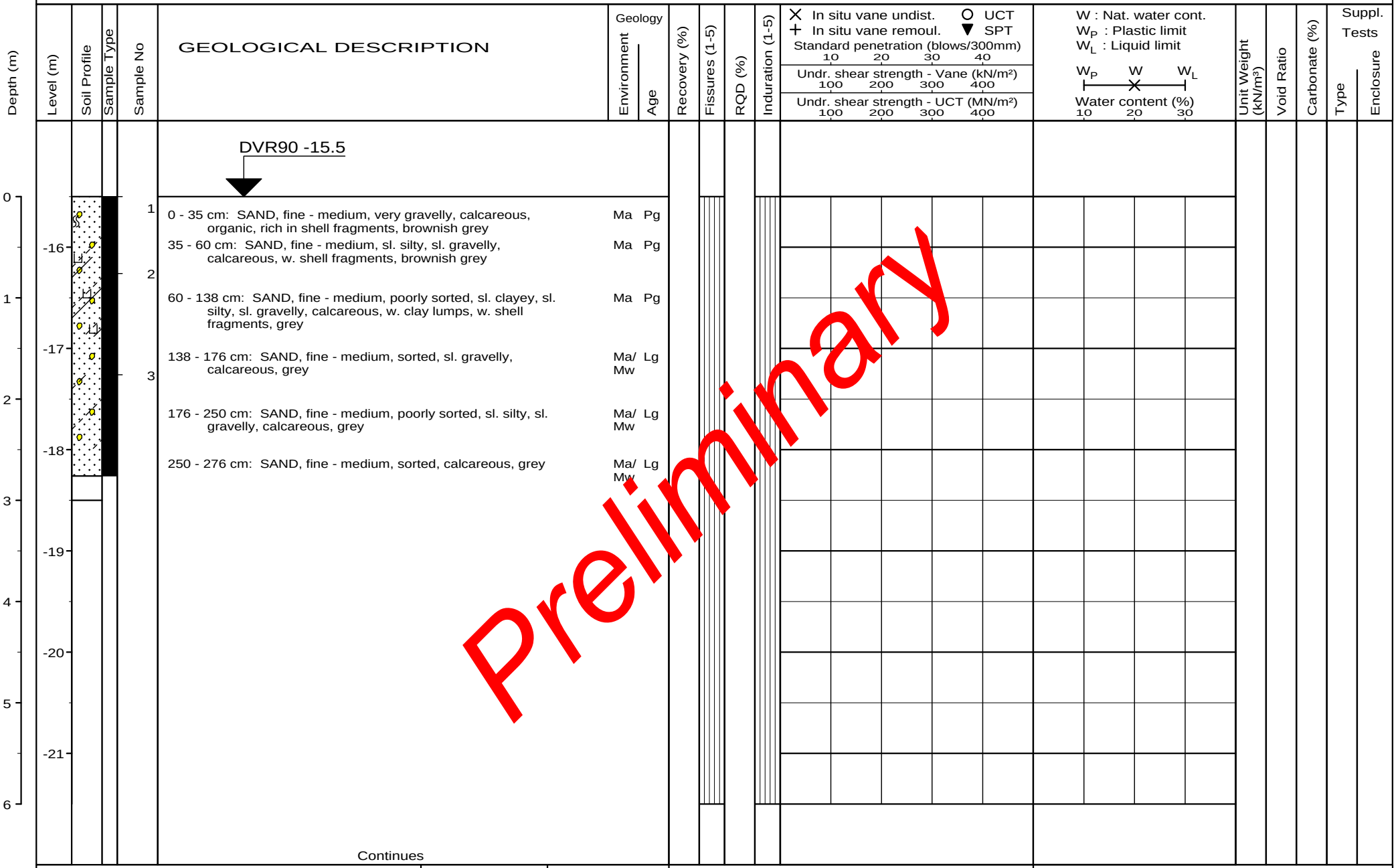
BORING NO. NORD_VIB02 Anholt. Djursland Wind Farm



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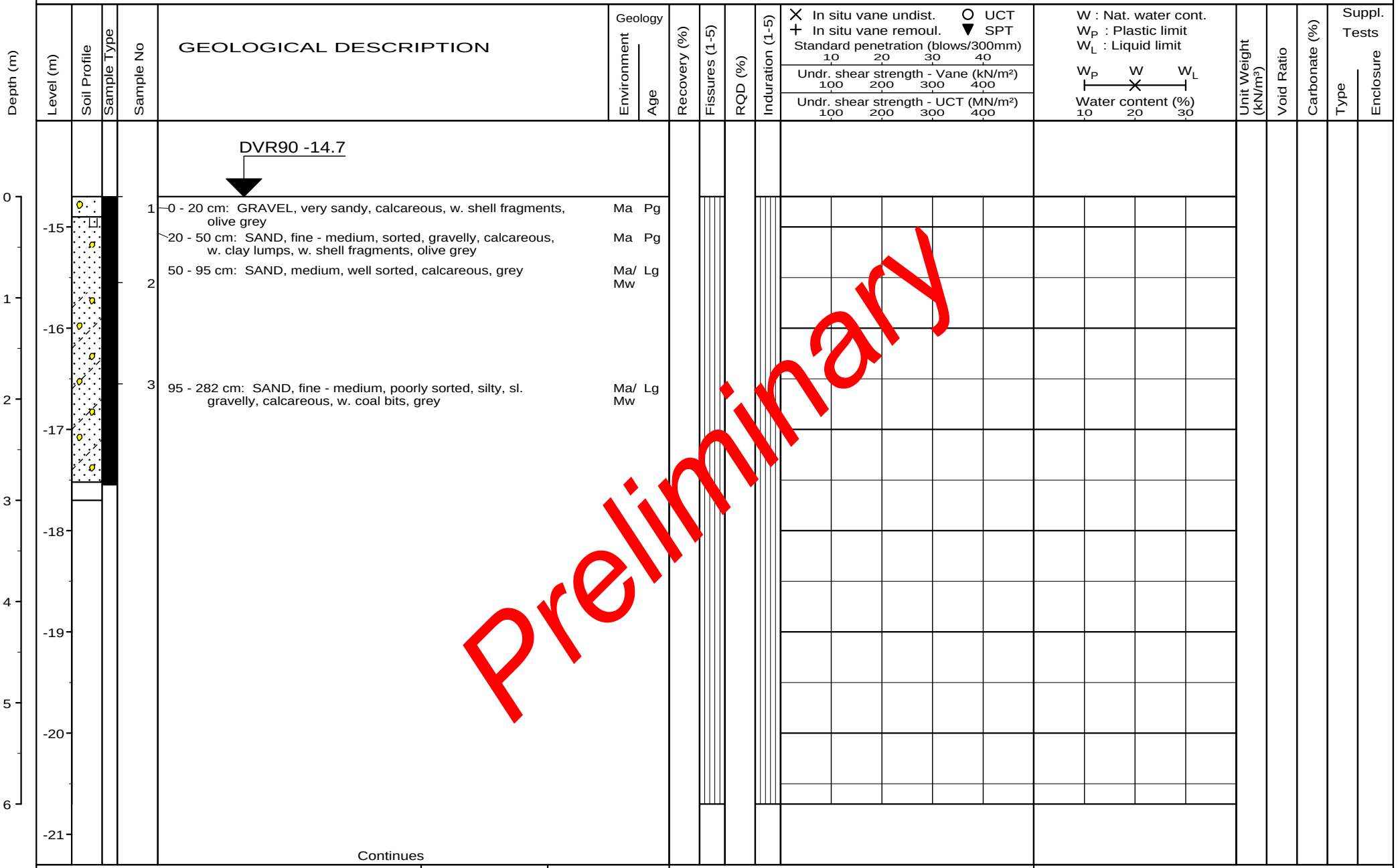
BORING NO. NORD_VIB03 Anholt. Djursland Wind Farm



Preliminary

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Comments :	Checked :	Date :	Borehole No.: NORD_VIB03 Date : 2009-05-30
	Approved :	Date :	Report No.: 2 Encl.No.: 2D.03

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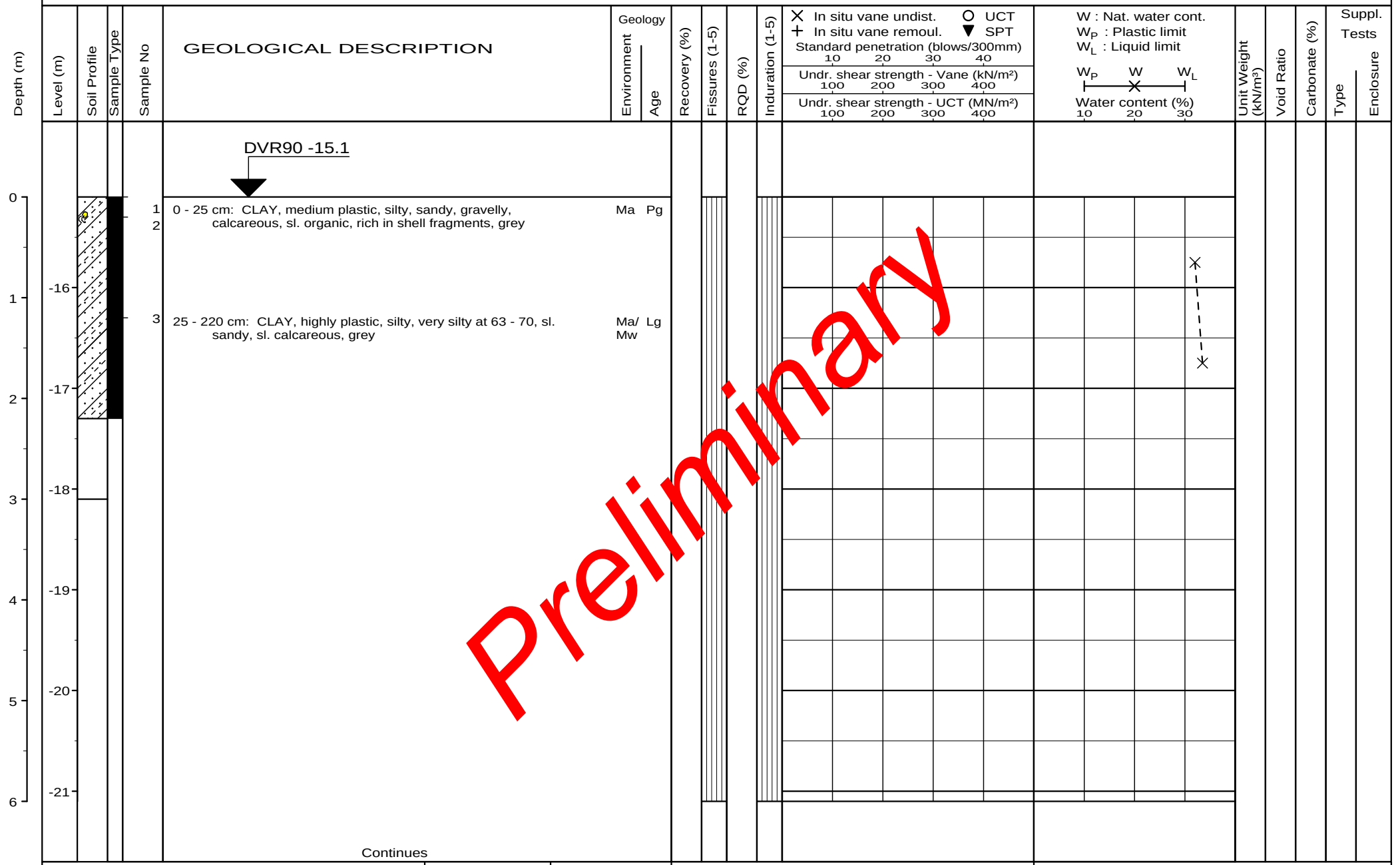

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Comments :	Checked :	Date :	Borehole No.: NORD_VIB04 Date : 2009-05-30
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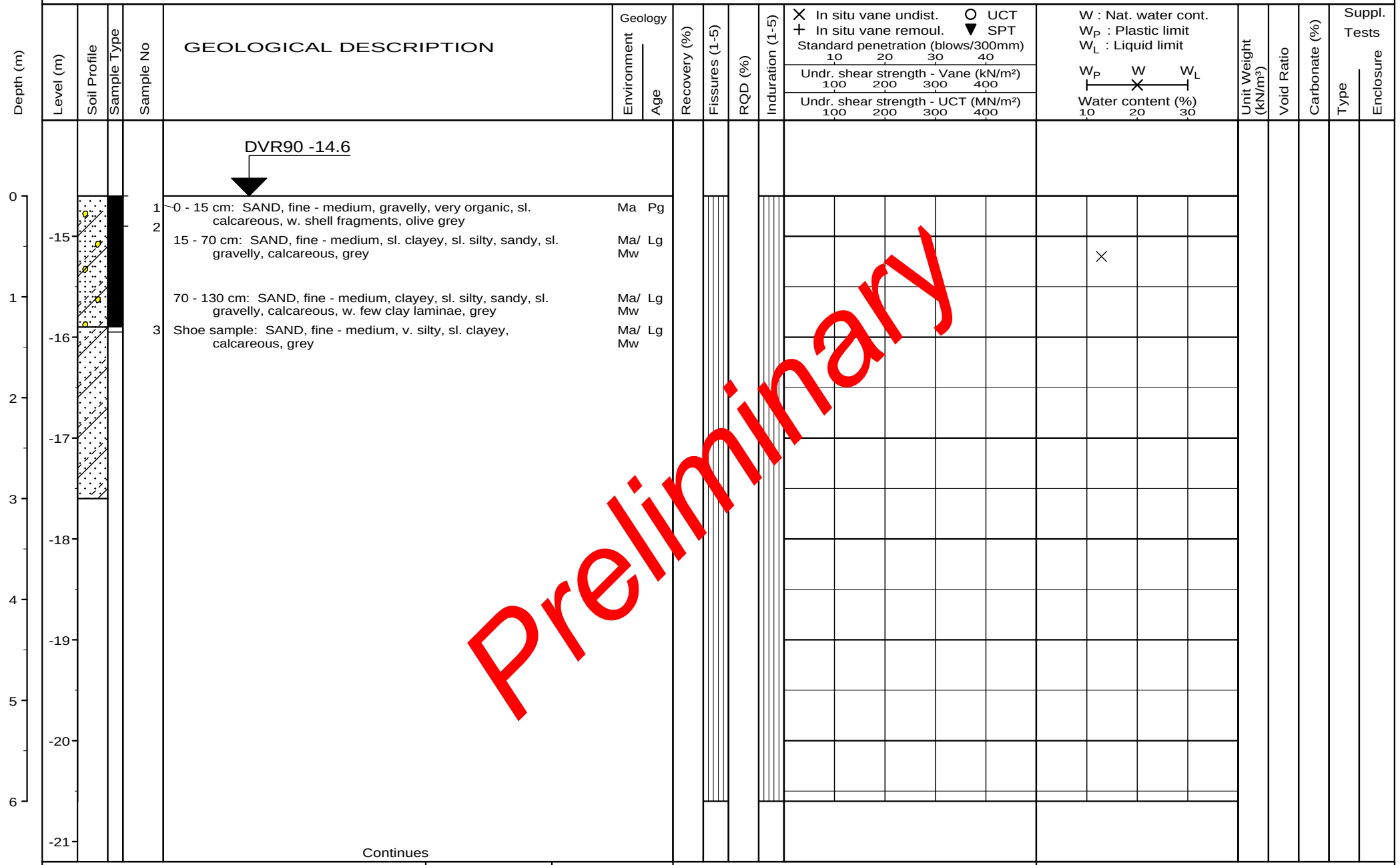

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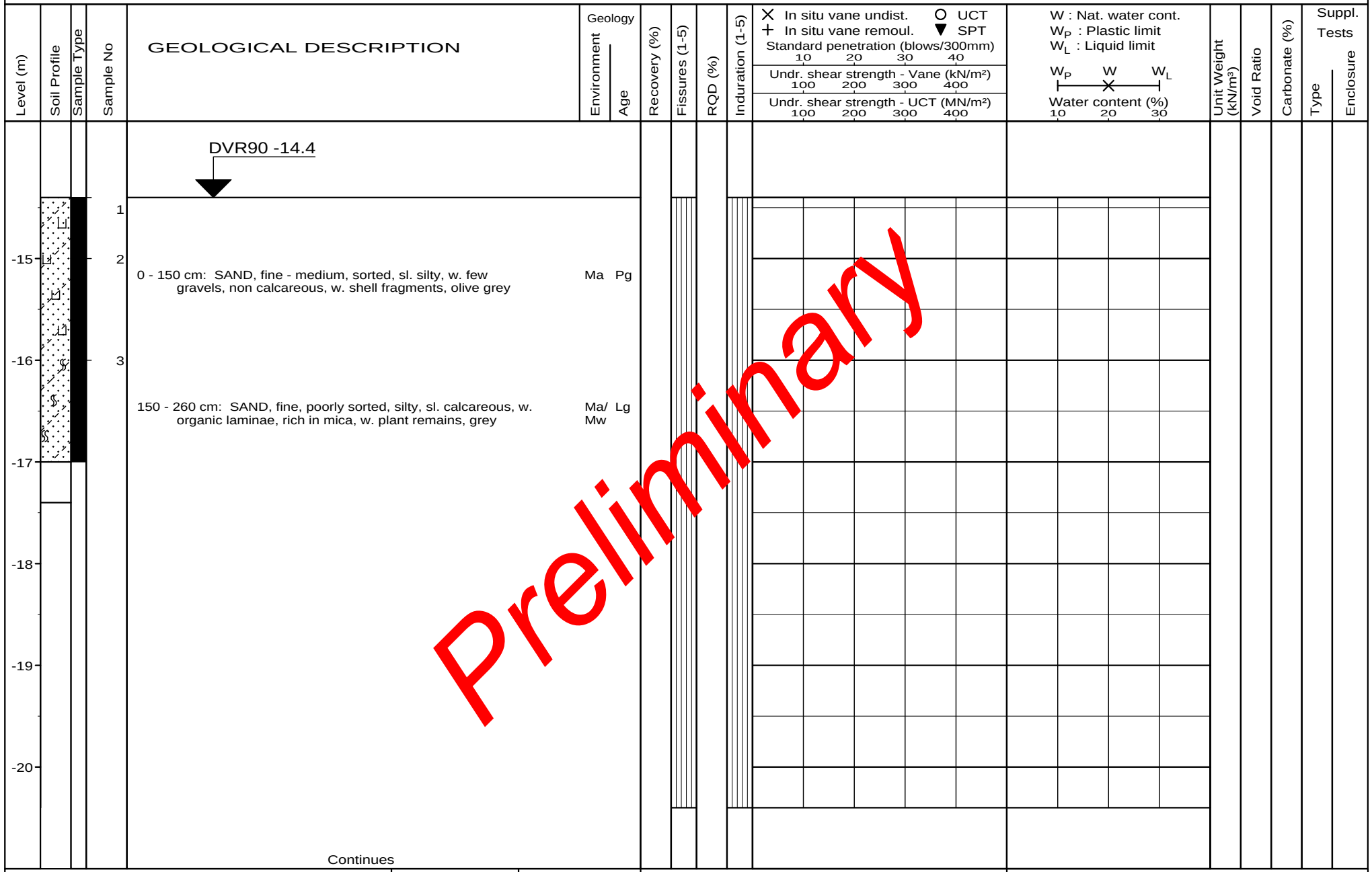

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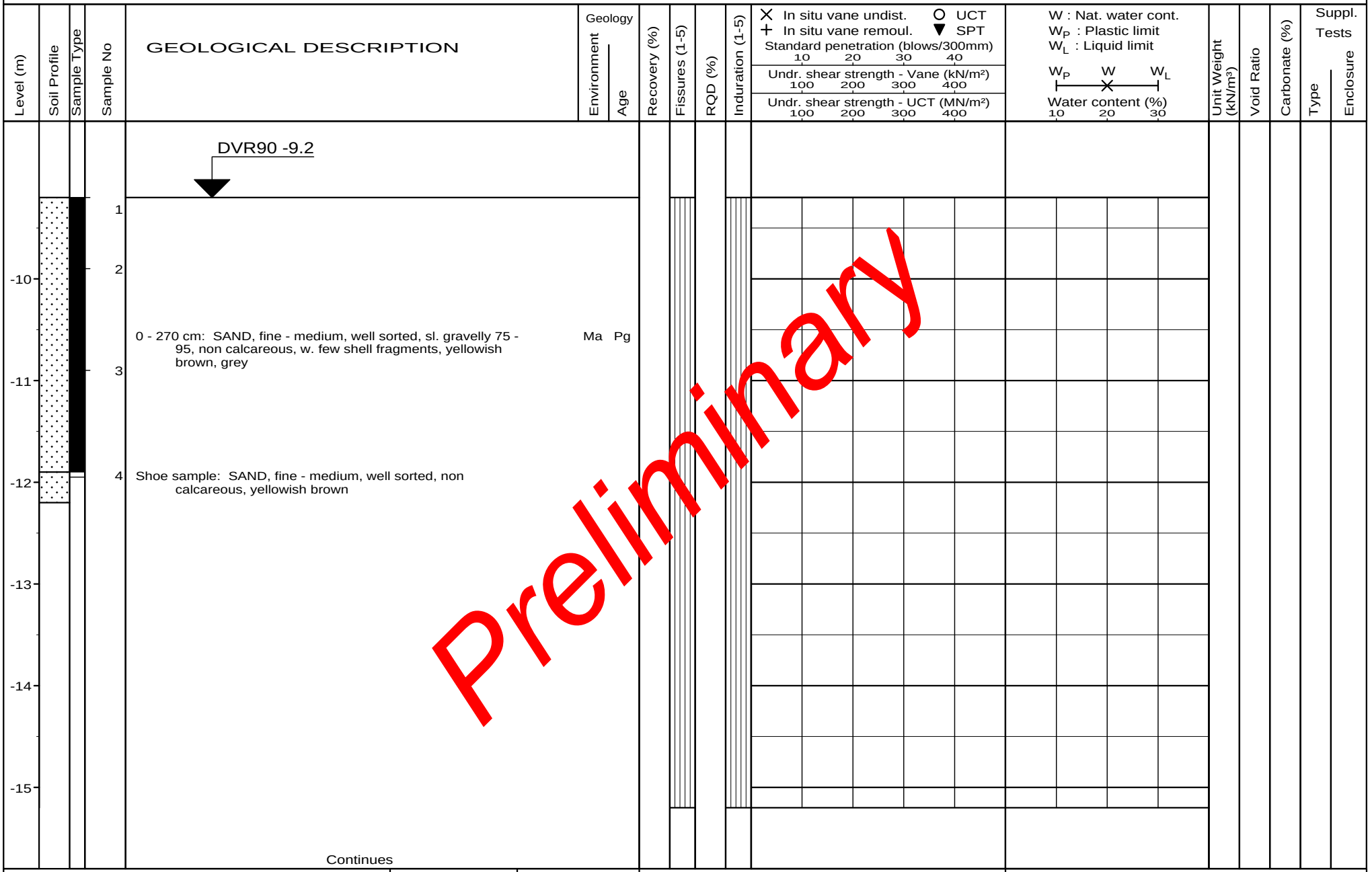

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BORING NO. NORD_VIB08 Anholt. Djursland Wind Farm

DVR90 -10.0

Depth (m)	Level (m)	Sample No	GEOLOGICAL DESCRIPTION	Geology: Environment	Geology: Age
0	-10	1	0 - 75 cm: SAND, fine - medium, well sorted, sl. organic 0 - 15, non calcareous, w. shell fragments, grey	Ma	Pg
1	-11	2	75 - 85 cm: SAND, medium - coarse, v. gravelly, w. shell fragments, grey	Ma	Pg
		3	85 - 200 cm: CLAY, highly plastic, silty, calcareous, rich in very sandy clay laminae, w. organic laminae, w. iron sulphides stains, rich in shells and shell fragments, w. plant remains, grey	Ma/ Mw	Lg
2	-12		200 - 280 cm: SAND, fine, silty, w. sandy clay lumps, calcareous, w. organic laminae, w. plant remains, grey	Mw	Lg
3	-13				
4	-14				
5	-15				
6	-16		Continues		

Soil Profile | Sample Type | Recovery (%) | Fissures (1-5) | RQD (%) | Induration (1-5)

In situ vane undist. ○ UCT
In situ vane remoul. ▼ SPT
Standard penetration (blows/300mm) 10 20 30 40
Undr. shear strength - Vane (kN/m²) 100 200 300 400
Undr. shear strength - UCT (MN/m²) 100 200 300 400

W : Nat. water cont.
W_P : Plastic limit
W_L : Liquid limit
W_P W W_L
Water content (%) 10 20 30

W=50

Unit Weight (kN/m³) | Void Ratio | Carbonate (%) | Suppl. Tests: Type | Enclosure

Preliminary

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	Approved :	Date :	Report No.: 2 Encl.No.: 2D.08

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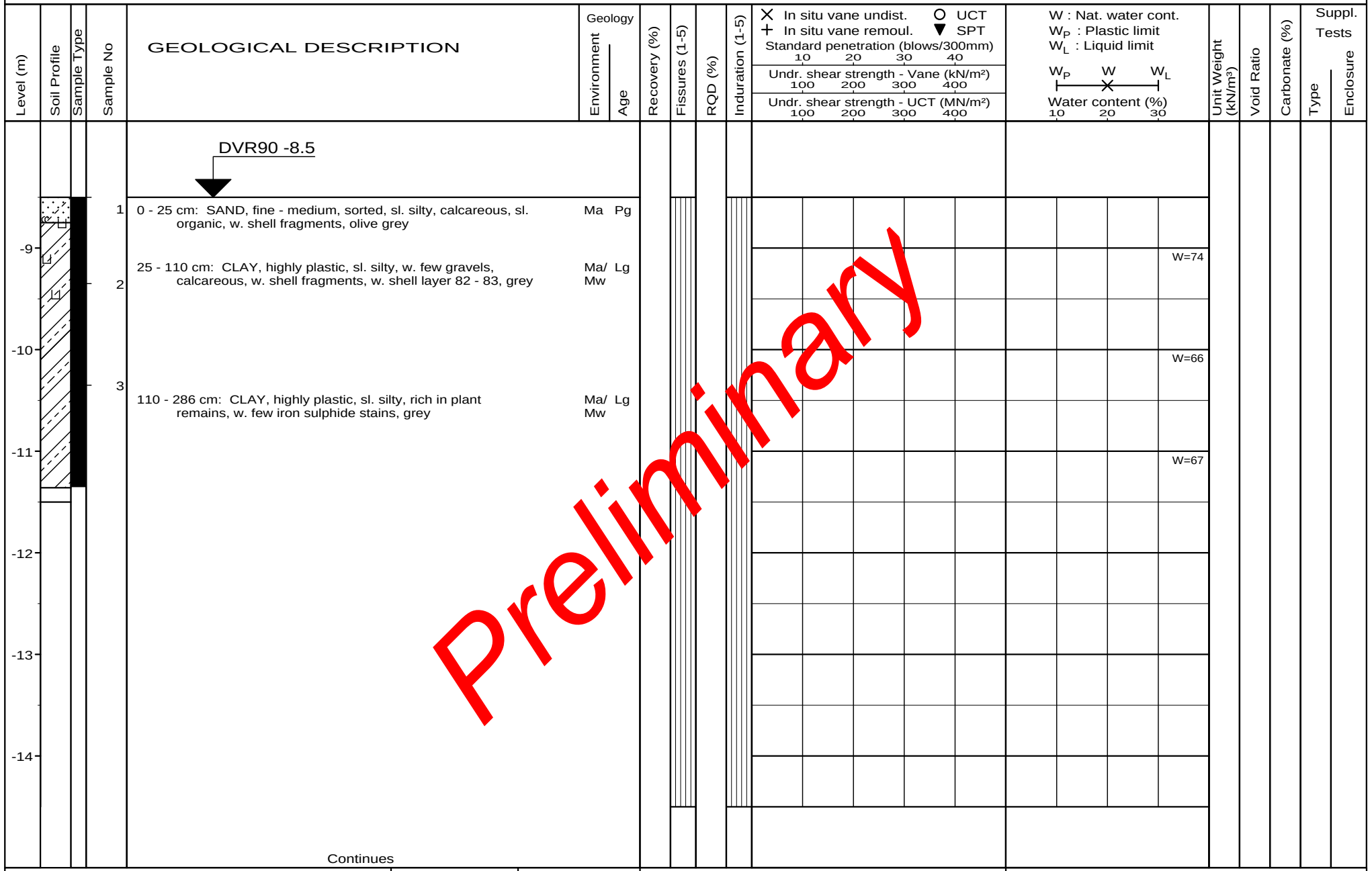
BORING NO. NORD_VIB09 Anholt. Djursland Wind Farm



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Comments :	Checked :	Date :	
	Approved :	Date :	

Job : 32490	Anholt. Djursland Wind Farm
Borehole No.: NORD_VIB09	Date : 2009-05-30
Report No.: 2	Encl.No.: 2D.09

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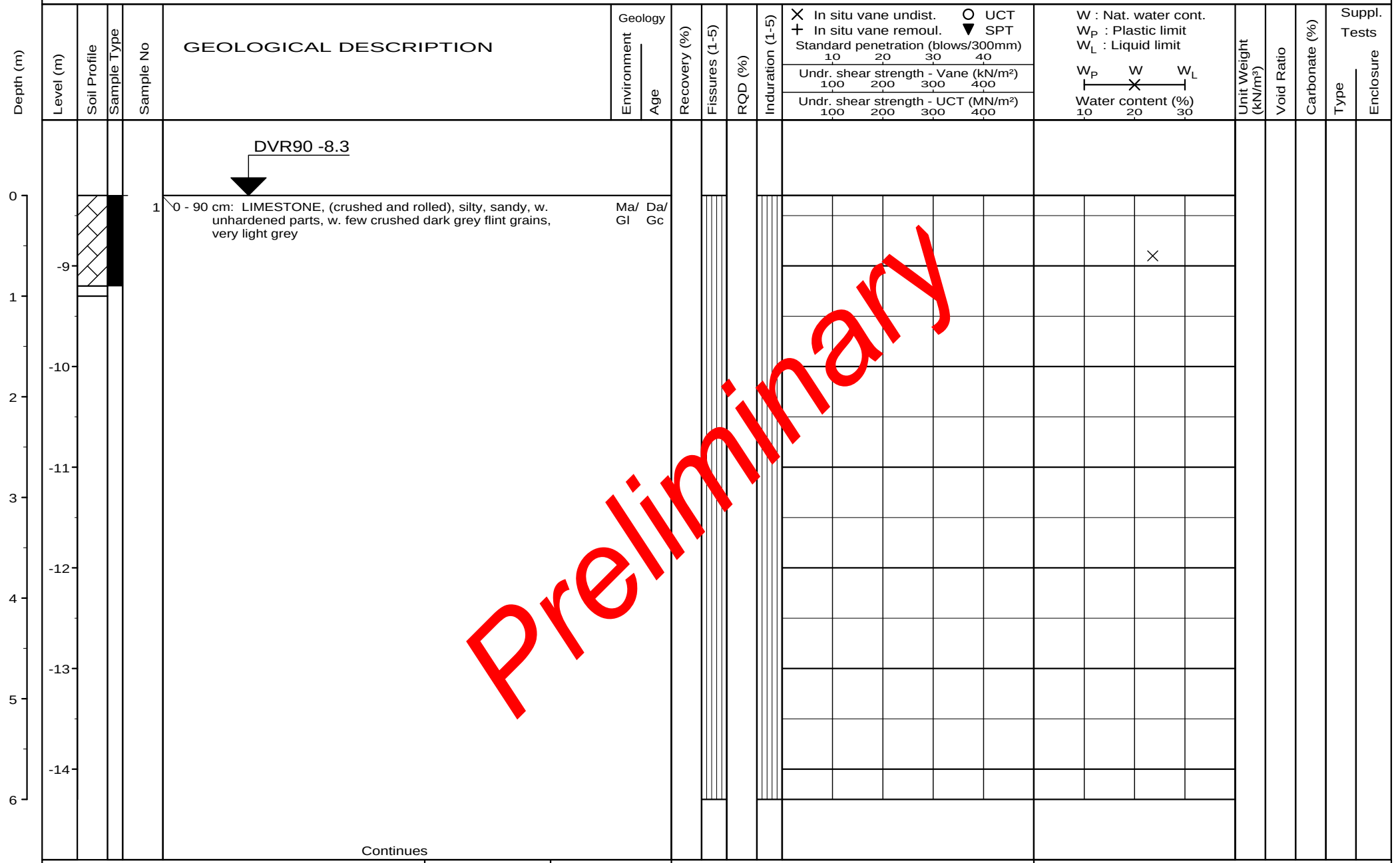

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Comments :	Checked :	Date :		Borehole No.: SYD_VIB01	Date : 2009-05-27
	Approved :	Date :		Report No.: 2	Encl.No.: 2D.10

BORING NO. SYD_VIB02 Anholt. Djursland Wind Farm

DVR90 -11.3

Depth (m)	Level (m)	Sample No	Geology: Environment	Geology: Age	GEOLOGICAL DESCRIPTION
0					
	-12	1	Ma	Pg	0 - 30 cm: GRAVEL, clayey, sandy, w. clay lumps, calcareous, w. shell fragments, grey
1		2	Ma	Pg	30 - 170 cm: SAND, very clayey, silty, sl. gravelly, w. highly plastic clay lumps, calcareous, w. rew shell fragments, (disturbed by drilling), grey
	-13	3			
2			Ma/ Mw	Lg	170 - 260 cm: CLAY, highly plastic, silty, rich in silty sand laminae, calcareous, w. few iron sulphide stains, grey
	-14		Ma/ M	Lg	260 - 290 cm: CLAY, v. silty, sl. sandy, w. few iron sulphide stains, calcareous, grey
3		4	Ma/ Mw	g	Shoe sample: CLAY, v. silty, sl. sandy, calcareous, grey
	-15				
4					
	-16				
5					
	-17				
6					

Continues

Preliminary

In situ vane undist. ○ UCT
In situ vane remoul. ▼ SPT
Standard penetration (blows/300mm) 10 20 30 40
Undr. shear strength - Vane (kN/m²) 100 200 300 400
Undr. shear strength - UCT (MN/m²) 100 200 300 400

W : Nat. water cont.
W_P : Plastic limit
W_L : Liquid limit
W_P W W_L
Water content (%) 10 20 30

Recovery (%) | Fissures (1-5) | RQD (%) | Induration (1-5) | Unit Weight (kN/m³) | Void Ratio | Carbonate (%) | Suppl. Tests: Type | Enclosure

Coordinates : E : 620593 (m) N : 6255362 (m)	Prepared : SAM	Date : 2009-06-12	Job : 32490 Anholt. Djursland Wind Farm
Comments :	Checked :	Date :	Borehole No.: SYD_VIB02 Date : 2009-05-27
	Approved :	Date :	Report No.: 2 Encl.No.: 2D.11

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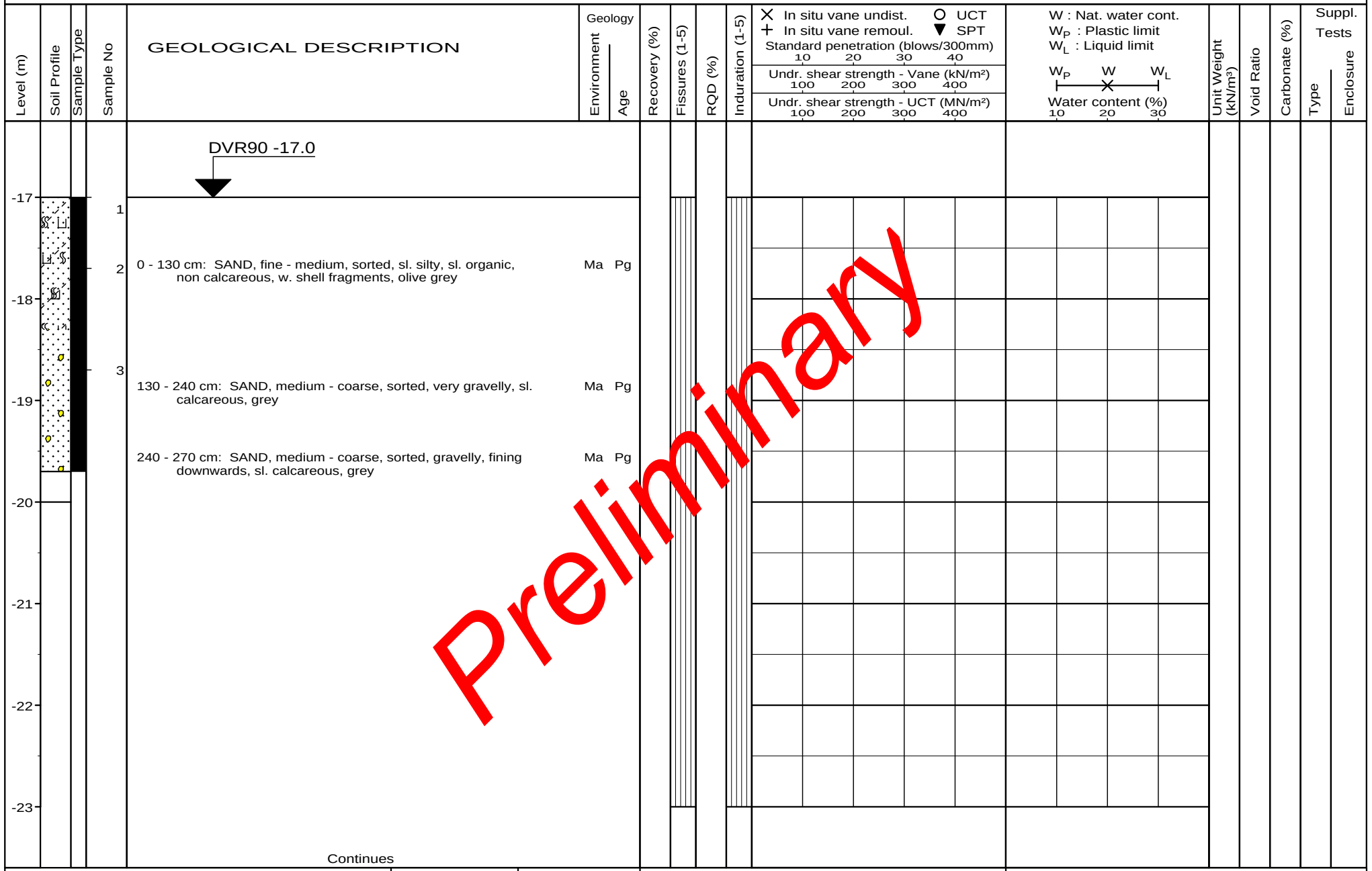
BORING NO. SYD_VIB03 Anholt. Djursland Wind Farm



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	Approved :	Date :	Report No.: 2 Encl.No.: 2D.12

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BORING NO. SYD_VIB04 Anholt. Djursland Wind Farm

DVR90 -17.9

Depth (m)	Level (m)	Sample No	Geology: Environment	Geology: Age	GEOLOGICAL DESCRIPTION
0	-18	1	Ma	Pg	0 - 25 cm: SAND, fine - medium, well sorted, non calcareous, sl. organic, w. shell fragments, olive grey
1	-19	2	Ma	Pg	25 - 135 cm: SAND, fine - medium, sorted, sl. silty, calcareous, sl. organic, w. shell fragments, grey
2	-20	3	Ma/ Mw	Lg	135 - 280 cm: CLAY, highly plastic, silty, w. very silty sand laminae, w. iron sulphide stains, calcareous, grey
3	-21	4	Ma/ Mw	Lg	Shoe sample: SAND, clayey, v. silty, w. shell fragments, w. few peat lumps ?, calcareous, grey
4	-22				
5	-23				
6	-24				

Continues

Recovery (%) | Fissures (1-5) | RQD (%) | Induration (1-5)

In situ vane undist. ○ UCT
In situ vane remoul. ▼ SPT
Standard penetration (blows/300mm) 10 20 30 40
Undr. shear strength - Vane (kN/m²) 100 200 300 400
Undr. shear strength - UCT (MN/m²) 100 200 300 400

W : Nat. water cont.
W_P : Plastic limit
W_L : Liquid limit
W_P W W_L
Water content (%) 10 20 30

Unit Weight (kN/m³) | Void Ratio | Carbonate (%) | Suppl. Tests: Type | Enclosure

Preliminary

Coordinates : E : 624619 (m) N : 6261576 (m)	Prepared : SAM	Date : 2009-06-12	Job : 32490 Anholt. Djursland Wind Farm
Comments :	Checked :	Date :	Borehole No.: SYD_VIB04 Date : 2009-05-29
	Approved :	Date :	Report No.: 2 Encl.No.: 2D.13

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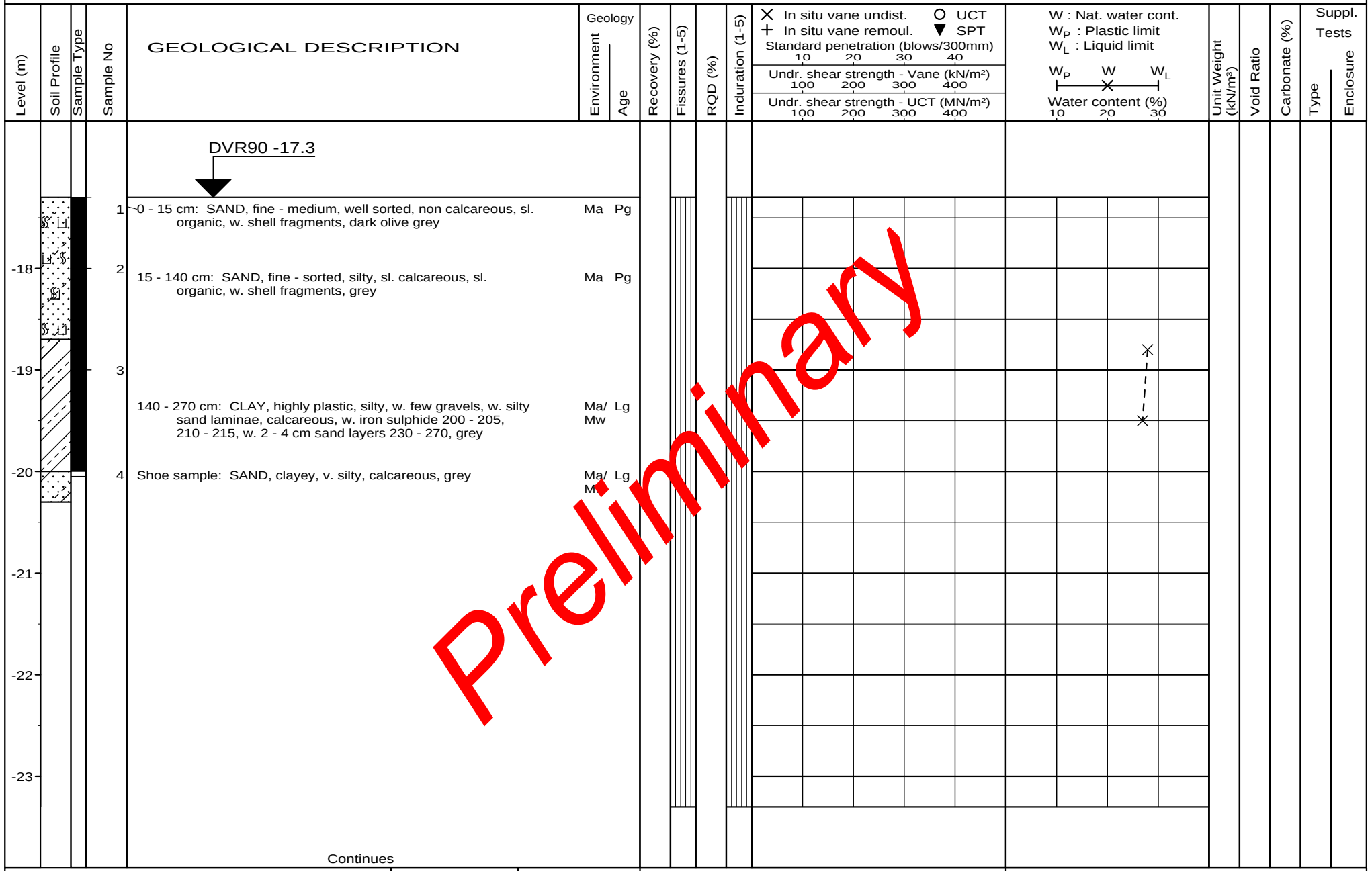
BORING NO. SYD_VIB05 Anholt. Djursland Wind Farm



Coordinates : E : 625664 (m) N : 6263361 (m)	Prepared : SAM	Date : 2009-06-12	Maglebjergvej 1 DK2800 Lyngby tlf +45 4588 4444 www.geo.dk
Comments :	Checked :	Date :	
	Approved :	Date :	

Job : 32490 Anholt. Djursland Wind Farm	
Borehole No.: SYD_VIB05	Date : 2009-05-29
Report No.: 2	Encl.No.: 2D.14

BORING NO. SYD_VIB06 Anholt. Djursland Wind Farm

DVR90 -16.9

Depth (m)	Level (m)	Sample No	Geology: Environment	Geology: Age	GEOLOGICAL DESCRIPTION
0	-17	1			
		2	Ma	Pg	0 - 120 cm: SAND, fine - medium, sorted, sl. silty, non calcareous, sl. organic, rich in shell fragments
1	-18		Ma	Pg	120 - 170 cm: SAND, fine, sorted, sl. silty, sl. calcareous, w. few shell fragments and plant remains, grey
		3	Ma/ Mw	Lg	170 - 190 cm: SILT, v. sandy, w. clay lumps, calcareous, grey
2	-19		Ma/ Mw	Lg	190 - 235 cm: CLAY, medium - highly plastic, silty, v. silty 205 - 220, calcareous, grey
			Ma/ Mw	Lg	235 - 265 cm: SILT, v. sandy, w. clay laminae, calcareous, grey
3	-20				
4	-21				
5	-22				
6	-23				

Continues

Recovery (%) | Fissures (1-5) | RQD (%) | Induration (1-5)

In situ vane undist. ○ UCT
In situ vane remoul. ▼ SPT
Standard penetration (blows/300mm) 10 20 30 40
Undr. shear strength - Vane (kN/m²) 100 200 300 400
Undr. shear strength - UCT (MN/m²) 100 200 300 400

W : Nat. water cont.
W_P : Plastic limit
W_L : Liquid limit
W_P W W_L
Water content (%) 10 20 30

Unit Weight (kN/m³) | Void Ratio | Carbonate (%) | Suppl. Tests: Type | Enclosure

Preliminary

Coordinates : E : 626765 (m) N : 6265242 (m)	Prepared : SAM	Date : 2009-06-12	Job : 32490 Anholt. Djursland Wind Farm
Comments :	Checked :	Date :	Borehole No.: SYD_VIB06 Date : 2009-05-29
	Approved :	Date :	Report No.: 2 Encl.No.: 2D.15

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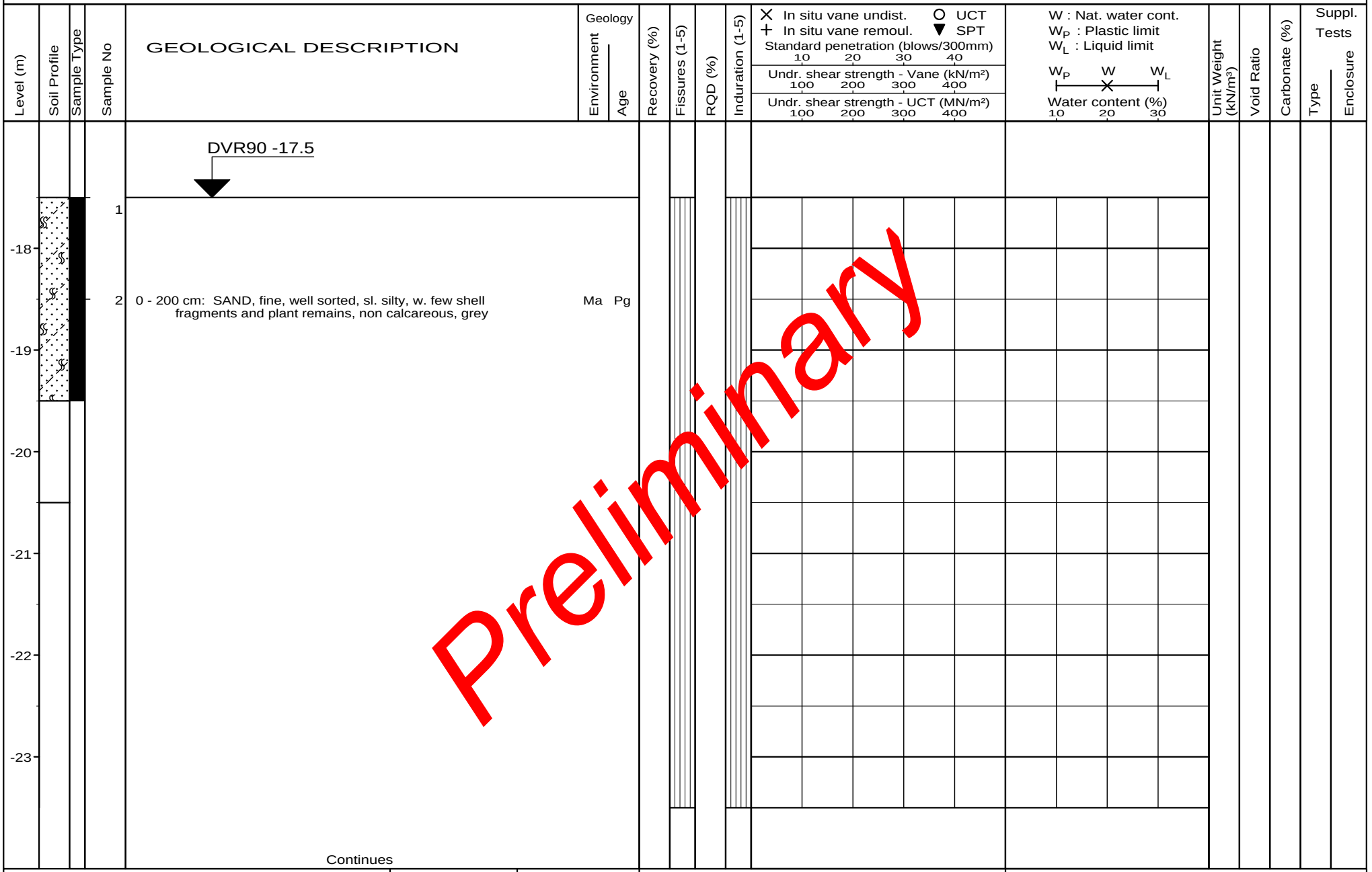
BORING NO. SYD_VIB07 Anholt. Djursland Wind Farm



Coordinates : E : 627691 (m) N : 6266826 (m)	Prepared : SAM	Date : 2009-06-12	Job : 32490 Anholt. Djursland Wind Farm
Comments :	Checked :	Date :	Borehole No.: SYD_VIB07 Date : 2009-05-29
	Approved :	Date :	Report No.: 2 Encl.No.: 2D.16

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BORING NO. SYD_VIB08 Anholt. Djursland Wind Farm

DVR90 -16.4

Depth (m)	Level (m)	Sample No	Geology: Environment	Geology: Age	GEOLOGICAL DESCRIPTION
0	-17	1	Ma	Pg	0 - 110 cm: SAND, fine - medium, sorted, non calcareous, w. shell fragments, grey
1		2	Ma	Pg	110 - 150 cm: SAND, fine - medium, poorly sorted, silty, calcareous, rich in shell fragments, grey
2	-18	3	Ma	Pg, sg	150 - 190 cm: SAND, fine - medium, clayey, w. silty clay laminae, calcareous, w. iron sulphide stains, grey
3	-19		Ma	Pg, sg	190 - 285 cm: SAND, fine - medium, v. clayey, w. highly plastic clay lumps, calcareous, w. iron sulphide stains, w. few shell fragments, grey
4	-20				
5	-21				
6	-22				

Continues

Preliminary

Recovery (%) | Fissures (1-5) | RQD (%) | Induration (1-5)

In situ vane undist. UCT
In situ vane remoul. SPT
Standard penetration (blows/300mm) 10 20 30 40
Undr. shear strength - Vane (kN/m²) 100 200 300 400
Undr. shear strength - UCT (MN/m²) 100 200 300 400

W : Nat. water cont.
W_P : Plastic limit
W_L : Liquid limit
W_P W W_L
Water content (%) 10 20 30

Unit Weight (kN/m³) | Void Ratio | Carbonate (%) | Suppl. Tests: Type | Enclosure

Coordinates : E : 628671 (m) N : 6268495 (m)	Prepared : SAM	Date : 2009-06-12	Job : 32490 Anholt. Djursland Wind Farm
Comments :	Checked :	Date :	Borehole No.: SYD_VIB08 Date : 2009-05-29
	Approved :	Date :	Report No.: 2 Encl.No.: 2D.17

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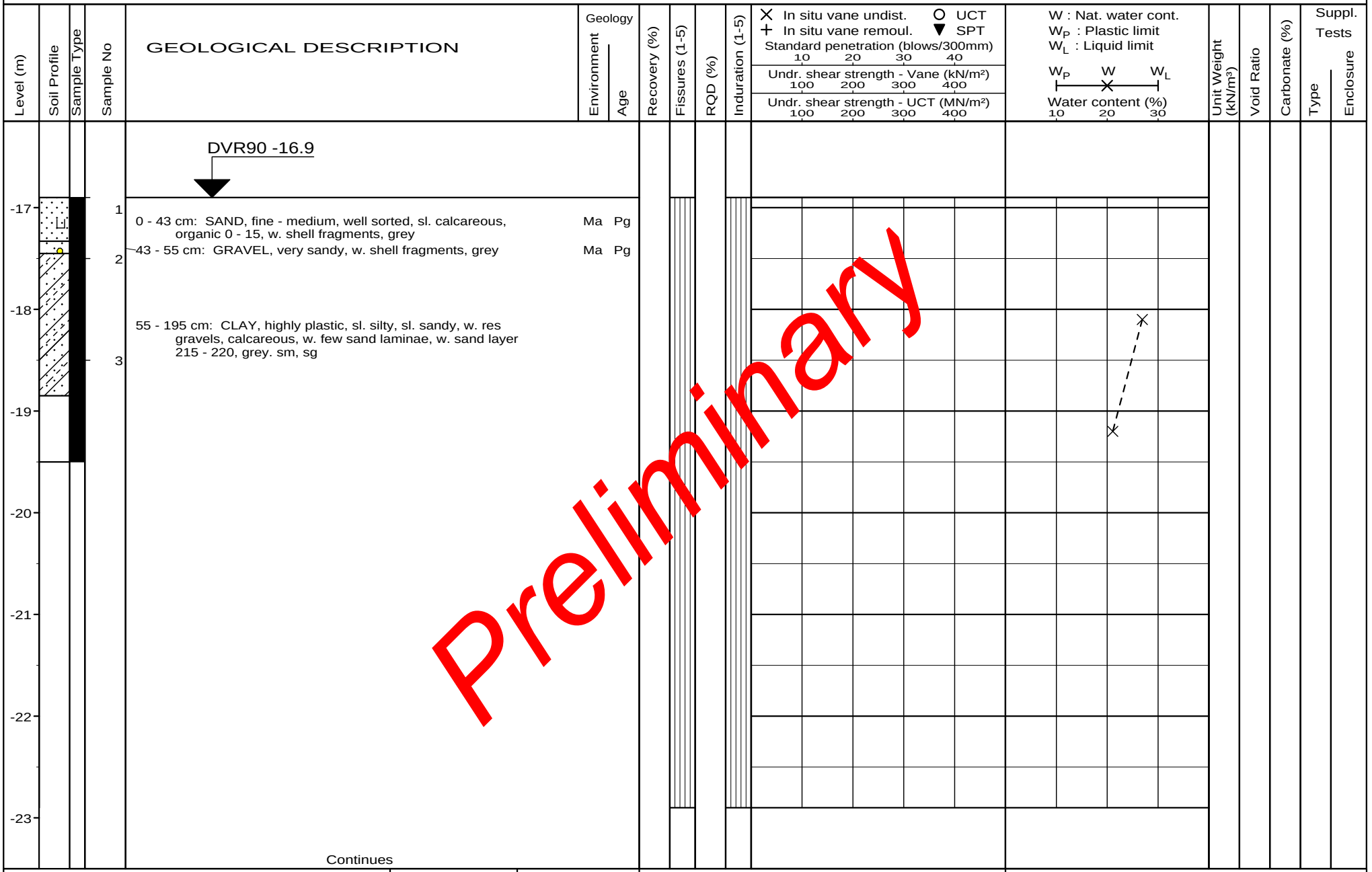
BORING NO. SYD_VIB09 Anholt. Djursland Wind Farm



Coordinates : E : 629388 (m) N : 6269730 (m)	Prepared : SAM	Date : 2009-06-12	Job : 32490 Anholt. Djursland Wind Farm
Comments :	Checked :	Date :	Borehole No.: SYD_VIB09 Date : 2009-05-29
	Approved :	Date :	Report No.: 2 Encl.No.: 2D.18

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BORING NO. SYD_VIB10 Anholt. Djursland Wind Farm

DVR90 -17.0

Depth (m)	Level (m)	Sample No	Geology: Environment	Geology: Age	GEOLOGICAL DESCRIPTION
0	-17	1	Ma	Pg	0 - 15 cm: SAND, fine - medium, sorted, organic, non calcareous, w. shell fragments, dark grey, olive grey
		2	Ma	Pg	15 - 130 cm: SAND, fine - medium, sorted, sl. silty, non calcareous, w. shell fragments, grey
1	-18		Ma/ Mw	Lg	130 - 165 cm: CLAY, highly plastic, silty, non calcareous, organic to very organic, w. shell fragments, olive grey
		3	Ma/ Mw	Lg	165 - 225 cm: SAND, fine - medium, sl. clayey to clayey, non calcareous, w. clay lumps, w. iron sulphide stains, grey
2	-19		Ma/ Mw	Lg	225 - 272 cm: CLAY, highly plastic, silty, sl. gravelly 240 - 260, w. silty sand layers and sand laminae, non calcareous, w. iron sulphide stains, grey
		4	Ma/ Mw	Lg	Shoe sample: CLAY, highly plastic, silty, sandy, non calcareous, w. iron sulphide stains, grey
3	-20				
4	-21				
5	-22				
6	-23				

Continues

Recovery (%) | Fissures (1-5) | RQD (%) | Induration (1-5)

In situ vane undist. ○ UCT
In situ vane remoul. ▼ SPT
Standard penetration (blows/300mm) 10 20 30 40
Undr. shear strength - Vane (kN/m²) 100 200 300 400
Undr. shear strength - UCT (MN/m²) 100 200 300 400

W : Nat. water cont.
W_P : Plastic limit
W_L : Liquid limit
W_P W W_L
Water content (%) 10 20 30

W=75

Unit Weight (kN/m³) | Void Ratio | Carbonate (%) | Suppl. Tests: Type | Enclosure

Preliminary

Coordinates : E : 630098 (m) N : 6270942 (m)	Prepared : SAM	Date : 2009-06-12	Job : 32490 Anholt. Djursland Wind Farm
Comments :	Checked :	Date :	Borehole No.: SYD_VIB10 Date : 2009-05-29
	Approved :	Date :	Report No.: 2 Encl.No.: 2D.19

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BORING NO. SYD_VIB11 Anholt. Djursland Wind Farm

DVR90 -17.4

Depth (m)	Level (m)	Sample No	Geology: Environment	Geology: Age	GEOLOGICAL DESCRIPTION
0		1			
	-18	2	Ma	Pg	0 - 140 cm: SAND, fine - medium, sorted, sl. silty, calcareous, w. shell fragments, grey
1					
	-19	3	Mw	Lg	140 - 200 cm: SAND, fine, poorly sorted, silty, w. few gravels, calcareous, grey
			Mw	Lg	200 - 230 cm: SAND, medium - coarse, sorted, sl. gravelly, coarsing downwards, sl. calcareous, grey
2			Mw	Lg	230 - 260 cm: SAND, fine, poorly sorted, silty, w. few gravels, calcareous, grey
	-20				
3					
	-21				
4					
	-22				
5					
	-23				
6					

Continues

Preliminary

Soil Profile | Sample Type | Recovery (%) | Fissures (1-5) | RQD (%) | Induration (1-5)

In situ vane undist. (×) / In situ vane remoul. (+) / UCT (○) / SPT (▼)

Standard penetration (blows/300mm): 10 20 30 40

Undr. shear strength - Vane (kN/m²): 100 200 300 400

Undr. shear strength - UCT (MN/m²): 100 200 300 400

W : Nat. water cont.
W_P : Plastic limit
W_L : Liquid limit

W_P W W_L

Water content (%): 10 20 30

Unit Weight (kN/m³) | Void Ratio | Carbonate (%) | Suppl. Tests: Type | Enclosure

Coordinates : E : 632176 (m) N : 6274493 (m)	Prepared : SAM	Date : 2009-06-12	Job : 32490 Anholt. Djursland Wind Farm
Comments :	Checked :	Date :	Borehole No.: SYD_VIB11 Date : 2009-05-31
	Approved :	Date :	Report No.: 2 Encl.No.: 2D.20

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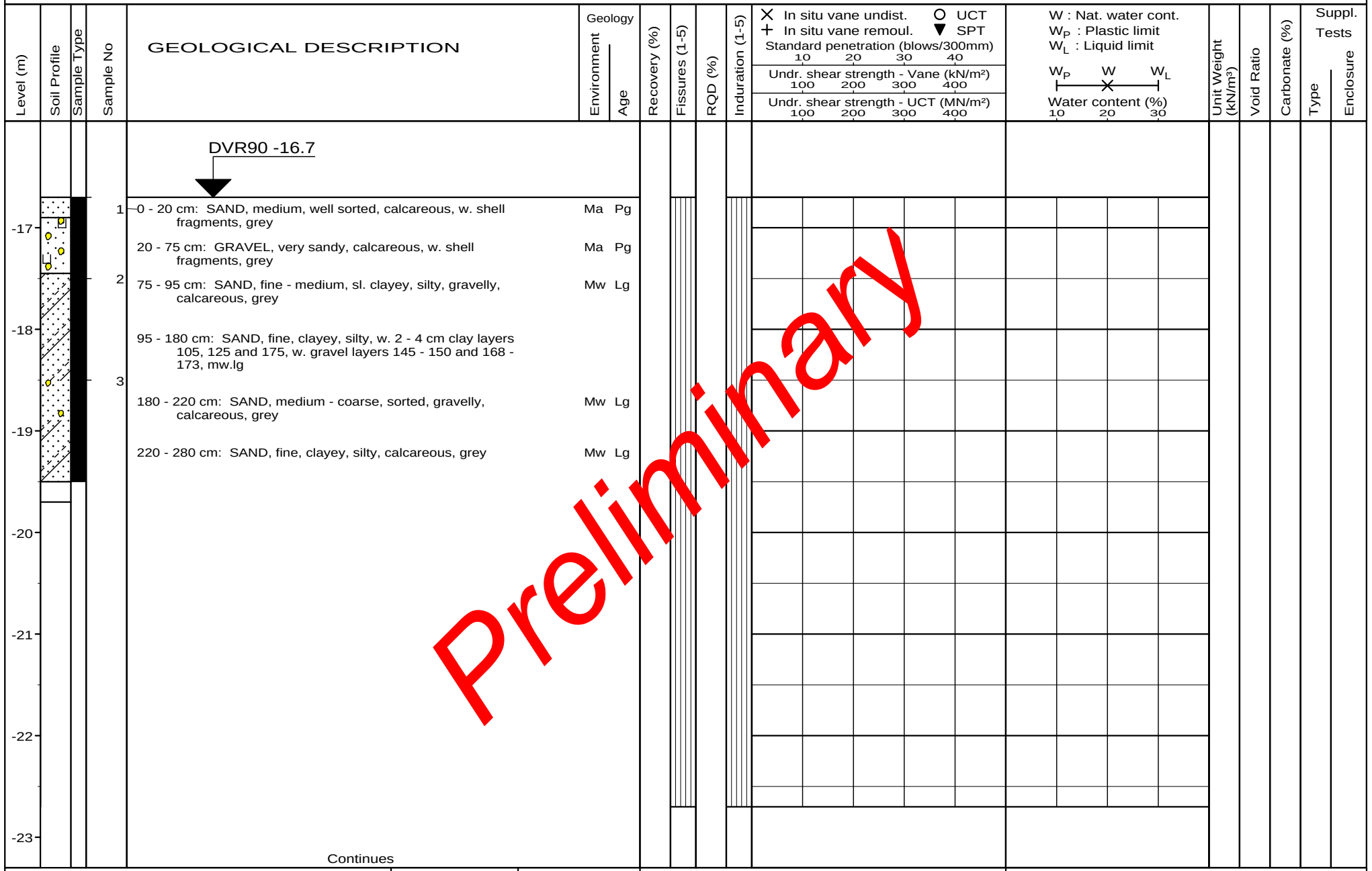
BRegister - PCOKUK 2.1 - 6/16/2009 4:30:48 PM

BORING NO. SYD_VIB12 Anholt. Djursland Wind Farm



Coordinates : E : 632001 (m) N : 6274195 (m)	Prepared : SAM	Date : 2009-06-12	Job : 32490 Anholt. Djursland Wind Farm
Comments :	Checked :	Date :	Borehole No.: SYD_VIB12 Date : 2009-05-31
	Approved :	Date :	Report No.: 2 Encl.No.: 2D.21

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Appendix 2
Patch test

PATCH TEST

Calibration of EM 3002D system for

GEUS

Offshore Windfarm, Anholt

05. May 2009

Initial setting of transducer mounting angles

The patch test was mainly carried out as a confidence and confirmation calibration on previously conducted calibration.

Initial settings:	PORT transducer	STBD transducer
Latency	0 ms	0 ms
Roll	40.0 º	- 40.0 º
Pitch	0.0 º	0.0 º
Heading	0.0 º	0.0 º

Final settings:	PORT transducer	STBD transducer
Latency	0 ms	0 ms
Roll	40.13 º	- 40.23 º
Pitch	1.37 º	1.47 º
Heading	- 0.25 º	- 0.25 º

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Calibration of EM3002D

Bar Check

A bar check was conducted on the 22nd April 2009. This was conducted in 8 meters of water. This confirmed the draft setting of the echosounders and depth observations observed in QINSy.

Latency Check PORT:

As both SIS and QINSy are synchronized with PPS and time interface from the GPS receiver the latency is expected to be negligible and hence this part of the patch test is mainly as confirmation of the time synchronisation.

Latency Lines

0011 Pitch line 1 STBD	3.8 kt
0013 Latency stbd	7 kt

By measuring the variation between the “fast” and ”slow” line the latency appeared to be negligible.

Latency Check STBD:

As both SIS and QINSy are synchronized with PPS and time interface from the GPS receiver the latency is expected to be negligible and hence this part of the patch test is mainly as confirmation of the time synchronisation.

0016 Pitch line 1 STBD	4.0 kt
0018 Latency stbd	8.0 kt

By measuring the variation between the “fast” and ”slow” line the latency appeared to be negligible.

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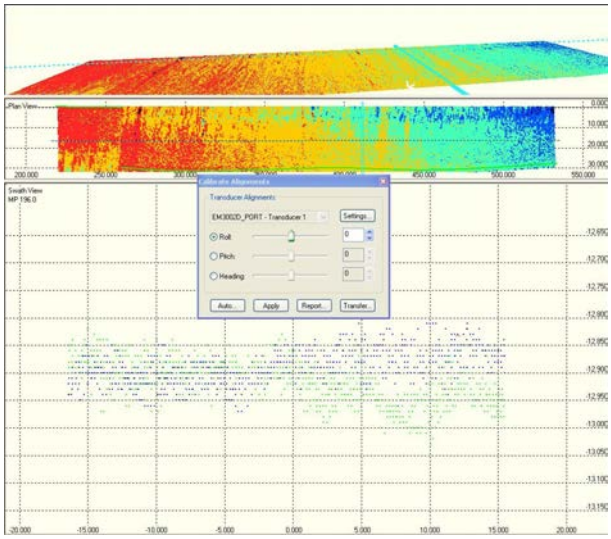
Roll Offset - PORT

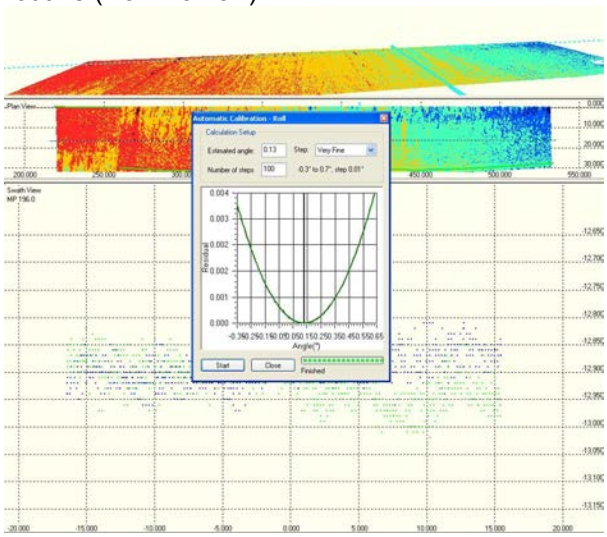
Roll = 0.13 º

0186 Roll 1 0001
0187 Roll 2 0001

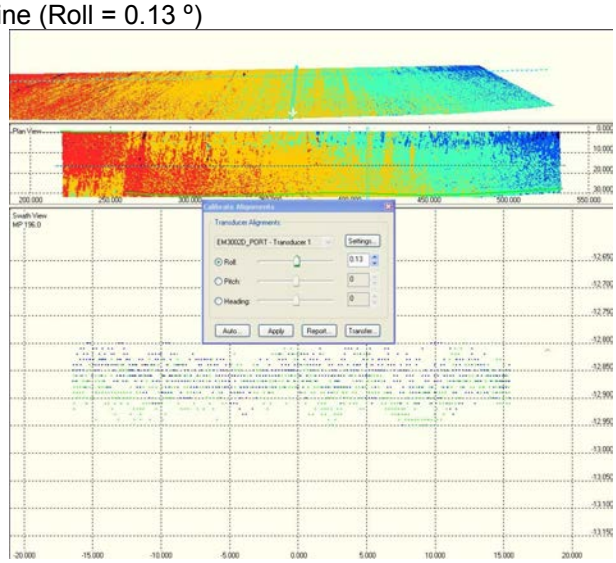
Before Calculation



Automatic calibration routine (Roll = 0.13 º)



After calibration routine (Roll = 0.13 º)



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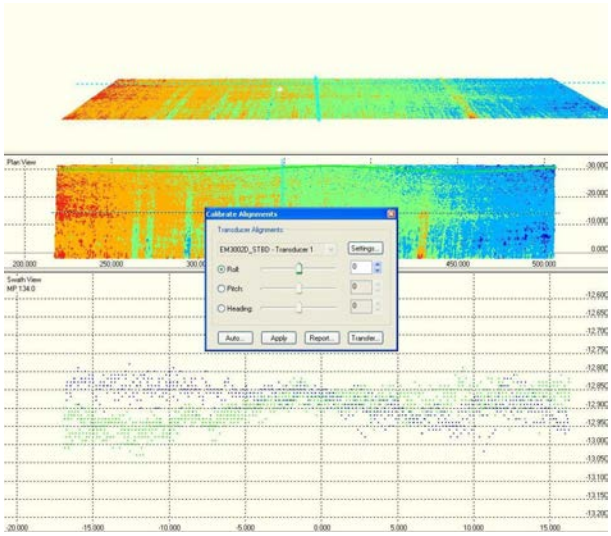
Roll Offset - STARBOARD

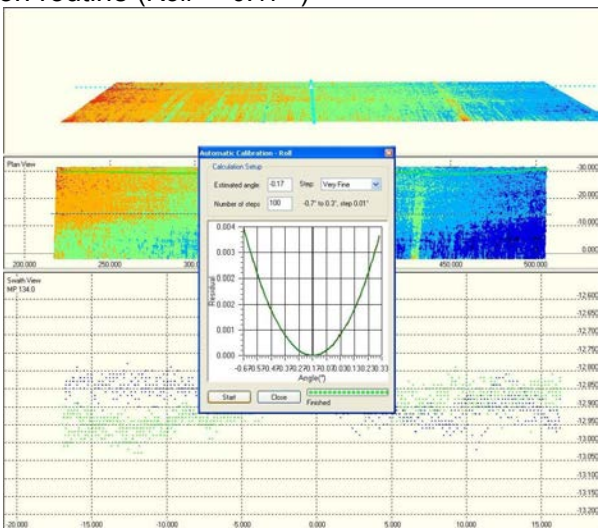
Roll = -0.17 º

0188 Roll 1 0001
0005 Roll 2 0001

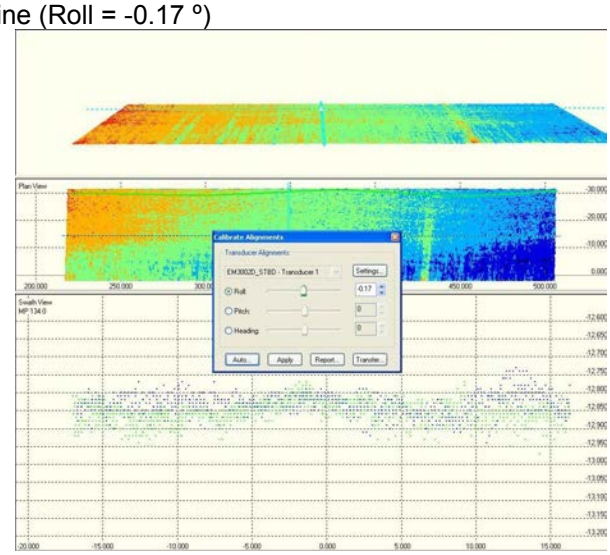
Before Calculation



Automatic Calculation routine (Roll = -0.17 º)



After calibration routine (Roll = -0.17 º)



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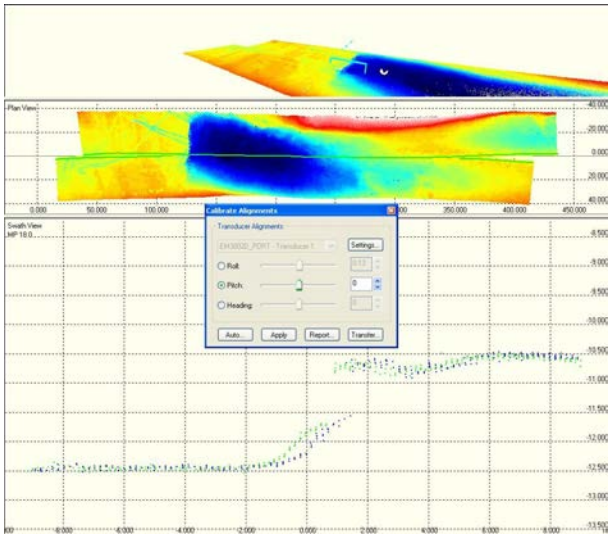
Pitch Offset – PORT

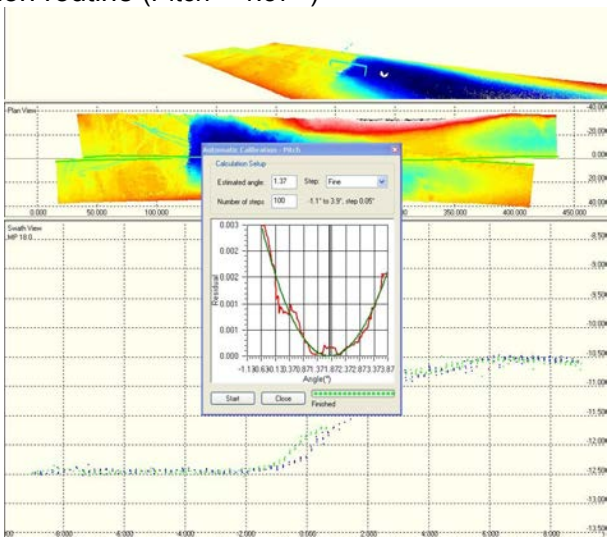
Pitch = 1.37 º

0194 Line 2
0195 Line 2

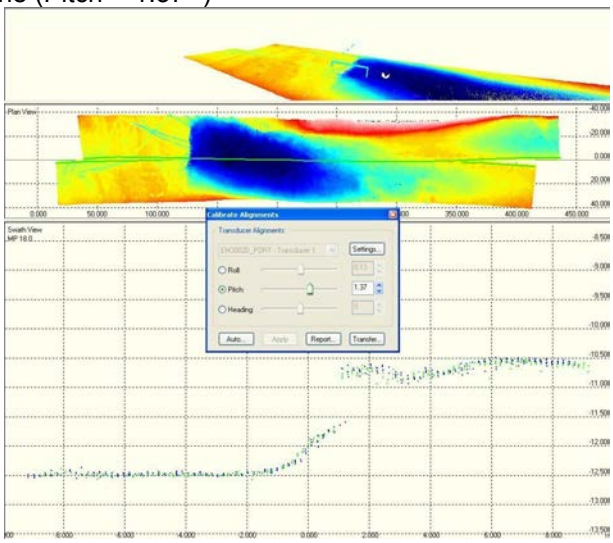
Before Calculation



Automatic Calculation routine (Pitch = 1.37 º)



After calibration routine (Pitch = 1.37 º)



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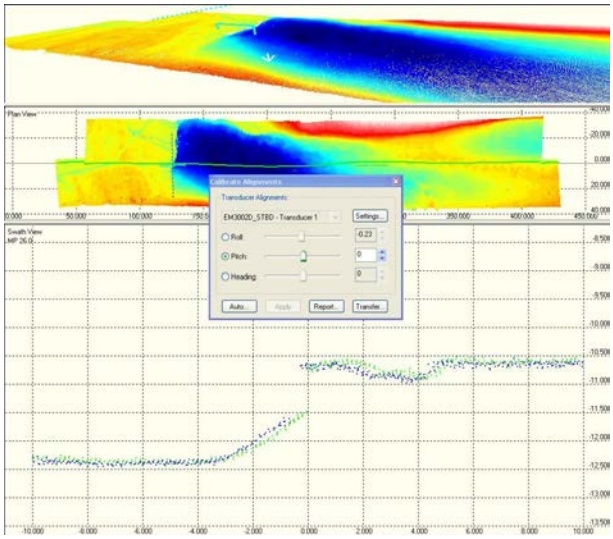
Pitch Offset – STARBOARD

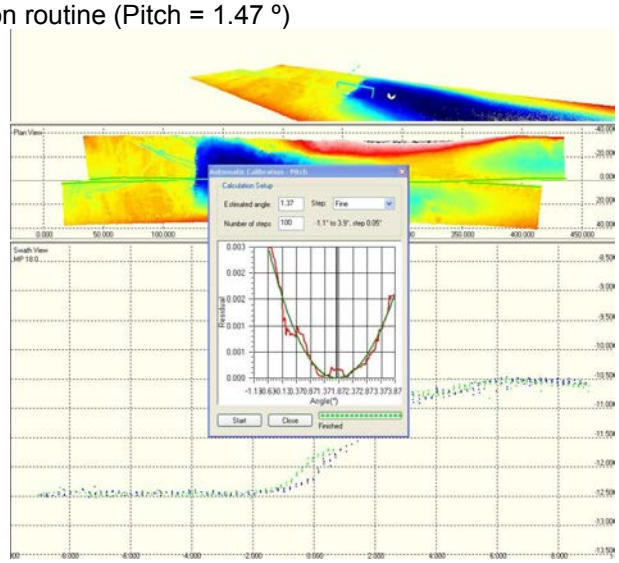
Pitch = 1.47 º

0191 Line 2
0192 Line 2

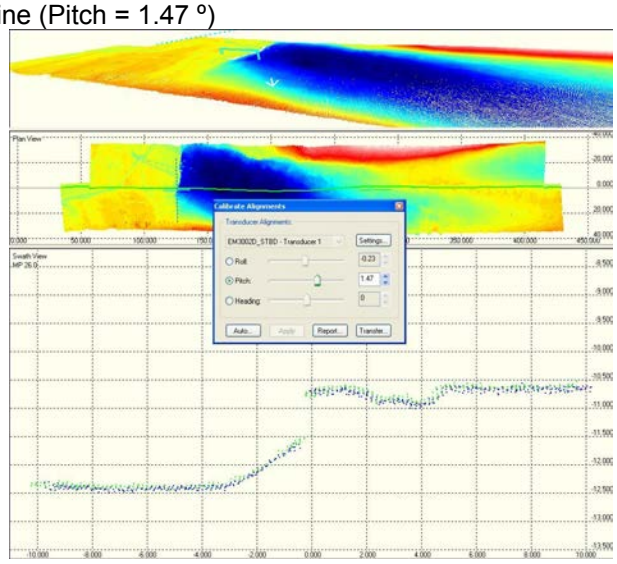
Before Calculation



Automatic Calculation routine (Pitch = 1.47 º)



After calibration routine (Pitch = 1.47 º)



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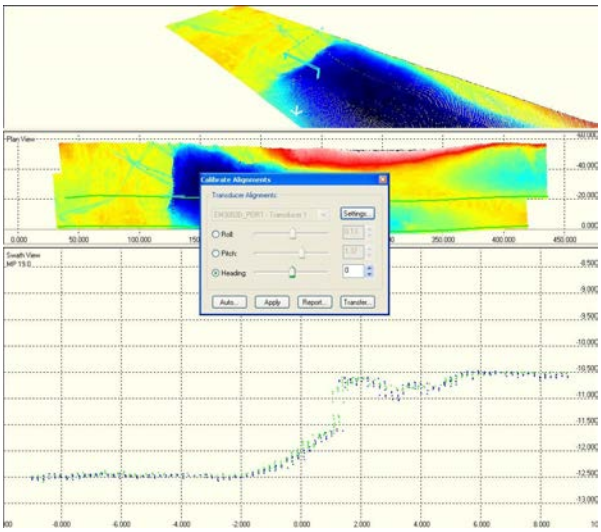
Heading Offset – PORT

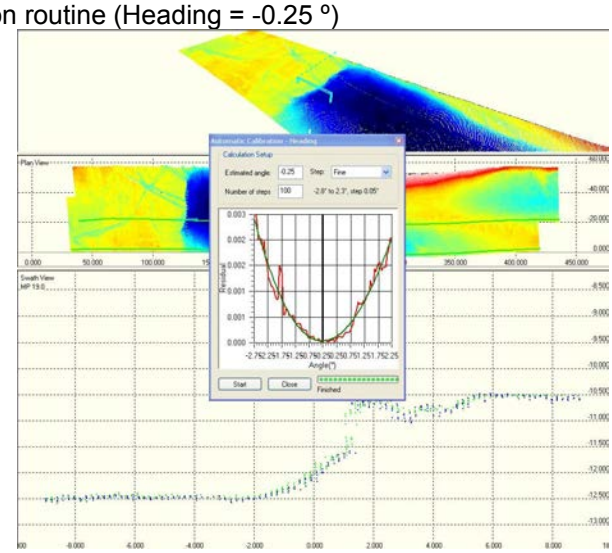
Heading = -0.25 º

0193 Line 1
0195 Line 2

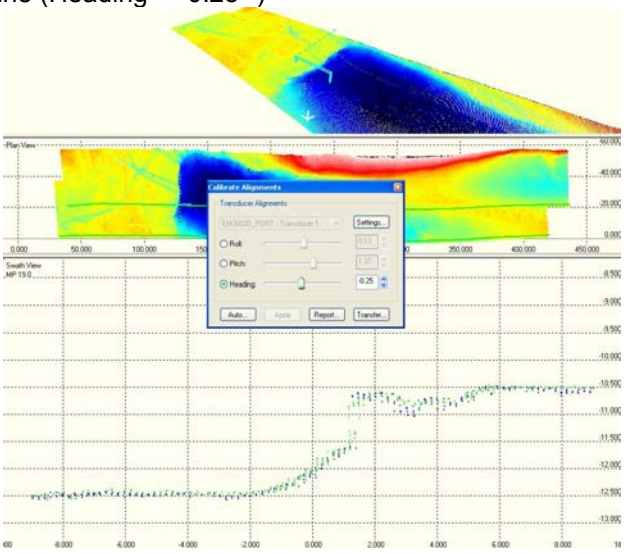
Before Calculation



Automatic Calculation routine (Heading = -0.25 º)



After calibration routine (Heading = -0.25 º)



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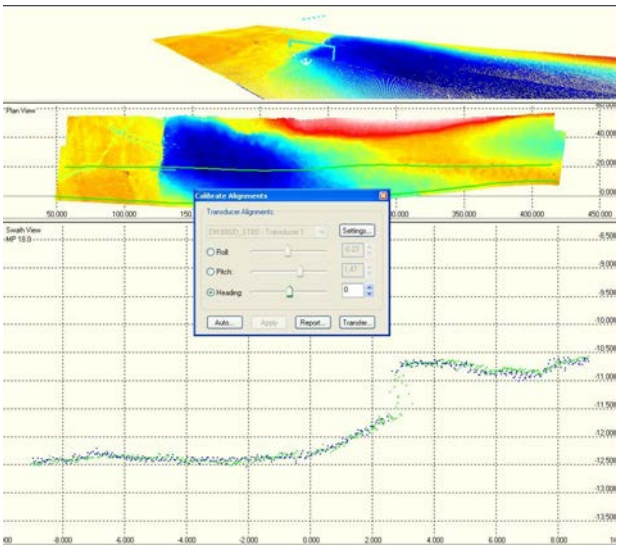
Heading Offset – STARBOARD

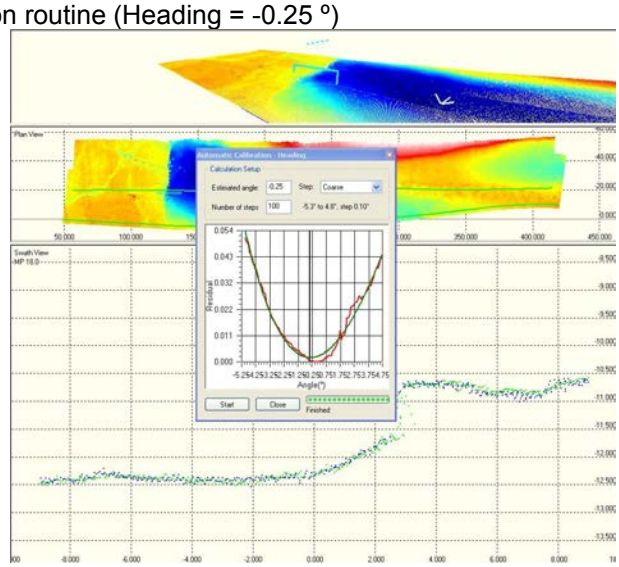
Heading = -0.25 º

0190 Heading Line 1 STBD
0192 Heading Line 2 STBD

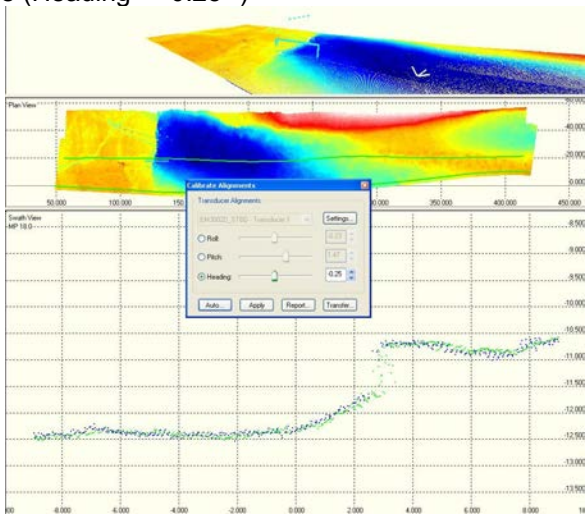
Before Calculation



Automatic Calculation routine (Heading = -0.25 º)



After calibration routine (Heading = -0.25 º)



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Result of Patch test of GEUS EM3002D multibeam system on board M/S MADOG on the 5th of May 2009.

Final result PORT Head: **Roll = 0.13 º Pitch = 1.37 º Heading = -0.25 º**
Final result STBD Head: **Roll = - 0.23 º Pitch = 1.47 º Heading = -0.25 º**

Final settings:	**PORT transducer**	**STBD transducer**
Latency	**0 ms**	**0 ms**
Roll	**40.13 º**	**- 40.23 º**
Pitch	**1.37 º**	**1.47 º**
Heading	**- 0.25 º**	**- 0.25 º**

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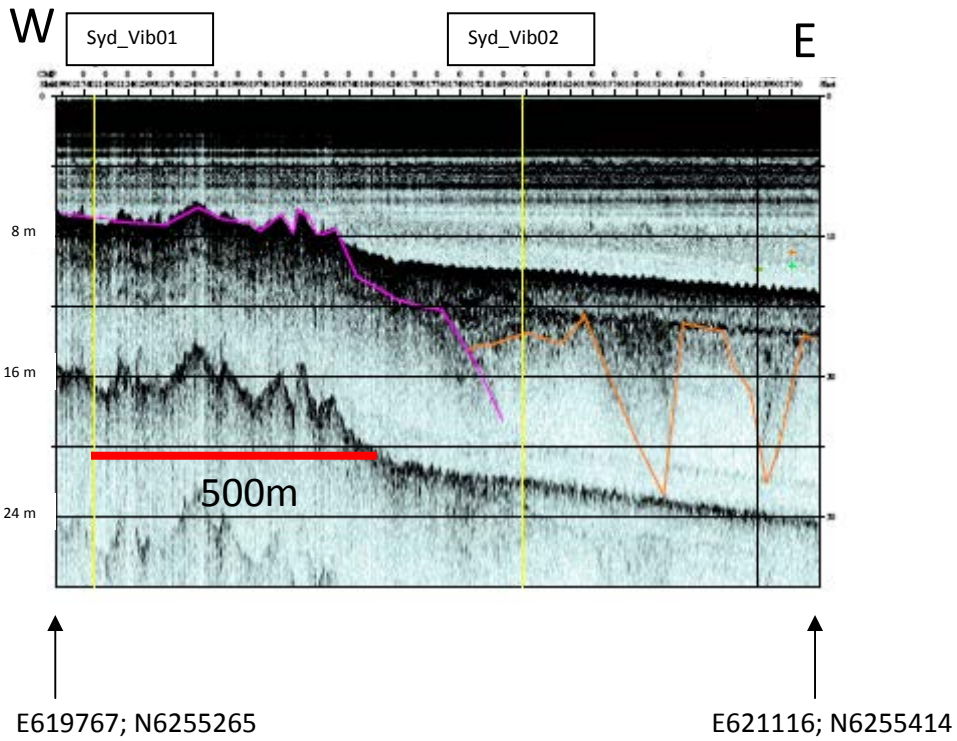
Appendix 3
Geological profiles of cable corridors

Cable Corridor South: Line AW-COR-03A



The depth scale is based on the depth of the chirp fish. The water depth is approximately the indicated depth + 1m.

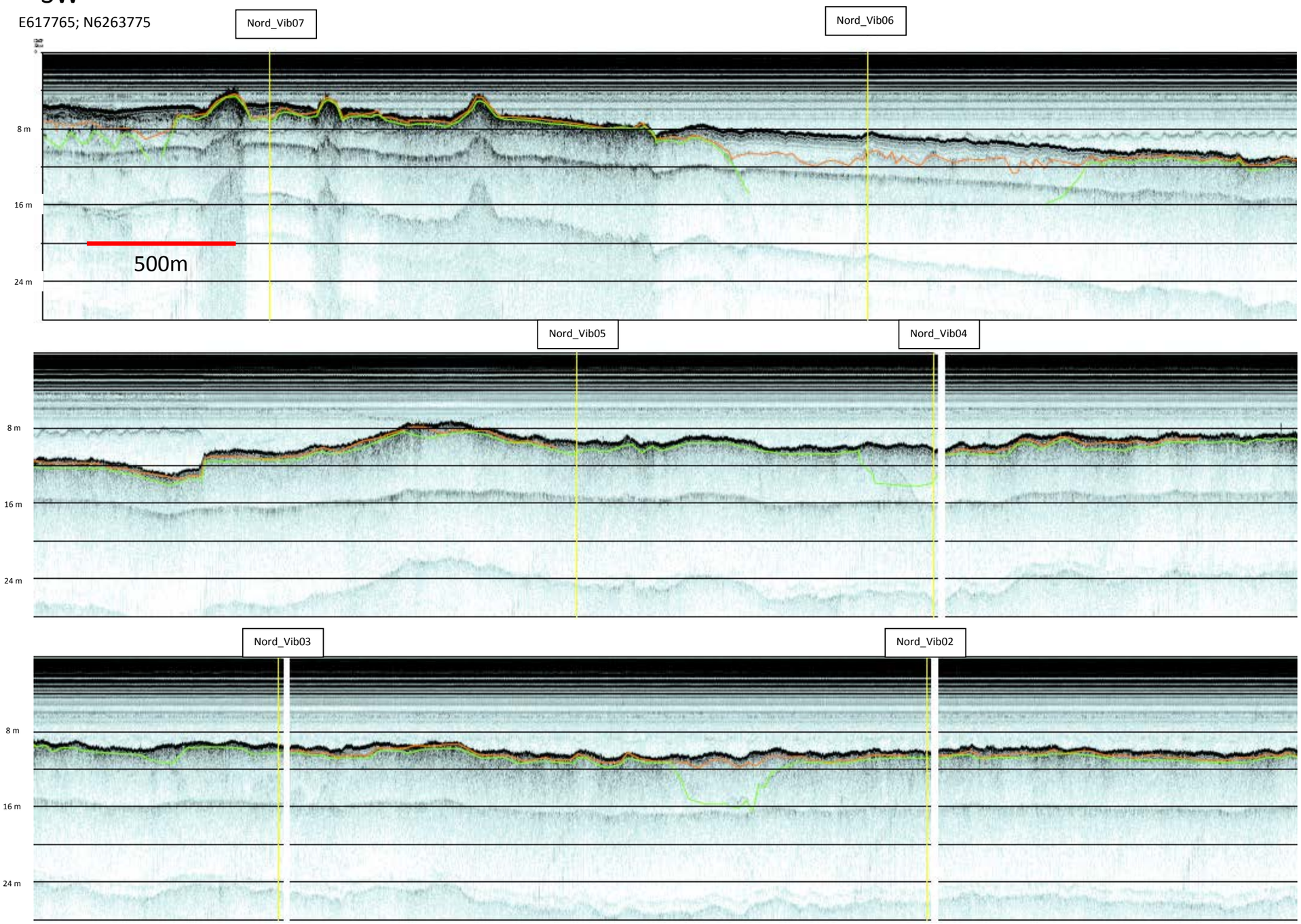
Bottom Holocene deposits

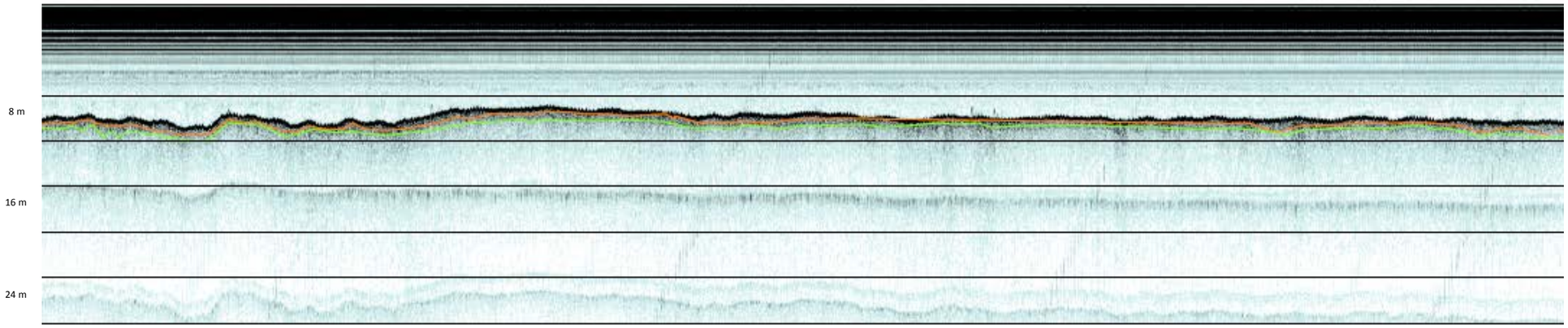
Top Limestone

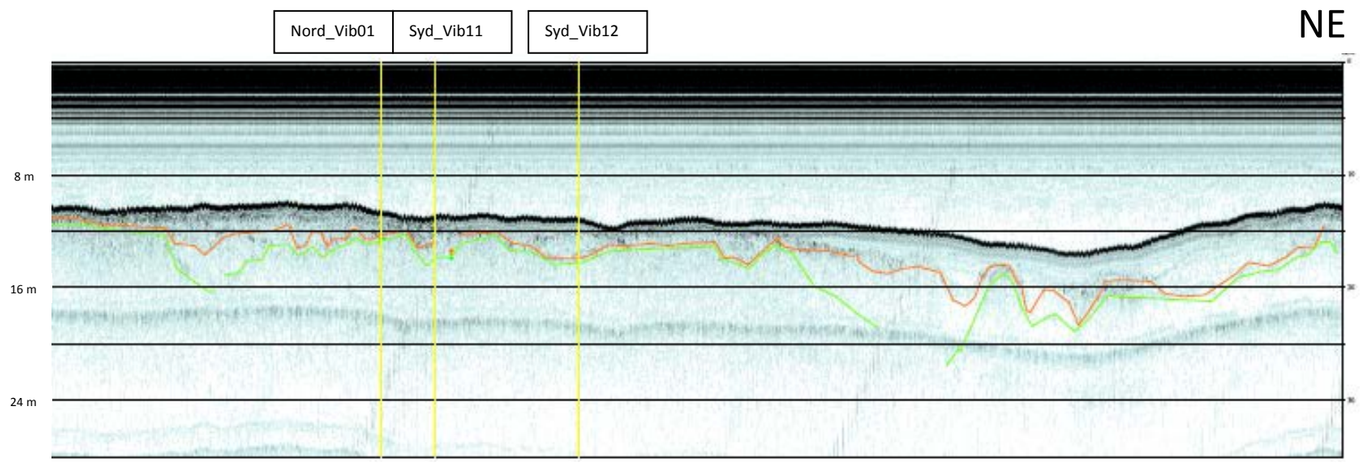
Cable Corridor Line AW-COR-06B

SW

E617765; N6263775







E633511; N6275410

The depth scale is based on the depth of the chirp fish. The water depth is approximately the indicated depth + 6m.

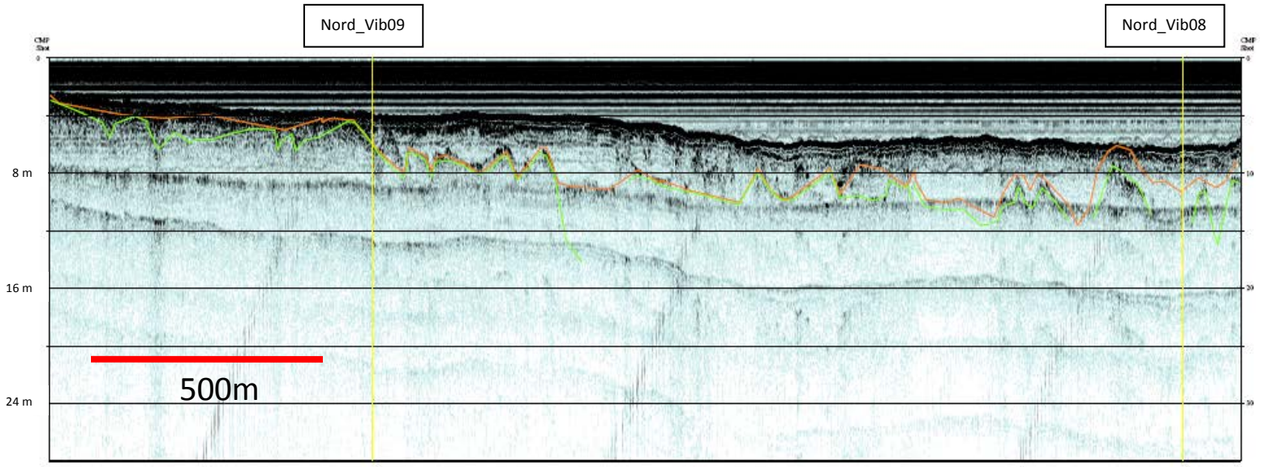
Bottom Holocene deposits

Top Glacial deposits

Cable Corridor North: Line AW-COR-06A

SW

NE



E615751; N6262295

E617830; N6263831

Bottom Holocene deposits

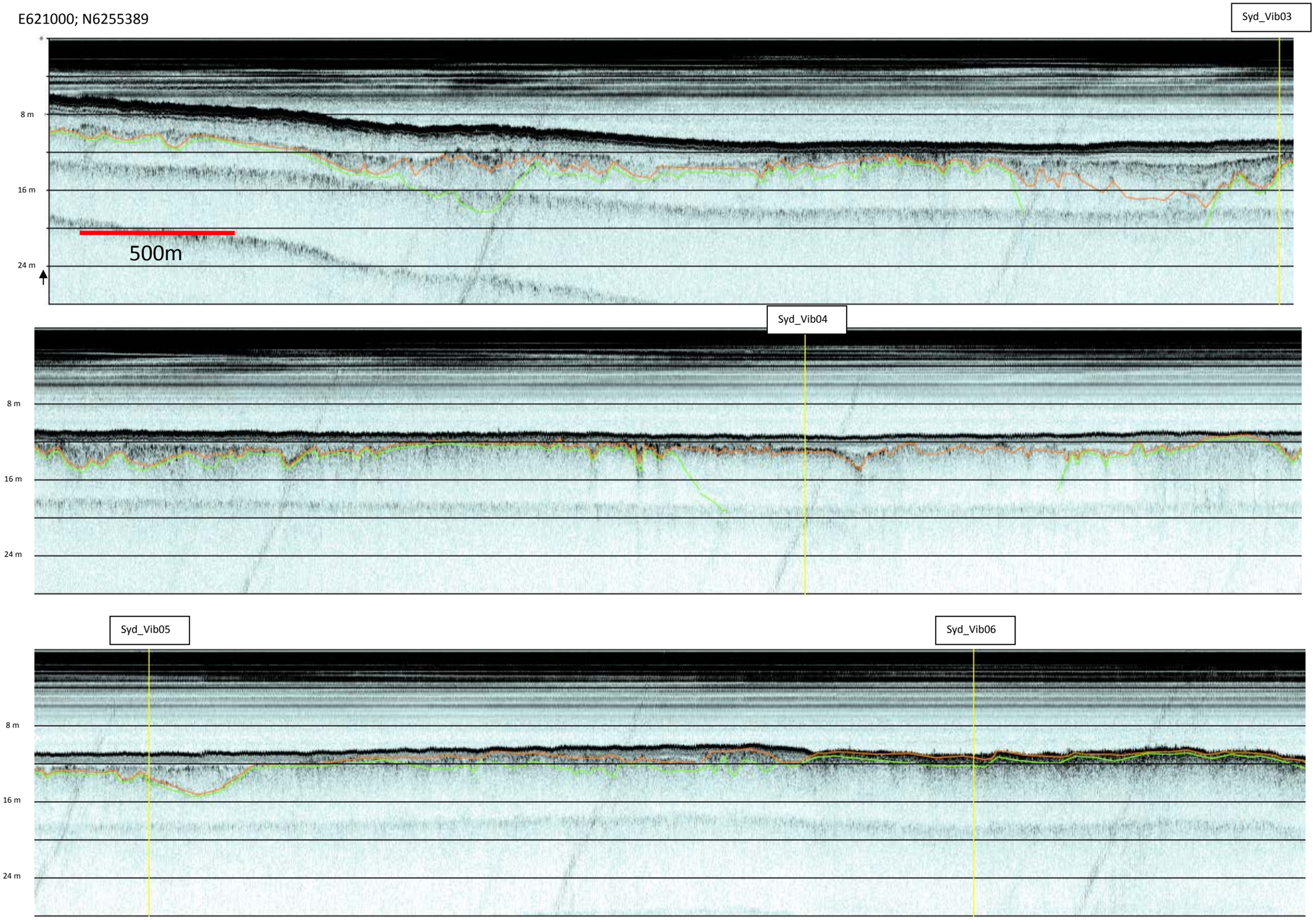
Top Glacial

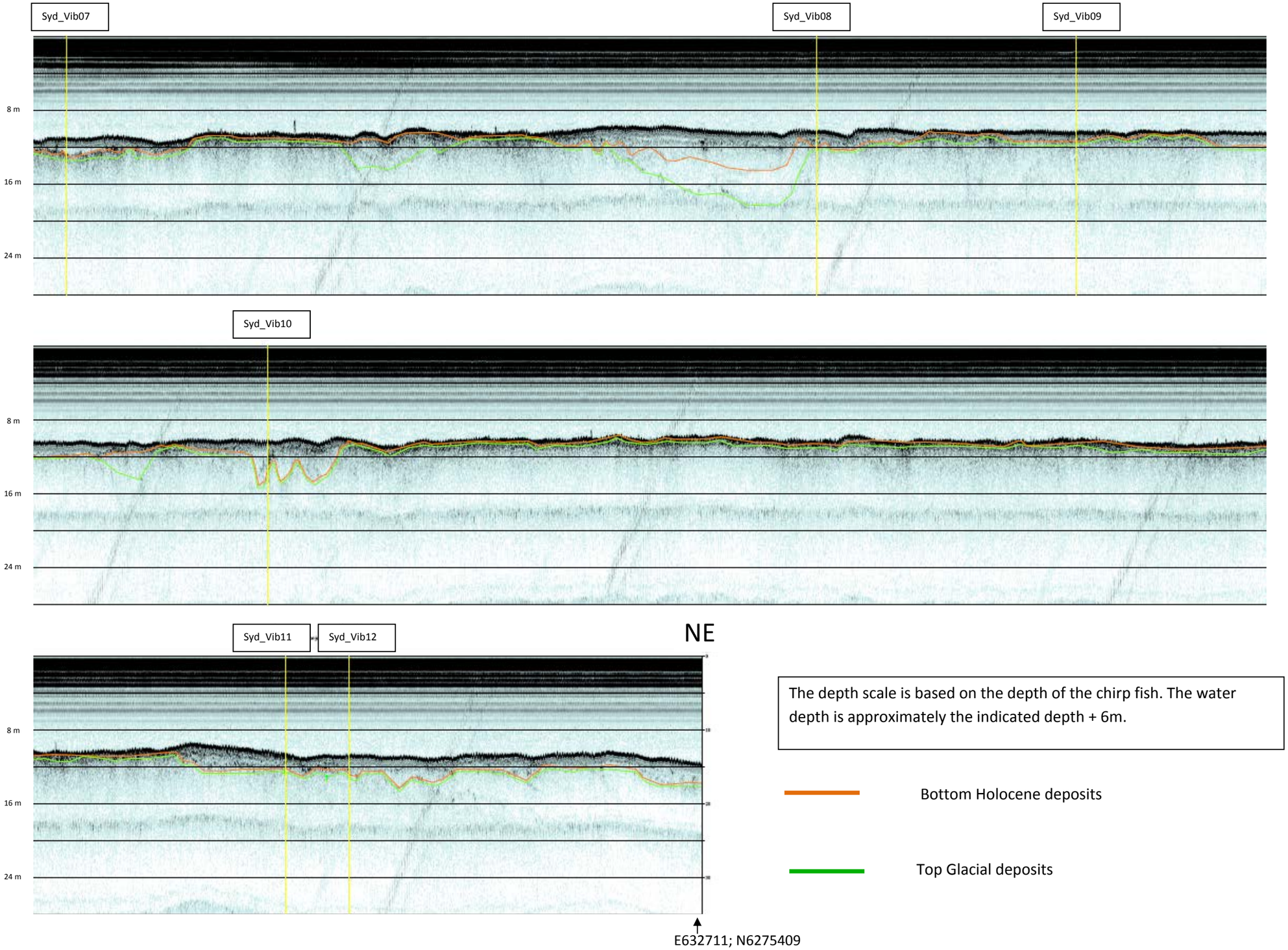
The depth scale is based on the depth of the chirp fish. The water depth is approximately the indicated depth + 4m.

Cable Corridor South: Line AW-COR-03B

SW

E621000; N6255389





The depth scale is based on the depth of the chirp fish. The water depth is approximately the indicated depth + 6m.

Bottom Holocene deposits

Top Glacial deposits

Appendix 4
Reference point control

Landinspektørfirmaet
KJÆR

Landinspektørfirmaet Kjær
Århusvej 22B
Postboks 104
8500 Grenaa
Tlf. 86 32 21 33
Fax 86 32 60 46
E-mail: kjaer@plf.dk
www.lsp-kjaer.dk

Landinspektørfirmaet Kjær
Strandvejen 7
Postboks 150
8400 Ebeltoft
Tlf. 86 34 22 34
Fax 86 34 22 49
E-mail: kjaer-ebeltoft@plf.dk

Landinspektørfirmaet Kjær ApS
Føllevej 5
8410 Rønde
Tlf. 86 37 29 33

Havvindmøllepark mellem Grenaa og Anholt.

Kontrolmåling af masterstation og 2 fikspunkter på mole i Grenaa havn.

J.nr. 091 067

Målinger udført med Leica type 1200 instrument.
RTK tjeneste: Leica SmartNet Danmark.

Masterstation på Fornæs Fyr:

UTM zone 32, WGS84 koordinater som gennemsnit af 8 uafhængige målinger:

Latitude	Longitude	Ellipsoidehøjde
56° 26′ 36,2672″	10° 57′ 26,1563″	73,40 m
Maksimal spredning i målingerne.		
0,0005″	0,0009″	0,02 m

Vestlige fikspunkt på mole, punkt 1001:

UTM zone 32, WGS84 koordinater som gennemsnit af 5 målinger:

Latitude	Longitude	Ellipsoidehøjde
56° 24′ 36,9540″	10° 55′ 32,6285″	39,56 m
Lig med:		
Easting	Northing	DVR90
618 819,49	6 253 406,11	2,00 m
Maksimal spredning i målingerne:		
0,0002″ = 0,01	0,0002″ = 0,01	0,01 m

Østlige fikspunkt på mole, punkt 1002:

UTM zone 32, WGS84 koordinater som gennemsnit af 5 målinger:

Latitude	Longitude	Ellipsoidehøjde
56° 24′ 37,1428″	10° 55′ 34,4179″	39,57 m
Lig med:		
Easting	Northing	DVR90
618 849,99	6 253 412,81	2,01 m
Maksimal spredning i målingerne:		
0,0003″ = 0,01	0,0002″ = 0,01 m	0,01 m

Grenaa, den 24.03.2009

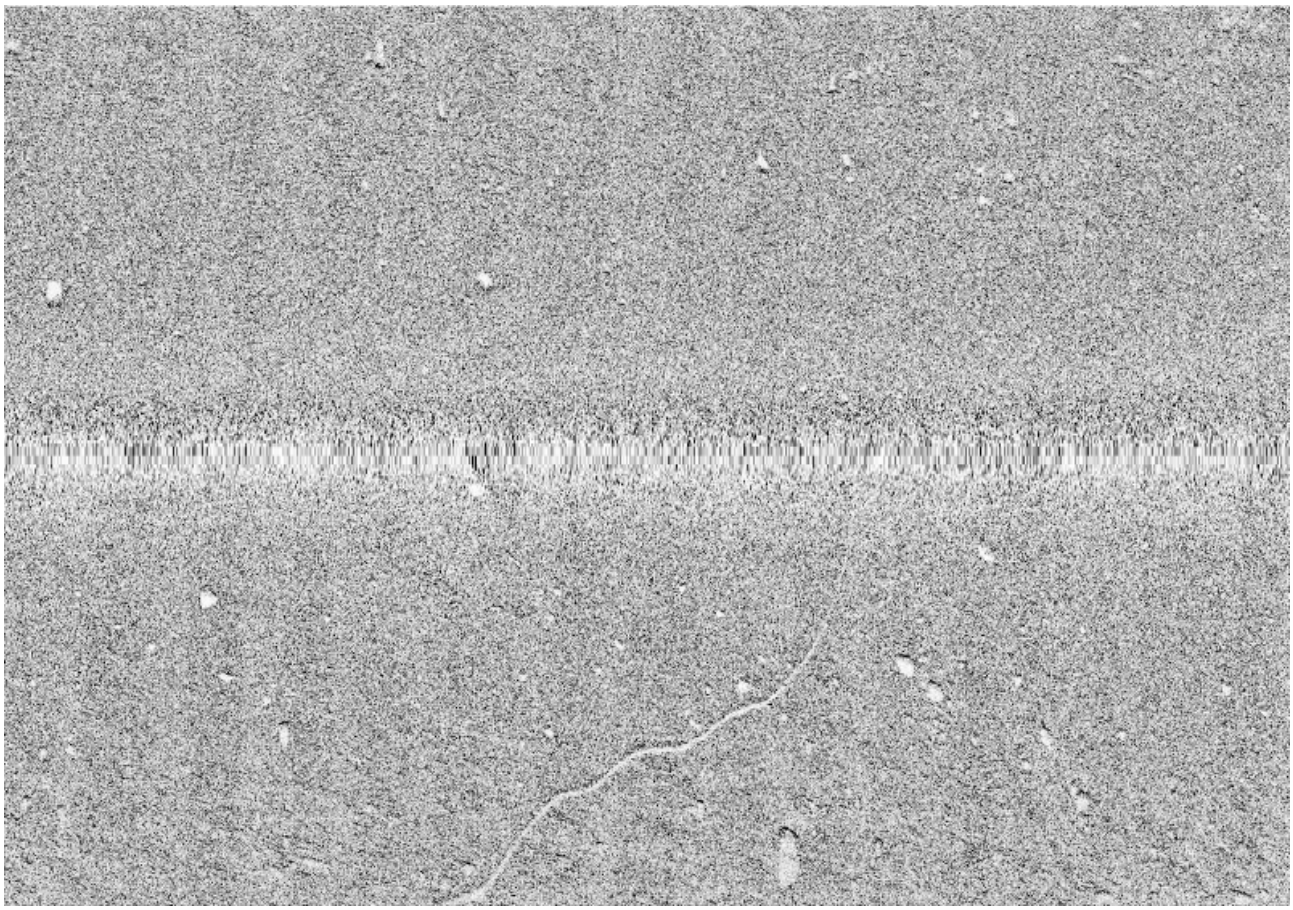
Landinspektør.

Ansvarlige indehavere:
Landinspektørerne
Ole Kjær
Kirsten Nielsen Kjær
Morten Knudsen

Ansatte inspektører:
Allan E. Olesen
Kirsten Coolidge
Vita Glad Petersen

Appendix 5
Unidentified objects from the side scan sonar

Unidentified object



Line debris from the southern corridor at the position: 630529E, 6271612N (EUREF89, UTM zone 32).

Appendix 6
Magnetic anomaly graphs and the matching side scan images

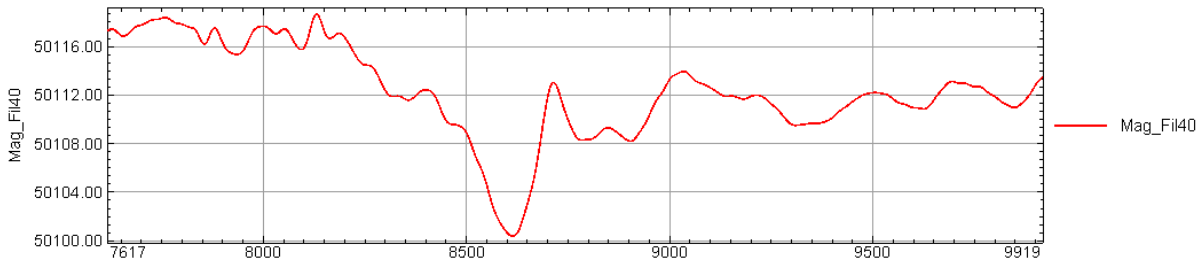
Magnetic Anomalies in Anholt Windfarm Project-Corridors

Jun-09

Instrument used is G-880 Cesium marine magnetometer
Projection: EUREF89, Zone 32N

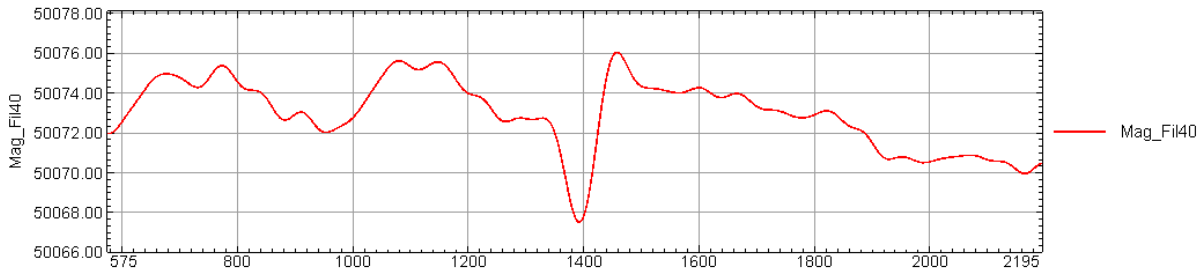
Anom#	Magnitude	Mag-BG	LocalAnor	Easting	Northing	longitude	Lattitude	Line #	R e m a r k s	
103	50265.85	50153.21	112.64	620366.32	6266141.81	10.9566577	56.5242278	AW-COR01A	Part of line corrupted	Minor parallel ripple marks, stones,
135	50100.37	50111.48	-11.11	617944.02	6263980.05	10.9163263	56.5054305	Line-AW-COR5B	negative anomaly	Minor parallel ripple marks, stones, large
137	50067.52	50074.19	-6.67	620832.19	6255339.33	10.9592213	56.4271131	AW-COR04B	negative anomaly	Minor parallel ripple marks, stones, large
138	50133.63	50119.79	13.84	624376.5	6261062.88	11.0193757	56.4775828	AW-COR04A		Minor parallel ripple marks, stones, large

Anomaly 135, Line WP24_L11



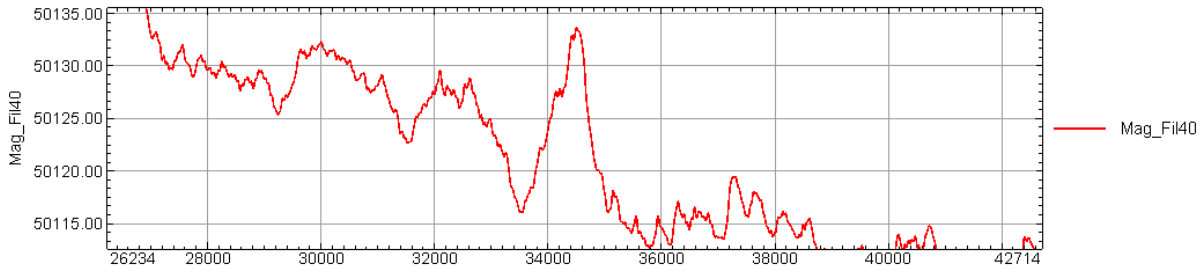
database: I:\marin-og-data02\anholtmagnetometer\An-WP24.gdb line/group: L_AW-COR-5B *2009/06/23*

Anomaly 137, Line WP21_L29

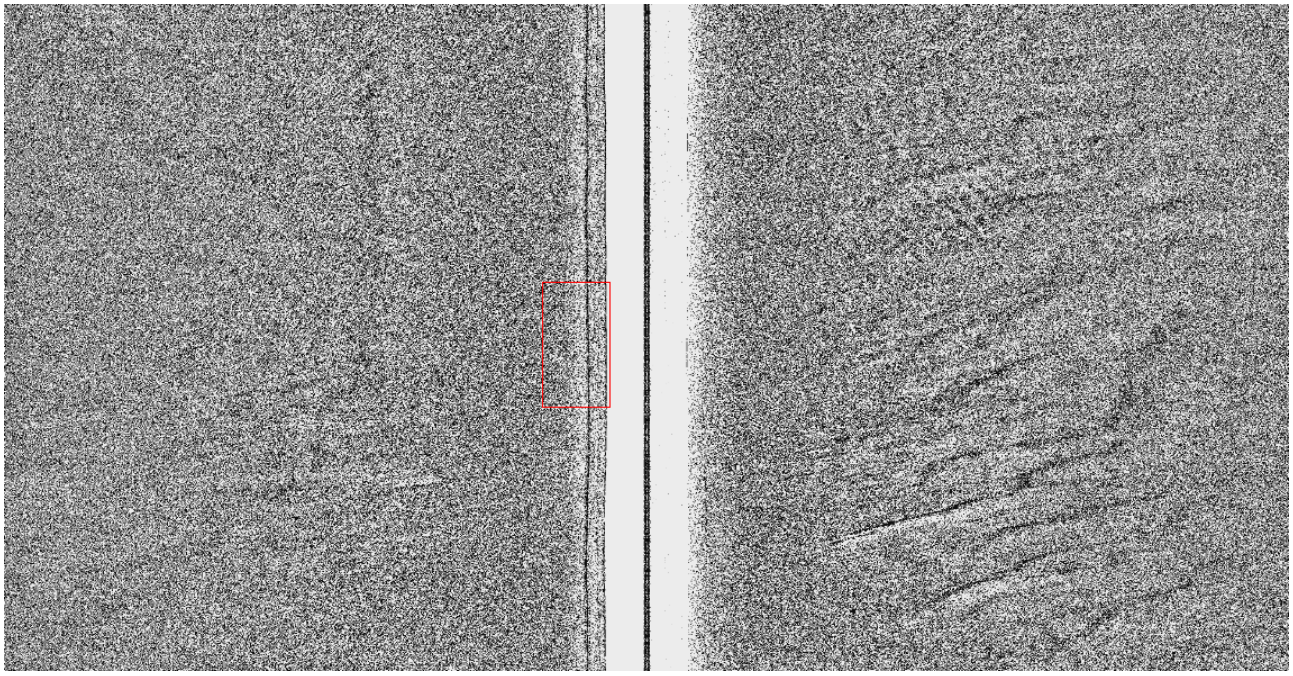


database: I:\marin-og-data02\anholtmagnetometer\An-WP21.gdb line/group: L_AW-COR04B *2009/06/24*

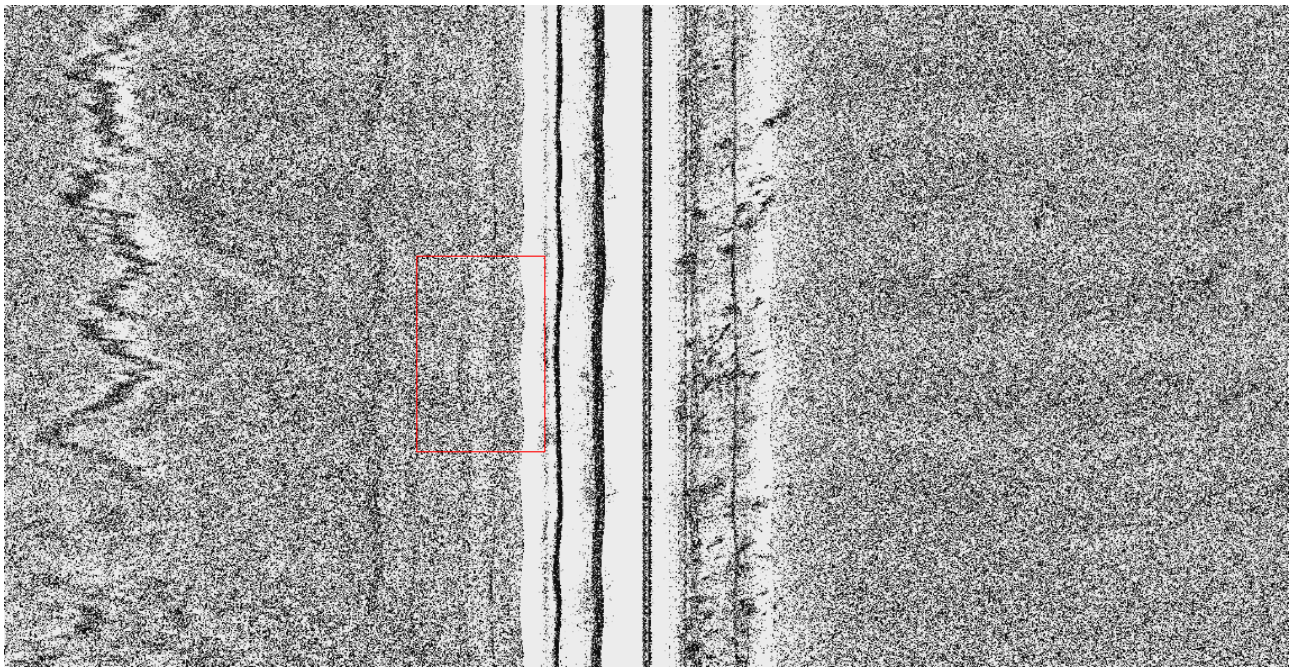
Anomaly 138, Line WP21_L28



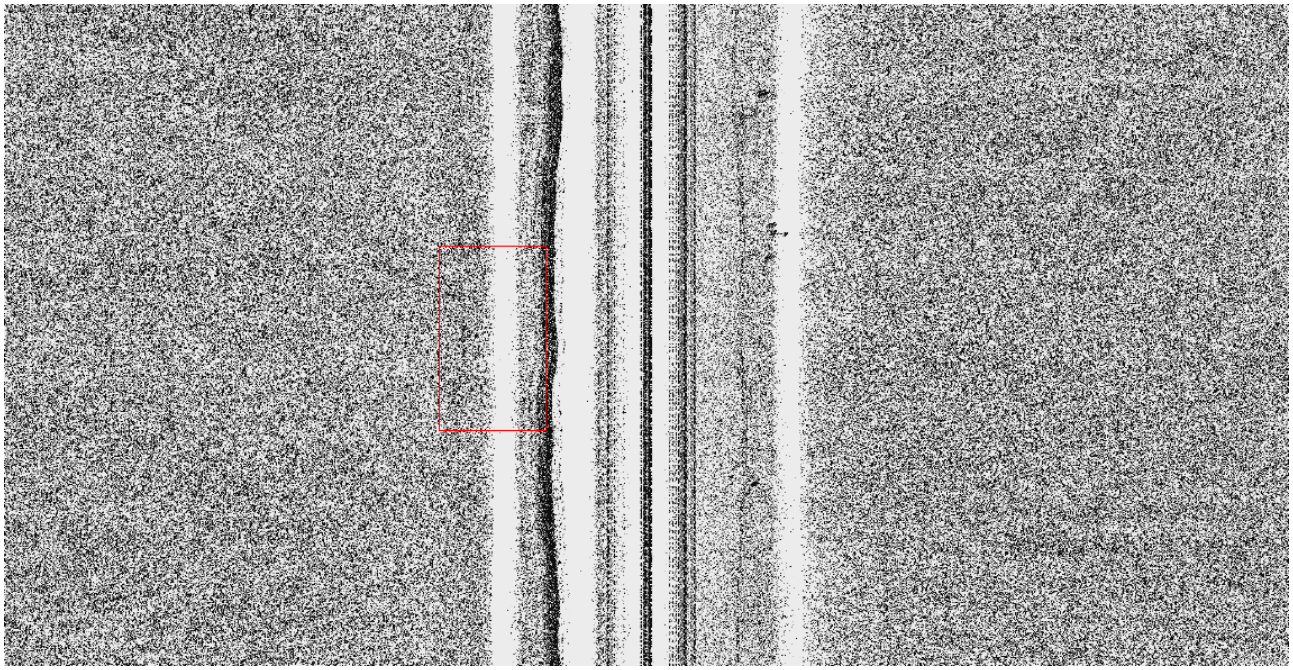
database: I:\marin-og-data02\anholtmagnetometer\An-WP21.gdb line/group: L_AW-COR04A *2009/06/24*



Anomaly 135, Line WP23-L11 (AW-COR05)



Anomaly 137, Line AW-COR04B



Anomaly 138, Line AW-COR04A

Appendix 7
Technical specifications of the equipment

The Geo-Sparker 200 source

Array Depth: Adjustable from 10cm to 40cm below surface.
Array Geometry: Planar configuration of 0.75 x 1.00m for enhanced downward projection of acoustic energy.
Number of active Electrode Modules: (1 - 4) corresponding to 50, 100, 150, or 200 tips can be selected onboard.
Electrode Modules can be used with: Small diameter tip, surface = 0.45 mm^2, for low power per tip Large diameter tips, surface = 2.50 mm^2, for high power per tip.
Energy Level: Recommended max energy per tip in PE mode: 3 Joule / tip for small diameter tips 12.5 Joule / tip for large diameter tips.
Standard Configuration: For use with the Geo-Spark 1000 PPS, a combination of 2 modules with 50 small diameter tips plus 2 modules with 50 large diameter tips.
Primary Pulse Length: Around 0.5 ms.
Dominant Frequencies: Between 500 - 2000 Hz, depending on the selected energy level PE Mode. The Geo-Spark 200 Multi-tip Sparker is specifically designed for operation with the Geo-Spark 1000 High Voltage Pulsed Power Supply in Preserving Electrode Mode. In this patented mode, the electrodes have negative potential with respect to the frame (ground referenced).

Combined Chirp/CW Side Scan Sonar/Sub-bottom profiling system

S P E C I F I C A T I O N S

CL-160 Shipboard Sub-System

Chirp Processing:	Sonar/status control PC based workstation; 5-DSP based sonar matched filter processing channels.
Display:	High resolution video display.
Recording:	Large capacity hard drive, DVD writable, other..
Status Display:	Vehicle pitch, roll, heading (standard); speed, altitude, and depth (optional). Customer input ship position, vehicle position, event marks; all status data recorded.
Sonar Display:	Side scan port, starb; dual channel sub-bottom; all sonar data recorded.
Corrections:	Slant range and speed; beam angle/grazing angle.
Multiplexor:	Digital MUX for coaxial cables (ADSL).
Sonar Data:	up to 5 megabit/sec.
Uplink Status:	9600 bit/sec.
Downlink Command:	9600 bits/sec.
Power Supply:	110/220 VAC autosensing.

Side Scan

Side Scan Transducers:	Multi-element array, dual channel 100/400 kHz 0.5° horizontal beam; 60° vertical beam.
Frequency:	100/400 kHz band swept FM; 4.5 cm resolution.
Processing:	Calibrated transmit waveform stored in ROM; match filter FFT digital signal processing.
Swath Selection:	25 meters to ±500 meters.

Sub-Bottom

Transducer:	Transmit projector array; line array receiving hydrophone; 30° conical radiation pattern.
Frequency:	1 kHz to 10 kHz swept FM (4 KW output), synchronous with side scan.
Resolution:	5 cm.
Processing:	Calibrated transmit waveform stored in ROM; matched filter FFT digital signal processing.
Scale Selection:	25 meters to 500 meters full scale.

TTV-290 Tow Vehicle Sub-System

Depth rating:	2000 meters.
Vehicle Dimensions:	18 inches (45 cm) OD x 64 inches (162.6 cm) long.
Weight:	In air: 300 lbs (136 Kg); in water: 170 lbs (77 Kg).

Kongsberg EM3002D Multibeam sonar

Technical Specifications

Overall specifications per Sonar Head

Frequency: 293, 300 or 307 kHz maximum ping rate: 40 Hz number of beams per ping and sonar head: 160 number of soundings per ping and sonar head: Up to 254 beam width: 1.5 x 1.5 degrees beam spacing: equidistant or equiangular coverage sector: 130 degrees per sonar head transmit beam steering: ±15 degrees in 0.5 degrees steps along track depth resolution: 1 cm pulse length: 150 µs range sampling rate: 14, 14.3 or 14.6 kHz (5 cm) beam forming method: Time delay with dynamic focusing in near-field. Data storage rate: 50 to 400 MB/h (max at about 5-10 m depth) frequencies of 293 and 307 kHz are used in dual sonar head systems. Receive beam width is inversely proportional with the cosine of the beam pointing angle with respect to the sonar head (i.e. beam width is 2.1° at ±45° beam pointing angle and 3.0° at ±60°).

Interfaces

- Serial lines with operator selectable baud rate, parity, data and stop bit length for:
- Motion sensor (roll, pitch, heave and optionally heading) in format supported by sensors from Applied Analytics, Seatex, TSS and IXSEA
- Gyrocompass in either NMEA 0183 HDT or SKR82/LR60 format
- Positions in either Simrad 90, NMEA 0183 GGA or GGK format
- Sonar head depth in Digiquartz compatible format
- External clock in NMEA 0183 ZDA format
- Sound speed sensor in AML Smartprobe format

EM 3002 / Base version

28 855-164929 / B

- Interface for a 1 PPS (pulse per second) clock sync signal
- Ethernet and serial line interface for input of tide and sound speed data and output of all data normally logged to disk.

Physical specifications

Sonar Head

Diameter: 332 mm. Height: 119 mm (+27 mm for connector). Weight: 25 kg (15 kg in water). Pressure rating: 500 m water depth. Diameter of cable to sonar head: 17 mm. Connector: Subconn LPBH9F. Material: Titanium Power: 24 Vdc, 1 A (available from the Processing Unit). A sonar head with pressure rating of 1500 m water depth is available with the same specifications except for height (121 mm) and a restriction in maximum swath width to 3.5 times depth (120° angular coverage sector).

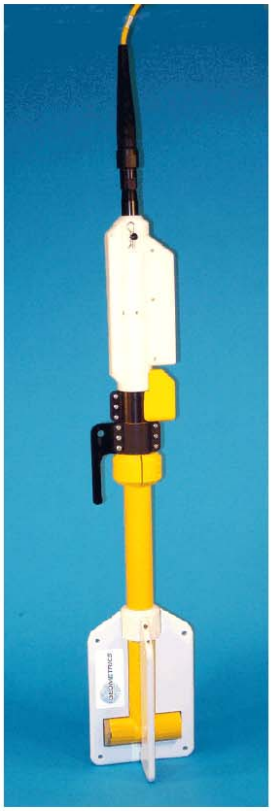
The Geometrics G-882 Magnetometer

Technical specifications

GEOMETRICS

G-882 MARINE MAGNETOMETER

- ***CESIUM VAPOR HIGH PERFORMANCE – Highest detection range and probability of detecting all sized ferrous targets***
- ***NEW STREAMLINED DESIGN FOR TOW SAFETY – Low probability of fouling in lines or rocks***
- ***NEW QUICK CONVERSION FROM NOSE TOW TO CG TOW – Simply remove an aluminum locking pin, move tow point and reinsert. New built in easy carry handle!***
- ***NEW INTERNAL CM-221 COUNTER MODULE – Provides Flash Memory for storage of default parameters set by user***
- ***NEW ECHOSOUNDER / ALTIMETER OPTION***
- ***NEW DEPTH RATING – 4,000 psi !***
- ***HIGHEST SENSITIVITY IN THE INDUSTRY – 0.004 nT/√Hz RMS with the internal CM-221 Mini-Counter***
- ***EASY PORTABILITY & HANDLING – no winch required, single man operation, only 44 lbs with 200 ft cable (without weights)***
- ***COMBINE TWO SYSTEMS FOR INCREASED COVERAGE – Internal CM-221 Mini-Counter provides multi-sensor data concatenation allowing side by side coverage which maximizes detection of small targets and reduces noise***



G-882 with Weight Collar Depth Option & Altimeter

Very high resolution Cesium Vapor performance is now available in a low cost, small size system for professional surveys in shallow or deep water. High sensitivity and sample rates are maintained for all applications. The well proven Cesium sensor is combined with a unique and new CM-221 Larmor counter and ruggedly packaged for small or large boat operation. Use your computer and standard printer with our MagLogLite™ software to log, display and print GPS position and magnetic field data. The G–882 is the lowest priced high performance full range marine magnetometer system ever offered.

The G-882 offers flexibility for operation from small boat, shallow water surveys as well as deep tow applications (4,000 psi rating, telemetry over steel coax available to 10Km). The G-882 also directly interfaces to all major Side Scan manufacturers for tandem tow configurations. Being small and lightweight (44 lbs net, without weights) it is easily deployed and operated by one person. But add several streamlined weight collars and the system can quickly weigh more than 100 lbs. for deep tow applications. Power may be supplied from a 24 to 30 VDC battery power or the included 110/220 VAC power supply. The tow cable employs high strength Kevlar strain member with a standard length of 200 ft (61 m) and optional cable length up to 500m with no telemetry required.

A rugged fiber-wound fiberglass housing is designed for operation is all parts of the world allowing sensor rotation for work in equatorial regions. The shipboard end of the tow cable is attached to an included junction box or optional on-board cable for quick and simple hookup to power and output of data into any Windows 98, ME, NT, 2000 or XP computer equipped with RS-232 serial ports.

The G-882 Cesium magnetometer provides the same operating sensitivity and sample rates as the larger deep tow model G-880. MagLogLite™ Logging Software is offered with each magnetometer and allows recording and display of data and position with Automatic Anomaly Detection and automatic anomaly printing on Windows™ printer! Additional options include: MagMap2000 plotting and contouring software and post acquisition processing software MagPick™ (free from our website.)

The G-882 system is particularly well suited for the detection and mapping of all sizes of ferrous objects. This includes anchors, chains, cables, pipelines, ballast stone and other scattered shipwreck debris, munitions of all sizes (UXO), aircraft, engines and any other object with magnetic expression. Objects as small as a 5 inch screwdriver are readily detected provided that the sensor is close to the seafloor and within practical detection range. (Refer to table at right).

The design of this high sensitivity G-882 marine unit is directed toward the largest number of user needs. It is intended to meet all marine requirements such as shallow survey, deep tow through long cables, integration with Side Scan Sonar systems and monitoring of fish depth and altitude.

Typical Detection Range For Common Objects

Ship 1000 tons	0.5 to 1 nT at 800 ft (244 m)
Anchor 20 tons	0.8 to 1.25 nT at 400 ft (120 m)
Automobile	1 to 2 nT at 100 ft (30 m)
Light Aircraft	0.5 to 2 nT at 40 ft (12 m)
Pipeline (12 inch)	1 to 2 nT at 200 ft (60 m)
Pipeline (6 inch)	1 to 2 nT at 100 ft (30 m)
100 KG of iron	1 to 2 nT at 50 ft (15 m)
100 lbs of iron	0.5 to 1 nT at 30 ft (9 m)
10 lbs of iron	0.5 to 1 nT at 20 ft (6 m)
1 lb of iron	0.5 to 1 nT at 10 ft (3 m)
Screwdriver 5 inch	0.5 to 2 nT at 12 ft (4 m)
1000 lb bomb	1 to 5 nT at 100 ft (30 m)
500 lb bomb	0.5 to 5 nT at 50 ft (16 m)
Grenade	0.5 to 2 nT at 10 ft (3 m)
20 mm shell	0.5 to 2 nT at 5 ft (1.8 m)

MODEL G-882 CESIUM MARINE MAGNETOMETER SYSTEM SPECIFICATIONS

OPERATING PRINCIPLE:	Self-oscillating split-beam Cesium Vapor (non-radioactive)
OPERATING RANGE:	20,000 to 100,000 nT
OPERATING ZONES:	The earth's field vector should be at an angle greater than 6° from the sensor's equator and greater than 6° away from the sensor's long axis. Automatic hemisphere switching.
CM-221 COUNTER SENSITIVITY:	<0.004 nT/ √Hz rms. Up to 20 samples per second
HEADING ERROR:	±1 nT (over entire 360° spin)
ABSOLUTE ACCURACY:	<2 nT throughout range
OUTPUT:	RS-232 at 1,200 to 19,200 Baud
MECHANICAL:	
Sensor Fish:	Body 2.75 in. (7 cm) dia., 4.5 ft (1.37 m) long with fin assembly (11 in. cross width), 40 lbs. (18 kg) Includes Sensor and Electronics and 1 main weight. Additional collar weights are 14lbs (6.4kg) each, total of 5 capable
Tow Cable:	Kevlar Reinforced multiconductor tow cable. Breaking strength 3,600 lbs, 0.48 in OD, 200 ft maximum. Weighs 17 lbs (7.7 kg) with terminations.
OPERATING TEMPERATURE:	-30° F to +122°F (-35°C to +50°C)
STORAGE TEMPERATURE:	-48° F to +158°F (-45°C to +70°C)
ALTITUDE:	Up to 30,000 ft (9,000 m)
WATER TIGHT:	O-Ring sealed for up to 4,000 psi (9000 ft or 2750 m) depth operation
POWER:	24 to 32 VDC, 0.75 amp at turn-on and 0.5 amp thereafter
ACCESSORIES:	
Standard:	View201 Utility Software operation manual and ship kit
Optional:	Telemetry to 10Km coax, gradiometer (longitudinal or transverse), reusable shipping case
MagLog Lite™ Software:	Logs, displays and prints Mag and GPS data at 10 Hz sample rate. Automatic anomaly detection and single sheet Windows printer support

SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE ***12/06***

For additional information on these and other products, contact:

RMS INSTRUMENTS
For Geophysical Exploration

6877-1 Goreway Drive
Mississauga, Ontario
Canada L4V 1L9

Tel: 905.677.5533
Fax: 905.677.5030
Web: www.rmsinst.com
E-mail: rms@rmsinst.com

Motion sensor: Seatex MRU-5

Orientation output data

Angular orientation range	±180°
Angular rate range	150°/s
Resolution in all axes	0.001°
Angular rate noise roll, pitch, yaw	0.025°/s RMS
Accuracy[1, 2] roll, pitch (for a ±5° amplitude)	0.02° RMS
Scale factor error	0.08% RMS

Acceleration sensors

Number of sensors	3
Acceleration range (all axes)	±30 m/s^2
Acceleration noise[2]	0.0020 m/s^2 RMS
Acceleration accuracy	0.01 m/s^2 RMS
Scale factor error	0.020% RMS

Heave motion output

Output range	±50 m, adjustable
Periods	0 to 25 s
Dynamic accuracy	5 cm or 5% whichever is highest

Data output

Analog channels	#4, ±10V, 14 bit resolution
Digital output variables	#16 (max), RS 232 or RS 422
Data output rate (max)	100 Hz
Internal update rate	400 Hz (angular)

Power

Power requirements	12-30V DC, max 8 W

Environment

Temperature range	-5° to +55°C
Humidity range, electronics	Sealed, no limit
Max vibration (operational)	0.5 m/s^2 (10-2000 Hz continuous)
Max vibration (non operational)	20 m/s^2 (0-2000 Hz continuous)
Max shock (non operational)	1000 m/s^2 (10 ms peak)

Other data

MTBF (computed)	50000 h
Housing dimensions	Ø105 x 204 mm (4.134" x 8.051")
Material	Anodised Aluminium
Weight	2.5 kg
Connector	Souriau 851-36RG 16-26S50

Velocity input formats

NMEA 0183, incl. VTG, VHW, VBW or IEEE single precision floating point

Heading input formats

NMEA 0183, HDT, HDM, LR 40 interface or IEEE single precision floating point (unit in radians)

Data output protocols

- MRU normal - Sounder
- Elac Nautik (analog) - Submetrix
- NMEA 0183 proprietary - Sonar R & D Imaging system
- Atlas Fansweep 15/-20 - Simrad EM 1000
- Digital Hippy 120 - Simrad EM 3000
- RDI ADCP - Reson Seabat

1) When the MRU is exposed to a combined two-axes sinusoidal angular motion with 10 minutes duration.

2) When the MRU is stationary over a 30 minutes period.

RTK Navigation system

AD Navigation DC-201 RTK receiver

Technical specifications

Tracking:

20 Channel Dual Constellation (DC) GPS/GLONASS L1/L2
Cold start: < 60 seconds
Warm start: < 10 seconds
Re-acquistion: < 1 second

Processing:

Co-op Tracking and Advanced Multipath Reduction

DC200 Series RTK Positioning[1] and Heading Accuracies[2]:

Horizontal: 1 cm + 0.15 ppm RMS
Vertical: 1.5 cm + 0.15 ppm RMS (DC201/202)
Heading: 0.01 degrees RMS (DC202 only)

Update Rate:

Positioning: 5Hz (DC201/202) 20Hz
Optional Heading: 10Hz (DC202 Only) 20Hz Optional

RTK Initialisation:

Typically 10-30 seconds

Operating Range[3]:

Up to 80 km

Built-in UHF Radio Modem:

Frequency Range: 380-470MHz
25Khz Channel Separation
19,200 bps on Air Transmission
Diversity Reception (Dual Antenna System)

Timing:

External PPS Output
PPS to TTL converted to RS232 Interrupt Signal

Output formats:

GPS based NMEA-0183 Messages
Proprietary ASCII and Binary Output Formats
CMR/RTCM, Differential Corrections

Input Formats:

CMR/RTCM, Differential Corrections

Accessories:

GPS/GLONASS L1/L2 Marine Antenna
AC and DC Power Cables
DB 9 Serial Cables

Physical specifications

Power input: 12-28 VDC or 110-230 AC
Size: 2U 19” rack unit, 254 mm (d), 89 mm (h)

Weight: 4.8 kg
Environmental:
Vibration, EMI: EN 60945
Temperature: Operation: -20 to 55°C
Storage: -40 to 70°C

Communications:

4 x RS232 com ports, DB9, 115,200 bps
1 x RS232 TTL, DB9
1 x PPS output, BNC-F
1 x GPS antenna input, TNC-F (N optional)
2 x UHF antenna input, TNC-F (N optional)

[1]) Performance is dependent on GPS/GLONASS satellite geometry, environment, ionosphere conditions and distance to the base station
[2]) Antenna separation > 10 meter
[3]) Operating range is depending on availability of differential correction dataNote.

RTK Navigation Receiver system

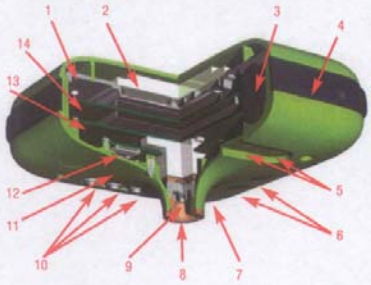
TRIUMPH-1

Standard Configuration

- TRIUMPH-1-G2T/G3T Receiver (0 MB)
- GPS L1/L2/L2C/L5
- GLONASS L1/L2 (G3T only)
- RAIM
- MinPad Interface
- RS232 Serial Port (460.8 kbps)
- Internal GNSS antenna
- Rechargeable Li-Ion Battery

Optional Feature

- Galileo E1/E5A
- Update Rate 1Hz, 5Hz, 10Hz, 20Hz, 50Hz & 100Hz
- RTK Rate 1 Hz, 5Hz, 10Hz, 20Hz, 50Hz & 100Hz
- Data Recording up to 2048MB
- Multi-Base Code Differential Rover
- Code Differential Base
- Advanced Multipath Reduction
- In-Band Interference Rejection
- Event Marker
- 1 PPS timing strobe
- Up to 2 high Speed (460.8 kbps) RS232 Serial Ports
- USB port
- Internal GSM/GPRS/EDGE Module
- Internal UHF Modem
- Ethernet
- Bluetooth® Interface
- Wi-Fi (IEEE 802.11b/g)
- KFK WAAS/EGNOS (SBAS)
- External GNSS Antenna TNC Female connector



1. Ground Plane
2. Internal GNSS Antenna
3. Rechargeable Li-Ion Battery Pack
4. Guard Bumper
5. 1PPS and Event Marker Connectors (optional)
6. On/Off and Control Buttons and LEDs
7. Bluetooth / WiFi Antenna
8. 5/8-11" Mounting Thread
9. UHF / GSM Antenna Connector
10. Communication and Power Ports
11. SIM Card Door
12. User Accessible SIM Card
13. GNSS Receiver and Power Board with on-board Memory
14. GNSS RF and Communication Board with on-board SIM Card

Description	
	Total 216 channels: all-in-view (GPS L1/L2/L2C/L5, Galileo E1/E5A, GLONASS L1/L2, SBAS) integrated receiver, rugged plastic and magnesium housing complete with MinPad interface
Tracking Specification	
Tracking Channels	
TRIUMPH-1-G2T	GPS L1/L2/L2C/L5 Galileo E1/E5A SBAS
TRIUMPH-1-G3T	GPS L1/L2/L2C/L5 Galileo E1/E5A GLONASS L1/L2 SBAS
Signals Tracked	L1/L2 C/A and P Code & Carrier
Performance Specifications	
Autonomous	<2 m
Static, Fast Static Accuracy	Horizontal: 0.3 cm + 0.5 ppm * base_line_length Vertical: 0.5 cm + 0.5 ppm * base_line_length
Kinematic Accuracy	Horizontal: 1 cm + 1 ppm * base_line_length Vertical: 1.5 cm + 1.5 ppm * base_line_length
RTK (OTF) Accuracy	Horizontal: 1 cm + 1 ppm * base_line_length Vertical: 1.5 cm + 1.5 ppm * base_line_length
DGPS Accuracy	< 0.25 m Post Processing < 0.5 m Real Time
Cold Start	<35 seconds
Warm Start	<5 seconds
Reacquisition	<1 second
Power Specification	
Battery	Two internal Li-Ion batteries (7.4 V, 4.4 Ah each) with internal charger
Operation Time	Up to 15 hours
External Power Input	+10 to +30 volts
GNSS Antenna Specifications	
GNSS Antenna	Integrated
Antenna Type	Microstrip (Zero Centered)
Ground Plane	Antenna on a flat ground plane
Radio Specifications	
GSM/GPRS/EDGE Module	Internal GSM/GPRS/EDGE quad-band module, GPRS/EDGE Class 10
UHF Radio Modem	Internal 406-470MHz radio transceiver, up to 38.4kbps
Base Power Output	1 Watt
I/O	
Communication Ports	2x serial (RS232) up to 460.8 kbps High speed USB 2.0 device port (480 Mbps) Full-duplex 10BASE-T/100BASE-TX Ethernet port Wi-Fi (IEEE 802.11b/g) Bluetooth V2.0+EDR Class 2 supporting SPP Slave and Master Profiles
Other I/O Signals	1 PPS synchronized Event Marker
Status Indicator	Six LEDs, two function keys (MinPad)
Memory & Recording	
Internal Memory	Up to 2048MB of onboard non-removable memory for data storage
Raw Data Recording	Up to 100 times per second (100Hz)
Data Type	Code and Carrier from GPS L1/L2, Galileo E1/E5A, GLONASS L1/L2 (G3T only)
Data Output	
Real time data outputs	RTCM SC104 versions 2.x and 3.x Input/Output
ASCII Output	NMEA 0183 versions 2.x and 3.0 Output
Output Rate	Code and Carrier
Environmental Specifications	
Enclosure	Molded magnesium alloy and plastic, waterproof IP67
Operating Temperature	-30° C to +55° C
Storage Temperature	-20° C to +45° C
Dimensions	W:178 mm x H:96 mm x D:178 mm
Weight	1700 g

Specifications are subject to change without notice.

JAVAD GNSS

www.javad.com

Rev.1.1 February 5, 2009

Appendix 8
Geodetic definitions

SURVEY DEFINITIONS

General Definitions

Line sequence number	:	1
Line description	:	Ramboell Windfarm pre-survey
Project identifier	:	GEUS2009
Start date of survey	:	
End date of survey	:	
Date of issue	:	
Prepared by	:	
Format name	:	
Format revision code	:	0.0

UTC to GPS time correction	:	15.00 s
Survey Unit Name	:	Meters
Conversion factor to meters	:	1.00000000

Geodetic Definitions

Magnetic Variation Information

Undefined

Datum Definitions

Survey Datum	:	ETRS89 (EUREF89)
Spheroid name	:	GRS 1980
Semi-major axis (a)	:	6378137.000 m
Semi-minor axis (b)	:	6356752.314 m
Conversion factor to meters	:	1.000000
Inverse flattening (1/f)	:	298.25722210
First eccentricity (e**2)	:	0.00669438
Second eccentricity (e'**2)	:	0.00673950

Datum Shift Definitions

Undefined

Height Datum Definition

Vertical datum	:	DKGEOID02 (Denmark)
Height file	:	DKGEOID02.BIN
Height level	:	No Level Correction
Height file	:	N/A
Height offset	:	0.000 m
MSL model	:	DKGEOID02 (Denmark)
MSL file	:	DKGEOID02.BIN
MSL level	:	No Level Correction
MSL file	:	N/A
MSL offset	:	0.000 m
MSL st.dev.	:	0.002 m
DTM mode	:	Absolute DTM's
DTM datum	:	DKGEOID02 (Denmark)
DTM file	:	DKGEOID02.BIN
DTM level	:	No Level Correction
DTM file	:	N/A
DTM offset	:	0.000 m

Projection Definition

Projection type	:	001
Projection name	:	Universal Transverse Mercator (North Oriented)
Conversion factor to meters	:	1.000000
UTM zone number	:	32
Latitude of grid origin	:	0;00;00.000 N
Longitude of grid origin	:	9;00;00.000 E
Grid Easting at grid origin	:	500000.000 E
Grid Northing at grid origin	:	0.000 N
Scale factor at longitude of origin	:	0.999600

Local Construction Grid Definition

Not Applicable

Offset Convention

Offset mode	:	Rectangular
Offset distances units	:	Meters
Offset angles units	:	Degrees

OBJECT DEFINITIONS

General Summary Information

Number of survey vessels or objects	:	1
Number of relay vessels or buoys	:	0
Number of external network nodes	:	0
Number of datums/spheroids defined	:	1

Vessel Definitions

Madog

Streamers	:	0	Gun arrays	:	0
Buoys	:	0	Echosounders	:	0
Satellite receivers	:	0	USBL systems	:	0
Network nodes	:	4	Pitch/Roll/Heave sensors		

Correction to GMT : 0.00 h
Correction to master vessel's time : 0.000000 s

Height above draft reference : -2.703 m
Madog CoG

SHAPE	Point	X	Y	Z	Pen	Fill	Style
	1	0.0	0.0	0.0	Up	On	Solid
	2	-2.2	-2.5	0.0	Down	On	Solid
	3	-2.8	-4.0	0.0	Down	On	Solid
	4	-3.5	-6.0	0.0	Down	On	Solid
	5	-3.5	-17.0	0.0	Down	On	Solid
	6	-2.9	-31.5	0.0	Down	On	Solid
	7	2.8	-31.5	0.0	Down	On	Solid
	8	3.5	-17.0	0.0	Down	On	Solid
	9	3.5	-6.0	0.0	Down	On	Solid
	10	2.8	-4.0	0.0	Down	On	Solid
	11	2.2	-2.5	0.0	Down	On	Solid

Gun Array Definitions

NETWORK DEFINITIONS

Fixed Node Definitions

Variable Node Definitions

Madog CoG

Object location	:	Madog	
X (Stbd = Positive):	:		0.000 m
Y (Bow = Positive):	:		0.000 m
Z (Up = Positive):	:		0.000 m

AD201 RTK

Object location	:	Madog	
X (Stbd = Positive):	:		0.000 m
Y (Bow = Positive):	:		2.000 m
Z (Up = Positive):	:		8.150 m

STBD EM3002 HEAD

Object location	:	Madog	
X (Stbd = Positive):	:		0.200 m
Y (Bow = Positive):	:		0.250 m
Z (Up = Positive):	:		-0.200 m

PORT EM3002 HEAD

Object location	:	Madog	
X (Stbd = Positive):	:		-0.200 m
Y (Bow = Positive):	:		0.250 m
Z (Up = Positive):	:		-0.200 m

Observation Definitions

Sound Velocity	:	Sound Velocity
"At" node	:	STBD EM3002 HEAD
Measurement unit code	:	Meters / Second
System description	:	AML SV
Propagation speed	:	0.0000000000 m/s
Lanewidth on baseline	:	0.0000000000 m/s
Scale factor	:	1.0000000000
Fixed system (C-O)	:	0.00000000 m/s
Variable (C-O)	:	0.000000 m/s
A priori SD	:	0.05 m/s
Maximum age	:	0.00 m/s
Quality indicator	:	No quality info recorded

AD RTK Heading	:	Bearing (True)
"At" node	:	Madog CoG
"To" node 1	:	
Measurement unit code	:	Degrees
System description	:	AD201 RTK Heading
Propagation speed	:	0.0000000000 m/s
Lanewidth on baseline	:	0.0000000000 m/s
Scale factor	:	1.0000000000
Fixed system (C-O)	:	0.00000000 °
Variable (C-O)	:	0.000000 °
A priori SD	:	0.50 °
Maximum age	:	0.00 °
Quality indicator	:	No quality info recorded

Vessel Gyro	:	Bearing (True)
"At" node	:	Madog CoG
"To" node 1	:	
Measurement unit code	:	Degrees
System description	:	Vessel Gyro
Propagation speed	:	0.0000000000 m/s
Lanewidth on baseline	:	0.0000000000 m/s
Scale factor	:	1.0000000000
Fixed system (C-O)	:	0.00000000 °
Variable (C-O)	:	0.000000 °
A priori SD	:	0.50 °
Maximum age	:	0.00 °
Quality indicator	:	No quality info recorded

Reference Station Definitions

SYSTEM DEFINITIONS

Position Navigation System

AD 202 RTK

Interfacing

Type	:	Position Navigation System			
Driver	:	NMEA Position (GPGGA)			
Executable and Cmdlin	:	DrvNMEA0183.exe MSL			
Port	:	7			
Baud rate	:	19200	Data bits	:	8
Parity	:	None	Stop bits	:	1
Update rate	:	0.000 s	Latency	:	0.000 s

Satellite System Definition

Position datum	:	ETRS89 (EUREF89)
Satellite system name	:	ETRS89 (E

Satellite Receiver Definition

Receiver number	:	0
Receiver description	:	
Node identifier	:	AD201 RTK
Object location	:	Madog
X (Stbd = Positive):	:	0.000 m
Y (Bow = Positive):	:	2.000 m
Z (Up = Positive):	:	8.150 m
Horizontal datum	:	ETRS89 (EUREF89)
Vertical datum	:	ETRS89 (EUREF89)
Height file	:	N/A
Height level	:	No Level Correction
Height file	:	N/A
Height offset	:	0.000 m

Connected Observations

Connected Nodes

Pitch Roll Heave Sensor

MRU5

Interfacing

Type	:	Pitch Roll Heave Sensor			
Driver	:	Simrad EM3000 R-P-H			
Executable and Cmdlin	:	DrvSimradMRU.exe EM3000			
Port	:	5			
Baud rate	:	19200	Data bits	:	8
Parity	:	None	Stop bits	:	1
Update rate	:	0.000 s	Latency	:	0.000 s

System Parameters

MRU5

Object	:	Madog
Location on object (Lever arm)	:	Madog CoG
PRH sensor reference number	:	1
Rotation convention pitch	:	Positive bow up
Rotation convention roll	:	Positive heeling to starboard
Angular variable measured	:	HRP (pitch first)
Angular measurement units	:	Degrees
Sign convention heave	:	Positive upwards
Measurement units heave	:	Meters
Quality indicator type pitch and roll	:	No quality info recorded
Quality indicator type heave	:	No quality info recorded
(C-O) pitch offset	:	0.000000
(C-O) roll offset	:	0.000000
(C-O) heave offset	:	0.000000

Description of pitch, roll and heave system

MRU5

Offset System

Offset System

Interfacing

Type	:	Offset System
Driver	:	Unknown Driver (0)
Executable and Cmdlin	:	

Gyro Compass

Madog Heading

Interfacing

Type	:	Gyro Compass			
Driver	:	NMEA Compass ($--HDT)			
Executable and Cmdlin	:	DrvGyroNMEA.exe 8			
Port	:	8			
Baud rate	:	19200	Data bits	:	8
Parity	:	None	Stop bits	:	1
Update rate	:	0.000 s	Latency	:	0.000 s

Connected Observations

AD RTK Heading	:	Bearing (True)

Connected Nodes

Madog CoG	:	Madog

Multibeam Echosounder

EM3002D_PORT

Interfacing

Type	:	Multibeam Echosounder
Driver	:	Simrad EM3002 (R-Theta Format)
Executable and Cmdlin	:	DrvSimradEM3000.exe 0
Port	:	16101

System Parameters

EM3002D_PORT

Object	:	Madog
Number of transducers	:	Single
Transducer node TX	:	PORT EM3002 HEAD
Heading offset	:	-0.250 °
Roll offset	:	40.130 °
Pitch offset	:	1.370 °
Maximum number of beams per ping	:	508
Unit is roll stabilized	:	No
Unit is pitch stabilized	:	No
Unit is heave compensated	:	No
Use sound velocity from unit	:	Yes

Underwater Sensor

AML SV

Interfacing

Type	:	Underwater Sensor			
Driver	:	Sound Velocity - Smart SV (AML, ASCII) (Active)			
Executable and Cmdlin	:	DrvSoundVelocity.exe ACT			
Port	:	10			
Baud rate	:	19200	Data bits	:	8
Parity	:	None	Stop bits	:	1
Update rate	:	0.000 s	Latency	:	0.000 s

Connected Observations

Sound Velocity	:	Sound Velocity

Connected Nodes

STBD EM3002 HEAD	:	Madog

Multibeam Echosounder

EM3002D_STBD

Interfacing

Type	:	Multibeam Echosounder
Driver	:	Simrad EM3002D Head II (R-Theta Format)
Executable and Cmdlin	:	DrvSimradEM3000.exe 0 DII
Port	:	16103

System Parameters

EM3002D_STBD

Object	:	Madog
Number of transducers	:	Single
Transducer node TX	:	STBD EM3002 HEAD
Heading offset	:	-0.250 °
Roll offset	:	-40.230 °
Pitch offset	:	1.470 °
Maximum number of beams per ping	:	508
Unit is roll stabilized	:	No
Unit is pitch stabilized	:	No
Unit is heave compensated	:	No
Use sound velocity from unit	:	Yes

Gyro Compass

Vessel Gyro

Interfacing

Type	:	Gyro Compass			
Driver	:	NMEA Compass ($--HDT)			
Executable and Cmdlin	:	DrvGyroNMEA.exe 8			
Port	:	12			
Baud rate	:	4800	Data bits	:	8
Parity	:	None	Stop bits	:	1
Update rate	:	0.000 s	Latency	:	0.000 s

Connected Observations

Vessel Gyro	:	Bearing (True)

Connected Nodes

Madog CoG	:	Madog

Output System

Autopilot

Interfacing

Type	:	Output System			
Driver	:	AutoPilot (with turning track) - NMEA APA			
Executable and Cmdlin	:	DrvOutAutoPilotUI.exe NMEA_APA			
Port	:	9			
Baud rate	:	4800	Data bits	:	8
Parity	:	None	Stop bits	:	1
Update rate	:	1.000 s	Latency	:	0.000 s

PPS System

PPS

Interfacing

Type	:	PPS System			
Driver	:	NMEA $GP PPS (COM1)			
Executable and Cmdlin	:	DrvPpsNMEA.exe 1			
Port	:	6			
Baud rate	:	19200	Data bits	:	8
Parity	:	None	Stop bits	:	1
Update rate	:	0.000 s	Latency	:	0.000 s

Appendix 9
Documentation of sound velocity data

- **Documentation of reliability of data illustrated by figures (instrument calibration, sound velocity etc.)**

Report of the multibeam patch test carried out on the 5th of May 2009 is rendered as a separate document.

Reports on other peripheral equipment rests with GEUS.

Due to severe variations over time as well as geographically of the speed of sound in the water masses there are some visible artefacts in the data caused by insufficient refraction correction.

During the entire project sound velocity profiles were obtained as often as practical possible in order to compensate for the variation in refraction. Throughout the project 91 soundvelocity profiles were measured.

All profiles were used in the QINSy Sound Velocity Manager in a table correction algorithm on each individual sounding point

Two main arguments were used in the processing:

A) Time from sound velocity cast
B) Range from cast position to depth point'

Method description:

When the sounding of a ping is processed the time is taken into account as well as the position with respect to one or more stations.

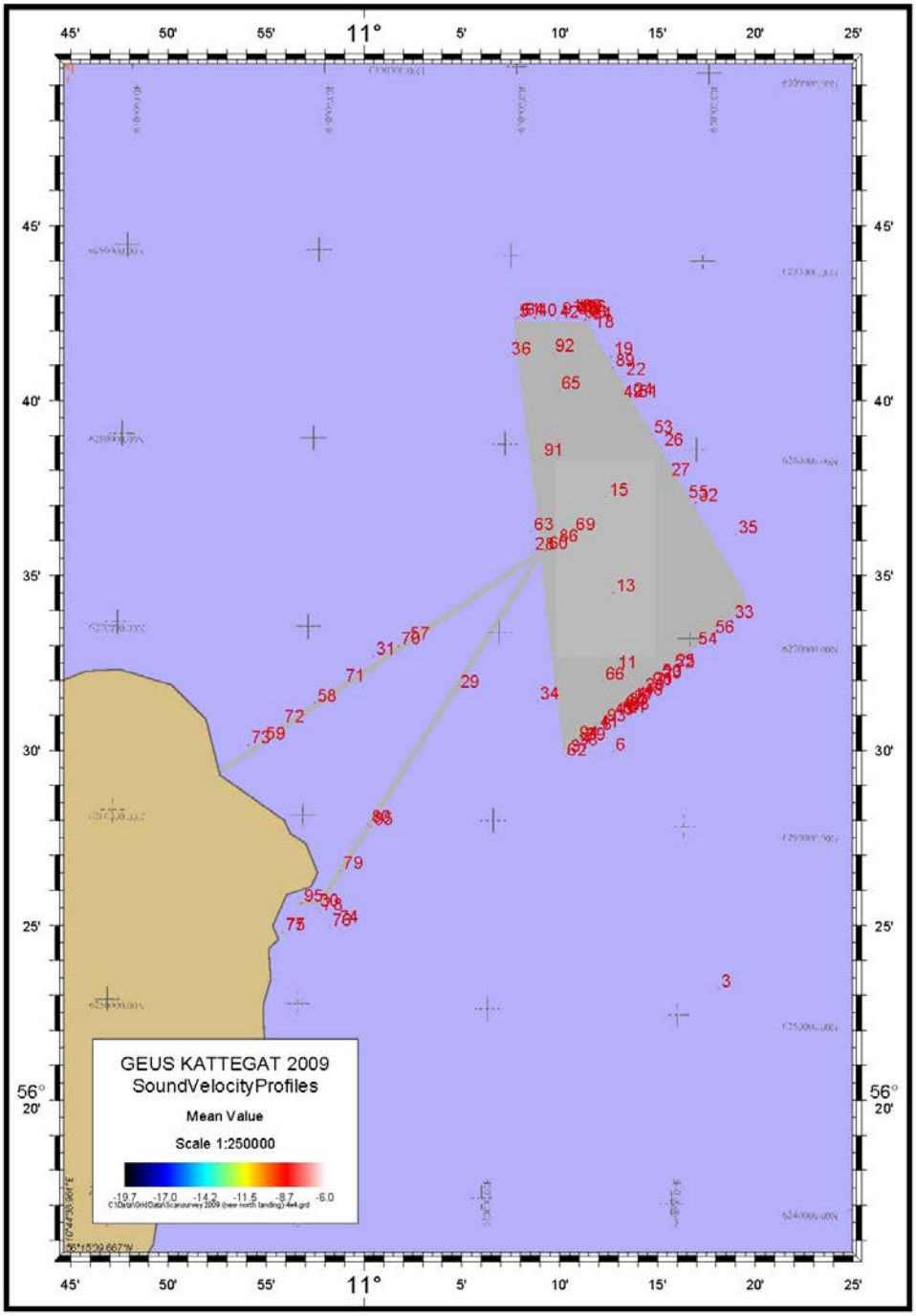
In detail:

- The user sets up a definition file and a SVP profile database. All the profiles that are to be taken into account are imported into the selected database (for this project 91 profiles).
  The position and acquisition times of the profiles were set as input parameter.
- The processor will first assign profiles to stations based on the search range, the position of the station and the profile positions. All profiles that lie within search range of the station are assigned to it. If search ranges overlap then it is assigned to multiple stations. The processor maintains a list of profiles per station.
- The processor sort the list of profiles per station on acquisition (cast) time, incrementing order. This is the basis for the profile interpolation algorithm.
- The processor then step through the QPDs and process the pings within. A virtual svp profile is calculated every 10 seconds. The time base of course is the time within the QPD not the actual time. This virtual profile is used for the ray tracing of the footprints.
- Profile Interpolation (pass 1)
  A ping with time T and position P is to be processed now. First for every station an interpolated profile is created based on time T. The validity time is taken into account as well. So this delivers for every station a profile but since we require a single virtual profile as input for the ray tracing another interpolation is carried out.
- Profile Interpolation (pass 2)
  This interpolation makes from the multiple profiles per station one single interpolated profile.

  Range to station Every stations' profile is granted a weight of 1/(distance station to ping) and the result will be the mean profile weighted on distance.

- Finally with the virtual svp the ray tracing algorithm is executed for each footprint. Results are stored in the validated footprints.

Overview and list of sound velocity profiles in use:

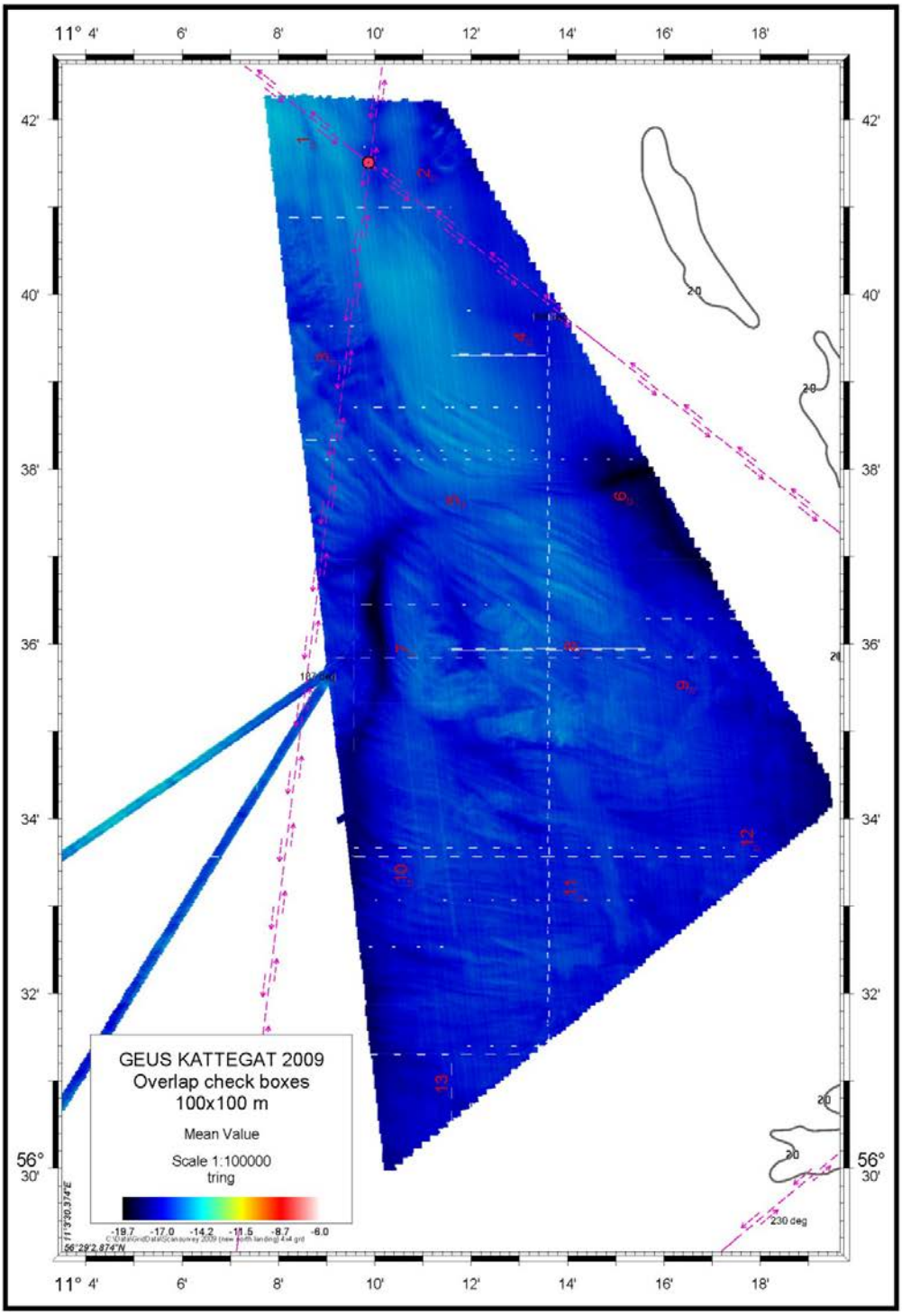


File name	Date	Time	Easting	Northing	File name	Date	Time	Easting	Northing
"svp3"	20/04/09	20:50:36	642129	6251479	"svp50"	02/05/09	03:29:08	638465	6267829
"svp4"	22/04/09	14:00:14	642129	6251479	"svp51"	02/05/09	05:22:12	636748	6282595
"svp5"	22/04/09	19:15:16	630361	6286662	"svp52"	02/05/09	10:42:00	639109	6268339
"svp6"	23/04/09	07:14:02	634195	6263854	"svp53"	02/05/09	12:09:48	637625	6280739
"svp7"	23/04/09	13:08:16	634492	6264305	"svp54"	02/05/09	18:35:34	640299	6269591
"svp8"	24/04/09	03:00:04	635438	6264909	"svp55"	02/05/09	19:52:06	639437	6278120
"svp9"	24/04/09	10:19:44	623612	6286842	"svp56"	02/05/09	22:58:32	641152	6270249
"svp10"	24/04/09	17:00:58	633158	6287047	"svp57"	03/05/09	03:56:04	625218	6269412
"SVP11"	24/04/09	19:40:44	636146	6268212	"svp58"	03/05/09	04:52:38	620445	6265954
"svp12"	24/04/09	23:33:30	633348	6286989	"svp59"	03/05/09	06:13:38	617807	6263872
"svp13"	25/04/09	01:19:56	635913	6272290	"svp60"	03/05/09	09:05:02	632309	6274408
"svp14"	25/04/09	02:56:46	636672	6266244	"svp61"	03/05/09	10:10:38	630499	6286722
"svp15"	25/04/09	04:23:16	635384	6277349	"SVP62"	03/05/09	12:18:00	633631	6263451
"svp16"	25/04/09	06:09:20	633869	6287001	"svp63"	03/05/09	13:32:20	631532	6275372
"svp17"	25/04/09	08:57:10	637030	6266543	"svp64"	03/05/09	14:48:28	630707	6286738
"svp18"	25/04/09	12:56:36	634345	6286193	"svp65"	03/05/09	17:09:32	632727	6282897
"svp19"	25/04/09	15:39:26	637603	6267036	"svp66"	03/05/09	19:23:54	635509	6265221
"svp20"	25/04/09	22:29:48	635391	6284803	"svp67"	03/05/09	23:15:38	636469	6265792
"svp21"	26/04/09	01:41:20	638056	6267380	"svp68"	04/05/09	01:13:44	633458	6286872
"svp22"	26/04/09	03:45:58	636067	6267380	"svp69"	04/05/09	02:23:32	633703	6275458
"svp23"	26/04/09	06:07:42	638475	6267721	"svp70"	04/05/09	03:28:16	624755	6269096
"svp24"	26/04/09	08:17:10	636508	6282693	"svp71"	04/05/09	04:05:08	621893	6267051
"svp25"	26/04/09	13:20:42	639157	6268371	"svp72"	04/05/09	04:41:48	618764	6264793
"svp26"	26/04/09	18:09:22	638176	6280097	"svp73"	04/05/09	05:32:00	617046	6263637
"svp27"	27/04/09	02:11:06	638578	6278503	"svp74"	04/05/09	06:07:44	622972	6267938
"svp28"	27/04/09	03:01:06	631596	6274358	"svp75"	05/05/09	11:46:38	619125	6253767
"svp29"	27/04/09	04:52:54	627920	6266896	"svp76"	05/05/09	12:05:02	621576	6254076
"svp30"	27/04/09	06:57:32	620885	6255094	"svp77"	05/05/09	14:39:38	619124	6253797
"svp31"	27/04/09	16:47:40	623445	6268519	"svp78"	07/05/09	17:28:22	621065	6254880
"svp32"	28/04/09	00:41:58	640066	6277192	"svp79"	07/05/09	18:05:32	622077	6257123
"svp33"	28/04/09	05:07:16	642157	6271056	"svp80"	07/05/09	18:51:30	623459	6259626
"svp34"	28/04/09	16:03:08	632130	6266429	"svp81"	07/05/09	20:02:14	636607	6265746
"svp35"	28/04/09	22:25:40	642225	6275564	"svp82"	07/05/09	22:10:56	633753	6286783
"svp36"	29/04/09	04:49:50	630056	6284641	"svp83"	08/05/09	00:34:20	636767	6266261
"svp37"	29/04/09	08:27:00	633792	6263683	"svp84"	08/05/09	02:28:20	634203	6286660
"svp38"	29/04/09	14:10:32	634218	6264638	"svp85"	09/05/09	21:44:58	623601	6259503
"svp39"	29/04/09	19:52:10	634599	6264347	"svp86"	09/05/09	23:03:34	632818	6274776
"svp40"	29/04/09	22:51:32	631349	6286729	"svp87"	10/05/09	00:37:50	633775	6286733
"svp41"	30/04/09	07:03:12	635277	6265034	"svp88"	10/05/09	02:25:46	636840	6266014
"svp42"	30/04/09	09:49:50	632504	6286694	"svp89"	10/05/09	04:23:48	635502	6284200
"svp43"	30/04/09	17:46:06	636031	6265725	"svp90"	10/05/09	05:55:28	637986	637986
"svp44"	30/04/09	22:58:22	636405	6265994	"svp91"	10/05/09	12:19:46	631919	6279336
"svp45"	01/05/09	01:37:48	633520	6286889	"svp92"	10/05/09	13:37:42	632320	6284884
"svp46"	01/05/09	07:15:38	633973	6286724					
"svp47"	01/05/09	09:58:16	637183	6266582					
"svp48"	01/05/09	14:59:02	637536	6266812					
"svp49"	01/05/09	21:16:58	635682	6284247					

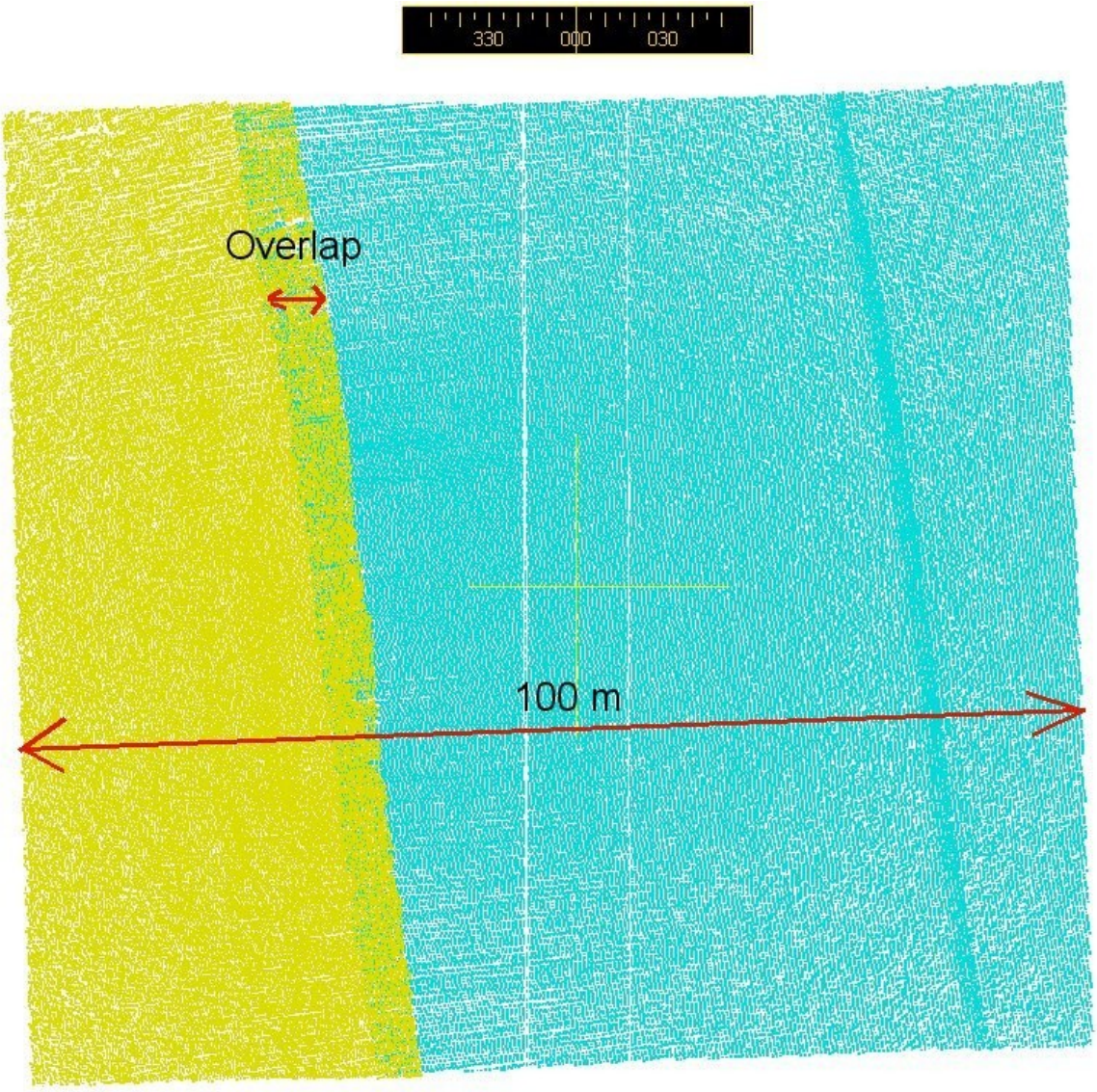
Appendix 10
Documentation of multibeam survey line spacing

- **Documentation of survey line spacing 10% overlap**

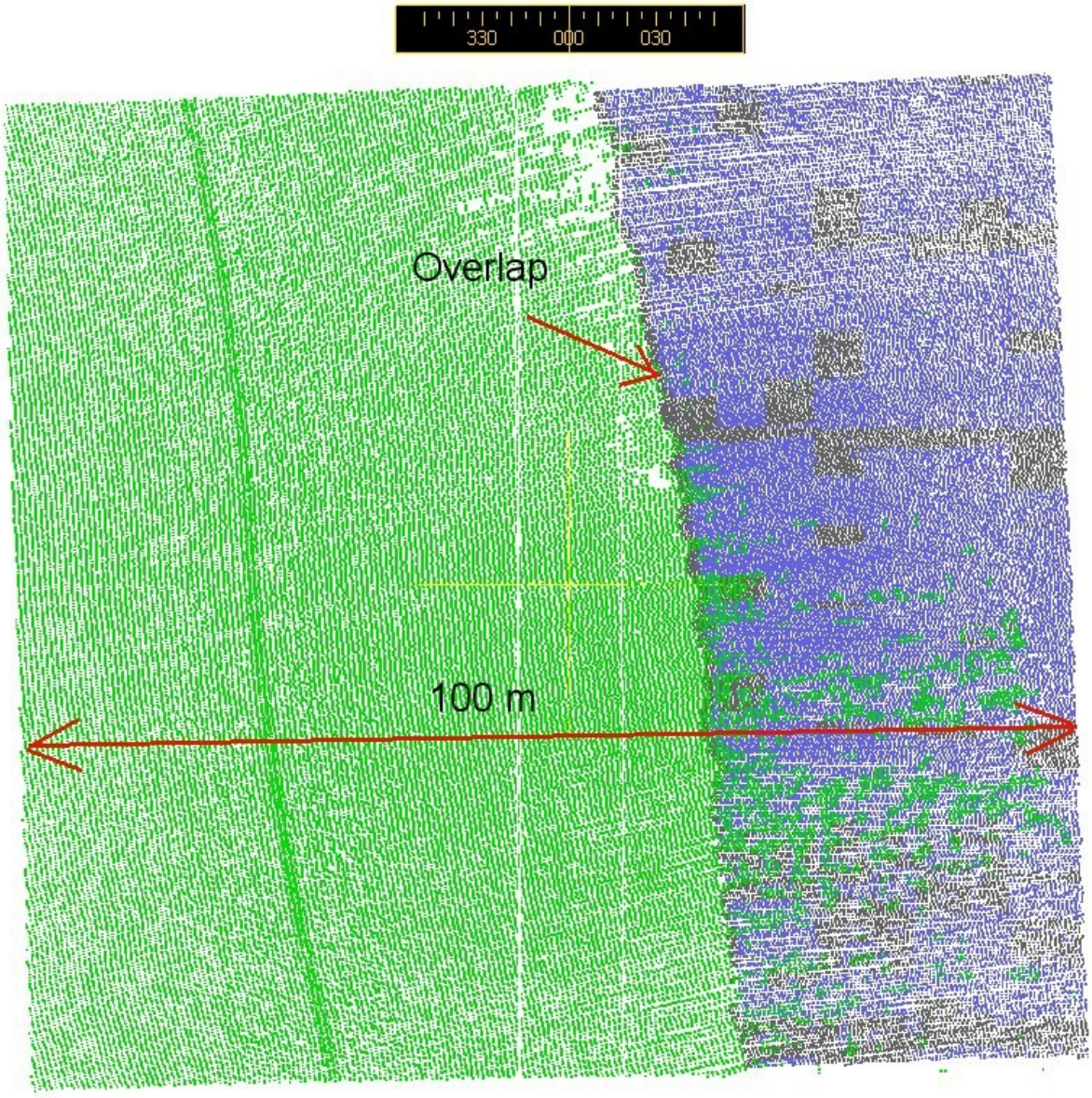
13 100x100 meter boxes were randomly chosen in the main survey area for illustration and documentation of the general overlap between adjacent survey lines.
The outer 7 beams on either side has been deselected in order to show the accurate and unambiguous overlap throughout the area.



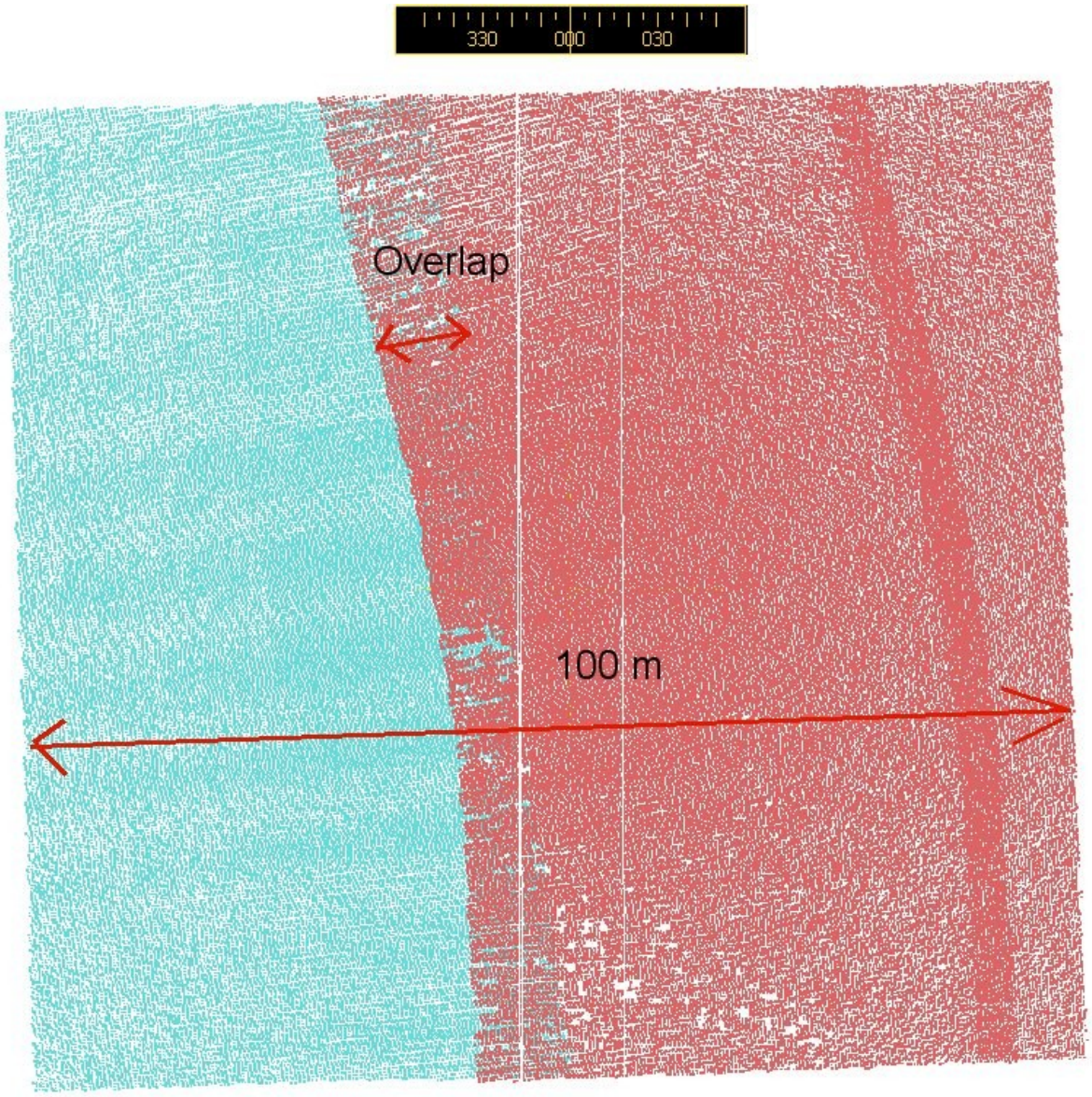
Selection area 1



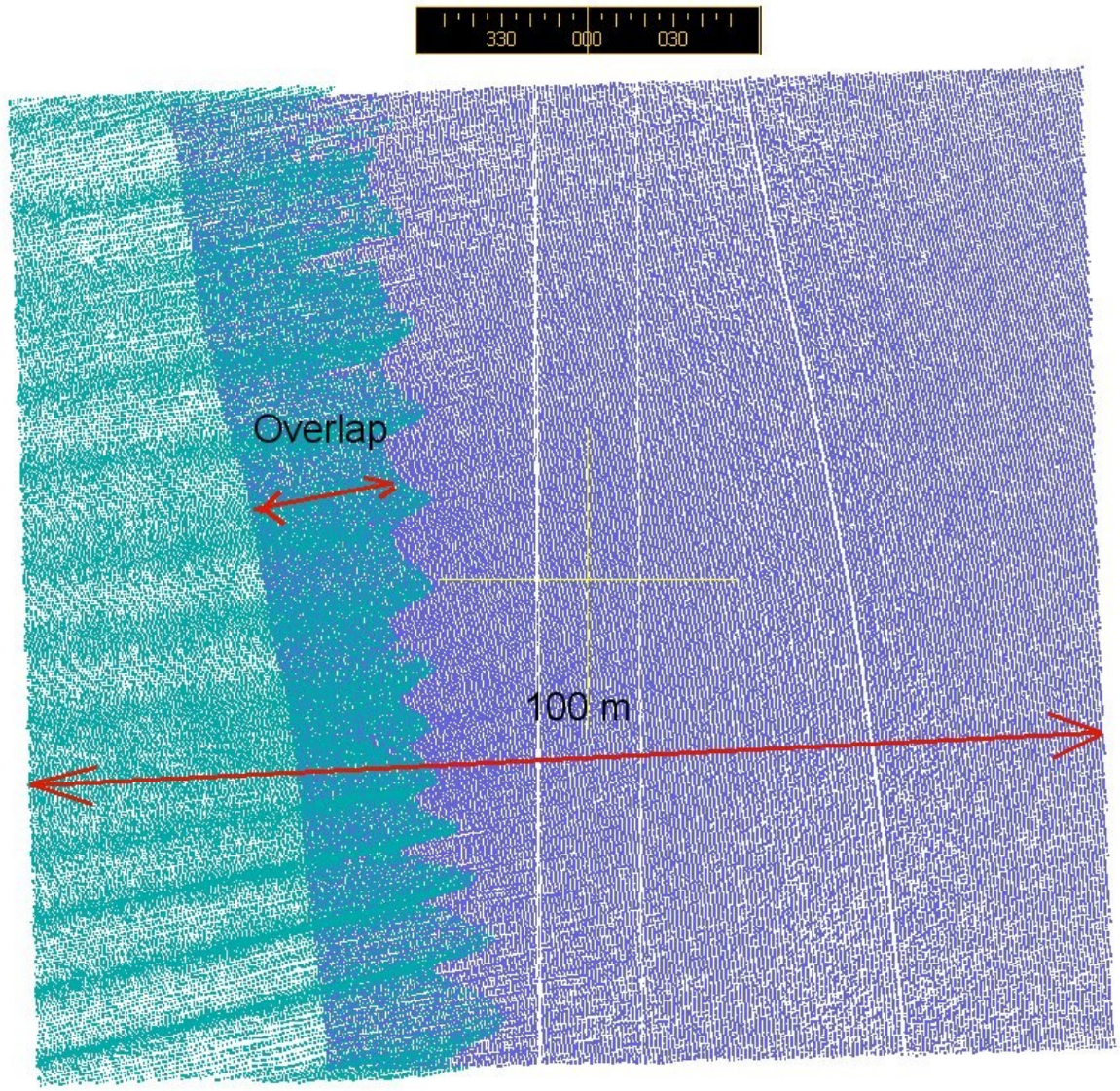
Selection area 2



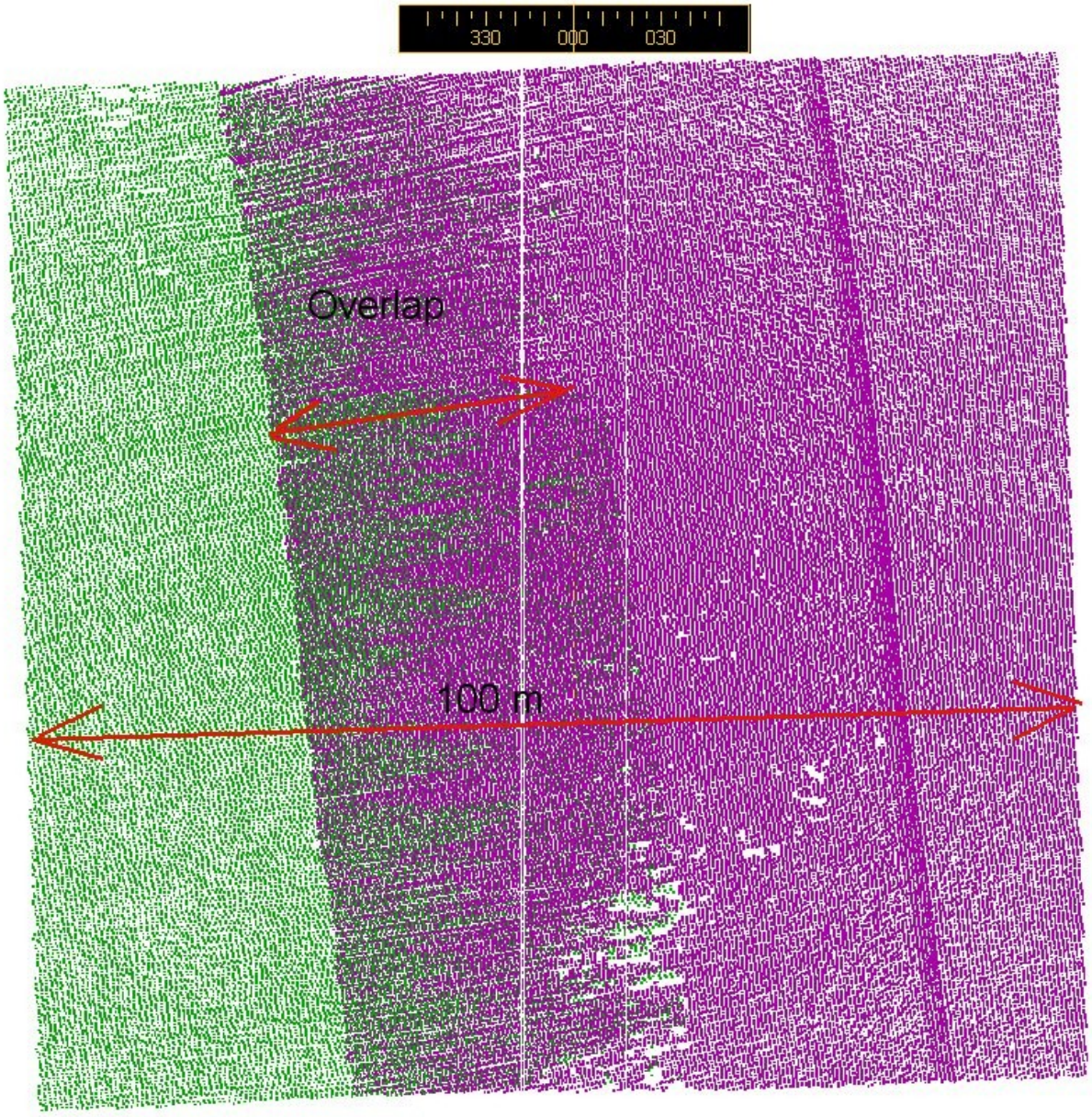
Selection area 3



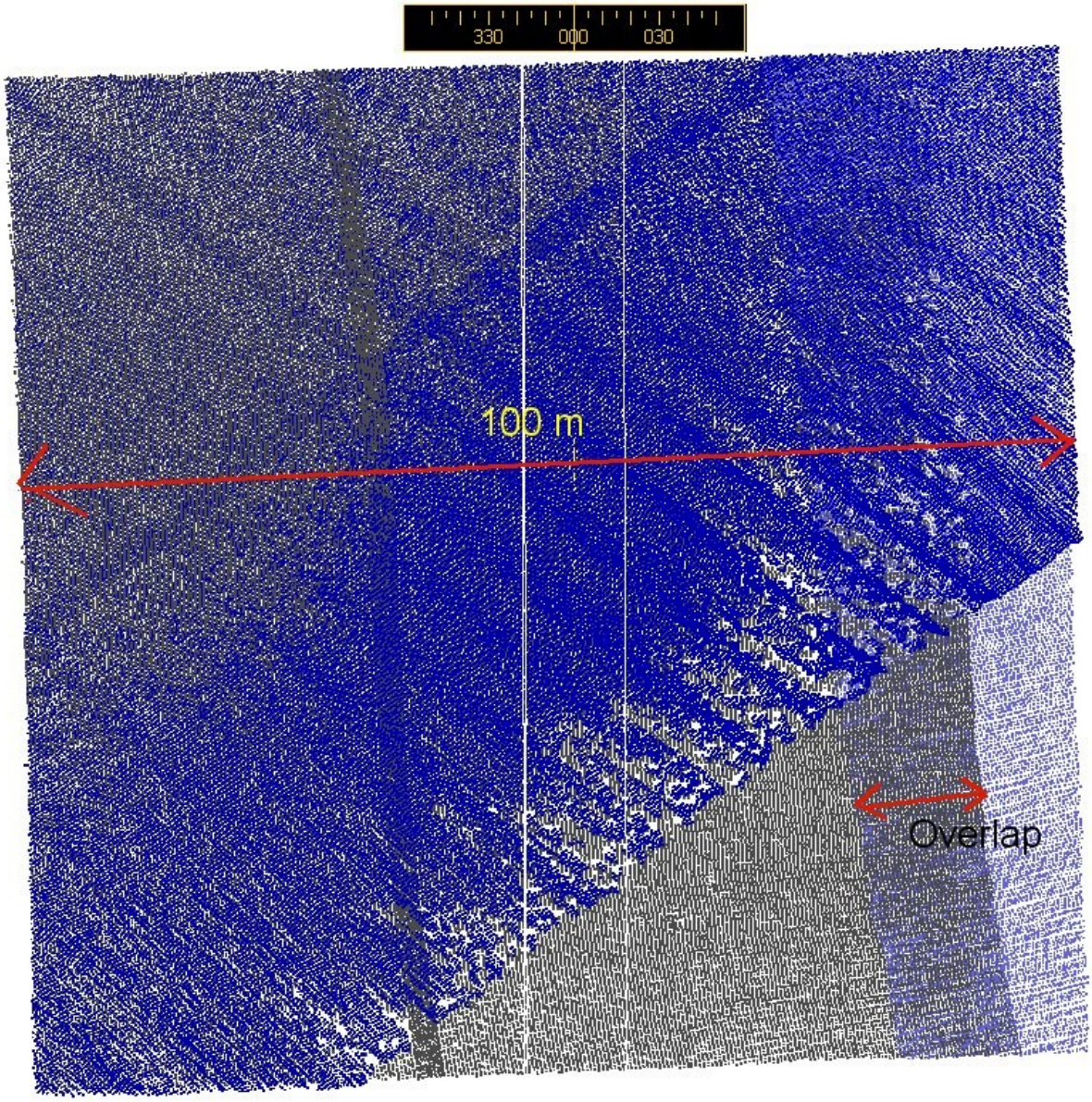
Selection area 4



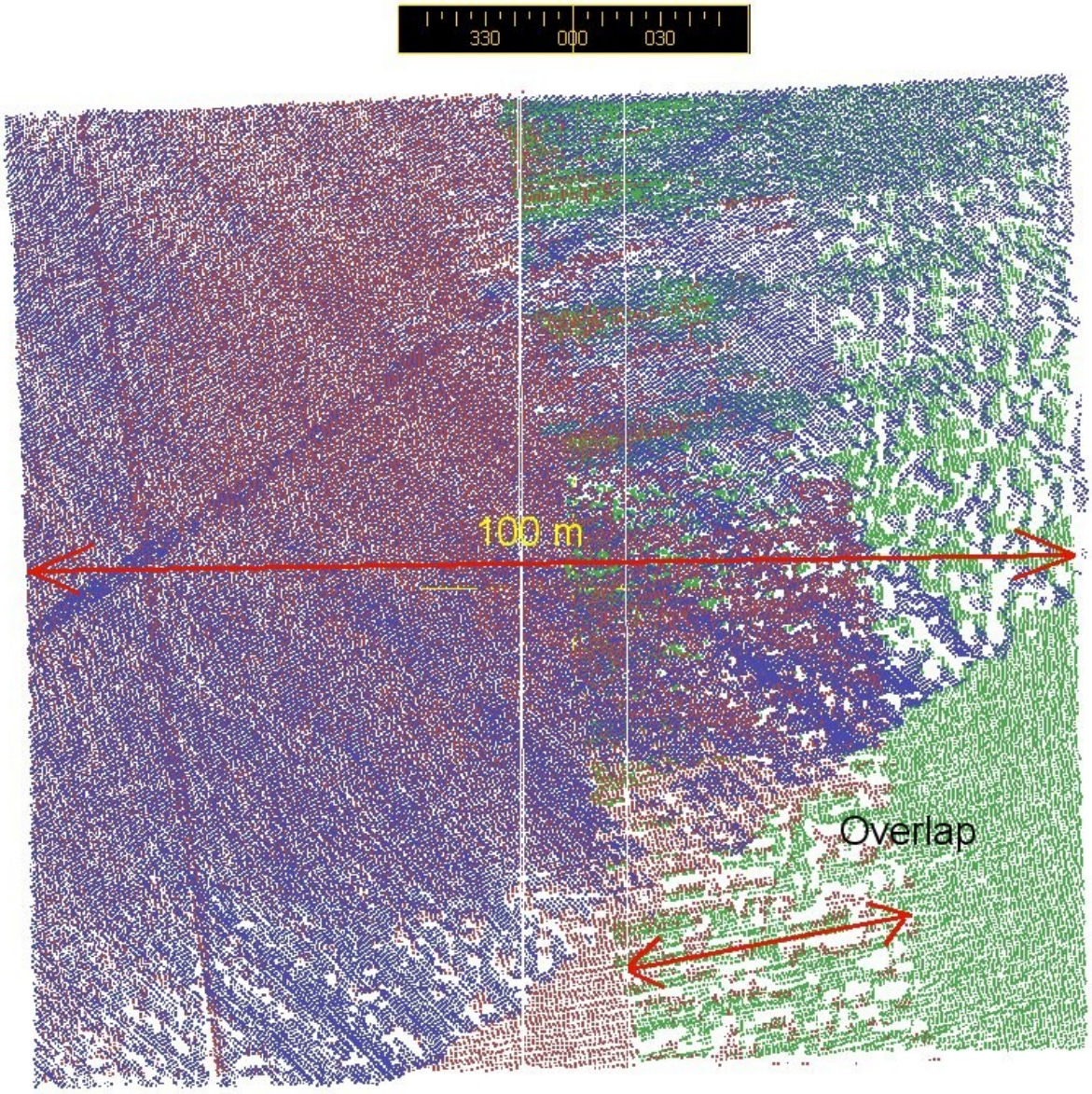
Selection area 5



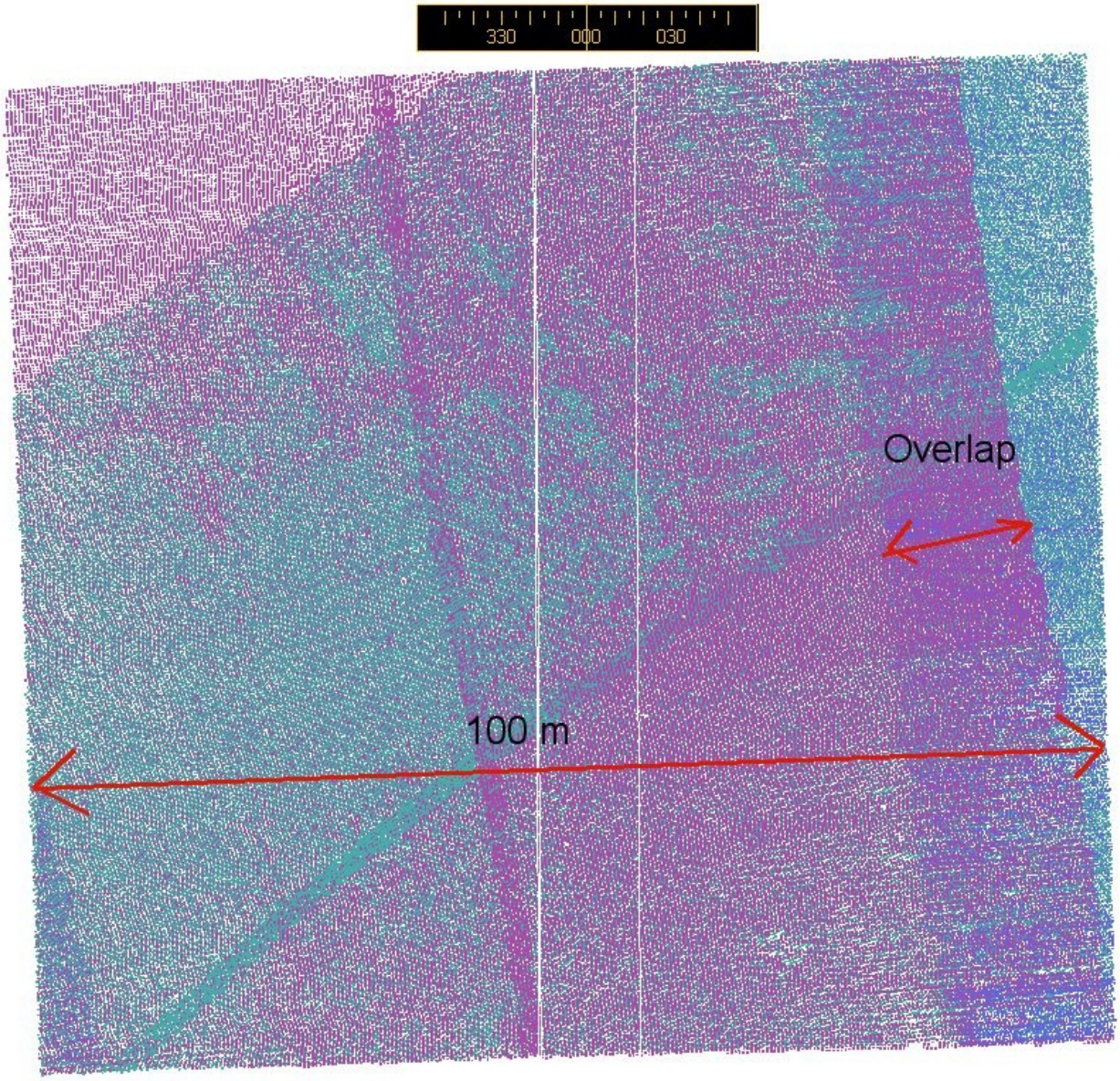
Selection area 6



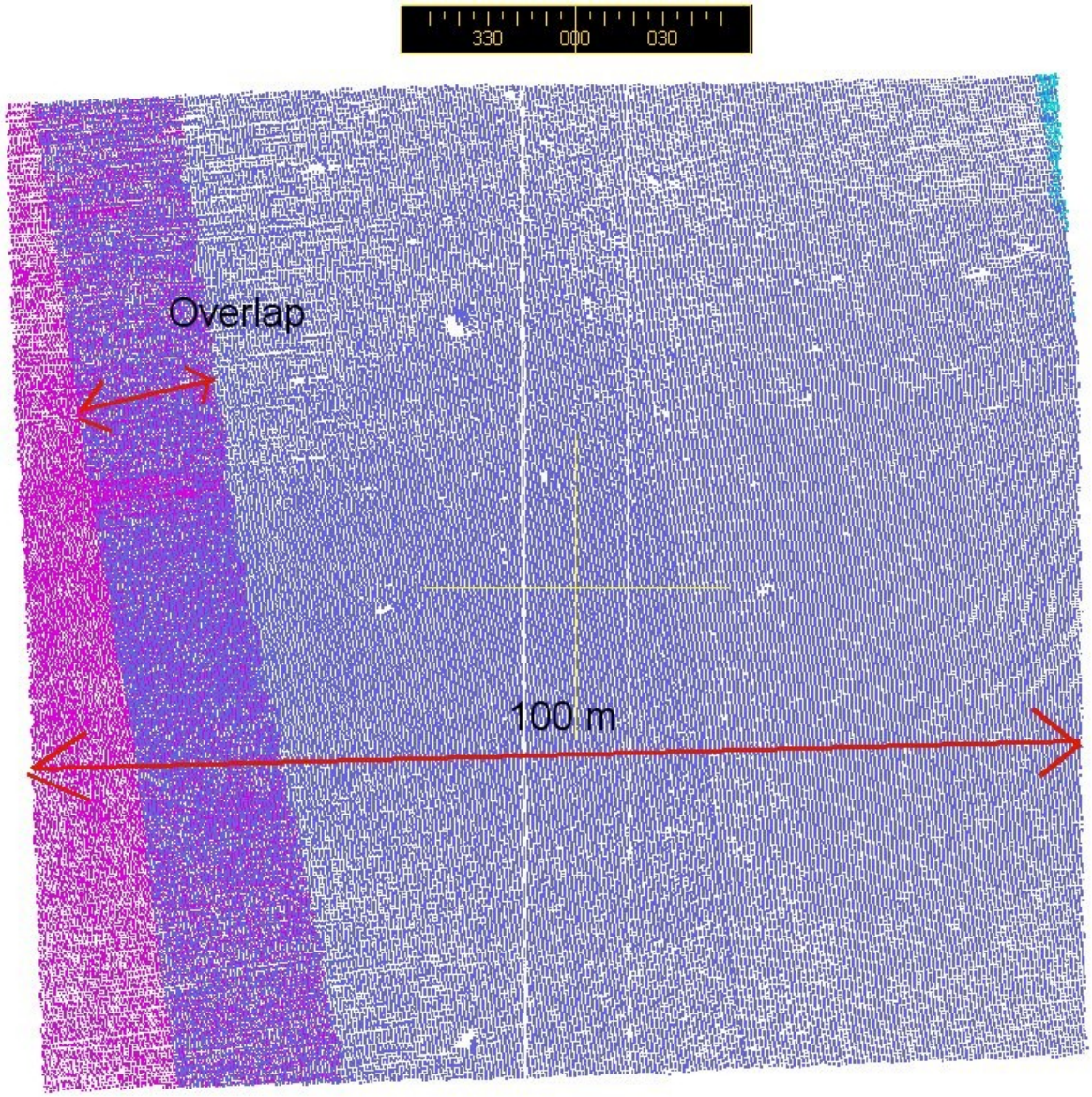
Selection area 7



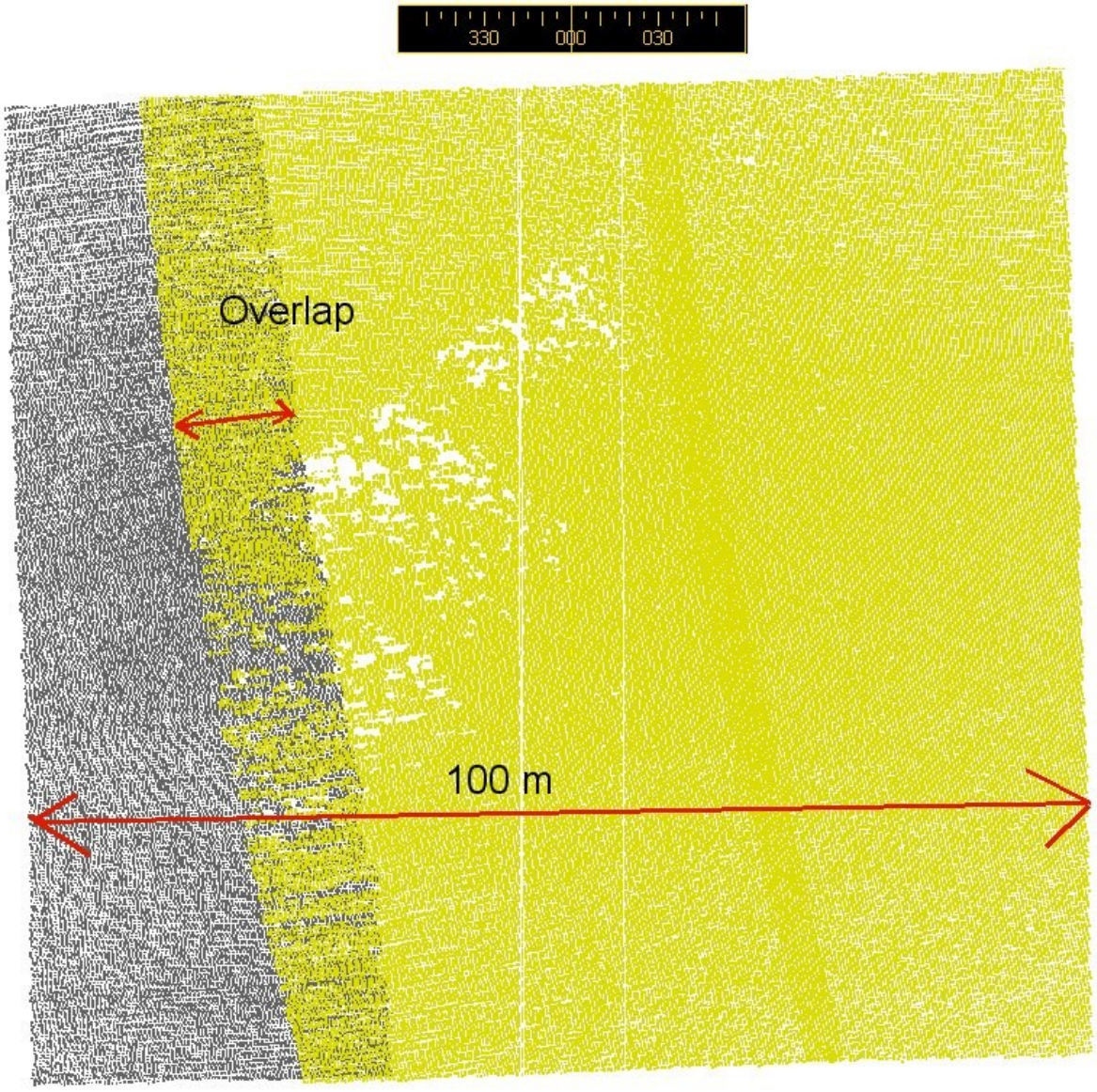
Selection area 8



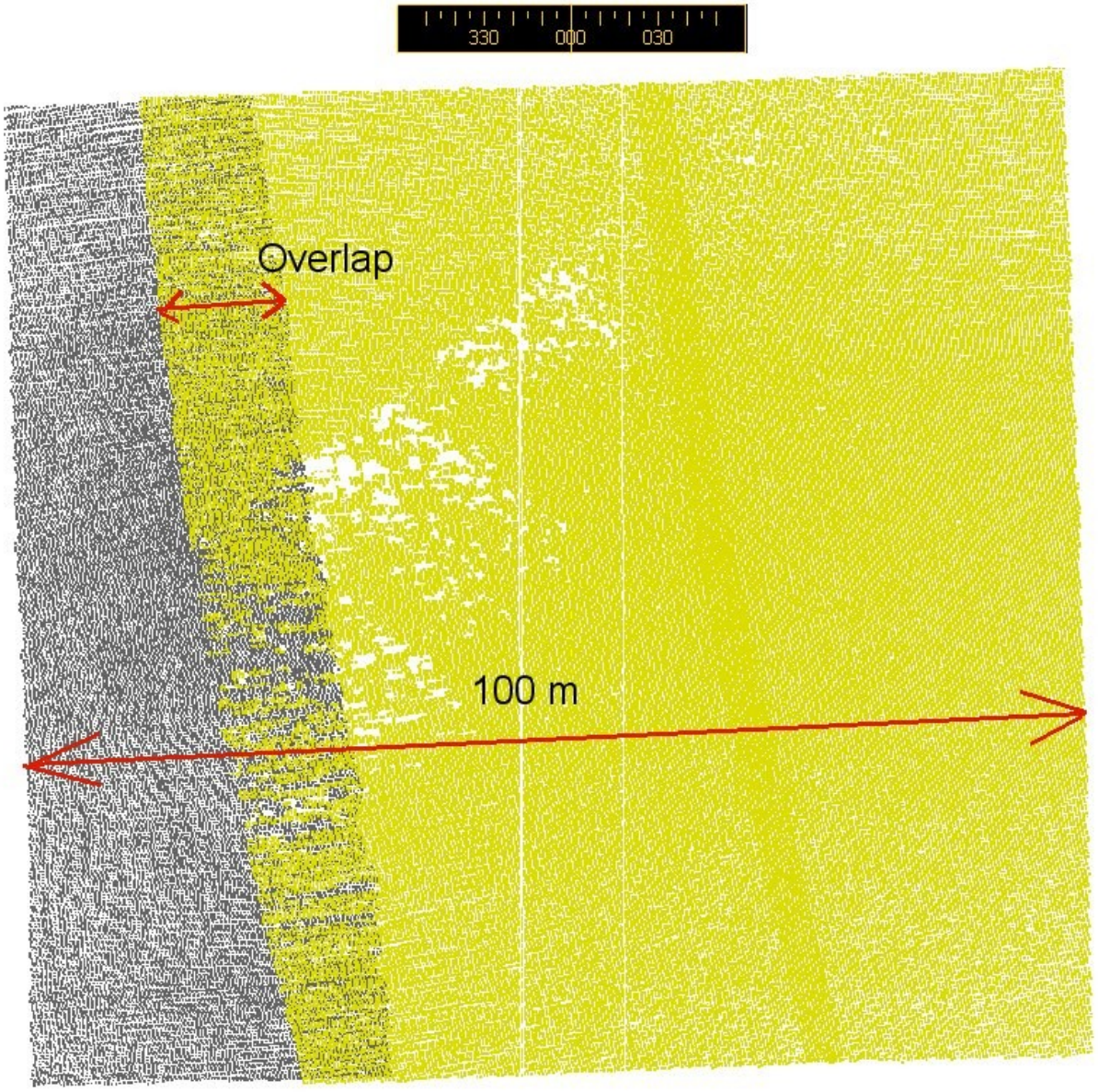
Selection area 9



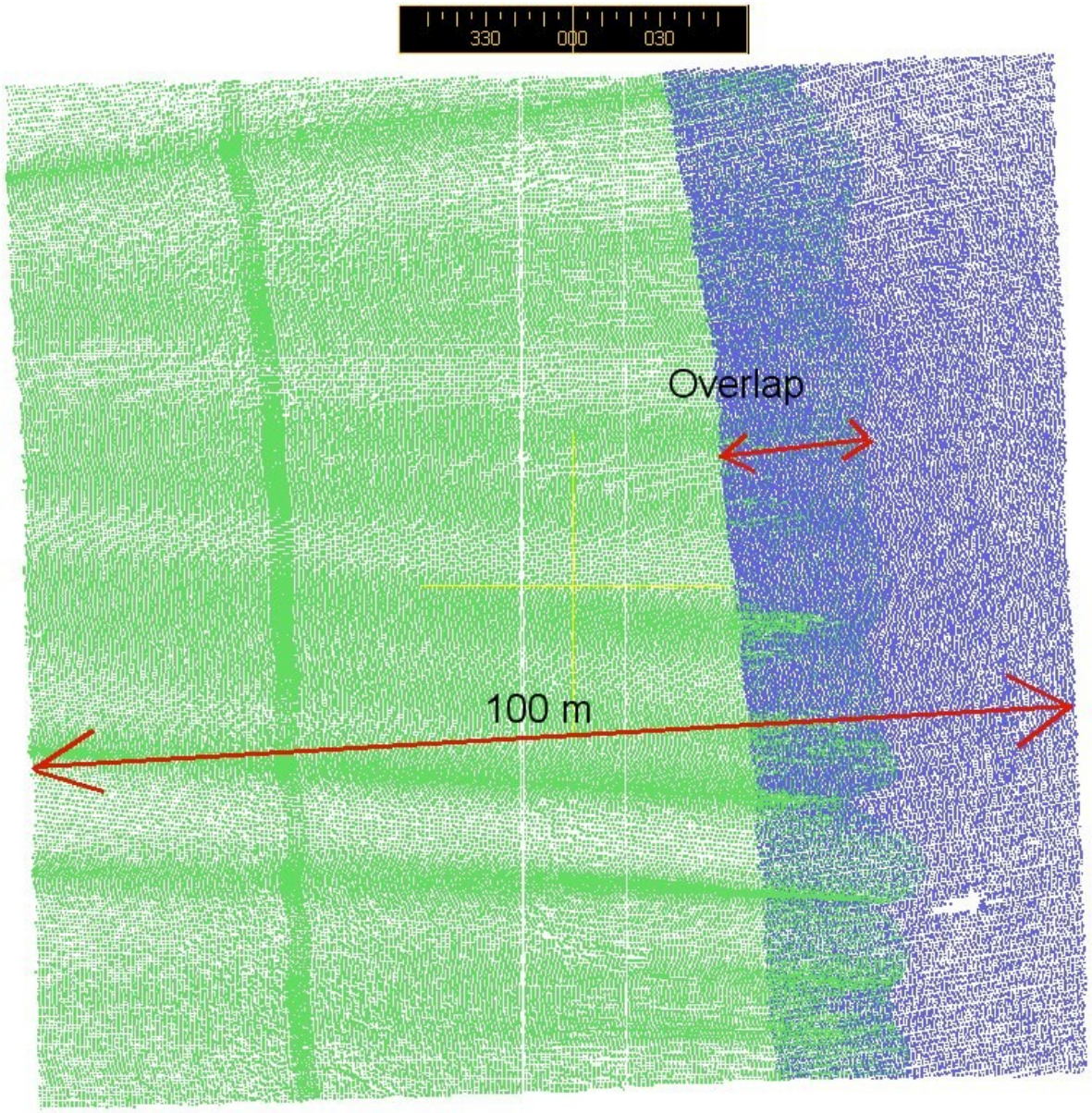
Selection area 10



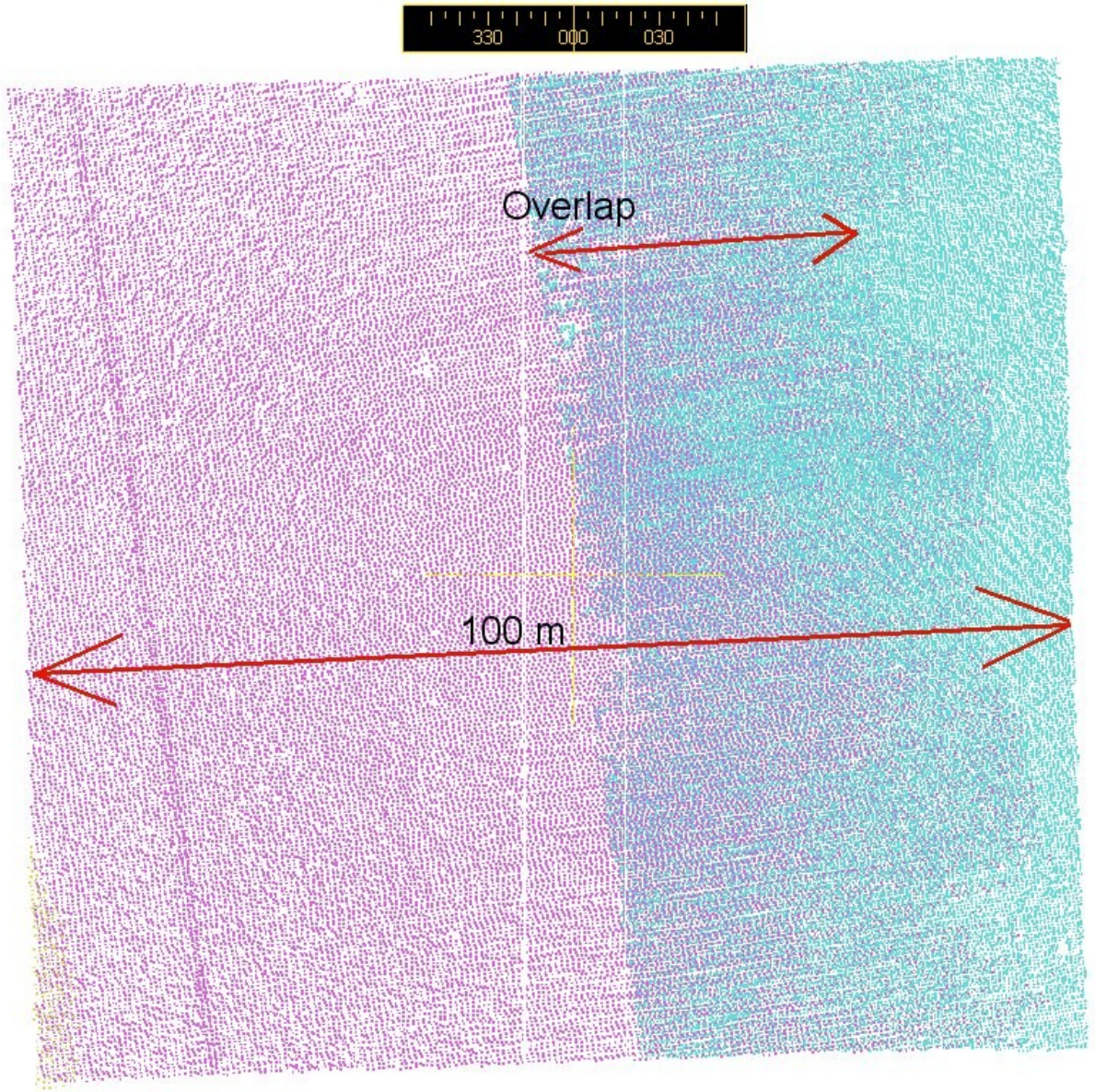
Selection area 11

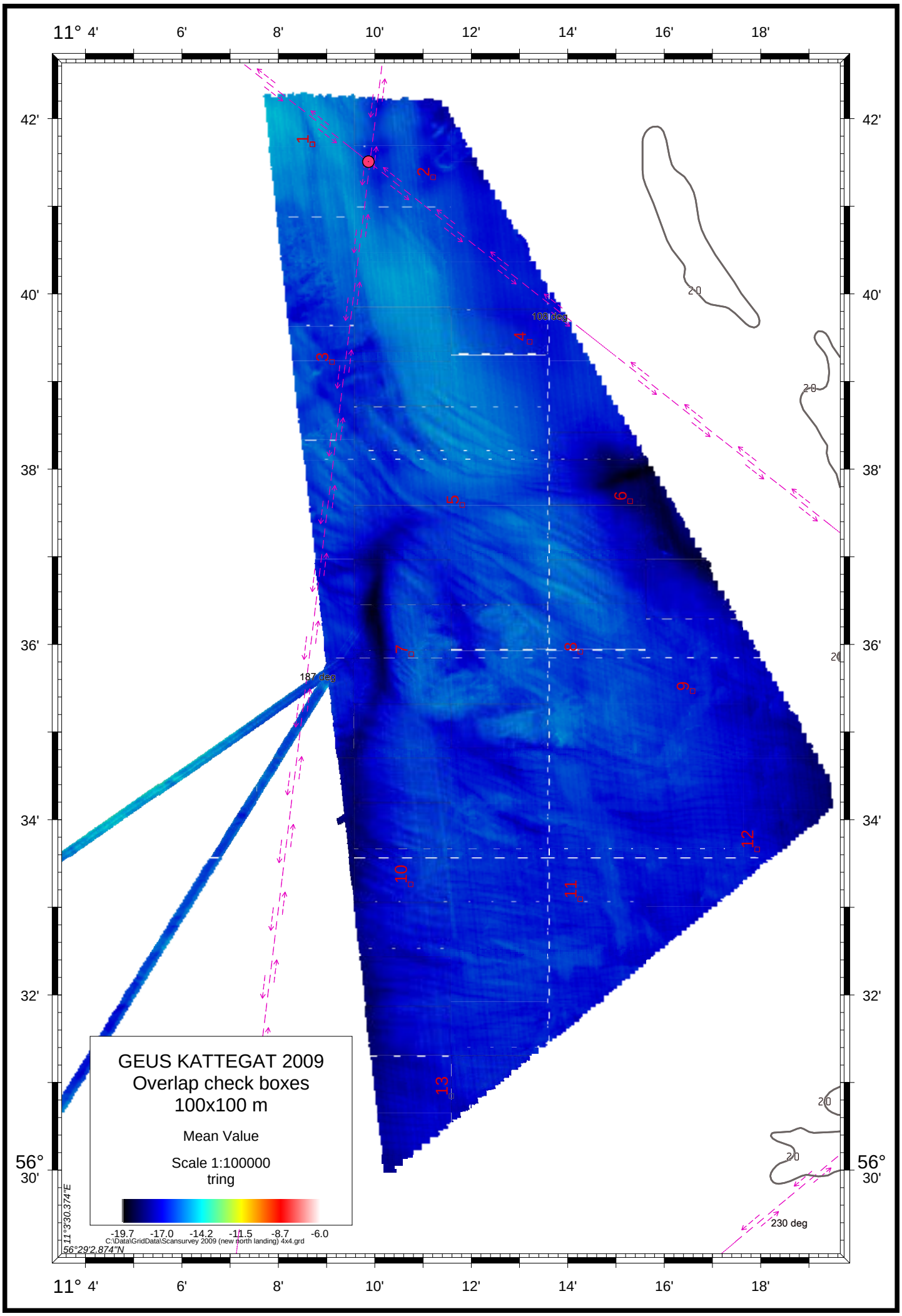


Selection area 12



Selection area 13




11° 4'
6'
8'
10'
12'
14'
16'
18'
42'
40'
38'
36'
34'
32'
30'
56°
1
2
3
4
5
6
7
8
9
10
11
12
13
108 deg
187 deg
230 deg
20
GEUS KATTEGAT 2009
Overlap check boxes
100x100 m
Mean Value
Scale 1:100000
tring
-19.7 -17.0 -14.2 -11.5 -8.7 -6.0
C:\Data\GridData\Scansurvey 2009 (new north landing) 4x4.grd
11°3'30.374"E
56°29'2.874"N

Appendix 11
Cross over tests

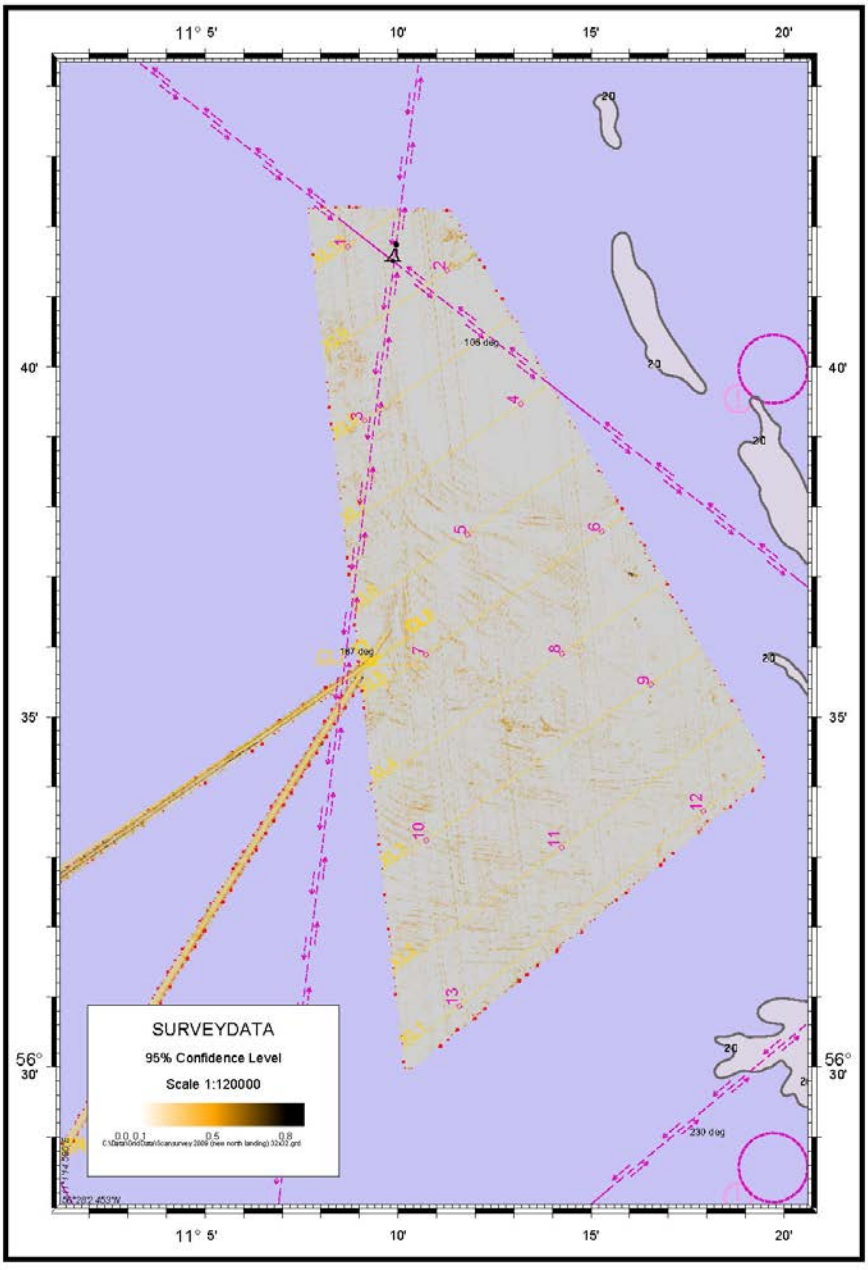
- **Cross over tests**

A number (13) of 100 x 100 m boxes were selected throughout the main area for “Cross over tests”.

The criteria for the selection were:

- Evenly distributed over the main survey area
- Selection areas should be square 100 x 100 meter boxes aligned in the same direction as the cross lines.

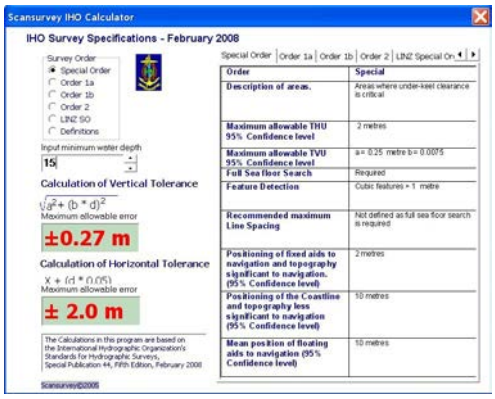
The distribution of the selected boxes as shown on this overview:

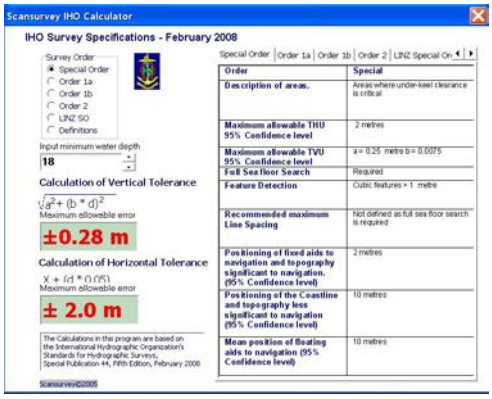


The vertical requirements for bathymetric data of project Offshore Windfarm Anholt, 2009 is according to the Marine geophysics scope of work dated February 2009 (page 11) similar to those of The International Hydrographic Organization Special Publication 44 (fifth edition, February 2008) as follows:

Sounding Accuracy at the 95% confidence level At least $\pm\sqrt{a^2+(b*d)^2}$ where a = 0.25 m and b = 0.0075

The water depth in the main project area ranged from 15 to 18 metres.





The maximum allowable error for water depth of 15 metres: **+/- 0.27 metres**

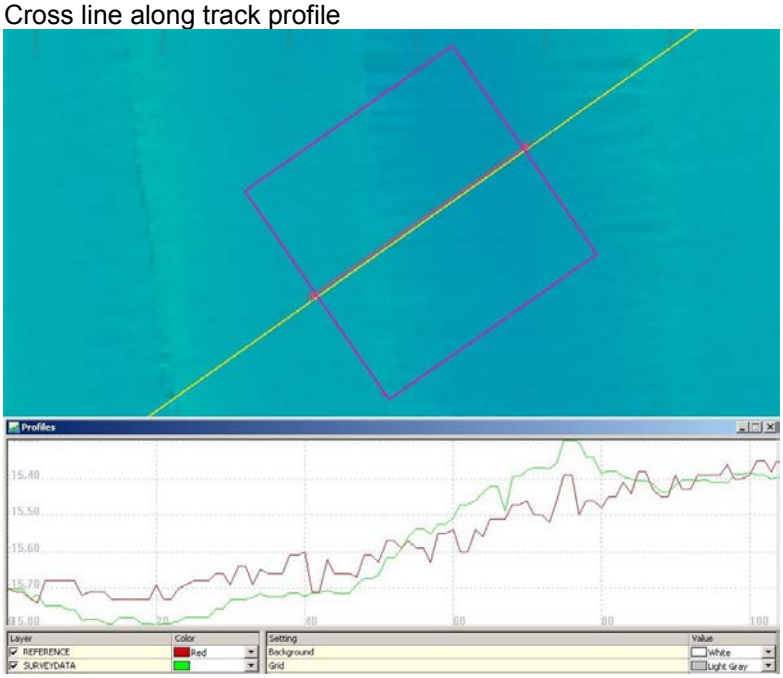
The maximum allowable error for water depth of 18 metres: **+/- 0.27 metres**

It should be noted that the following “cross line tests” analysis are not based on calculation of Total Propagated Error but solely on calculation on the variation of the the data values within the selected box.

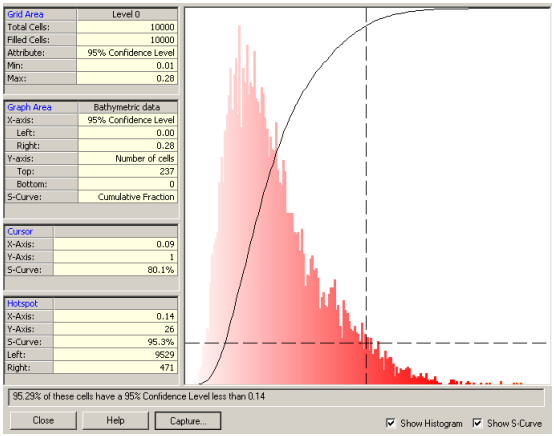
Selection Box 1

Approximate maximum difference in profile:	0.15 metres
Selection box Standard Deviation:	0.14

Cross line along track profile



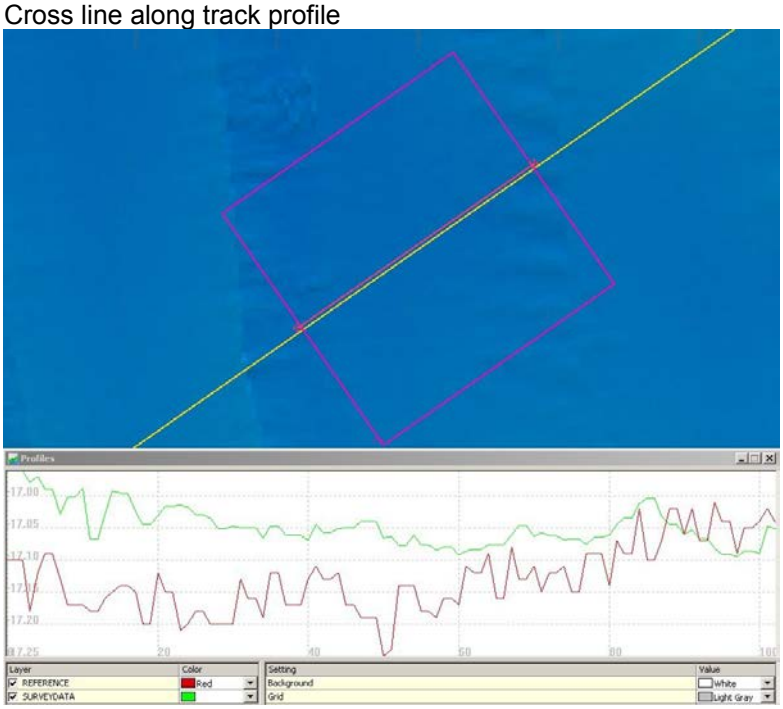
Selection box Confidence Level (Standard Deviation)



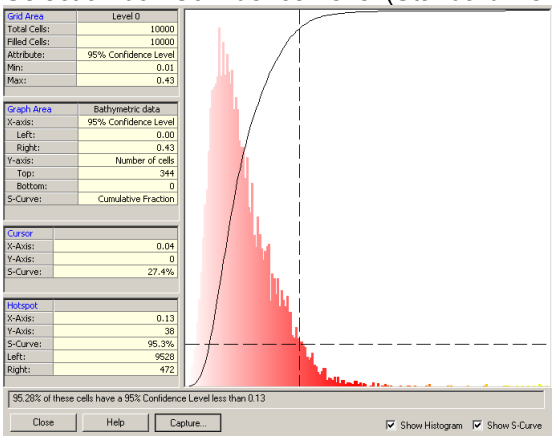
Selection Box 2

Approximate maximum difference in profile:	0.17 metres
Selection box Standard Deviation:	0.13

Cross line along track profile



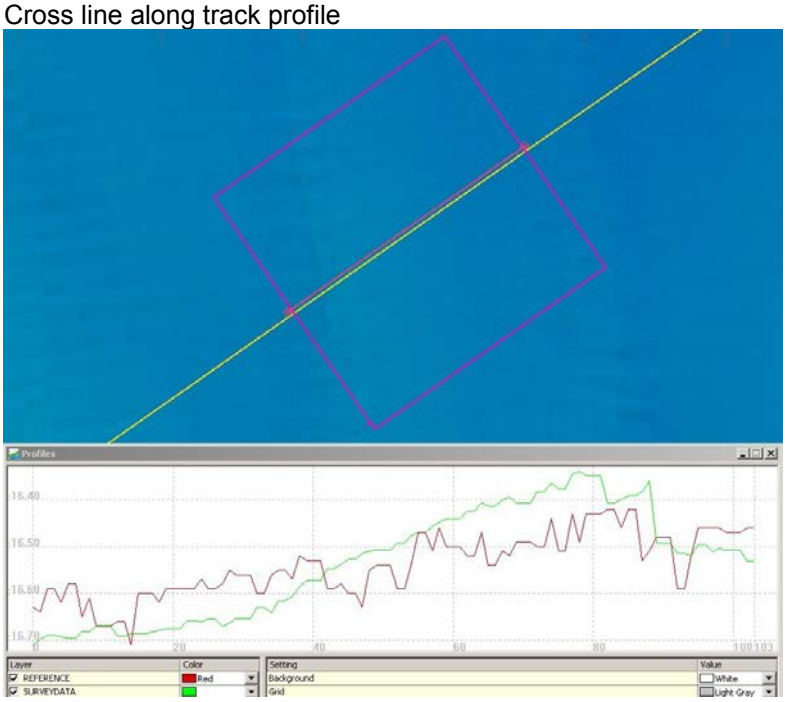
Selection box Confidence Level (Standard Deviation)



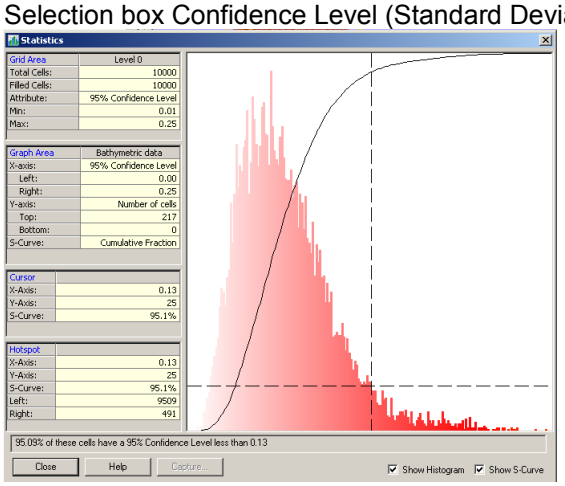
Selection Box 3

Approximate maximum difference in profile:	0.13 metres
Selection box Standard Deviation:	0.13

Cross line along track profile



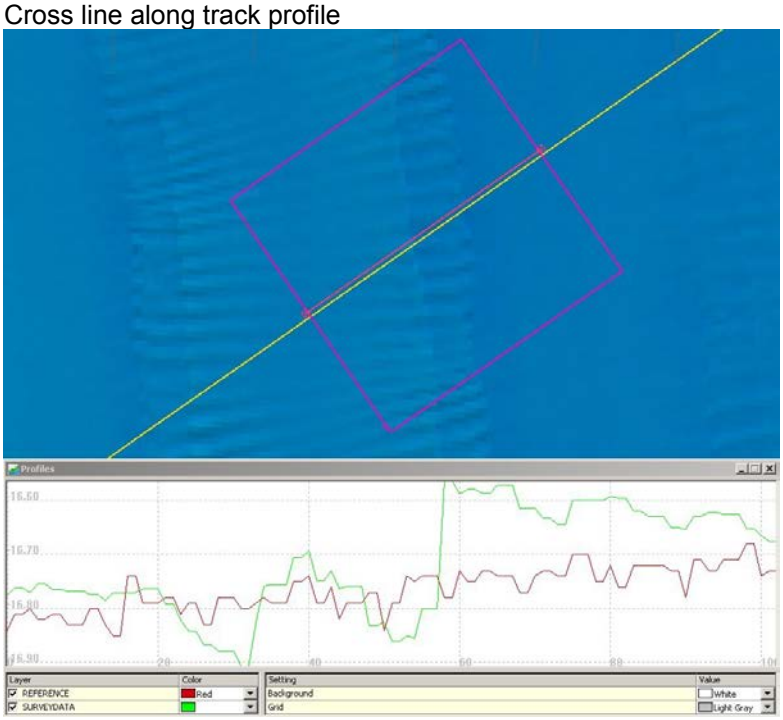
Selection box Confidence Level (Standard Deviation)



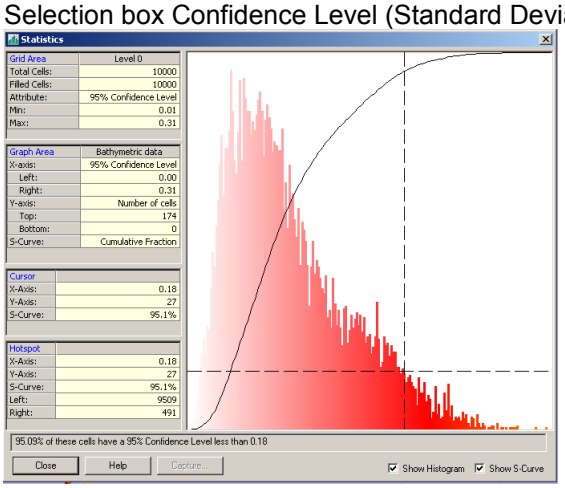
Selection Box 4

Approximate maximum difference in profile:	0.20 metres
Selection box Standard Deviation:	0.18

Cross line along track profile



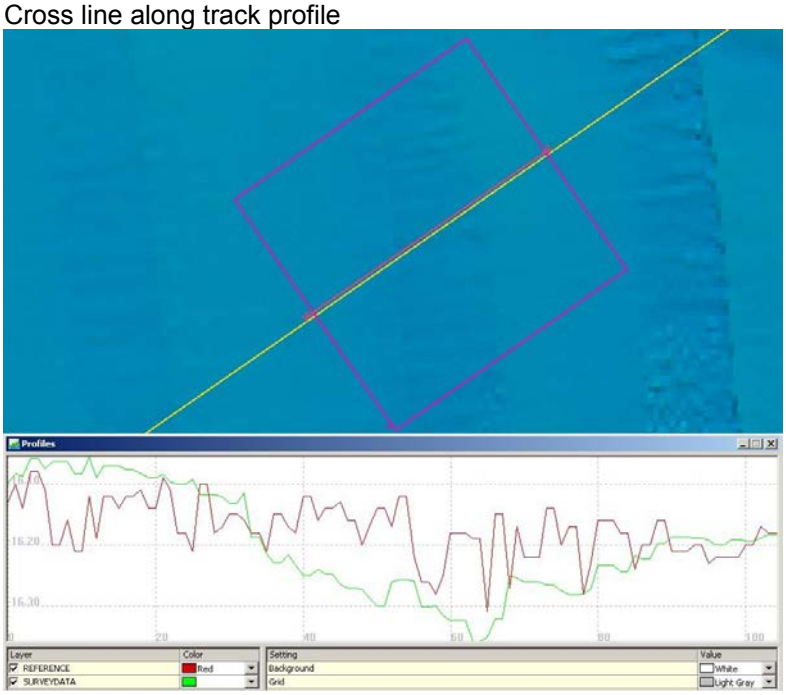
Selection box Confidence Level (Standard Deviation)



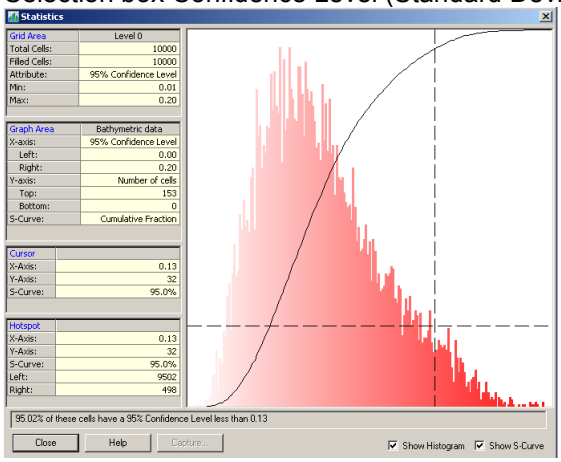
Selection Box 5

Approximate maximum difference in profile:	0.17 metres
Selection box Standard Deviation:	0.13

Cross line along track profile



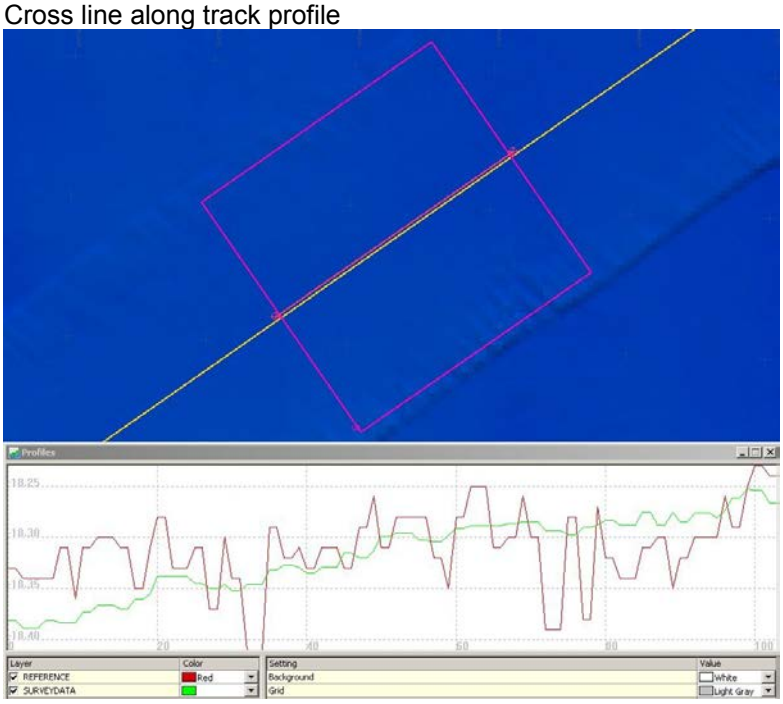
Selection box Confidence Level (Standard Deviation)



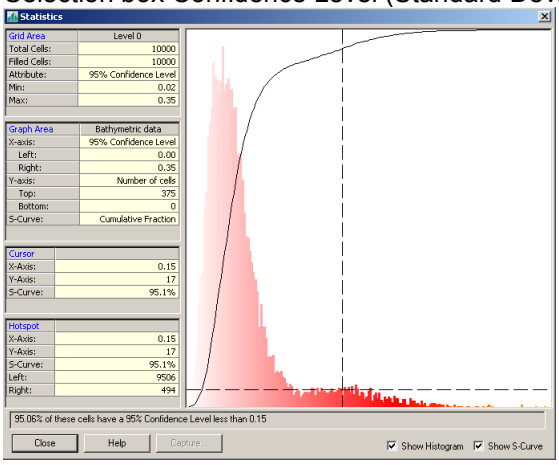
Selection Box 6

Approximate maximum difference in profile:	0.08 metres
Selection box Standard Deviation:	0.15

Cross line along track profile



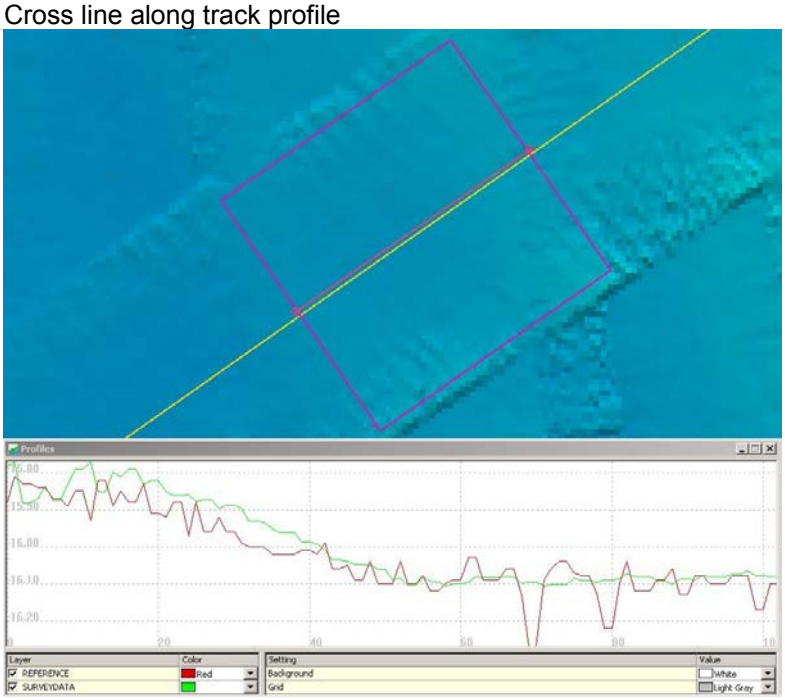
Selection box Confidence Level (Standard Deviation)



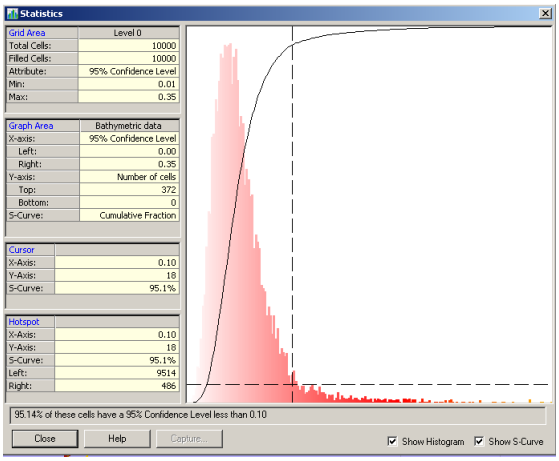
Selection Box 7

Approximate maximum difference in profile:	0.20 metres
Selection box Standard Deviation:	0.10

Cross line along track profile



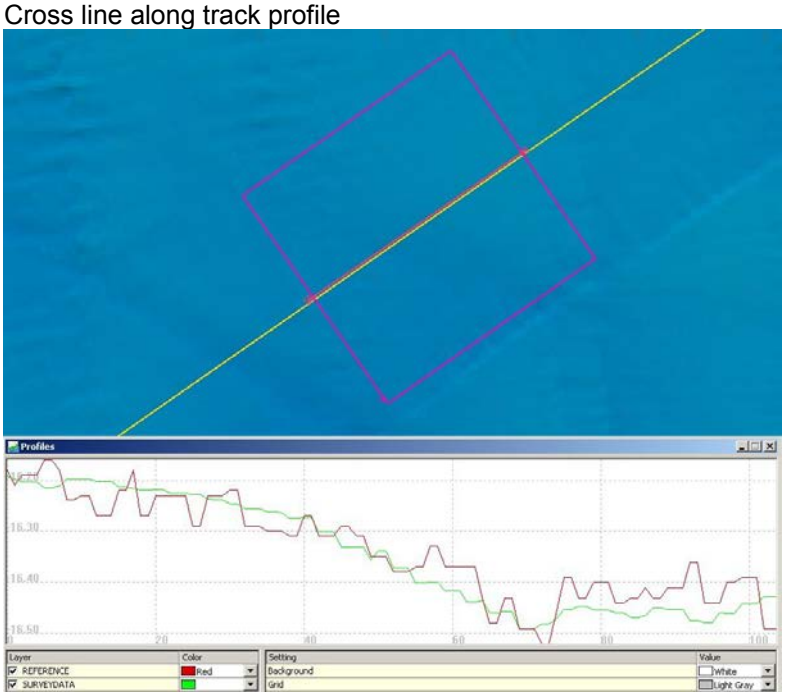
Selection box Confidence Level (Standard Deviation)



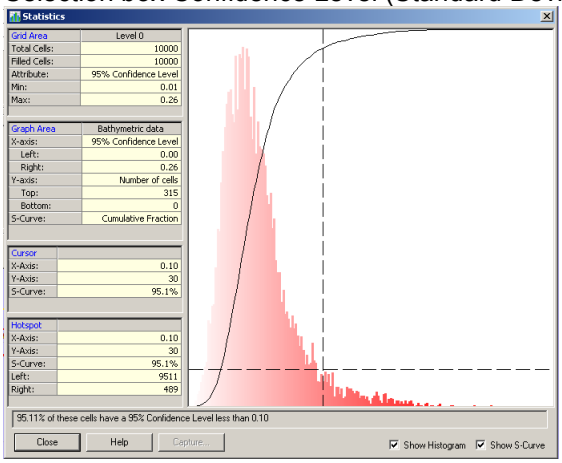
Selection Box 8

Approximate maximum difference in profile:	0.10 metres
Selection box Standard Deviation:	0.1

Cross line along track profile



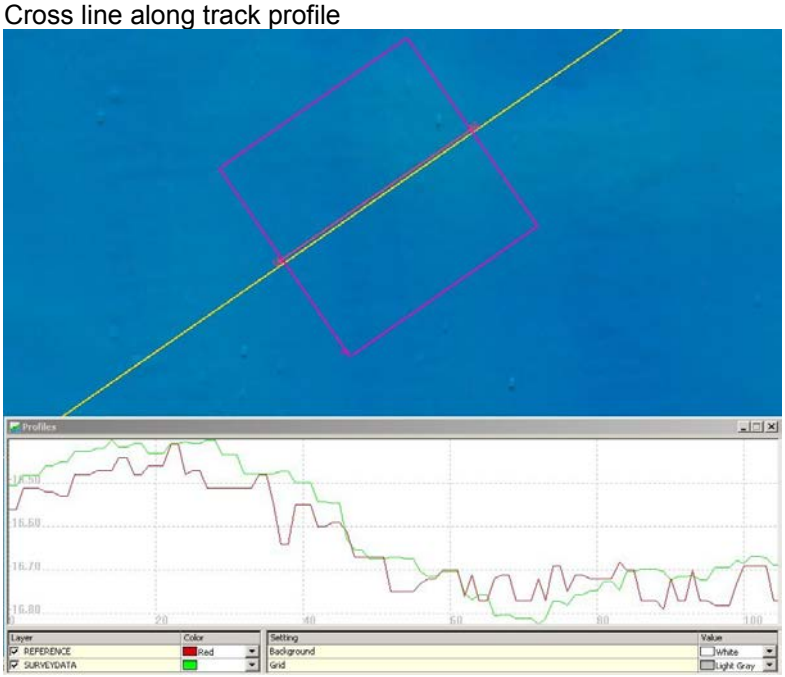
Selection box Confidence Level (Standard Deviation)



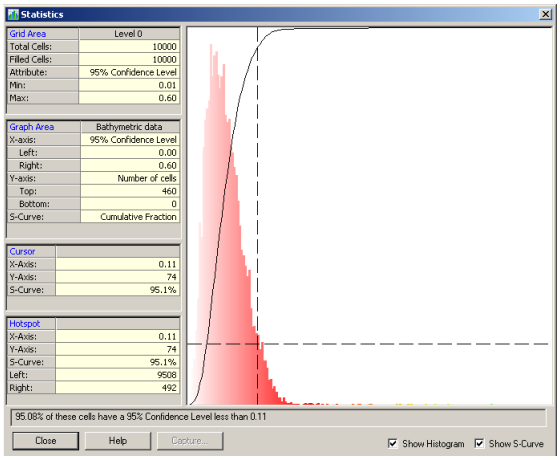
Selection Box 9

Approximate maximum difference in profile:	0.15 metres
Selection box Standard Deviation:	0.11

Cross line along track profile



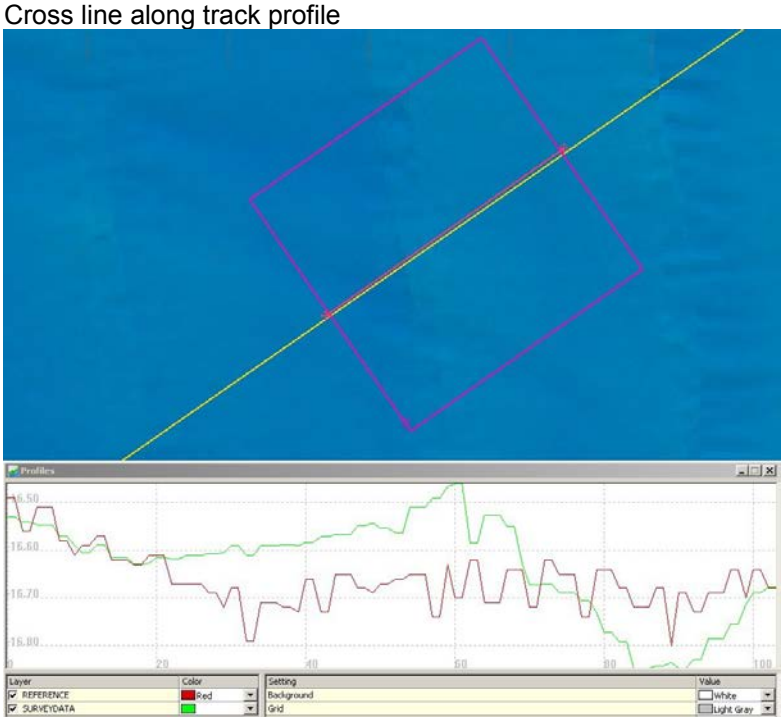
Selection box Confidence Level (Standard Deviation)



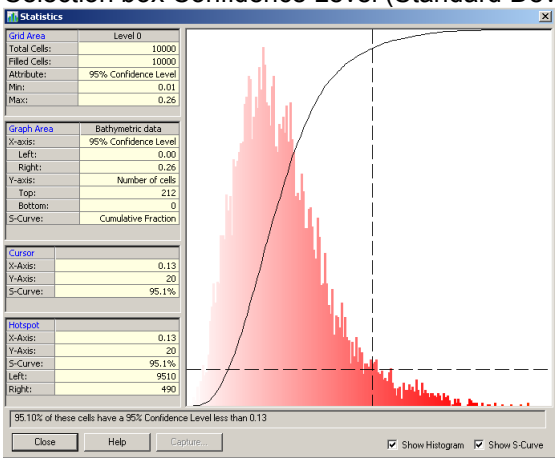
Selection Box 10

Approximate maximum difference in profile:	0.25 metres
Selection box Standard Deviation:	0.13

Cross line along track profile



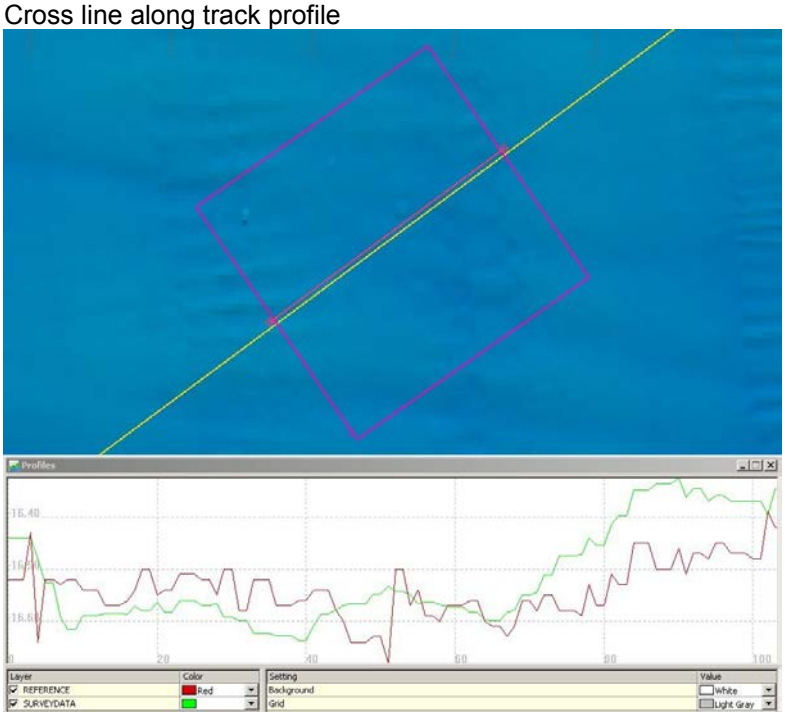
Selection box Confidence Level (Standard Deviation)



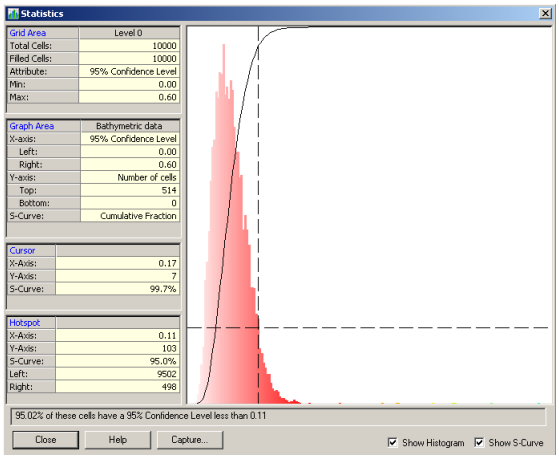
Selection Box 11

Approximate maximum difference in profile:	0.17 metres
Selection box Standard Deviation:	0.11

Cross line along track profile



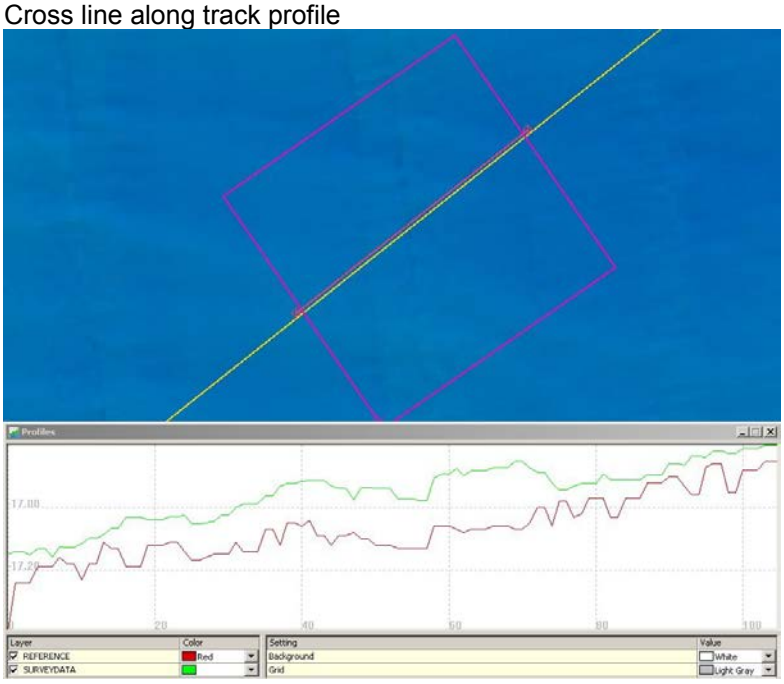
Selection box Confidence Level (Standard Deviation)



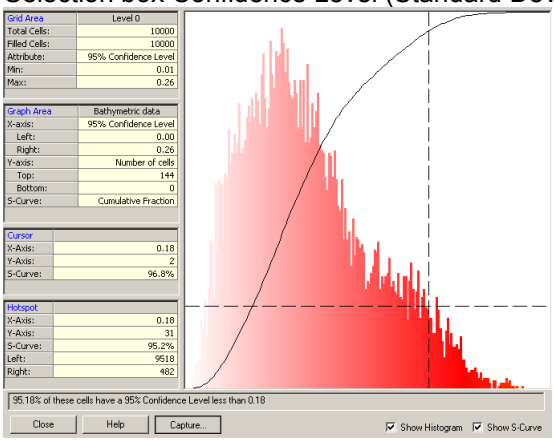
Selection Box 12

Approximate maximum difference in profile:	0.20 metres
Selection box Standard Deviation:	0.18

Cross line along track profile



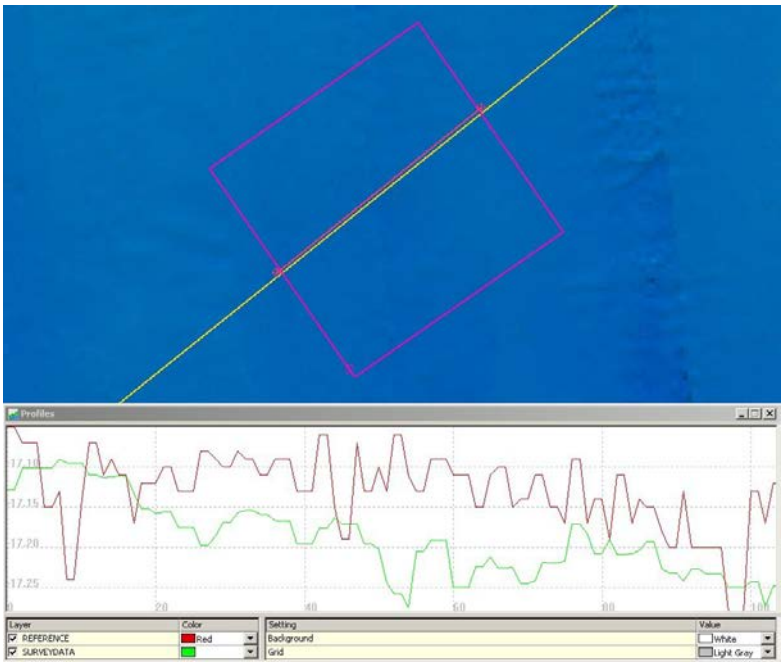
Selection box Confidence Level (Standard Deviation)



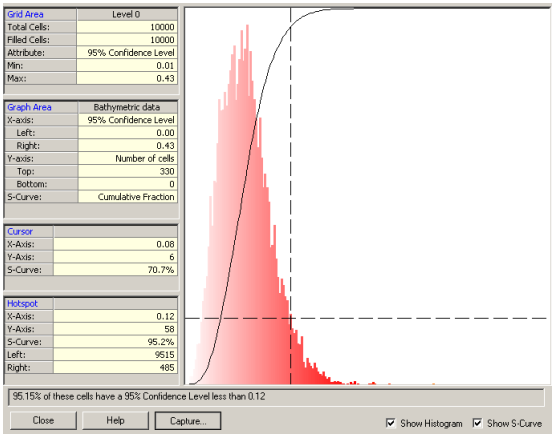
Selection Box 13

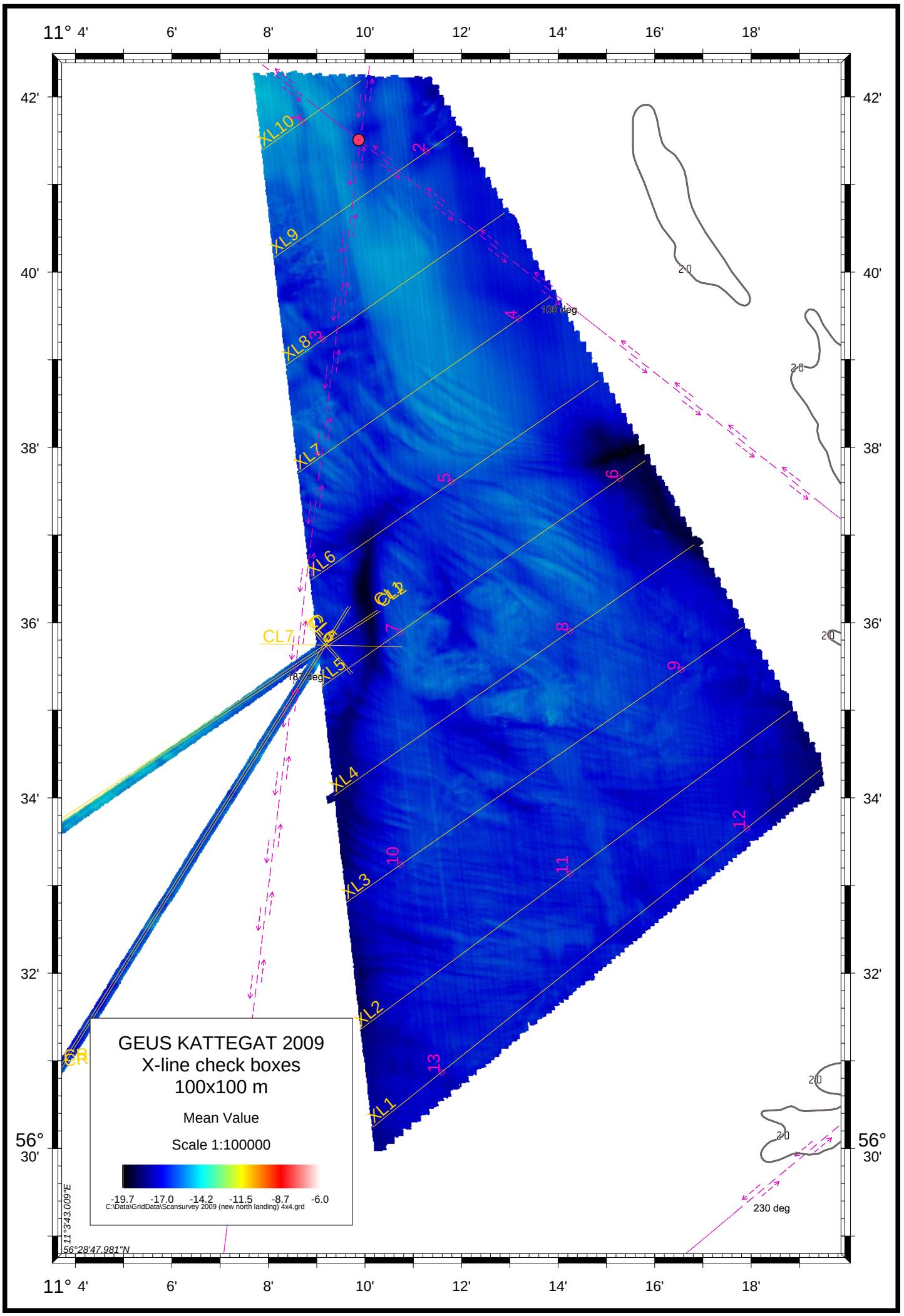
Approximate maximum difference in profile:	0.20 metres
Selection box Standard Deviation:	0.12

Cross line along track profile



Selection box Confidence Level (Standard Deviation)




11° 4' 6' 8' 10' 12' 14' 16' 18'
42' 40' 38' 36' 34' 32' 56° 30'
XL10
XL9
XL8
XL7
XL6
XL5
XL4
XL3
XL2
XL1
CL7
CL2
CL1
2
3
4
5
6
7
8
9
10
11
12
13
108 deg
187 deg
230 deg
20
GEUS KATTEGAT 2009
X-line check boxes
100x100 m
Mean Value
Scale 1:100000
-19.7 -17.0 -14.2 -11.5 -8.7 -6.0
C:\Data\GridData\Scansurvey 2009 (new north landing) 4x4.grd
11°3'43.009"E
56°28'47.981"N

Scansurvey IHO Calculator

IHO Survey Specifications - February 2008

Survey Order
- (•) Special Order
- ( ) Order 1a
- ( ) Order 1b
- ( ) Order 2
- ( ) LINZ SO
- ( ) Definitions

Input minimum water depth

15

Calculation of Vertical Tolerance

$\sqrt{a^2 + (b * d)^2}$

Maximum allowable error

±0.27 m

Calculation of Horizontal Tolerance

$X + (d * 0.05)$

Maximum allowable error

± 2.0 m

The Calculations in this program are based on the International Hydrographic Organization's Standards for Hydrographic Surveys, Special Publication 44, Fifth Edition, February 2008

Scansurvey©2005

Special Order | Order 1a | Order 1b | Order 2 | LINZ Special Or

Order	Special
Description of areas.	Areas where under-keel clearance is critical
Maximum allowable THU 95% Confidence level	2 metres
Maximum allowable TVU 95% Confidence level	a= 0.25 metre b= 0.0075
Full Sea floor Search	Required
Feature Detection	Cubic features > 1 metre
Recommended maximum Line Spacing	Not defined as full sea floor search is required
Positioning of fixed aids to navigation and topography significant to navigation. (95% Confidence level)	2 metres
Positioning of the Coastline and topography less significant to navigation (95% Confidence level)	10 metres
Mean position of floating aids to navigation (95% Confidence level)	10 metres

Scansurvey IHO Calculator

IHO Survey Specifications - February 2008

Survey Order
- (•) Special Order
- ( ) Order 1a
- ( ) Order 1b
- ( ) Order 2
- ( ) LINZ SO
- ( ) Definitions

Input minimum water depth

18

Calculation of Vertical Tolerance

$\sqrt{a^2 + (b * d)^2}$

Maximum allowable error

±0.28 m

Calculation of Horizontal Tolerance

$X + (d * 0.05)$

Maximum allowable error

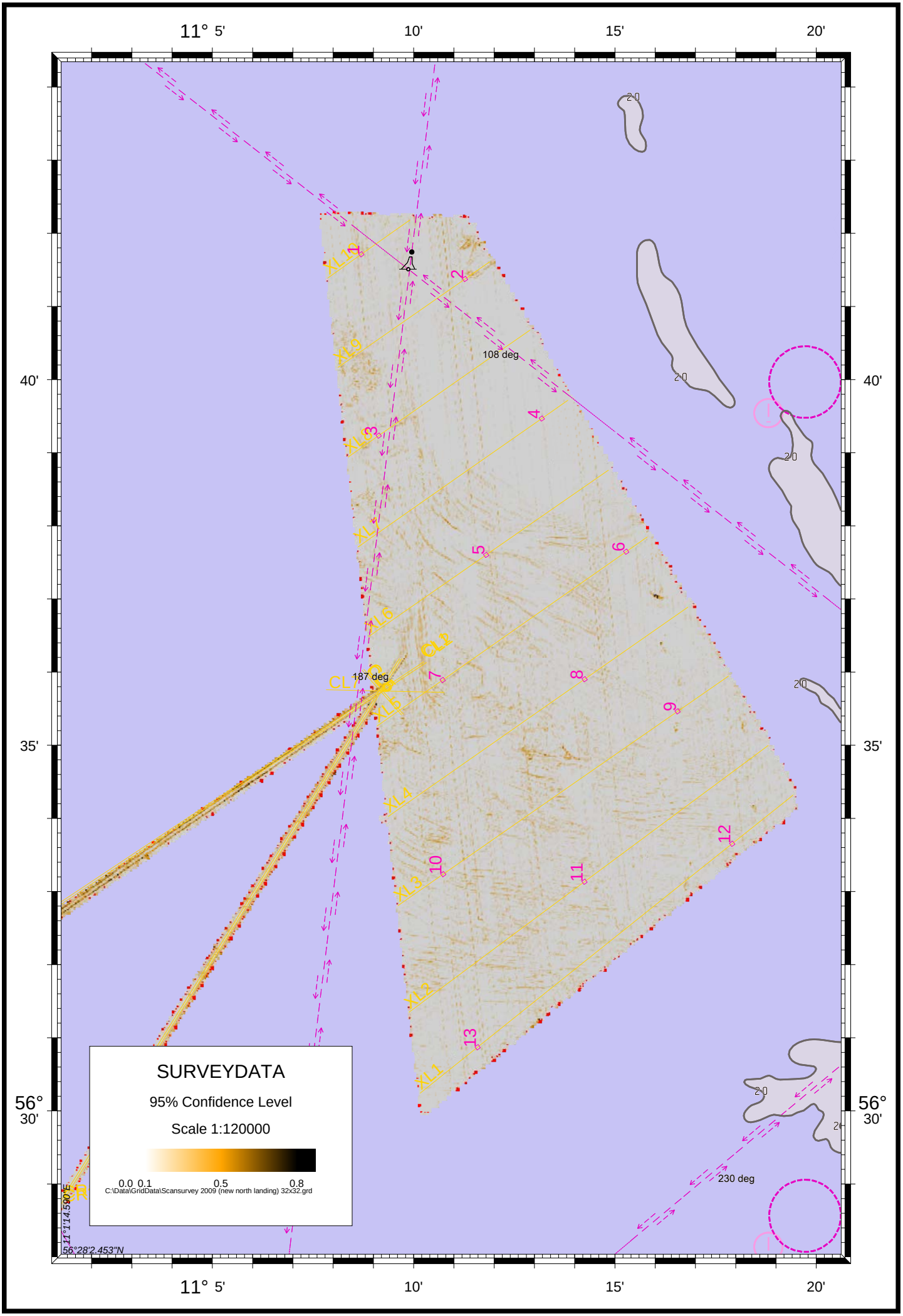
± 2.0 m

The Calculations in this program are based on the International Hydrographic Organization's Standards for Hydrographic Surveys, Special Publication 44, Fifth Edition, February 2008

Scansurvey©2005

Special Order | Order 1a | Order 1b | Order 2 | LINZ Special Or

Order	Special
Description of areas.	Areas where under-keel clearance is critical
Maximum allowable THU 95% Confidence level	2 metres
Maximum allowable TVU 95% Confidence level	a= 0.25 metre b= 0.0075
Full Sea floor Search	Required
Feature Detection	Cubic features > 1 metre
Recommended maximum Line Spacing	Not defined as full sea floor search is required
Positioning of fixed aids to navigation and topography significant to navigation. (95% Confidence level)	2 metres
Positioning of the Coastline and topography less significant to navigation (95% Confidence level)	10 metres
Mean position of floating aids to navigation (95% Confidence level)	10 metres


11° 5'
10'
15'
20'
40'
35'
56° 30'
108 deg
187 deg
230 deg
XL12
XL11
XL10
XL9
XL8
XL7
XL6
XL5
XL4
XL3
XL2
XL1
CL1
CL2
CL3
2
4
5
6
7
8
9
10
11
12
13
20
SURVEYDATA
95% Confidence Level
Scale 1:120000
0.0 0.1 0.5 0.8
C:\Data\GridData\Scansurvey 2009 (new north landing) 32x32.grd
11°1'14.590"E
56°28'2.453"N

Profiles

17.00

17.20

0 20 40 60 80 100

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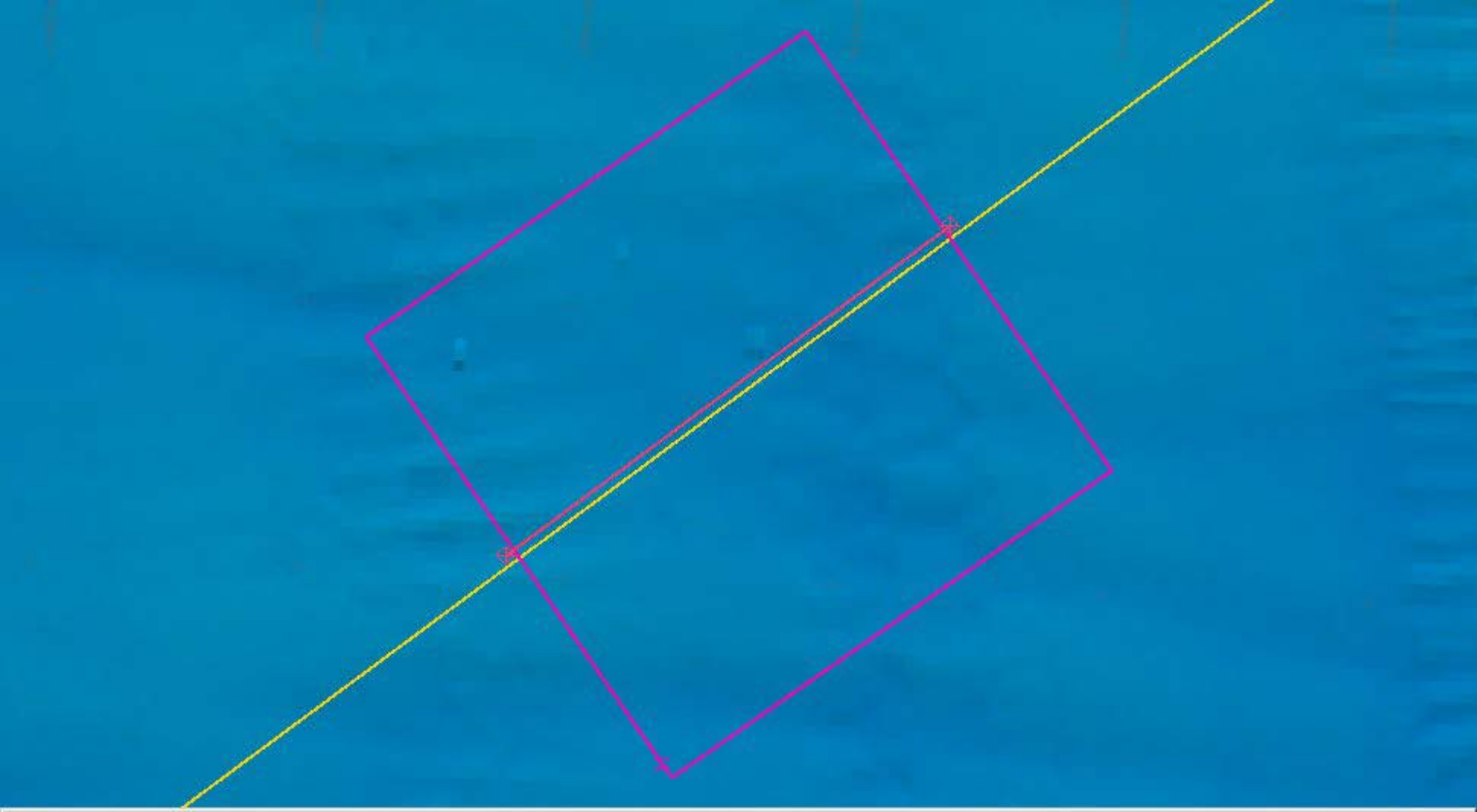
SURVEYDATA	

Setting	Value
Background	White
Grid	Light Gray



Profiles

16.40

16.60

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Layer	Color
REFERENCE	Red
SURVEYDATA	

Setting	Value
Background	White
Grid	Light Gray

Profiles

16.50
16.60
16.70
16.80
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20
40
60
80
100

Layer	Color
REFERENCE	Red
SURVEYDATA	

Setting	Value
Background	White
Grid	Light Gray

Profiles

16.50
16.60
16.70
16.80
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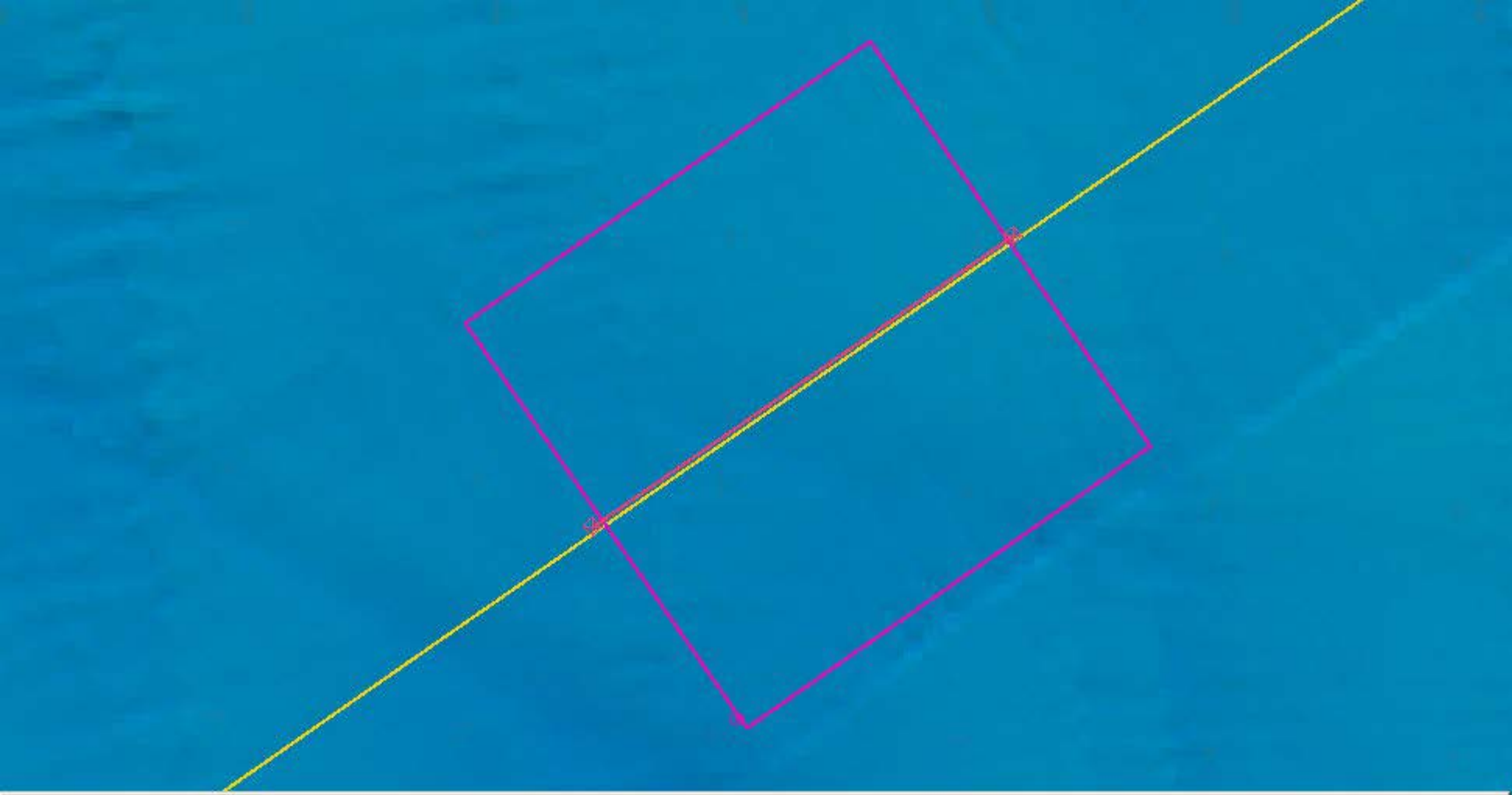
40
60
80
100

Layer	Color
REFERENCE	Red
SURVEYDATA	

Setting	Value
Background	White
Grid	Light Gray



Profiles

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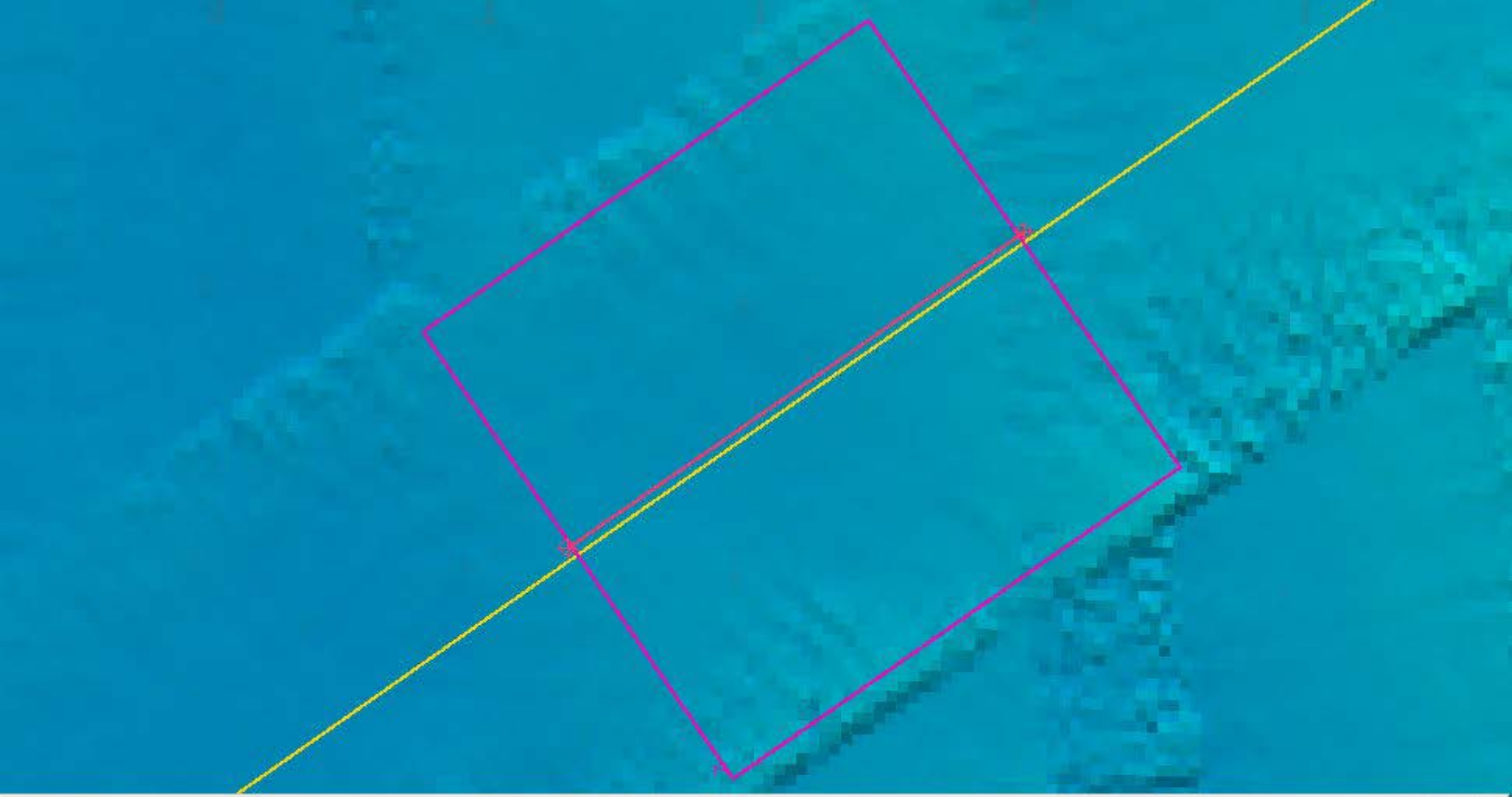
SURVEYDATA	

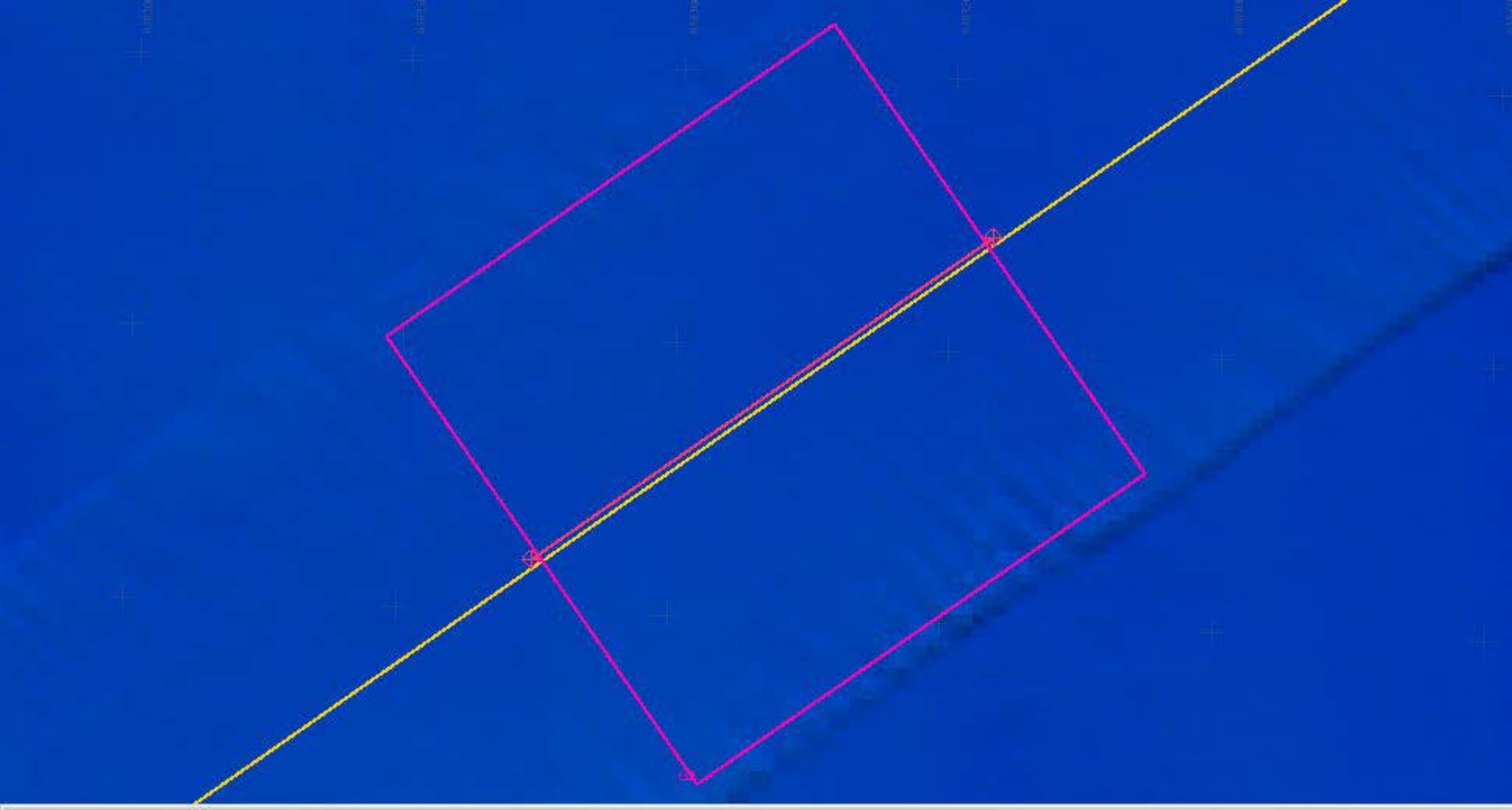
Setting	Value
Background	White
Grid	Light Gray



Profiles

Layer	Color
REFERENCE	Red
SURVEYDATA	

Setting	Value
Background	White
Grid	Light Gray



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Setting	Value
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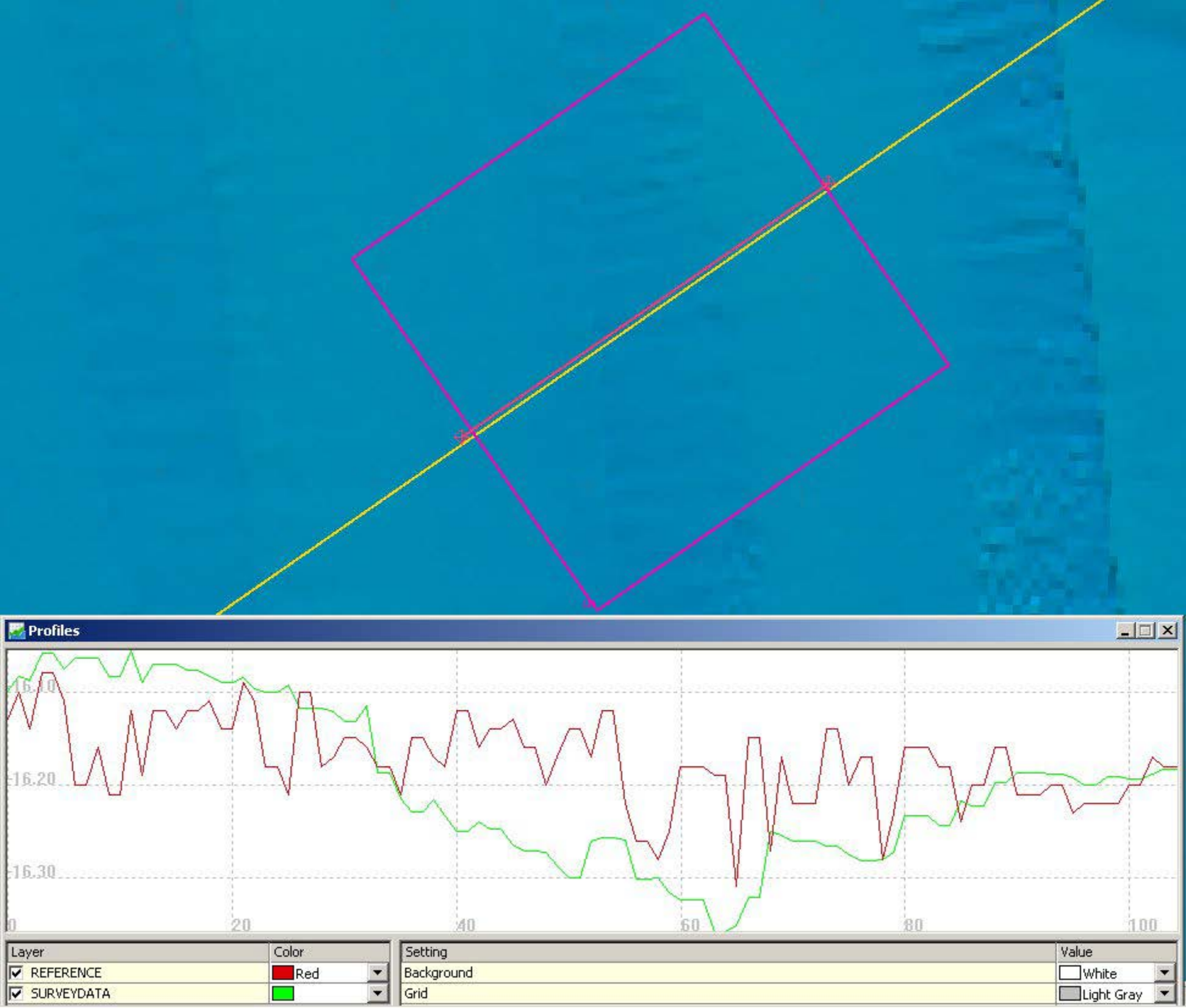
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20
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80
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Layer
Color
REFERENCE
Red
SURVEYDATA
Setting
Value
Background
White
Grid
Light Gray

Profiles

16.60
16.70
16.80
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80
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Layer	Color
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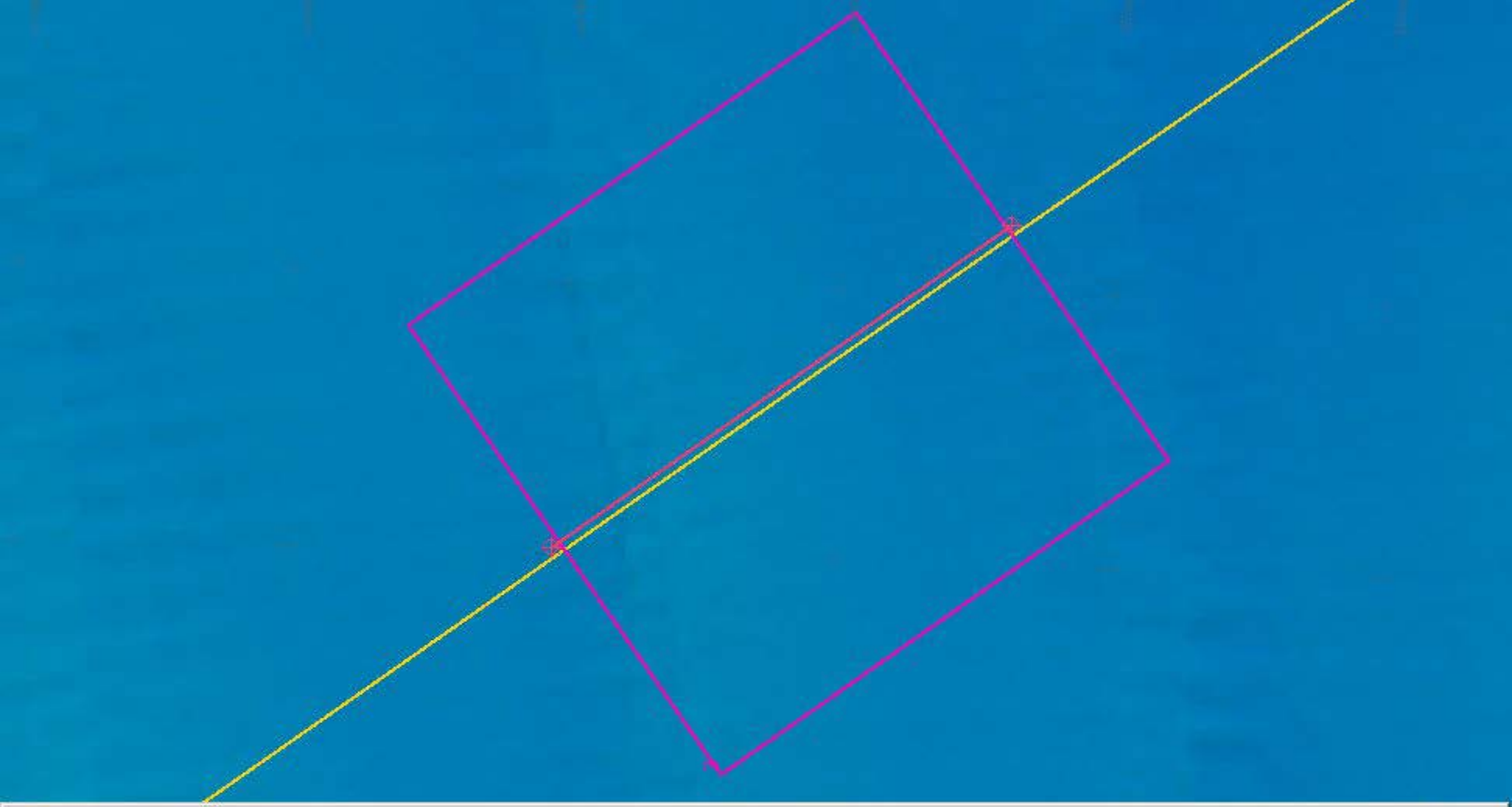
SURVEYDATA	

Setting	Value
Background	White
Grid	Light Gray



Profiles

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40
60
80
100
103

Layer	Color
REFERENCE	Red
SURVEYDATA	

Setting	Value
Background	White
Grid	Light Gray

Profiles

17.00
17.05
17.10
17.15
17.20
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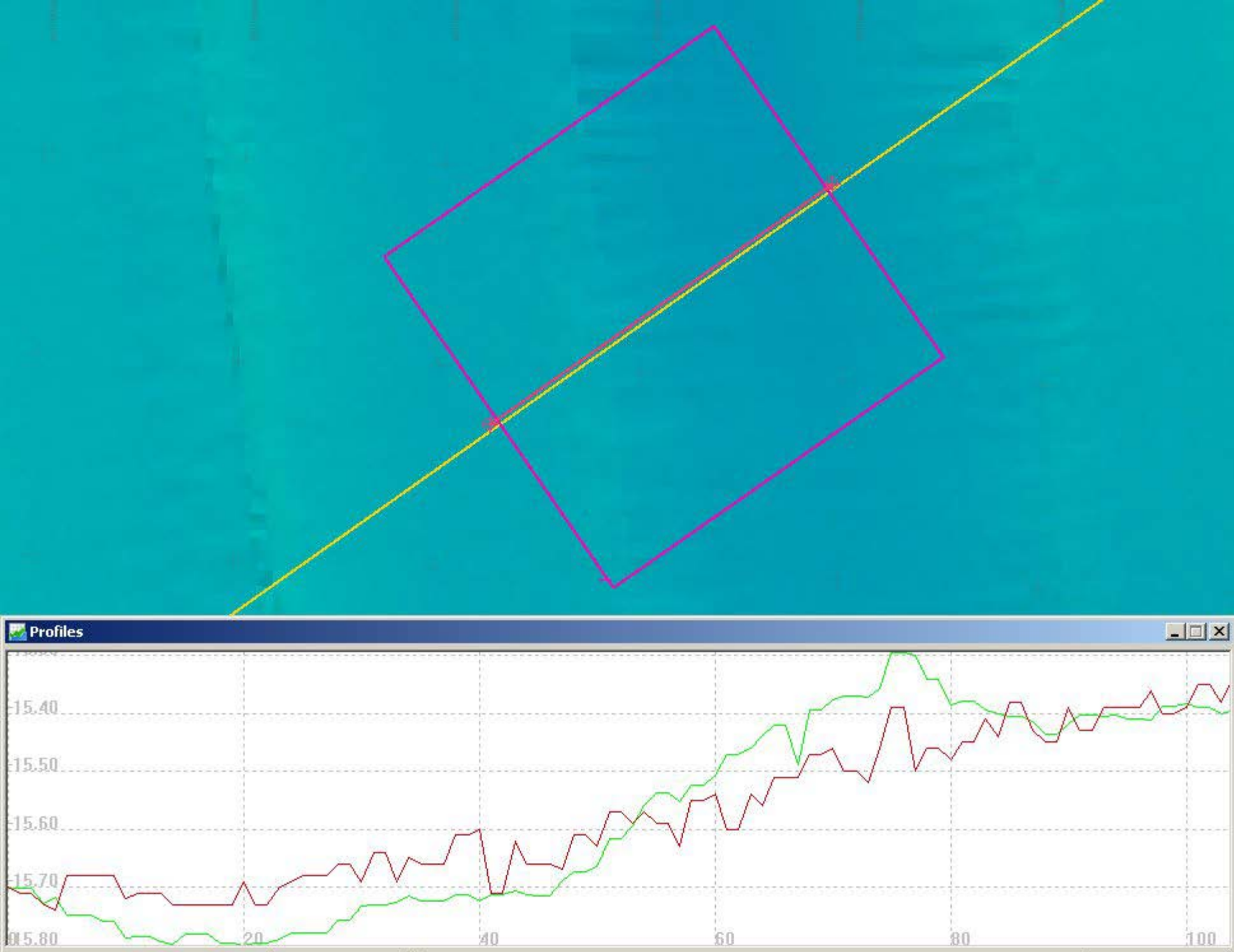
Layer	Color
REFERENCE	Red
SURVEYDATA	

Setting	Value
Background	White
Grid	Light Gray


Profiles
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15.80
20
40
60
80
100
Layer
Color
REFERENCE
Red
SURVEYDATA
Setting
Value
Background
White
Grid
Light Gray

Profiles

17.10
17.15
17.20
17.25
0
20
40
60
80
100

Layer	Color
REFERENCE	Red
SURVEYDATA	

Setting	Value
Background	White
Grid	Light Gray

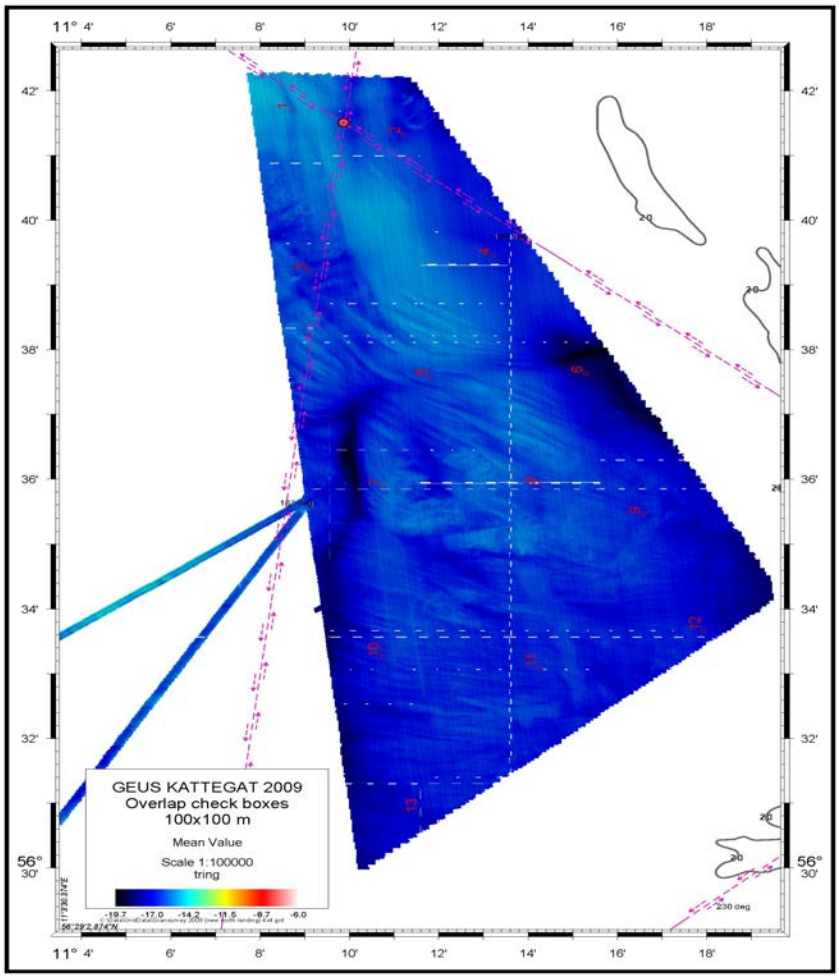
Appendix 12
Binning statistics

- ## Binning statistics

For the general analyses of the characteristics of the binning of data throughout the main survey area the same 13 boxes as were used for “Overlap documentation” has been selected.

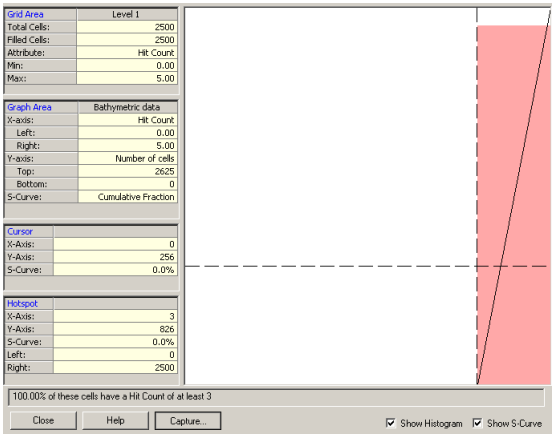
To make sure that the selected data represents the general data set all data from cross lines has been omitted from the box analysis

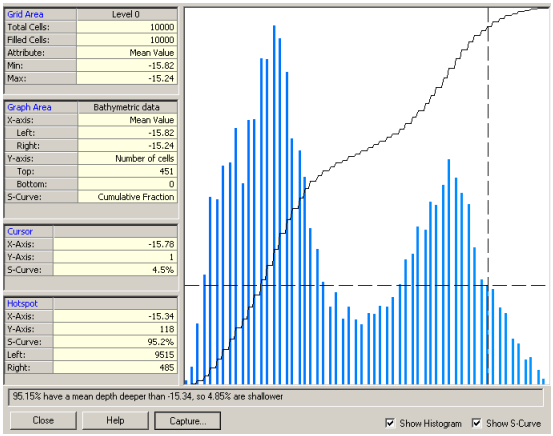
The standard deviation of the data in these boxes has not been evaluated. A more thorough evaluation of the standard deviation of the data please refer to the chapter “Cross over tests”.



Selection Box 1

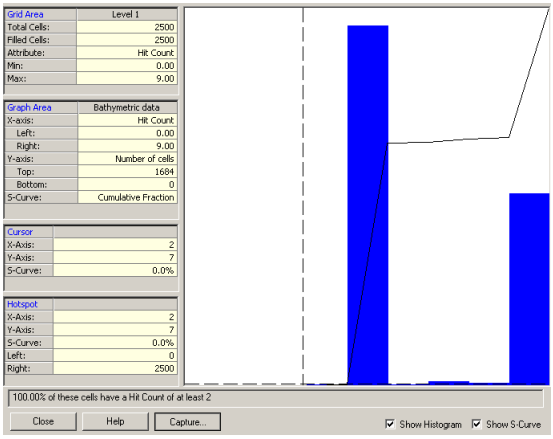
Hit Count per 2x2 m cell:	100 % of the cells are having 3 or more hits
Minimum Depth in box:	- 15.24 metres
Maximum Depth in box:	- 15.82 metres
Mean depth in box:	- 15.34 metres

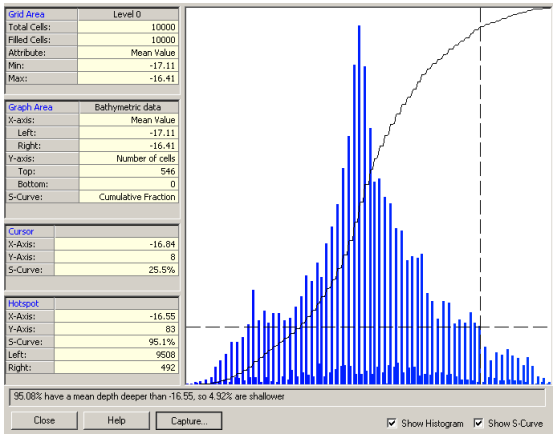




Selection Box 2

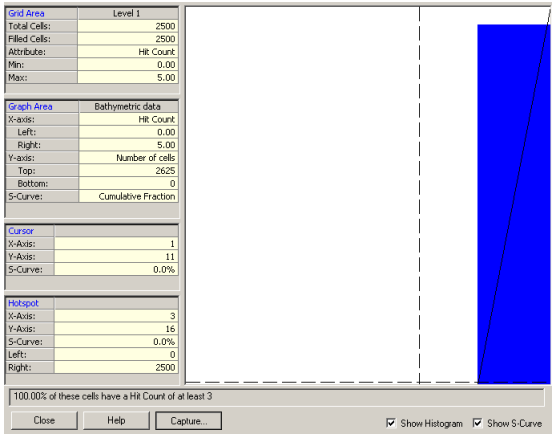
Hit Count per 2x2 m cell:	100 % of the cells are having 2 or more hits
Minimum Depth in box:	- 16.41 metres
Maximum Depth in box:	- 17.11 metres
Mean depth in box:	- 16.55 metres

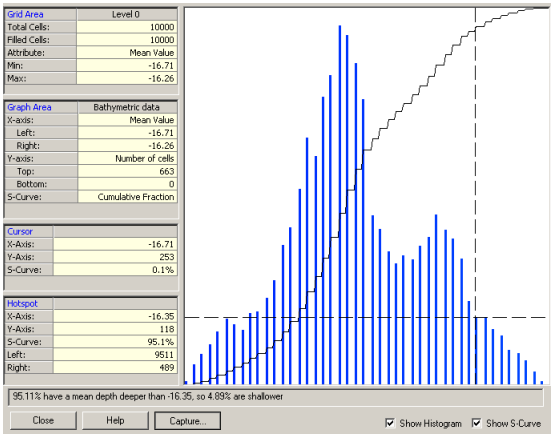




Selection Box 3

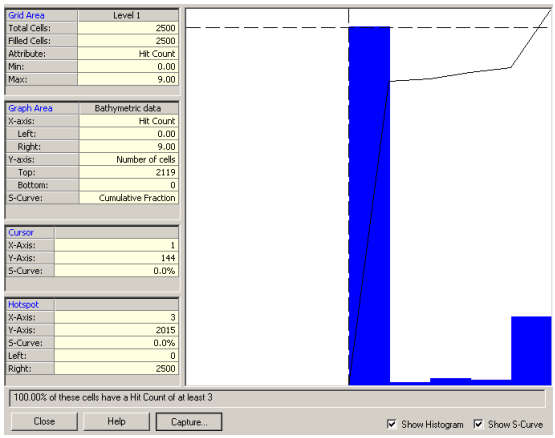
Hit Count per 2x2 m cell:	100 % of the cells are having 3 or more hits
Minimum Depth in box:	- 16.26 metres
Maximum Depth in box:	- 16.71 metres
Mean depth in box:	- 16.35 metres

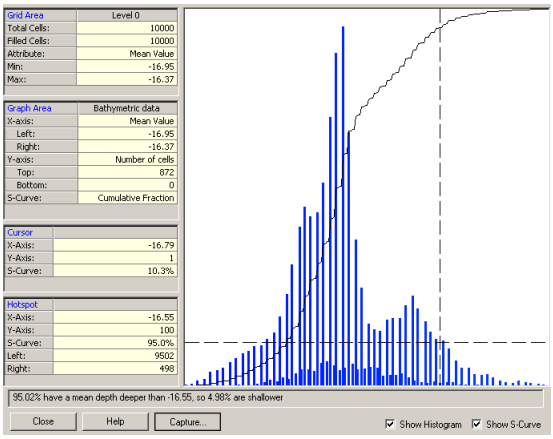




Selection Box 4

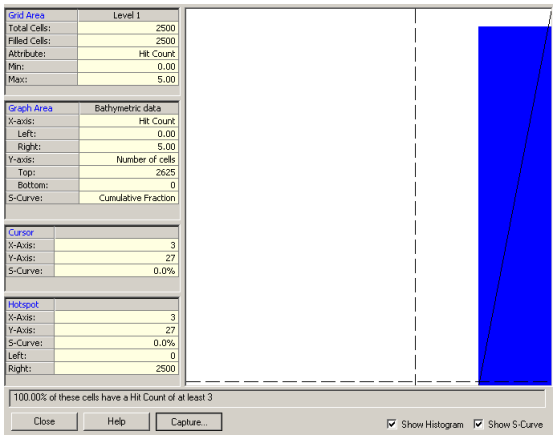
Hit Count per 2x2 m cell:	100 % of the cells are having 3 or more hits
Minimum Depth in box:	- 16.37 metres
Maximum Depth in box:	- 16.95 metres
Mean depth in box:	- 16.55 metres

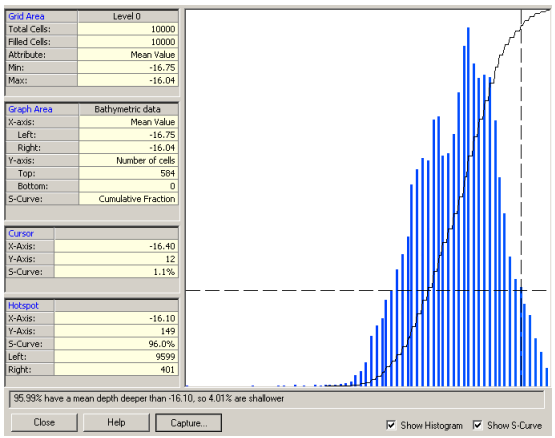




Selection Box 5

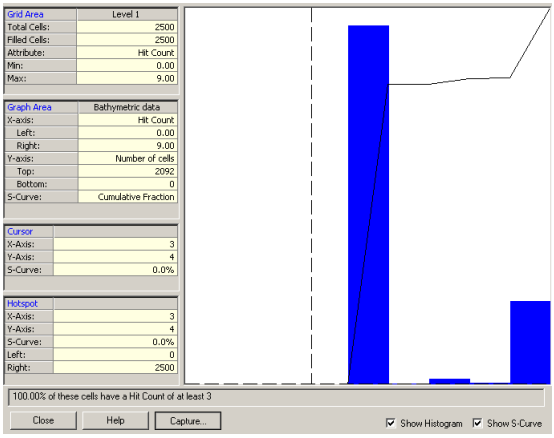
Hit Count per 2x2 m cell:	100 % of the cells are having 3 or more hits
Minimum Depth in box:	- 16.04 metres
Maximum Depth in box:	- 16.75 metres
Mean depth in box:	- 16.10 metres

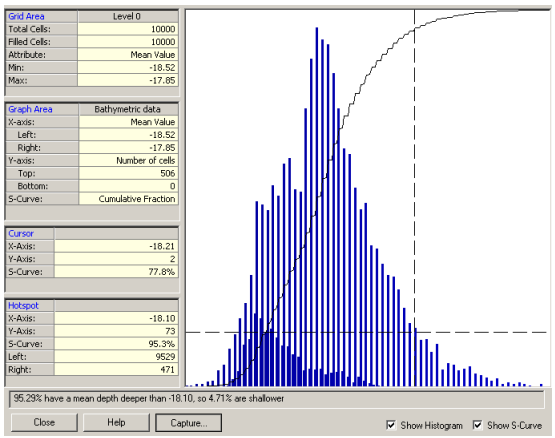




Selection Box 6

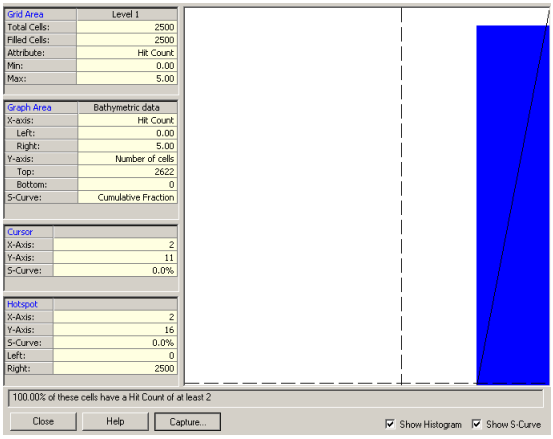
Hit Count per 2x2 m cell:	100 % of the cells are having 3 or more hits
Minimum Depth in box:	- 17.85 metres
Maximum Depth in box:	- 18.52 metres
Mean depth in box:	- 18.10 metres

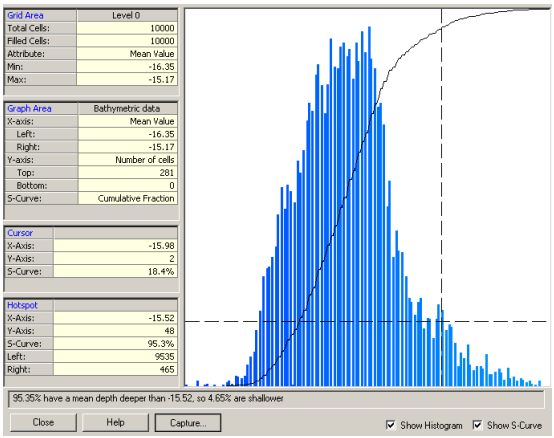




Selection Box 7

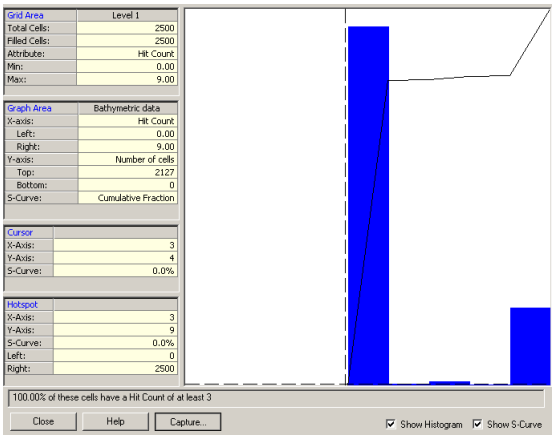
Hit Count per 2x2 m cell:	100 % of the cells are having 2 or more hits
Minimum Depth in box:	- 15.17 metres
Maximum Depth in box:	- 16.35 metres
Mean depth in box:	- 15.52 metres

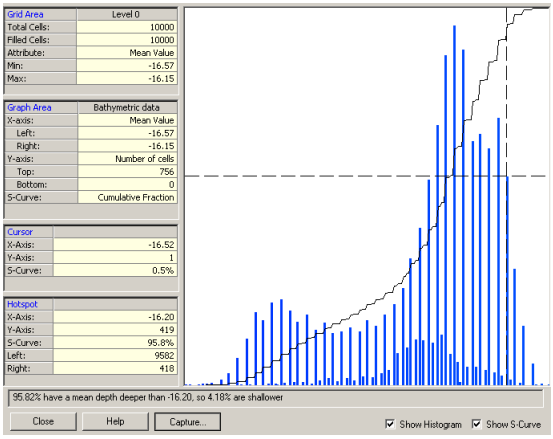




Selection Box 8

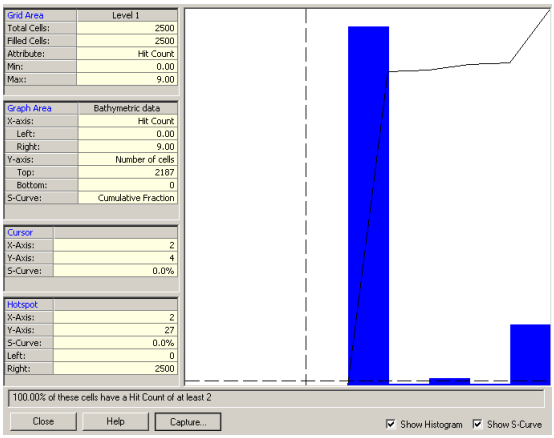
Hit Count per 2x2 m cell:	100 % of the cells are having 3 or more hits
Minimum Depth in box:	- 16.15 metres
Maximum Depth in box:	- 16.57 metres
Mean depth in box:	- 16.20 metres

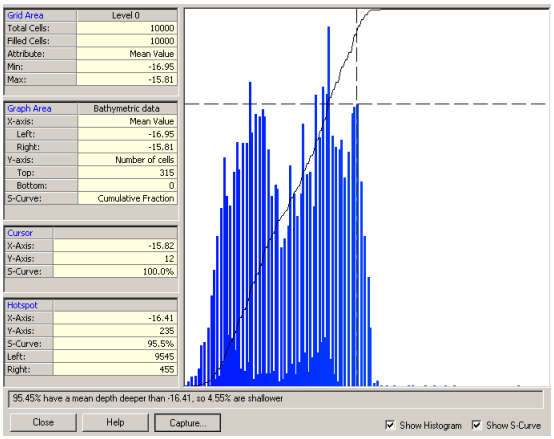




Selection Box 9

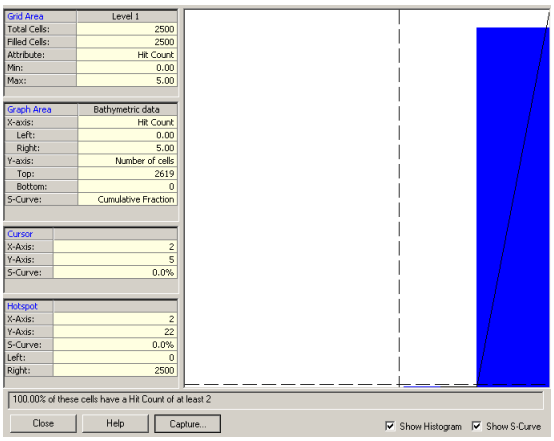
Hit Count per 2x2 m cell:	100 % of the cells are having 2 or more hits
Minimum Depth in box:	- 15.81 metres
Maximum Depth in box:	- 16.95 metres
Mean depth in box:	- 16.41 metres

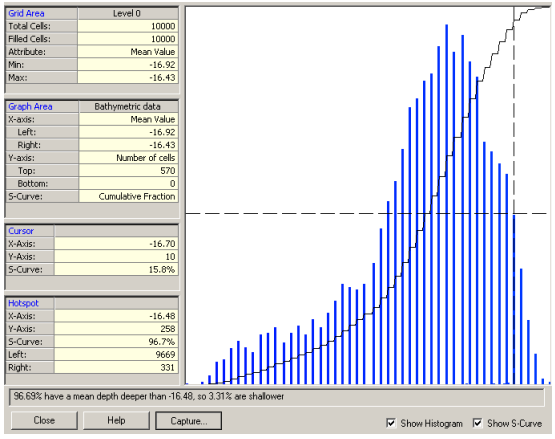




Selection Box 10

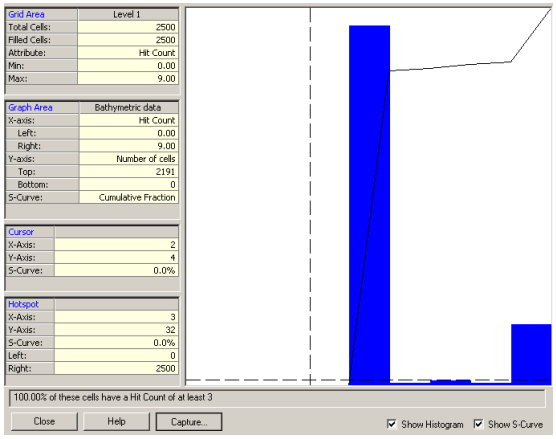
Hit Count per 2x2 m cell:	100 % of the cells are having 2 or more hits
Minimum Depth in box:	- 16.43 metres
Maximum Depth in box:	- 16.92 metres
Mean depth in box:	- 16.48 metres

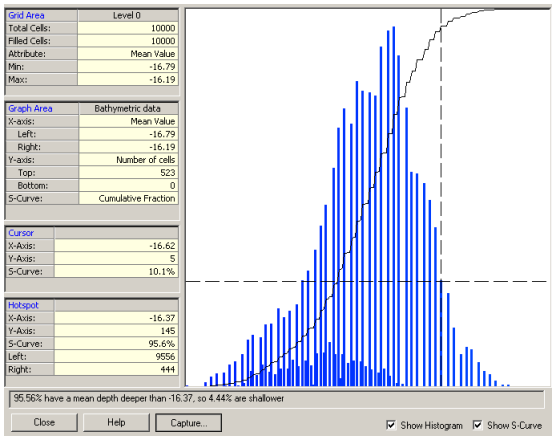




Selection Box 11

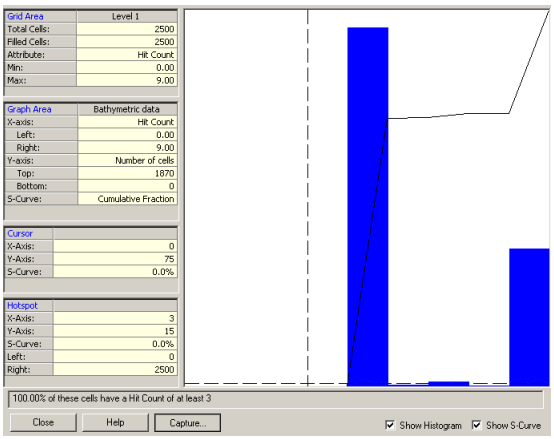
Hit Count per 2x2 m cell:	100 % of the cells are having 3 or more hits
Minimum Depth in box:	- 16.19 metres
Maximum Depth in box:	- 16.79 metres
Mean depth in box:	- 16.37 metres

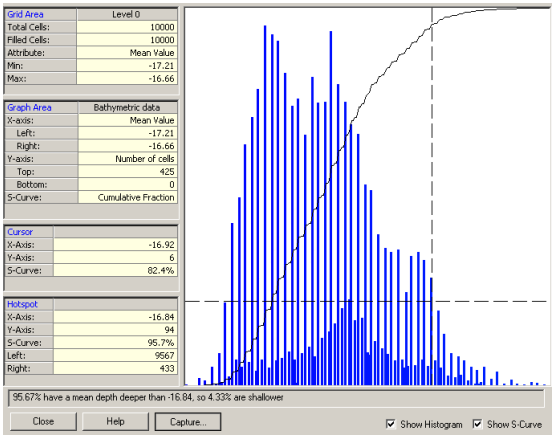




Selection Box 12

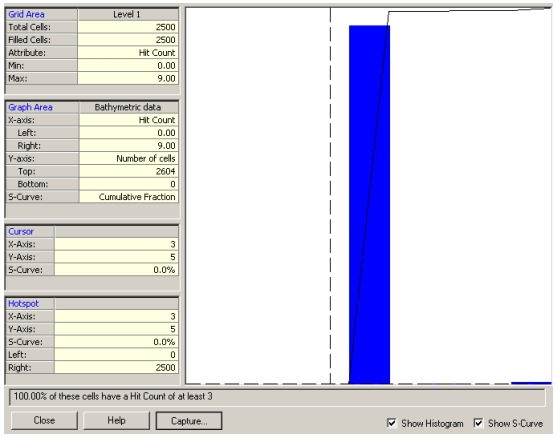
Hit Count per 2x2 m cell:	100 % of the cells are having 3 or more hits
Minimum Depth in box:	- 16.66 metres
Maximum Depth in box:	- 17.21 metres
Mean depth in box:	- 16.84 metres

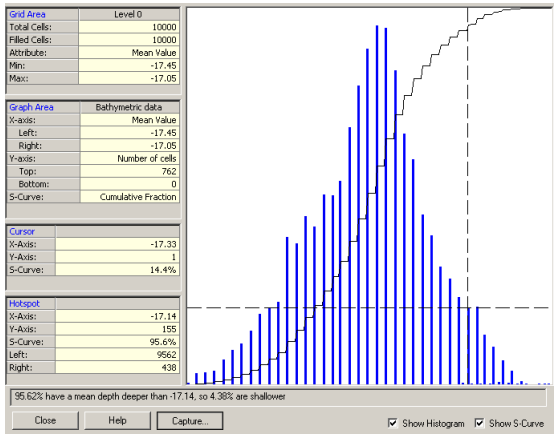


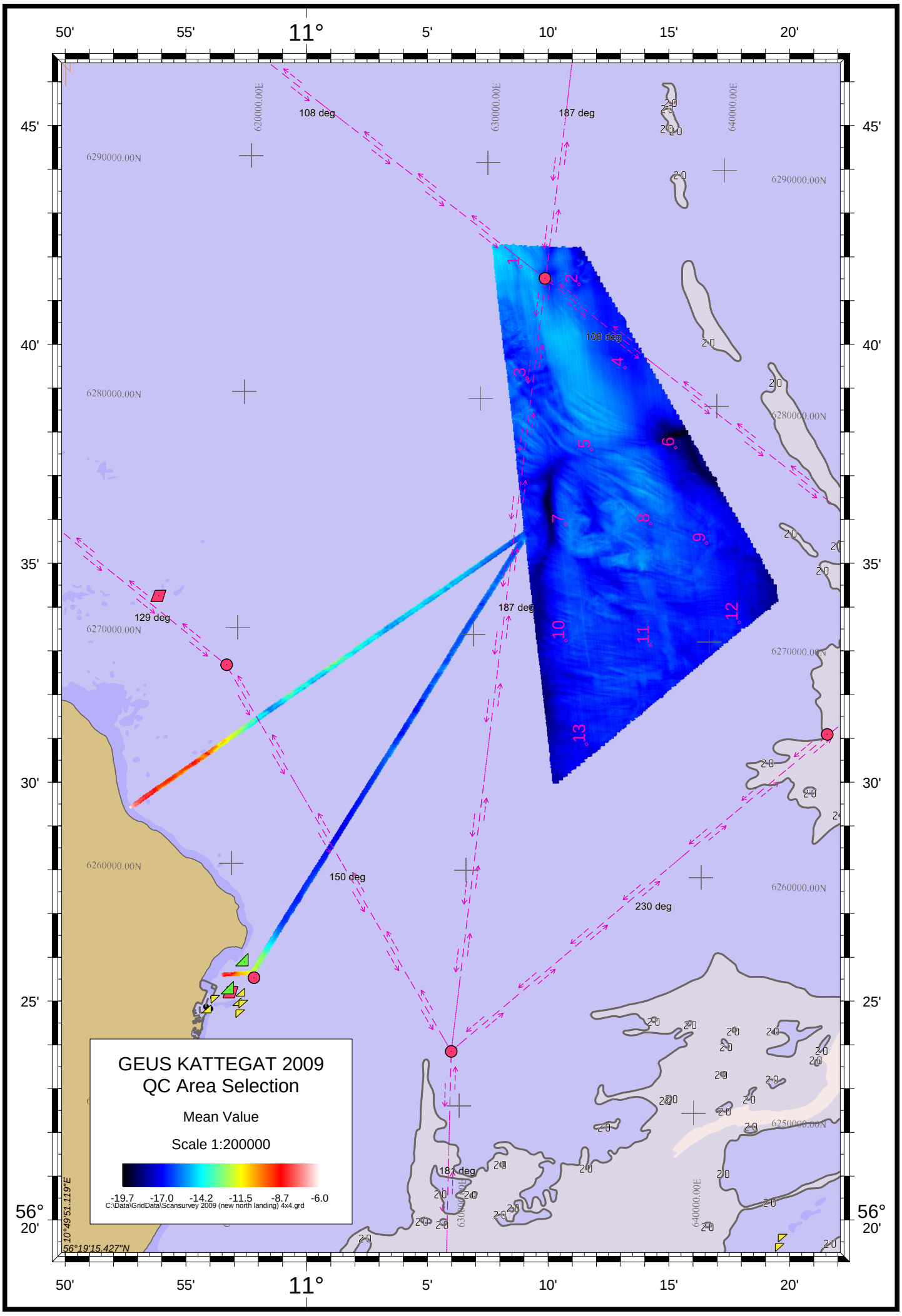


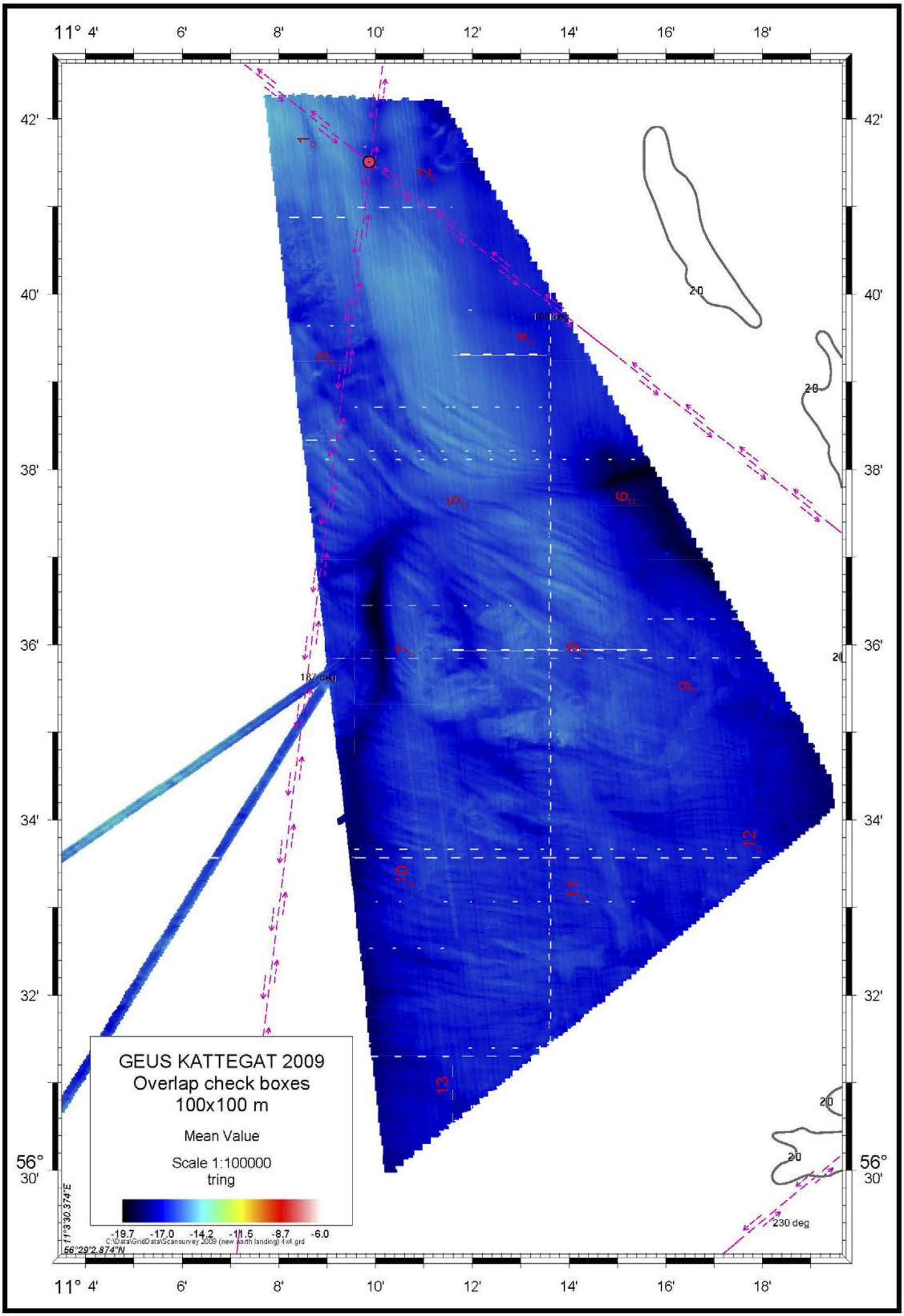
Selection Box 13

Hit Count per 2x2 m cell:	100 % of the cells are having 3 or more hits
Minimum Depth in box:	- 17.05 metres
Maximum Depth in box:	- 17.45 metres
Mean depth in box:	- 17.14 metres






GEUS KATTEGAT 2009
QC Area Selection
Mean Value
Scale 1:200000
-19.7 -17.0 -14.2 -11.5 -8.7 -6.0
C:\Data\GridData\Scansurvey 2009 (new north landing) 4x4.grd
108 deg
187 deg
129 deg
150 deg
230 deg
181 deg
50' 55' 11° 5' 10' 15' 20'
45' 40' 35' 30' 25' 56° 20'
6290000.00N
6280000.00N
6270000.00N
6260000.00N
6250000.00N
620000.00E
630000.00E
640000.00E
10°49'51.119"E
56°19'15.427"N

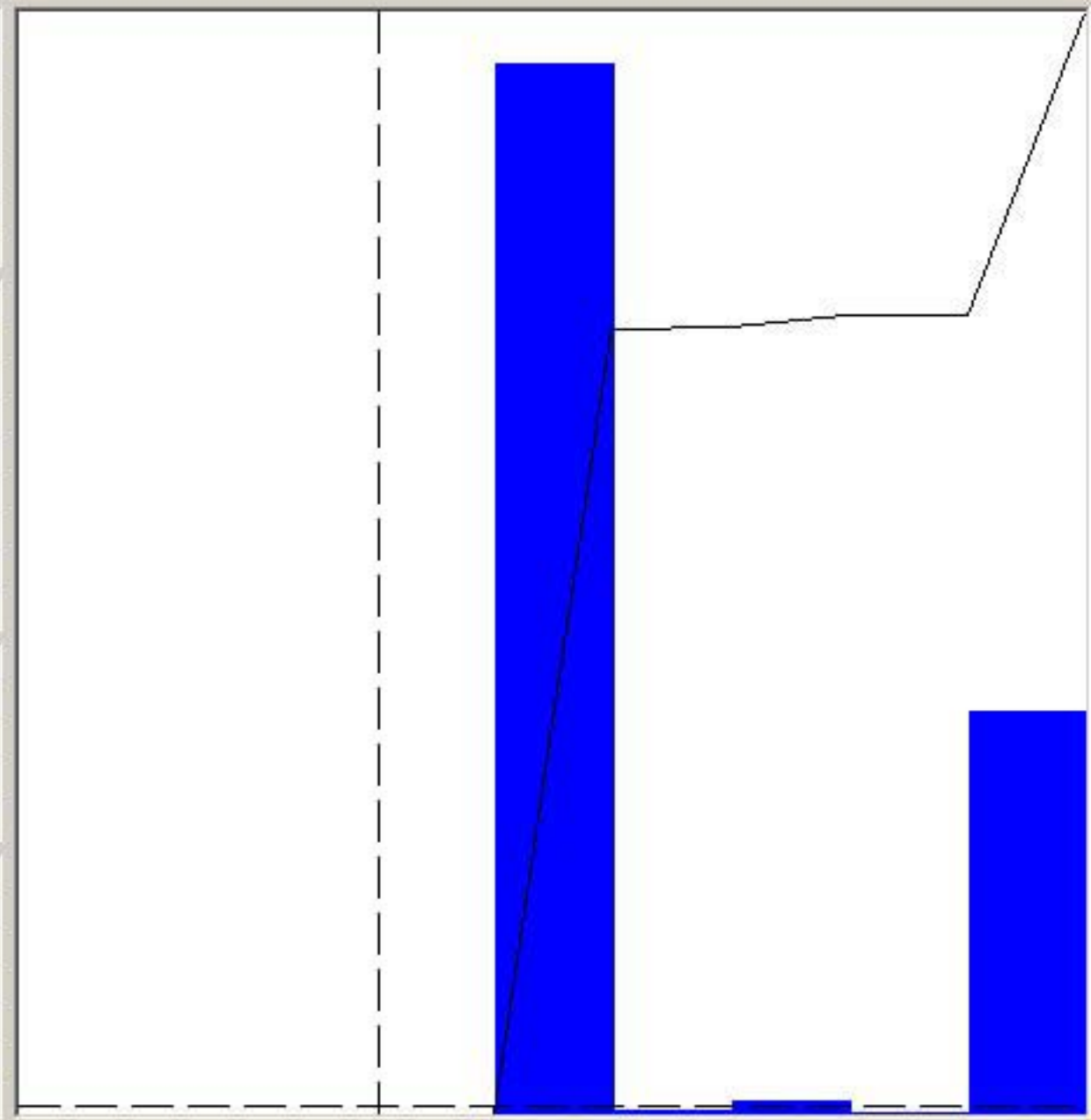

11° 4'
6'
8'
10'
12'
14'
16'
18'
42'
40'
38'
36'
34'
32'
56° 30'
20
20
20
20
187 deg
230 deg
GEUS KATTEGAT 2009
Overlap check boxes
100x100 m
Mean Value
Scale 1:100000
tring
-19.7
-17.0
-14.2
-11.5
-8.7
-6.0
C:\Data\GridData\Scansurvey 2009 (new north landing) 4x4.grd
11°3'30.374"E
56°29'2.874"N

Grid Area	Level 1
Total Cells:	2500
Filled Cells:	2500
Attribute:	Hit Count
Min:	0.00
Max:	9.00

Graph Area	Bathymetric data
X-axis:	Hit Count
Left:	0.00
Right:	9.00
Y-axis:	Number of cells
Top:	1870
Bottom:	0
S-Curve:	Cumulative Fraction

Cursor	
X-Axis:	0
Y-Axis:	75
S-Curve:	0.0%

Hotspot	
X-Axis:	3
Y-Axis:	15
S-Curve:	0.0%
Left:	0
Right:	2500



100.00% of these cells have a Hit Count of at least 3

Close | Help | Capture...

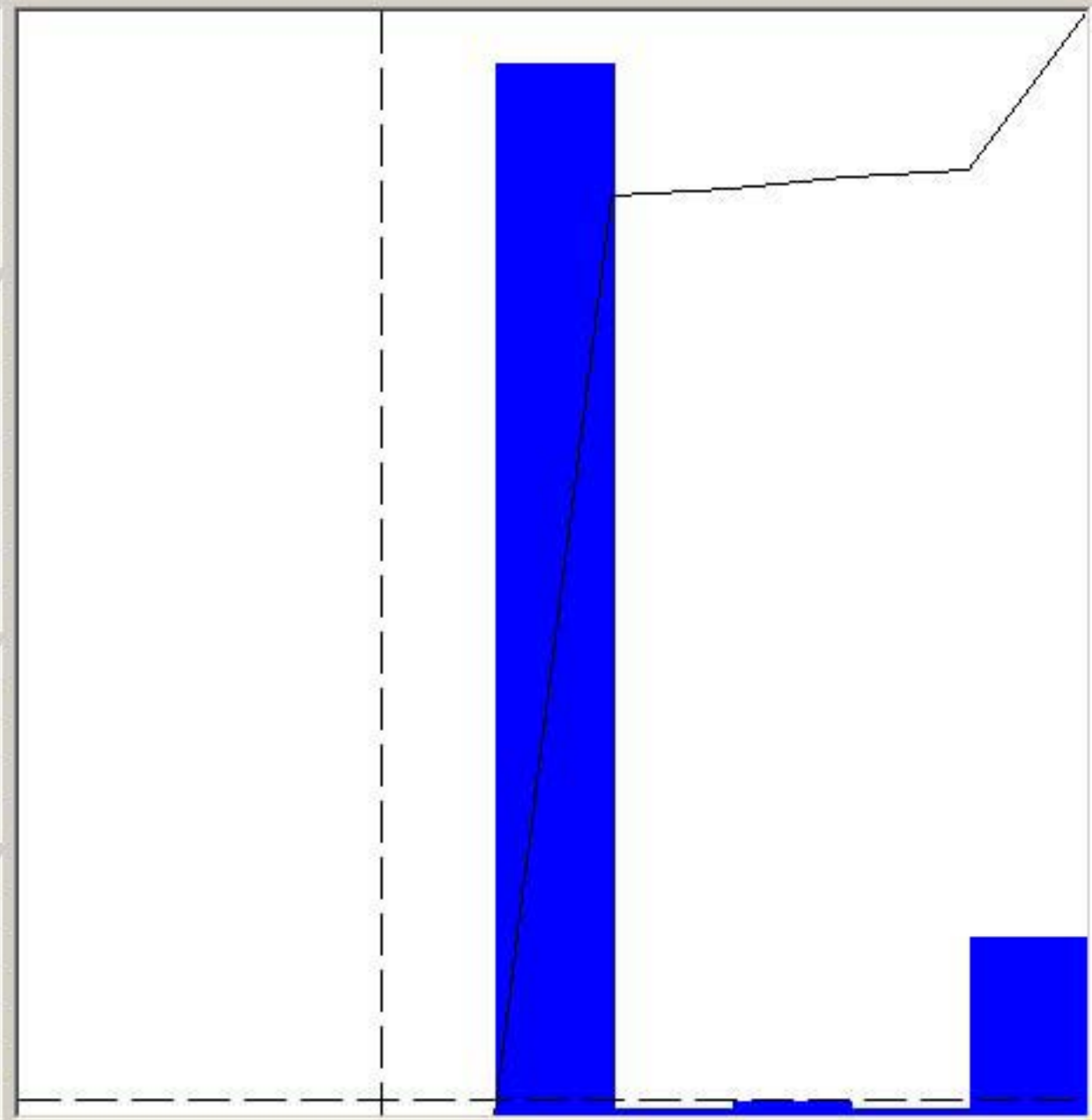
☑ Show Histogram ☑ Show S-Curve

Grid Area	Level 1
Total Cells:	2500
Filled Cells:	2500
Attribute:	Hit Count
Min:	0.00
Max:	9.00

Graph Area	Bathymetric data
X-axis:	Hit Count
Left:	0.00
Right:	9.00
Y-axis:	Number of cells
Top:	2191
Bottom:	0
S-Curve:	Cumulative Fraction

Cursor	
X-Axis:	2
Y-Axis:	4
S-Curve:	0.0%

Hotspot	
X-Axis:	3
Y-Axis:	32
S-Curve:	0.0%
Left:	0
Right:	2500



100.00% of these cells have a Hit Count of at least 3

Close | Help | Capture...

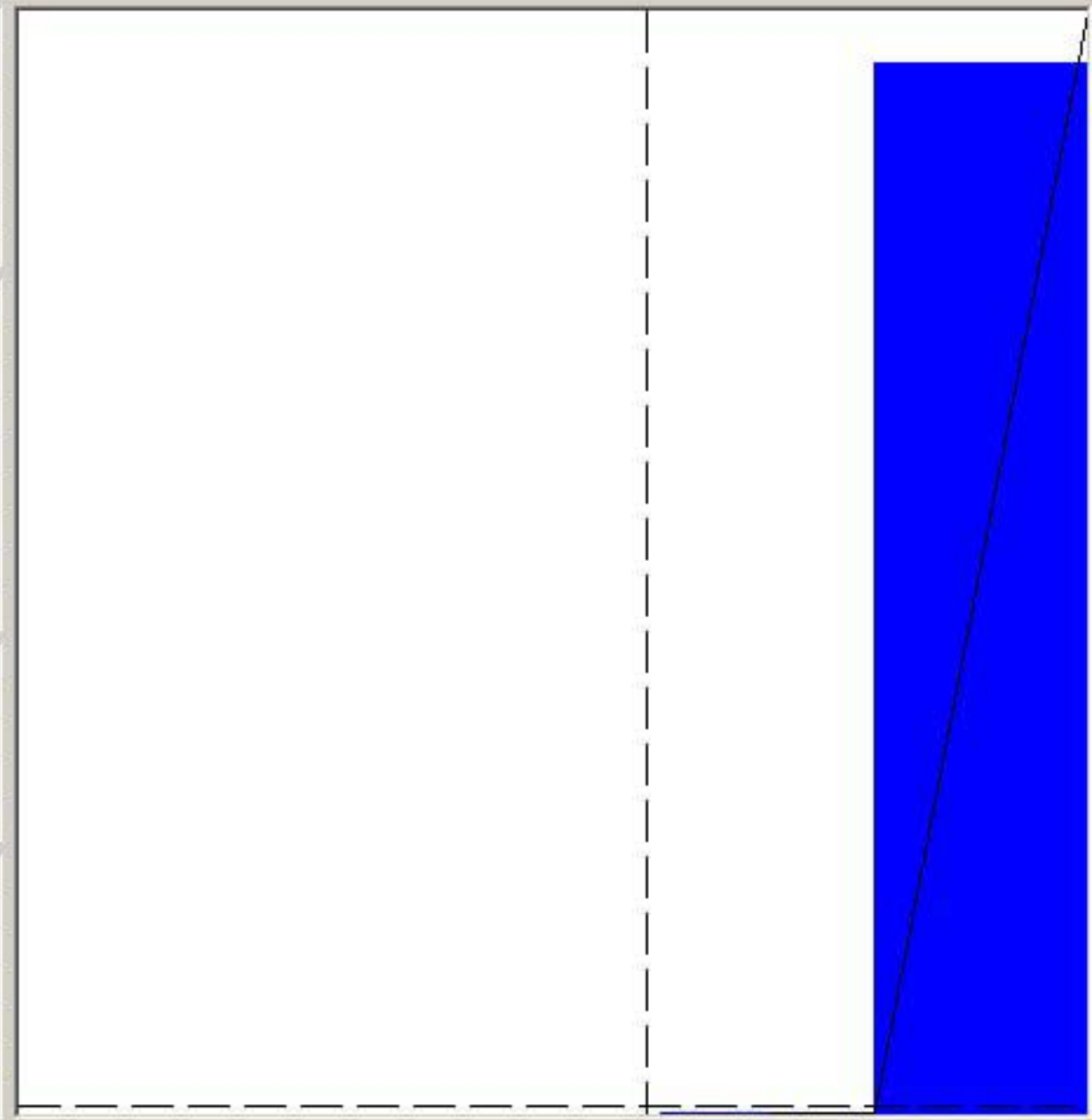
☑ Show Histogram ☑ Show S-Curve

Grid Area	Level 1
Total Cells:	2500
Filled Cells:	2500
Attribute:	Hit Count
Min:	0.00
Max:	5.00

Graph Area	Bathymetric data
X-axis:	Hit Count
Left:	0.00
Right:	5.00
Y-axis:	Number of cells
Top:	2619
Bottom:	0
S-Curve:	Cumulative Fraction

Cursor	
X-Axis:	2
Y-Axis:	5
S-Curve:	0.0%

Hotspot	
X-Axis:	2
Y-Axis:	22
S-Curve:	0.0%
Left:	0
Right:	2500



100.00% of these cells have a Hit Count of at least 2

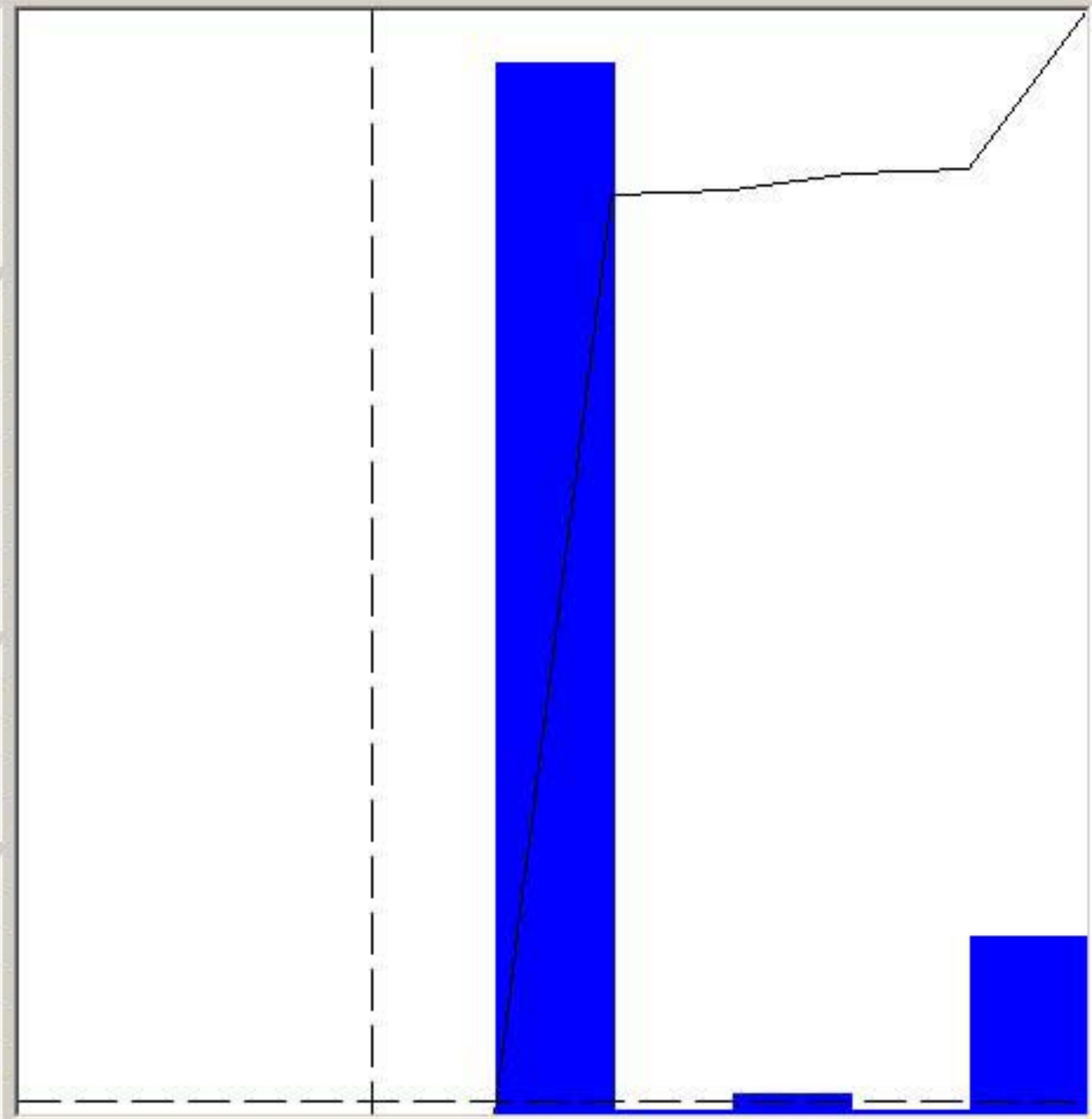
Close | Help | Capture... | ☑ Show Histogram | ☑ Show S-Curve

Grid Area	Level 1
Total Cells:	2500
Filled Cells:	2500
Attribute:	Hit Count
Min:	0.00
Max:	9.00

Graph Area	Bathymetric data
X-axis:	Hit Count
Left:	0.00
Right:	9.00
Y-axis:	Number of cells
Top:	2187
Bottom:	0
S-Curve:	Cumulative Fraction

Cursor	
X-Axis:	2
Y-Axis:	4
S-Curve:	0.0%

Hotspot	
X-Axis:	2
Y-Axis:	27
S-Curve:	0.0%
Left:	0
Right:	2500



100.00% of these cells have a Hit Count of at least 2

Close | Help | Capture...

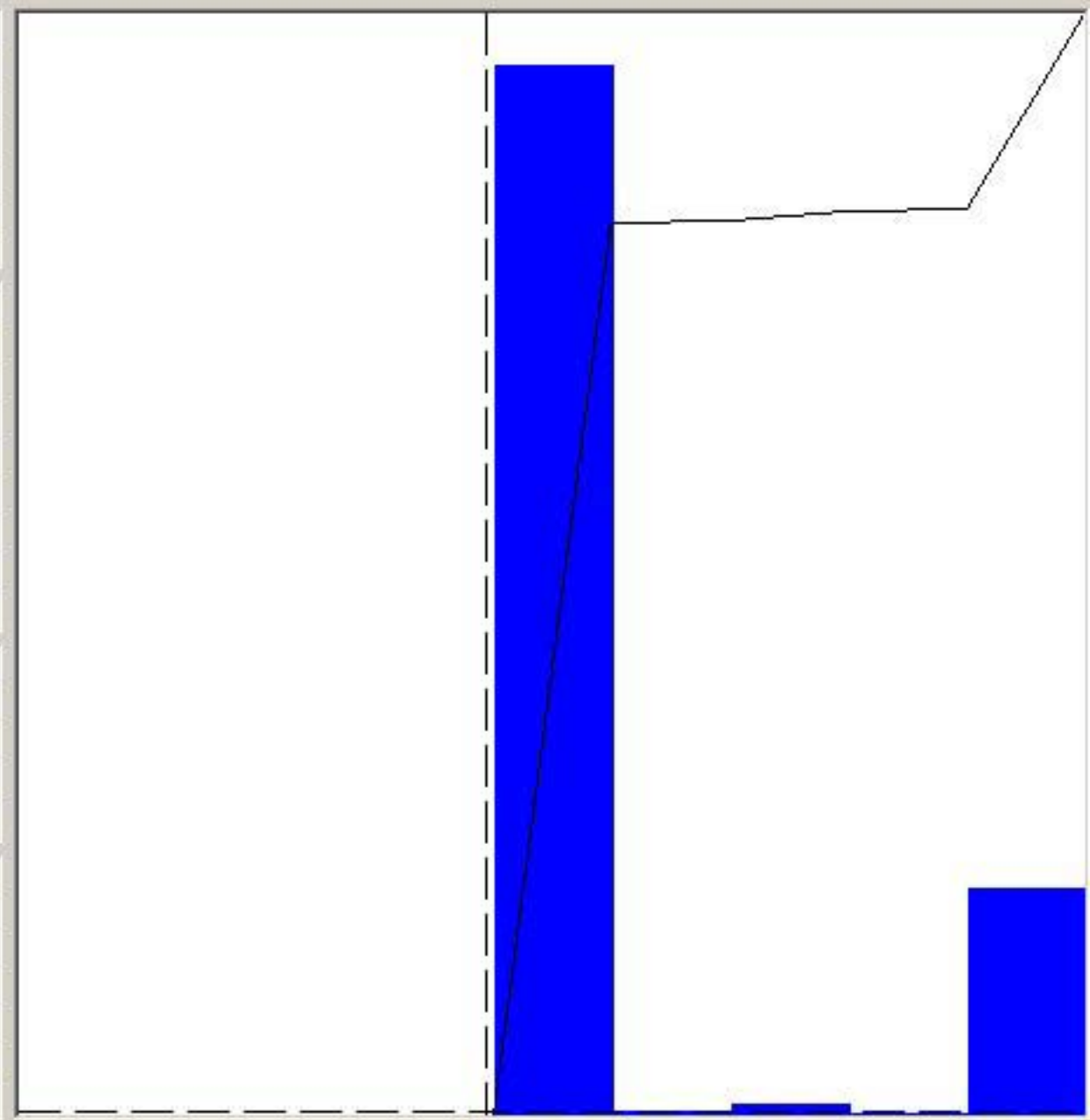
☑ Show Histogram ☑ Show S-Curve

Grid Area	Level 1
Total Cells:	2500
Filled Cells:	2500
Attribute:	Hit Count
Min:	0.00
Max:	9.00

Graph Area	Bathymetric data
X-axis:	Hit Count
Left:	0.00
Right:	9.00
Y-axis:	Number of cells
Top:	2127
Bottom:	0
S-Curve:	Cumulative Fraction

Cursor	
X-Axis:	3
Y-Axis:	4
S-Curve:	0.0%

Hotspot	
X-Axis:	3
Y-Axis:	9
S-Curve:	0.0%
Left:	0
Right:	2500



100.00% of these cells have a Hit Count of at least 3

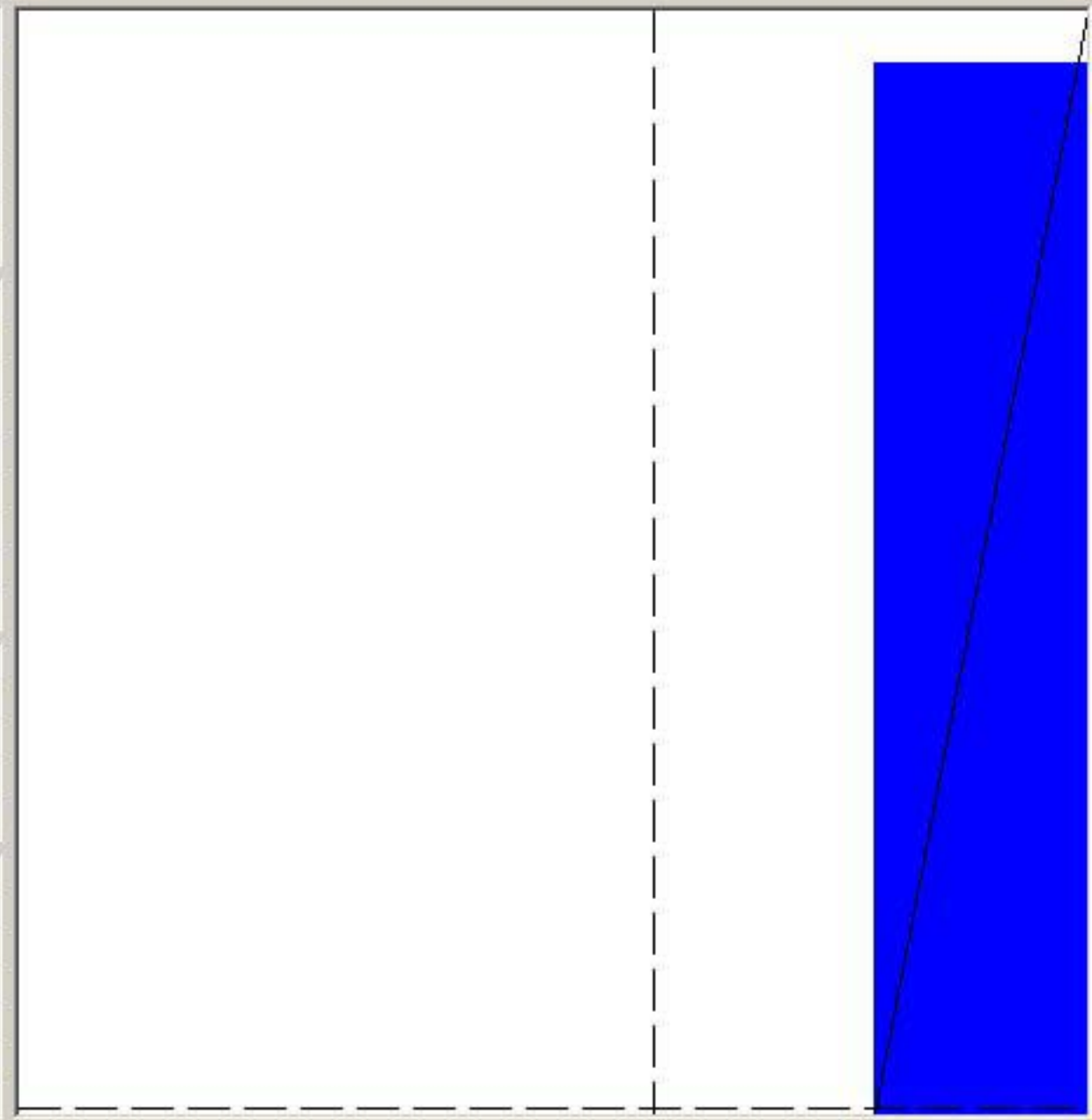
Close | Help | Capture... | ☑ Show Histogram | ☑ Show S-Curve

Grid Area	Level 1
Total Cells:	2500
Filled Cells:	2500
Attribute:	Hit Count
Min:	0.00
Max:	5.00

Graph Area	Bathymetric data
X-axis:	Hit Count
Left:	0.00
Right:	5.00
Y-axis:	Number of cells
Top:	2622
Bottom:	0
S-Curve:	Cumulative Fraction

Cursor	
X-Axis:	2
Y-Axis:	11
S-Curve:	0.0%

Hotspot	
X-Axis:	2
Y-Axis:	16
S-Curve:	0.0%
Left:	0
Right:	2500



100.00% of these cells have a Hit Count of at least 2

Close | Help | Capture...

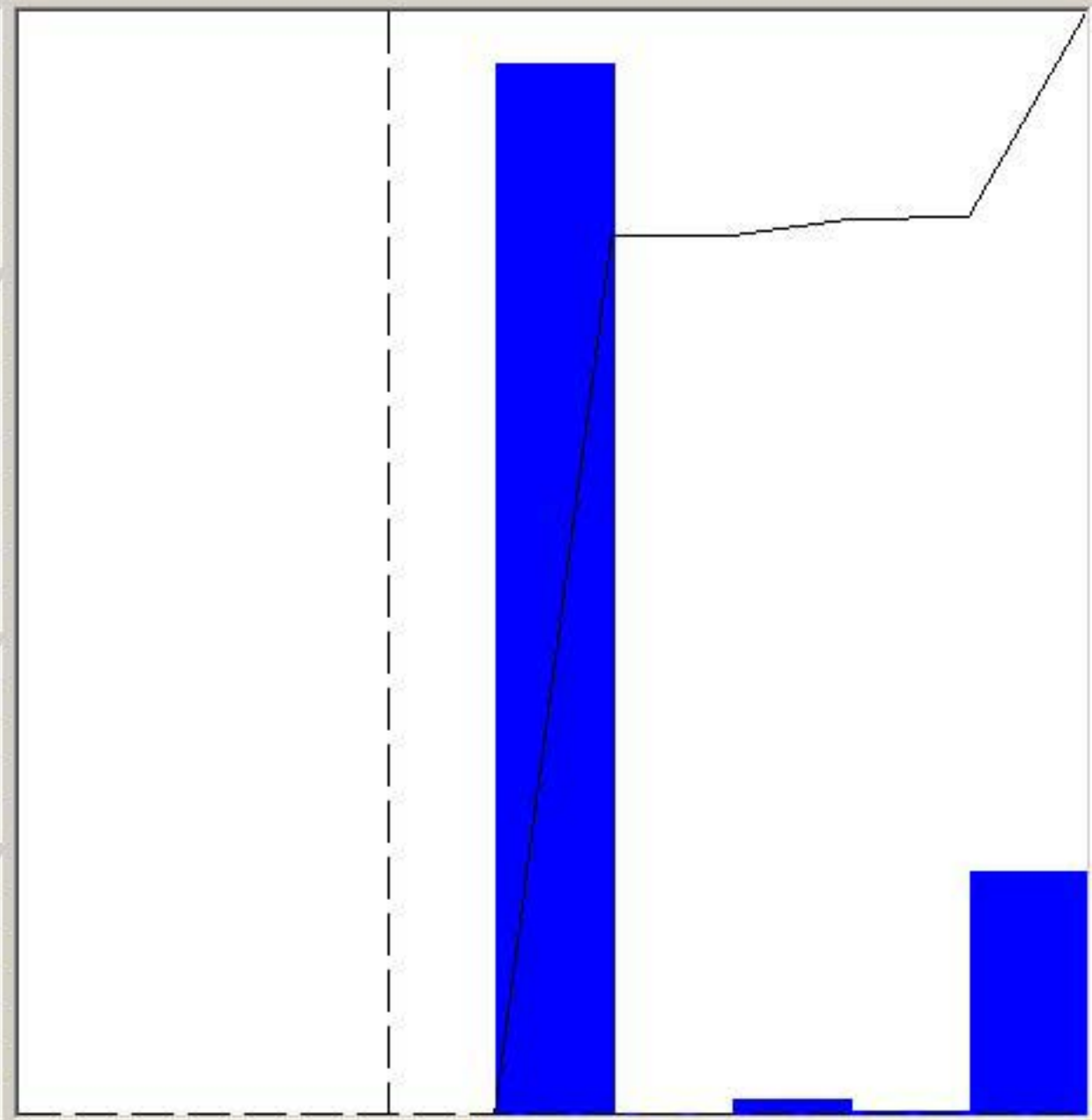
☑ Show Histogram ☑ Show S-Curve

Grid Area	Level 1
Total Cells:	2500
Filled Cells:	2500
Attribute:	Hit Count
Min:	0.00
Max:	9.00

Graph Area	Bathymetric data
X-axis:	Hit Count
Left:	0.00
Right:	9.00
Y-axis:	Number of cells
Top:	2092
Bottom:	0
S-Curve:	Cumulative Fraction

Cursor	
X-Axis:	3
Y-Axis:	4
S-Curve:	0.0%

Hotspot	
X-Axis:	3
Y-Axis:	4
S-Curve:	0.0%
Left:	0
Right:	2500



100.00% of these cells have a Hit Count of at least 3

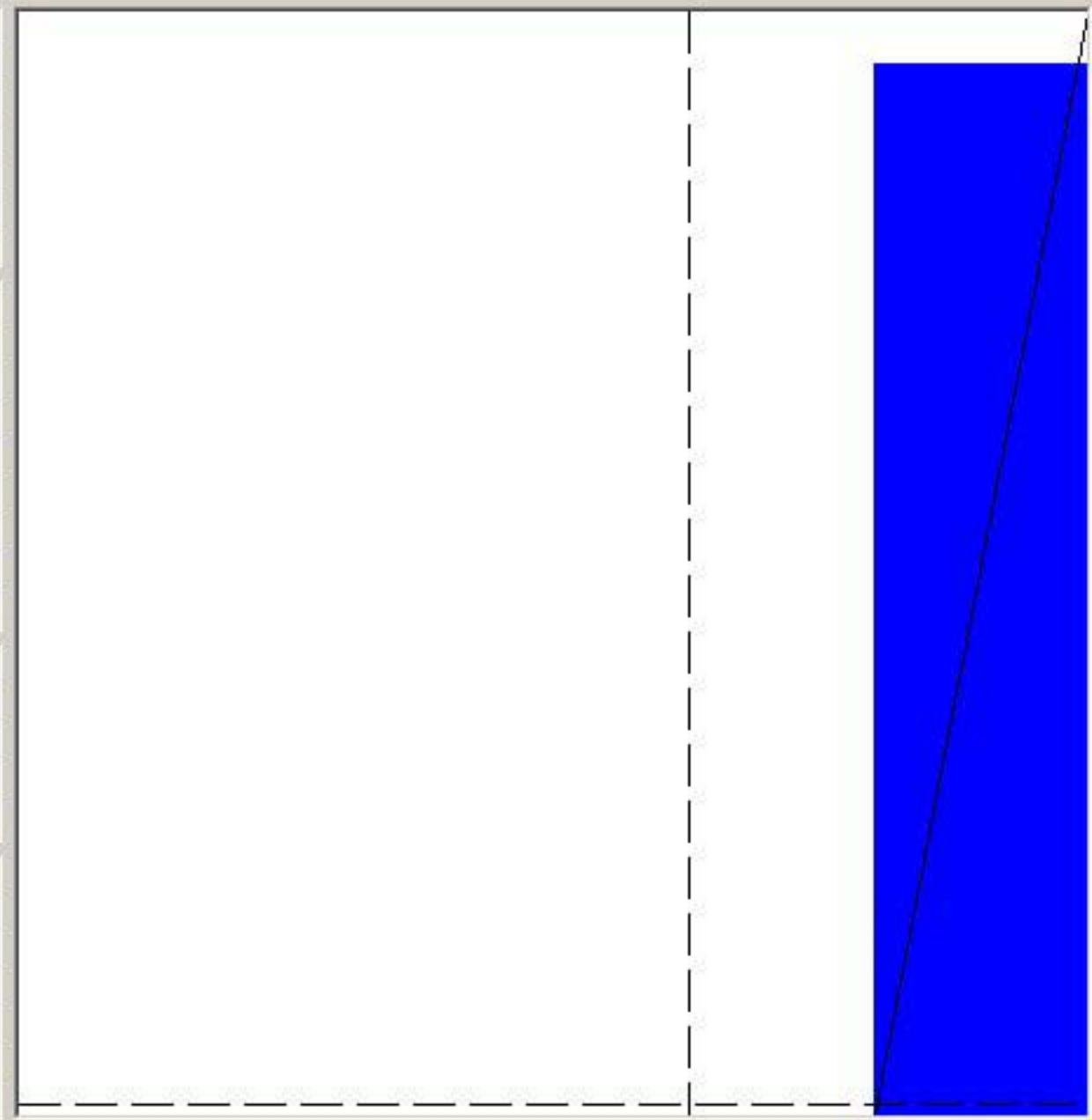
Close | Help | Capture... | ☑ Show Histogram | ☑ Show S-Curve

Grid Area	Level 1
Total Cells:	2500
Filled Cells:	2500
Attribute:	Hit Count
Min:	0.00
Max:	5.00

Graph Area	Bathymetric data
X-axis:	Hit Count
Left:	0.00
Right:	5.00
Y-axis:	Number of cells
Top:	2625
Bottom:	0
S-Curve:	Cumulative Fraction

Cursor	
X-Axis:	3
Y-Axis:	27
S-Curve:	0.0%

Hotspot	
X-Axis:	3
Y-Axis:	27
S-Curve:	0.0%
Left:	0
Right:	2500



100.00% of these cells have a Hit Count of at least 3

Close | Help | Capture...

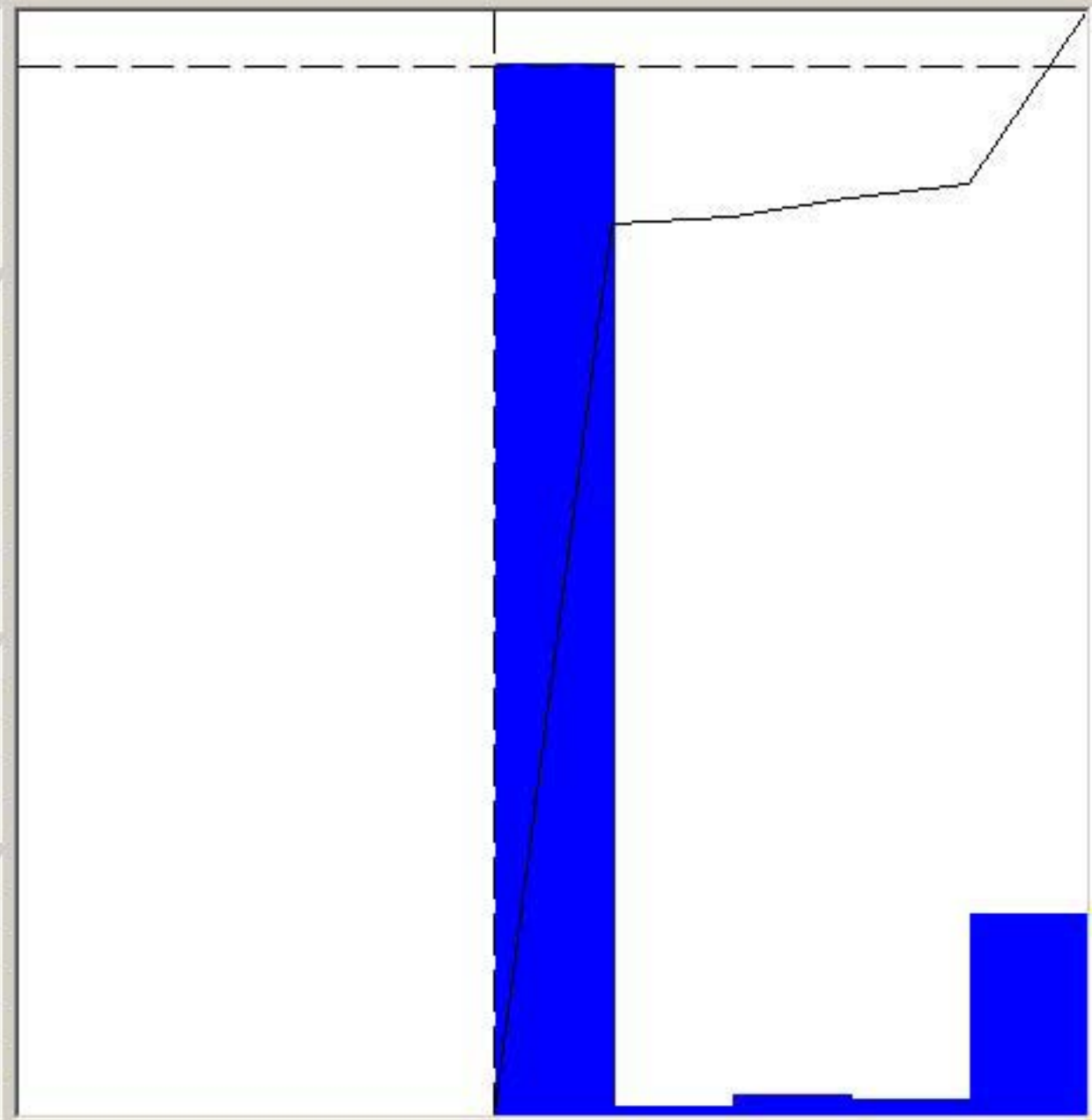
☑ Show Histogram ☑ Show S-Curve

Grid Area	Level 1
Total Cells:	2500
Filled Cells:	2500
Attribute:	Hit Count
Min:	0.00
Max:	9.00

Graph Area	Bathymetric data
X-axis:	Hit Count
Left:	0.00
Right:	9.00
Y-axis:	Number of cells
Top:	2119
Bottom:	0
S-Curve:	Cumulative Fraction

Cursor	
X-Axis:	1
Y-Axis:	144
S-Curve:	0.0%

Hotspot	
X-Axis:	3
Y-Axis:	2015
S-Curve:	0.0%
Left:	0
Right:	2500



100.00% of these cells have a Hit Count of at least 3

Close | Help | Capture...

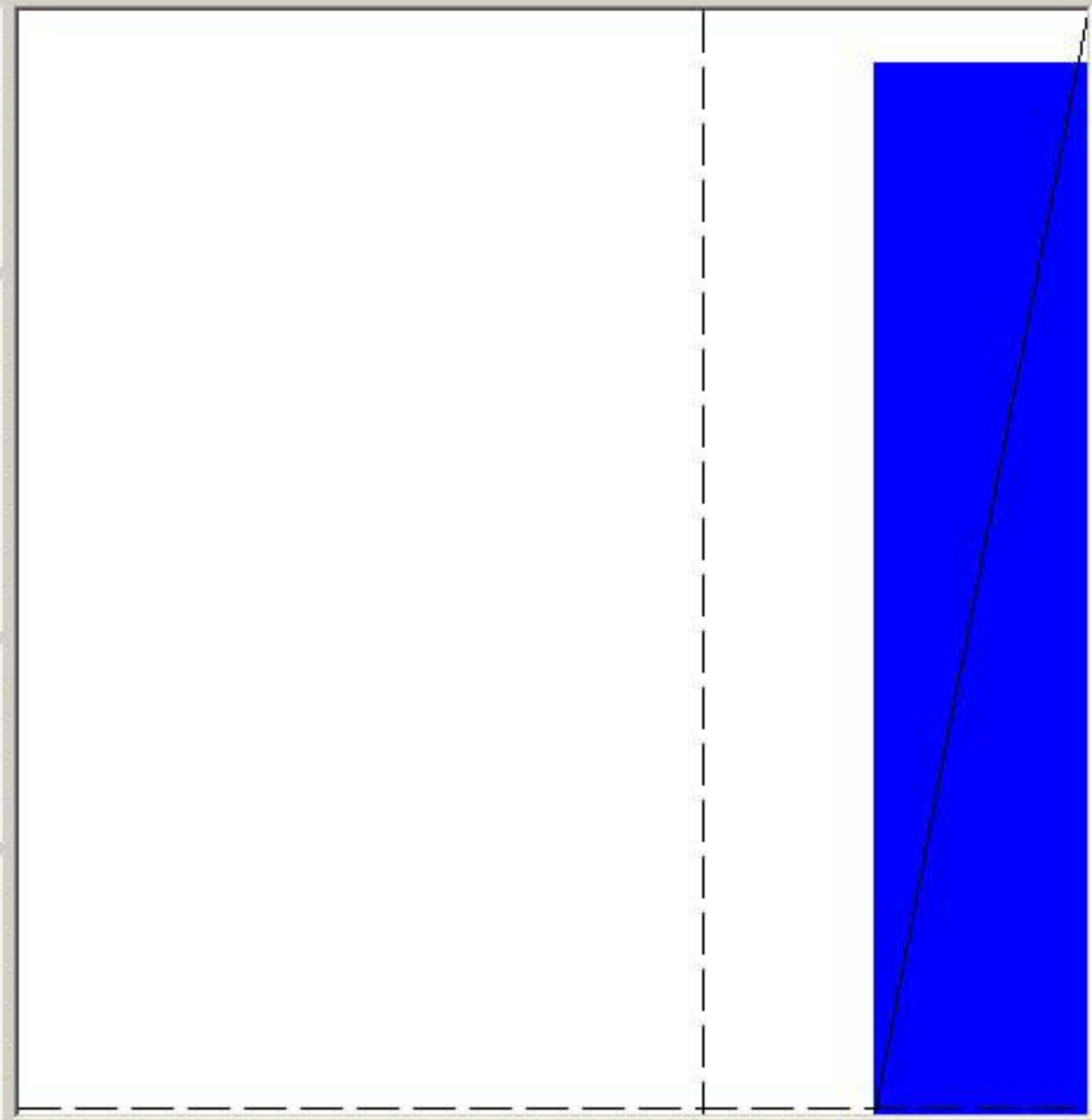
☑ Show Histogram ☑ Show S-Curve

Grid Area	Level 1
Total Cells:	2500
Filled Cells:	2500
Attribute:	Hit Count
Min:	0.00
Max:	5.00

Graph Area	Bathymetric data
X-axis:	Hit Count
Left:	0.00
Right:	5.00
Y-axis:	Number of cells
Top:	2625
Bottom:	0
S-Curve:	Cumulative Fraction

Cursor	
X-Axis:	1
Y-Axis:	11
S-Curve:	0.0%

Hotspot	
X-Axis:	3
Y-Axis:	16
S-Curve:	0.0%
Left:	0
Right:	2500



100.00% of these cells have a Hit Count of at least 3

Close | Help | Capture...

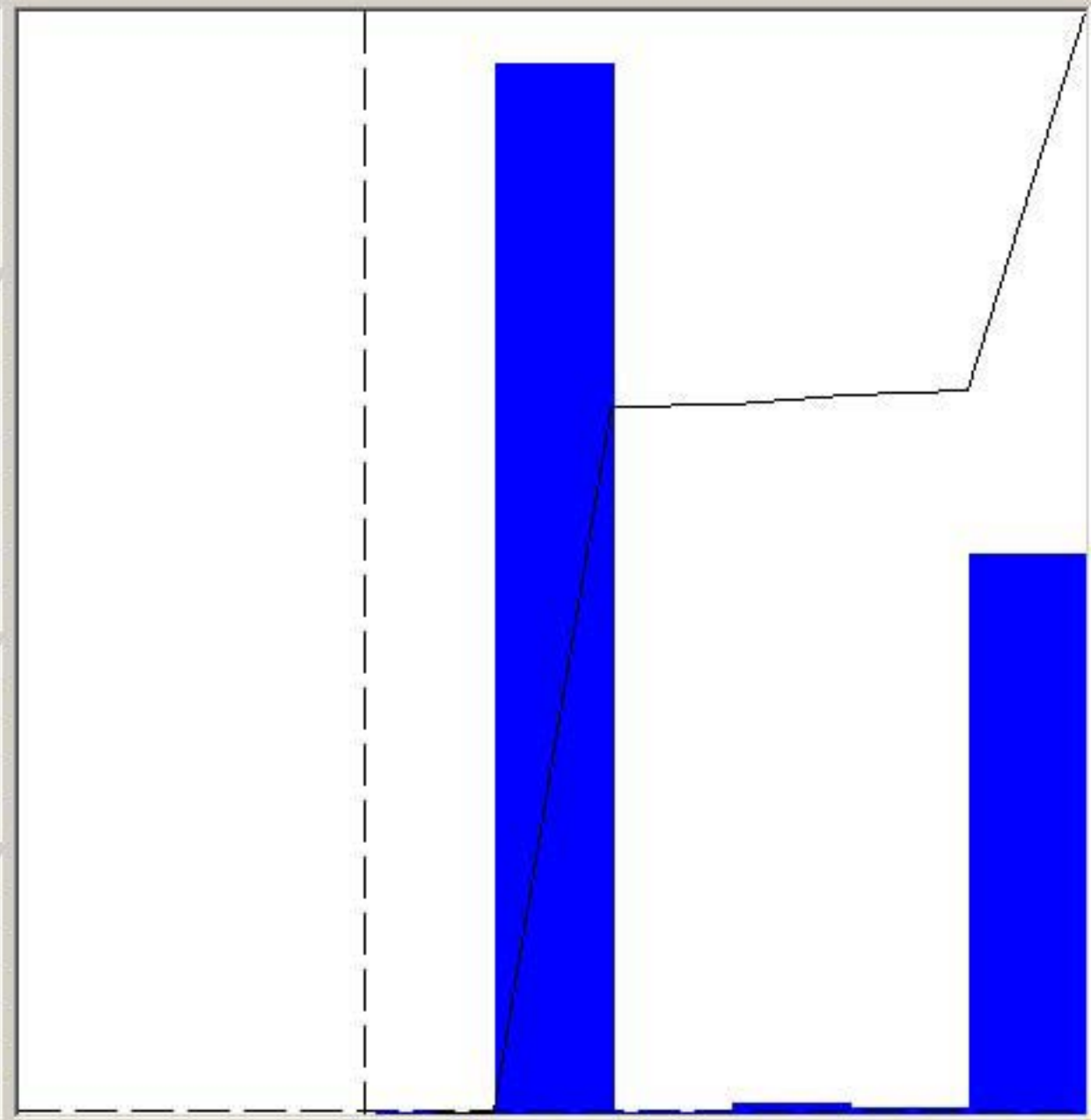
☑ Show Histogram ☑ Show S-Curve

Grid Area	Level 1
Total Cells:	2500
Filled Cells:	2500
Attribute:	Hit Count
Min:	0.00
Max:	9.00

Graph Area	Bathymetric data
X-axis:	Hit Count
Left:	0.00
Right:	9.00
Y-axis:	Number of cells
Top:	1684
Bottom:	0
S-Curve:	Cumulative Fraction

Cursor	
X-Axis:	2
Y-Axis:	7
S-Curve:	0.0%

Hotspot	
X-Axis:	2
Y-Axis:	7
S-Curve:	0.0%
Left:	0
Right:	2500



100.00% of these cells have a Hit Count of at least 2

Close | Help | Capture...

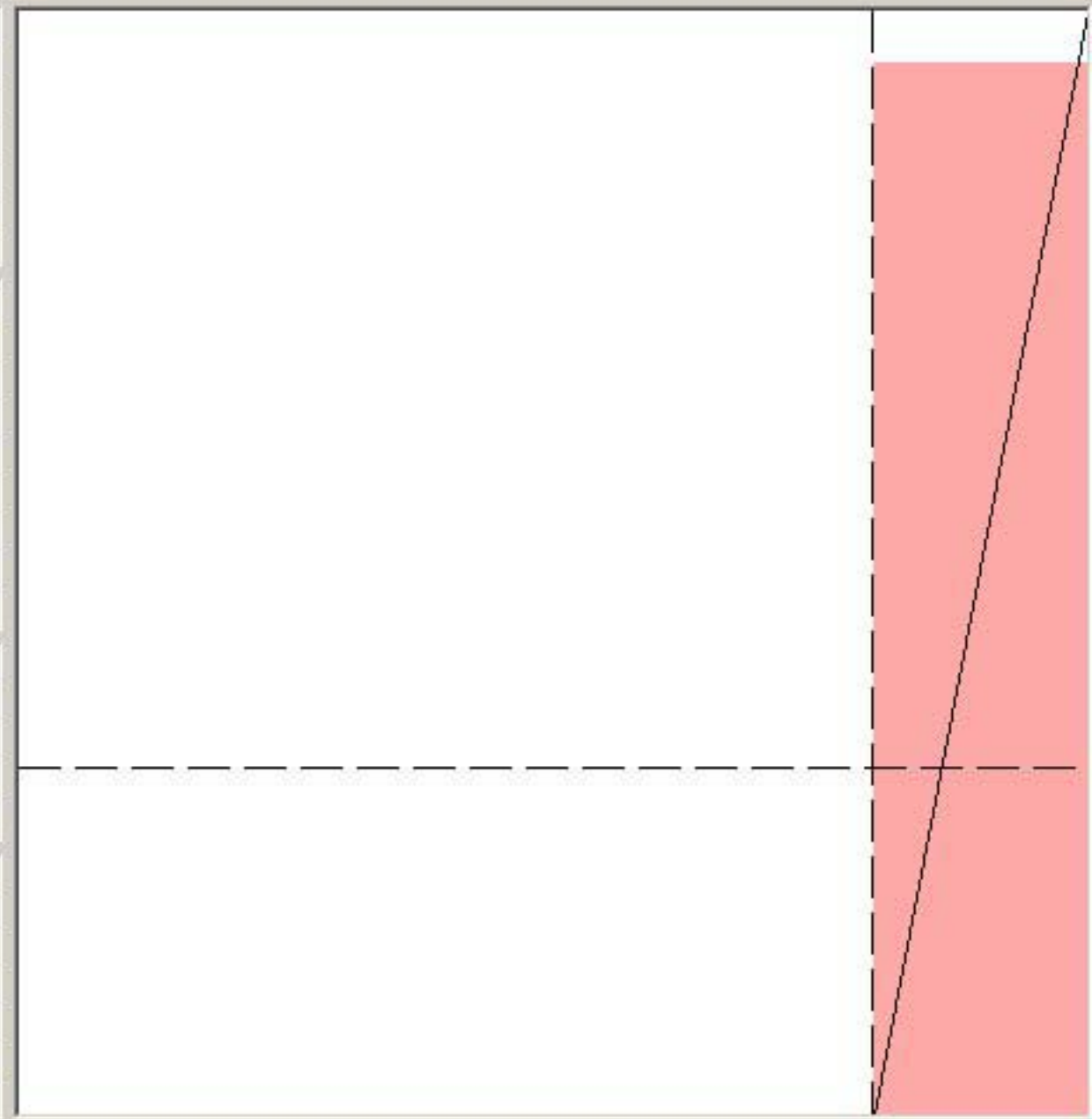
☑ Show Histogram ☑ Show S-Curve

Grid Area	Level 1
Total Cells:	2500
Filled Cells:	2500
Attribute:	Hit Count
Min:	0.00
Max:	5.00

Graph Area	Bathymetric data
X-axis:	Hit Count
Left:	0.00
Right:	5.00
Y-axis:	Number of cells
Top:	2625
Bottom:	0
S-Curve:	Cumulative Fraction

Cursor	
X-Axis:	0
Y-Axis:	256
S-Curve:	0.0%

Hotspot	
X-Axis:	3
Y-Axis:	826
S-Curve:	0.0%
Left:	0
Right:	2500



100.00% of these cells have a Hit Count of at least 3

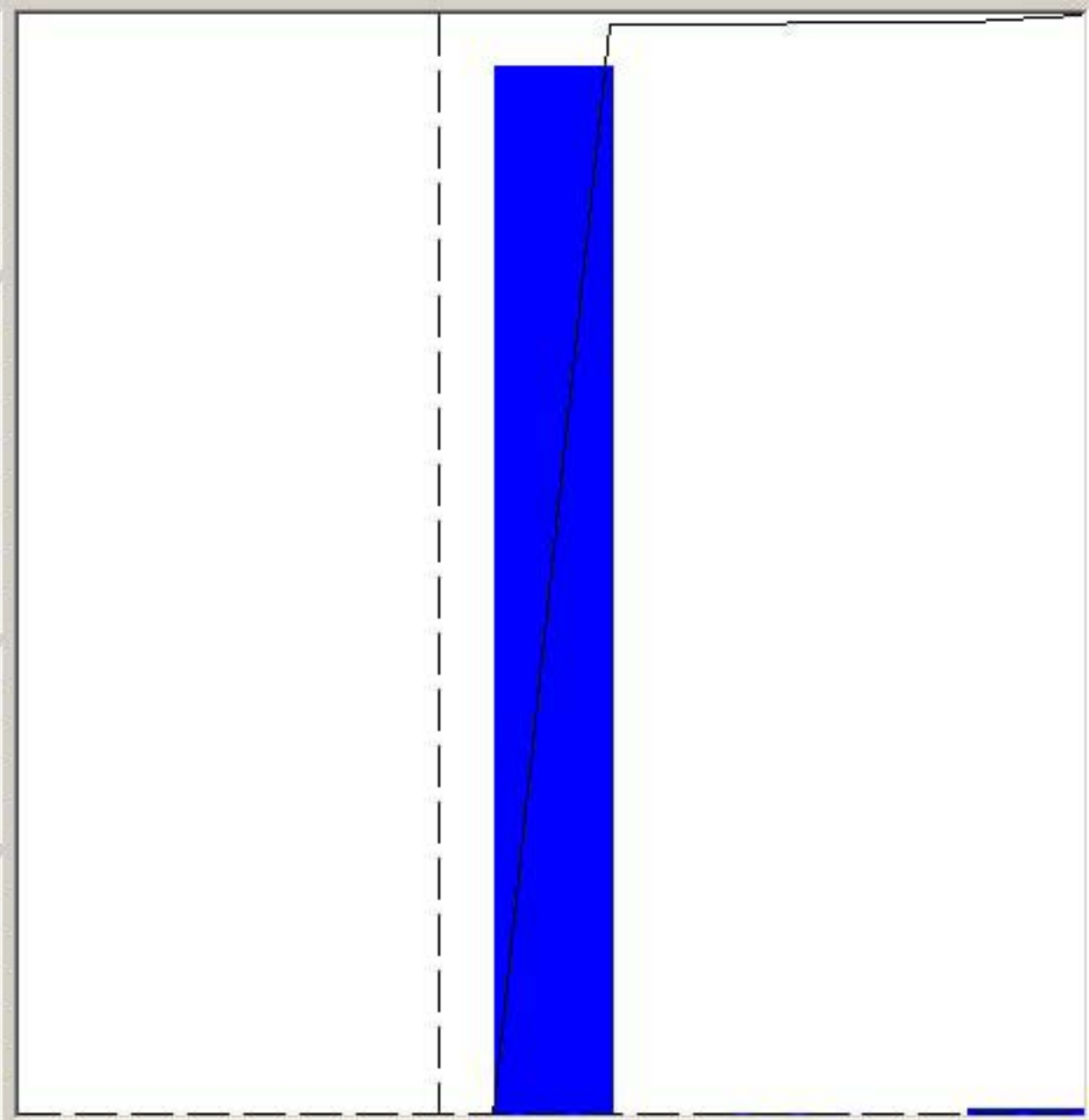
Close | Help | Capture... | ☑ Show Histogram | ☑ Show S-Curve

Grid Area	Level 1
Total Cells:	2500
Filled Cells:	2500
Attribute:	Hit Count
Min:	0.00
Max:	9.00

Graph Area	Bathymetric data
X-axis:	Hit Count
Left:	0.00
Right:	9.00
Y-axis:	Number of cells
Top:	2604
Bottom:	0
S-Curve:	Cumulative Fraction

Cursor	
X-Axis:	3
Y-Axis:	5
S-Curve:	0.0%

Hotspot	
X-Axis:	3
Y-Axis:	5
S-Curve:	0.0%
Left:	0
Right:	2500



100.00% of these cells have a Hit Count of at least 3

Close | Help | Capture...

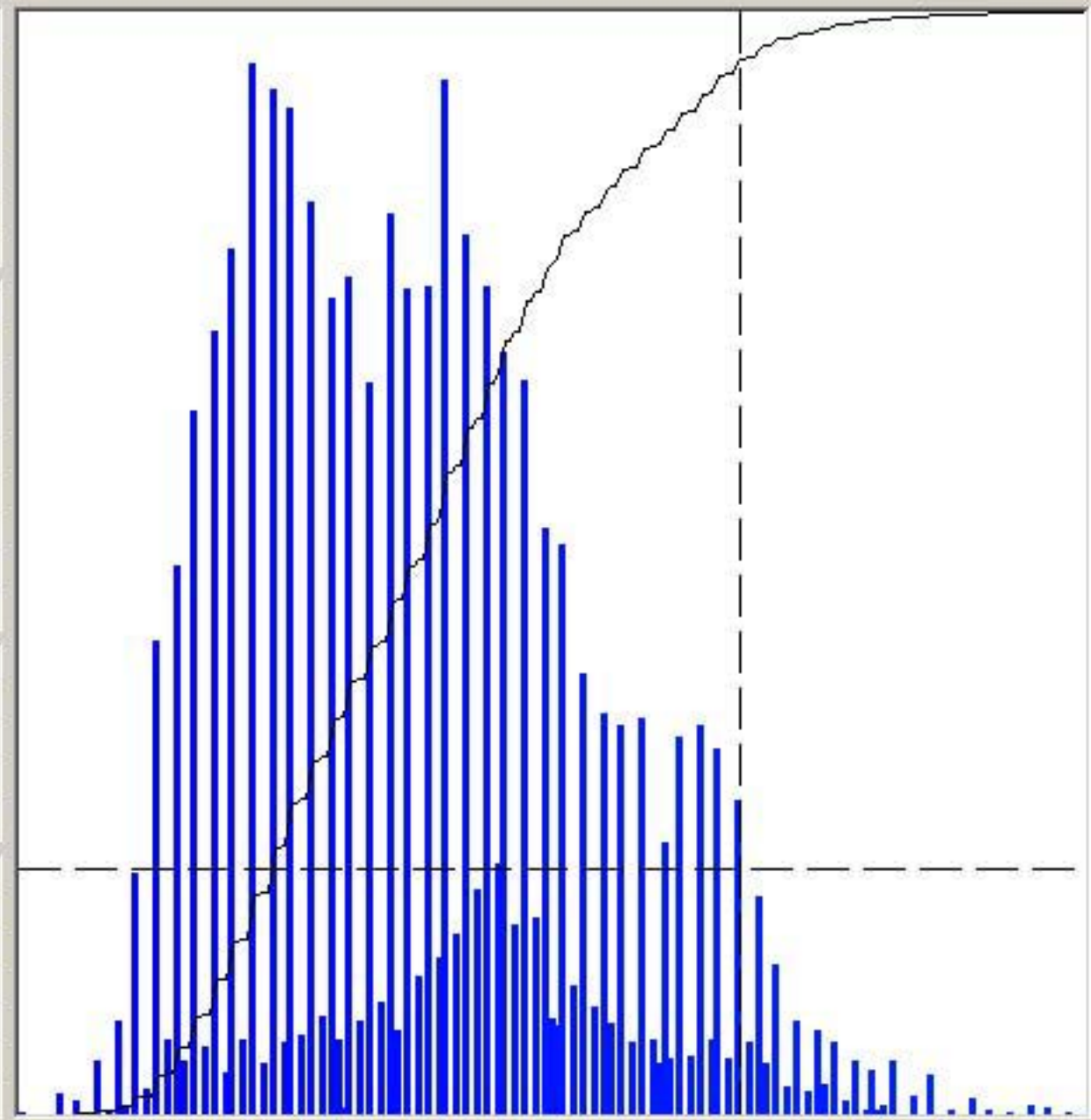
☑ Show Histogram ☑ Show S-Curve

Grid Area	Level 0
Total Cells:	10000
Filled Cells:	10000
Attribute:	Mean Value
Min:	-17.21
Max:	-16.66

Graph Area	Bathymetric data
X-axis:	Mean Value
Left:	-17.21
Right:	-16.66
Y-axis:	Number of cells
Top:	425
Bottom:	0
S-Curve:	Cumulative Fraction

Cursor	
X-Axis:	-16.92
Y-Axis:	6
S-Curve:	82.4%

Hotspot	
X-Axis:	-16.84
Y-Axis:	94
S-Curve:	95.7%
Left:	9567
Right:	433



95.67% have a mean depth deeper than -16.84, so 4.33% are shallower

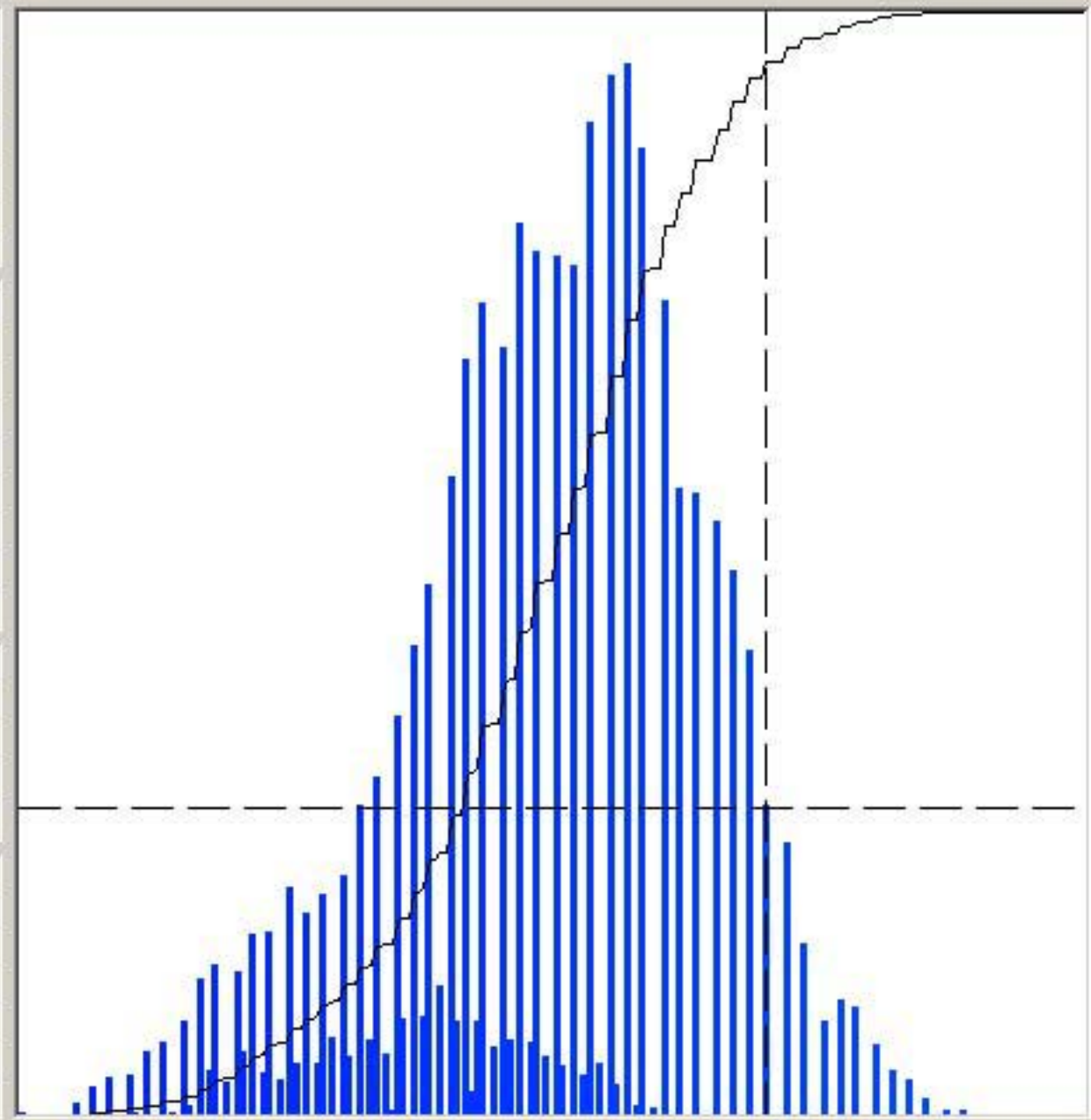
Close | Help | Capture... | ☑ Show Histogram | ☑ Show S-Curve

Grid Area	Level 0
Total Cells:	10000
Filled Cells:	10000
Attribute:	Mean Value
Min:	-16.79
Max:	-16.19

Graph Area	Bathymetric data
X-axis:	Mean Value
Left:	-16.79
Right:	-16.19
Y-axis:	Number of cells
Top:	523
Bottom:	0
S-Curve:	Cumulative Fraction

Cursor	
X-Axis:	-16.62
Y-Axis:	5
S-Curve:	10.1%

Hotspot	
X-Axis:	-16.37
Y-Axis:	145
S-Curve:	95.6%
Left:	9556
Right:	444



95.56% have a mean depth deeper than -16.37, so 4.44% are shallower

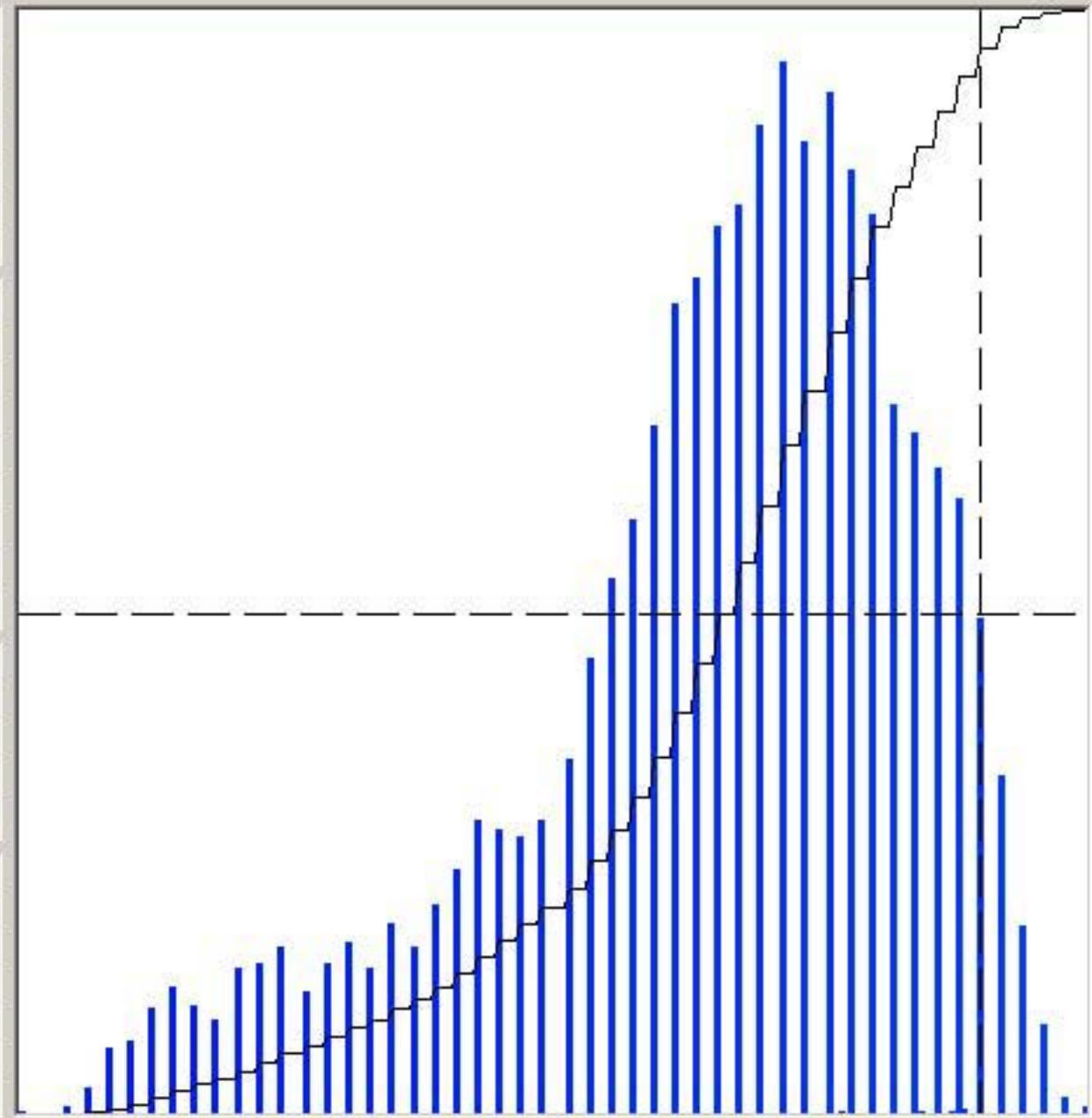
Close | Help | Capture... | ☑ Show Histogram | ☑ Show S-Curve

Grid Area	Level 0
Total Cells:	10000
Filled Cells:	10000
Attribute:	Mean Value
Min:	-16.92
Max:	-16.43

Graph Area	Bathymetric data
X-axis:	Mean Value
Left:	-16.92
Right:	-16.43
Y-axis:	Number of cells
Top:	570
Bottom:	0
S-Curve:	Cumulative Fraction

Cursor	
X-Axis:	-16.70
Y-Axis:	10
S-Curve:	15.8%

Hotspot	
X-Axis:	-16.48
Y-Axis:	258
S-Curve:	96.7%
Left:	9669
Right:	331



96.69% have a mean depth deeper than -16.48, so 3.31% are shallower

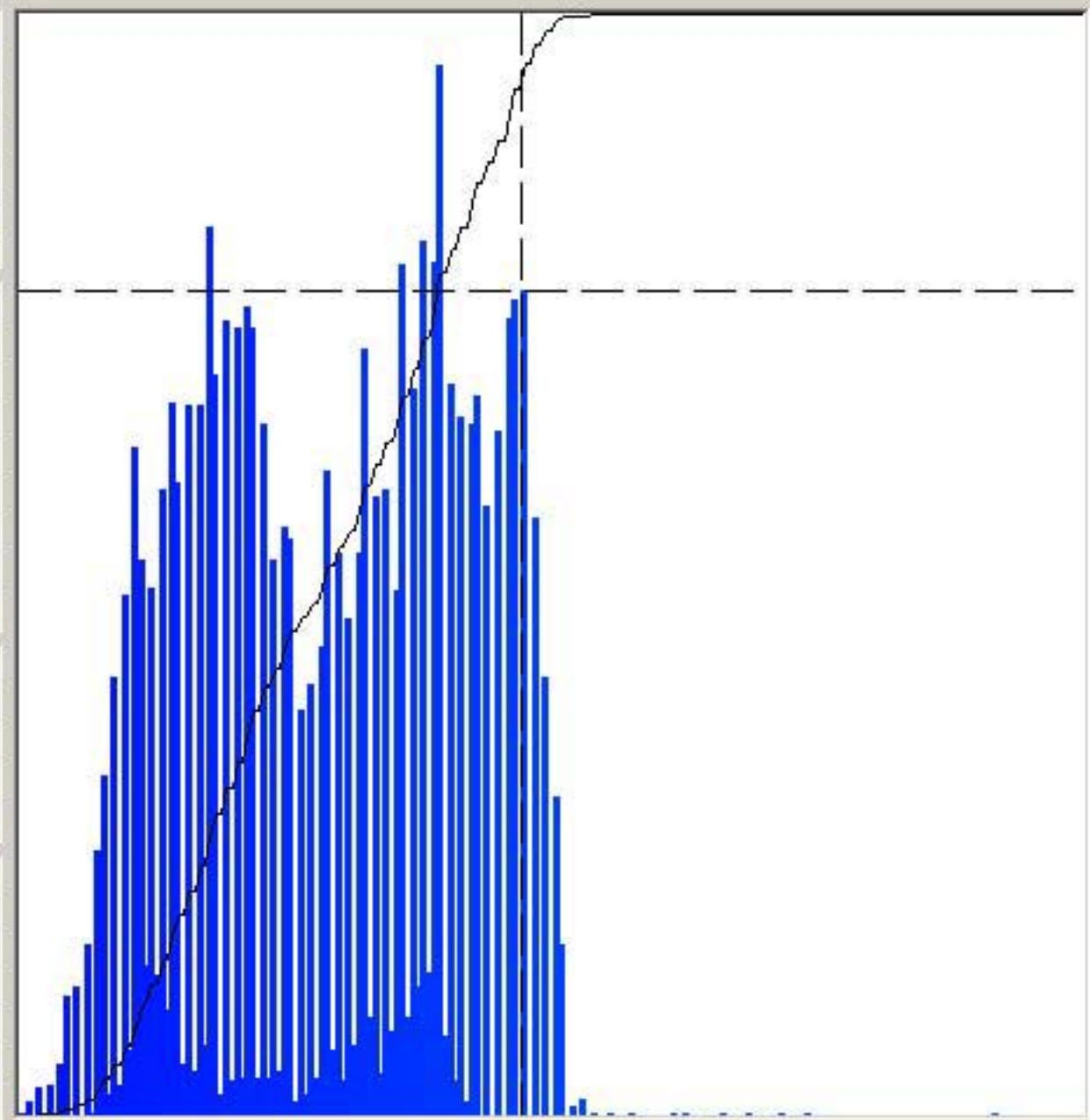
Close | Help | Capture... | ☑ Show Histogram | ☑ Show S-Curve

Grid Area	Level 0
Total Cells:	10000
Filled Cells:	10000
Attribute:	Mean Value
Min:	-16.95
Max:	-15.81

Graph Area	Bathymetric data
X-axis:	Mean Value
Left:	-16.95
Right:	-15.81
Y-axis:	Number of cells
Top:	315
Bottom:	0
S-Curve:	Cumulative Fraction

Cursor	
X-Axis:	-15.82
Y-Axis:	12
S-Curve:	100.0%

Hotspot	
X-Axis:	-16.41
Y-Axis:	235
S-Curve:	95.5%
Left:	9545
Right:	455



95.45% have a mean depth deeper than -16.41, so 4.55% are shallower

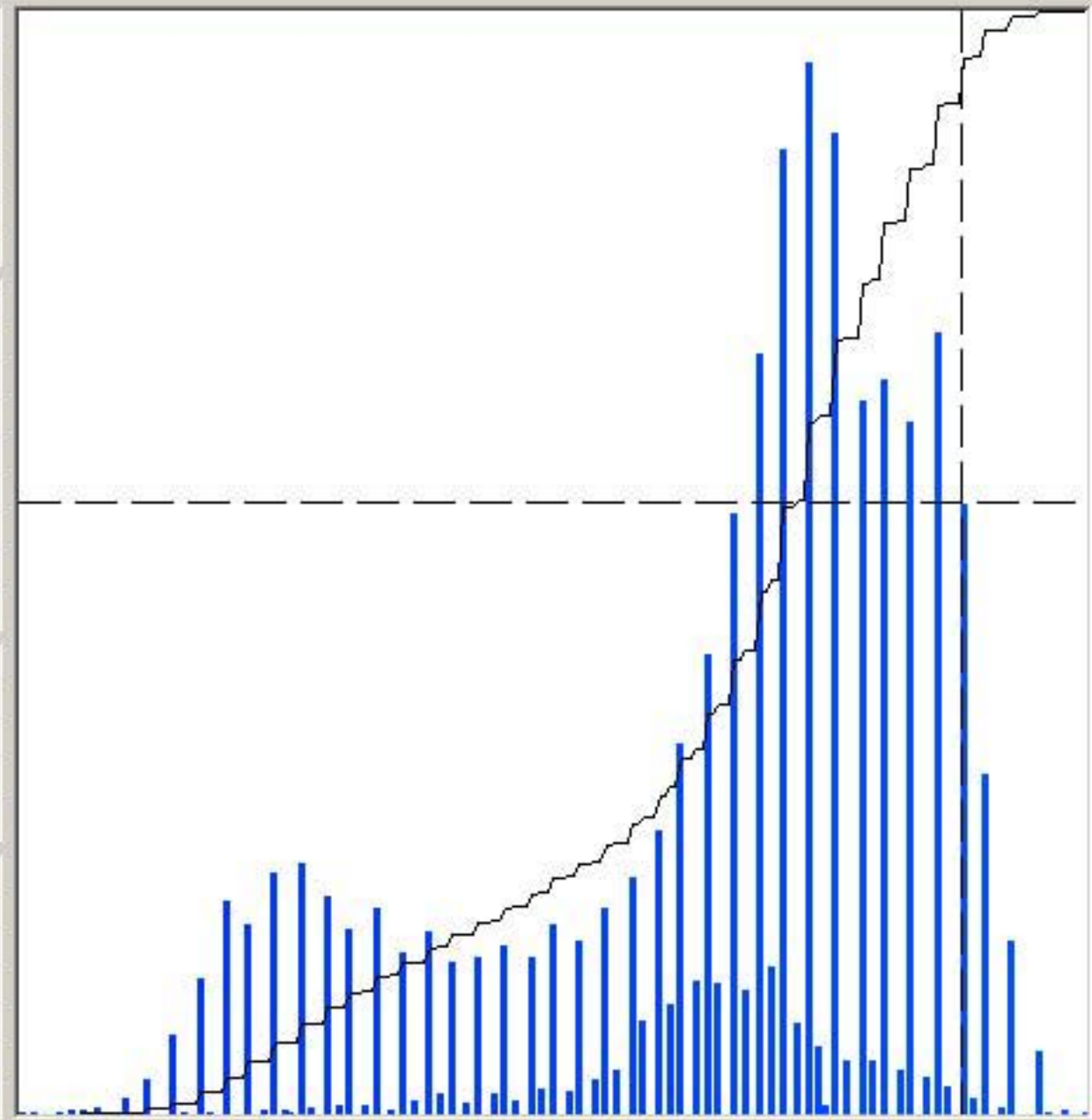
Close | Help | Capture... | ☑ Show Histogram | ☑ Show S-Curve

Grid Area	Level 0
Total Cells:	10000
Filled Cells:	10000
Attribute:	Mean Value
Min:	-16.57
Max:	-16.15

Graph Area	Bathymetric data
X-axis:	Mean Value
Left:	-16.57
Right:	-16.15
Y-axis:	Number of cells
Top:	756
Bottom:	0
S-Curve:	Cumulative Fraction

Cursor	
X-Axis:	-16.52
Y-Axis:	1
S-Curve:	0.5%

Hotspot	
X-Axis:	-16.20
Y-Axis:	419
S-Curve:	95.8%
Left:	9582
Right:	418



95.82% have a mean depth deeper than -16.20, so 4.18% are shallower

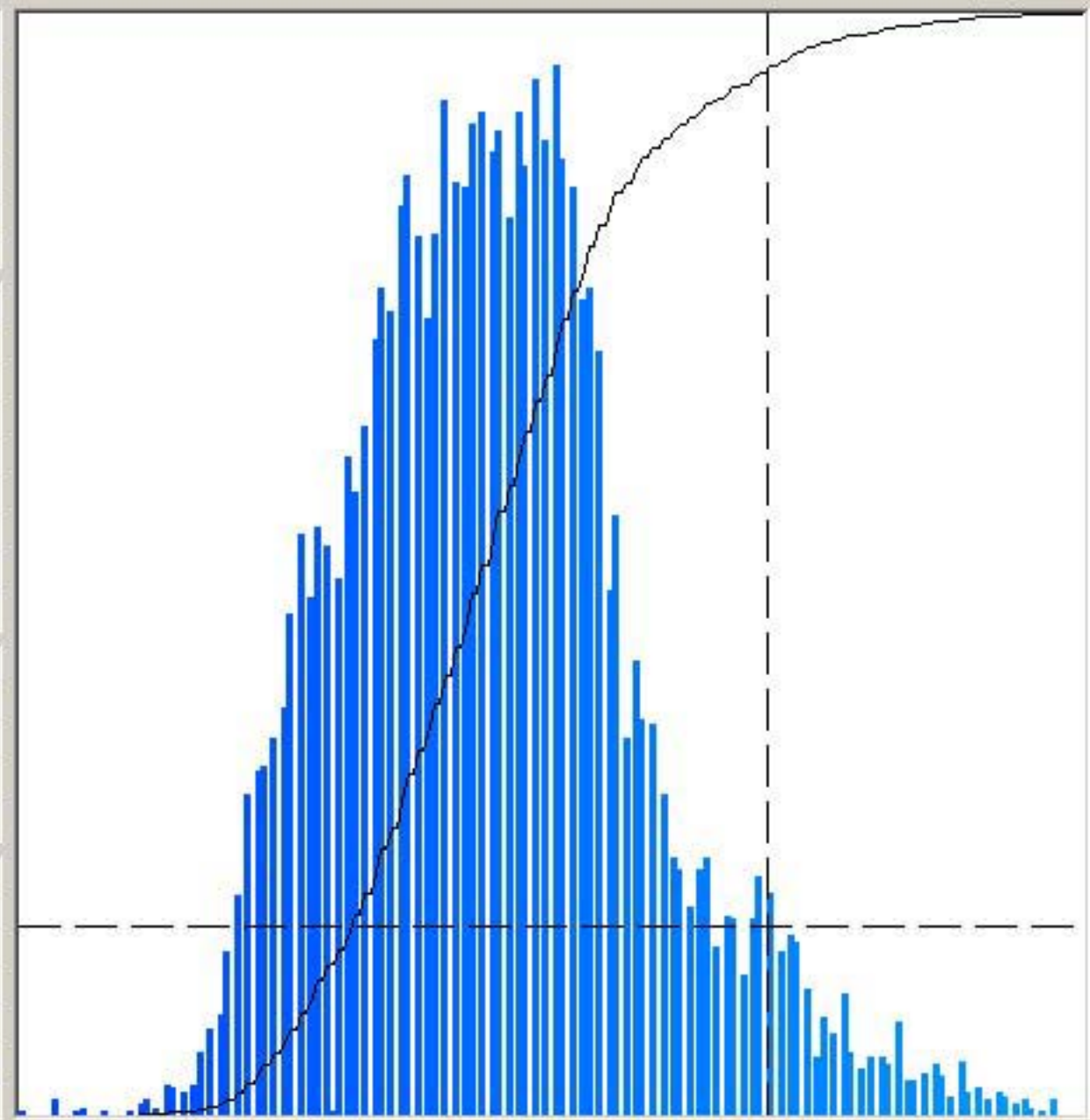
Close | Help | Capture... | ☑ Show Histogram | ☑ Show S-Curve

Grid Area	Level 0
Total Cells:	10000
Filled Cells:	10000
Attribute:	Mean Value
Min:	-16.35
Max:	-15.17

Graph Area	Bathymetric data
X-axis:	Mean Value
Left:	-16.35
Right:	-15.17
Y-axis:	Number of cells
Top:	281
Bottom:	0
S-Curve:	Cumulative Fraction

Cursor	
X-Axis:	-15.98
Y-Axis:	2
S-Curve:	18.4%

Hotspot	
X-Axis:	-15.52
Y-Axis:	48
S-Curve:	95.3%
Left:	9535
Right:	465



95.35% have a mean depth deeper than -15.52, so 4.65% are shallower

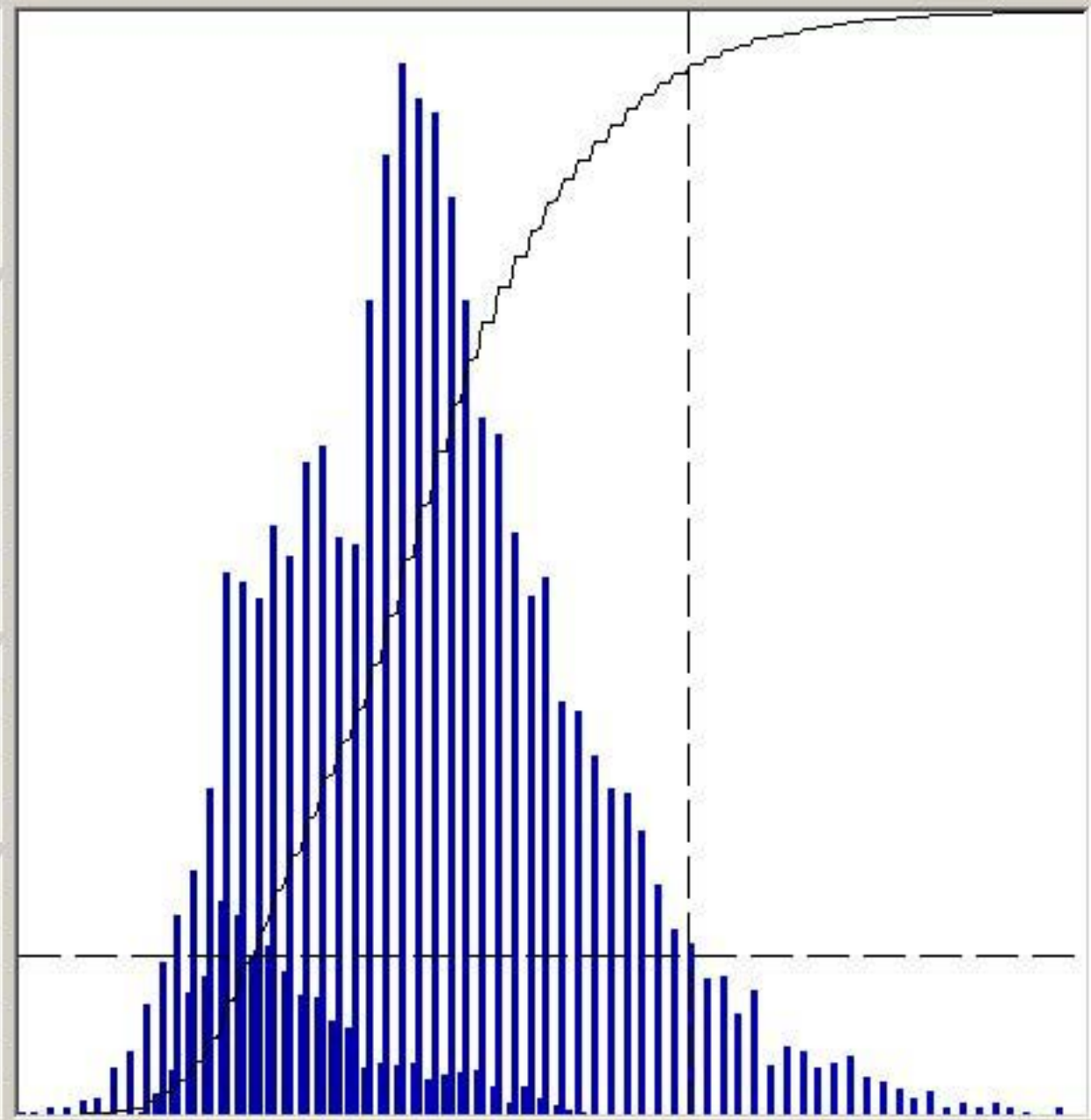
Close | Help | Capture... | ☑ Show Histogram | ☑ Show S-Curve

Grid Area	Level 0
Total Cells:	10000
Filled Cells:	10000
Attribute:	Mean Value
Min:	-18.52
Max:	-17.85

Graph Area	Bathymetric data
X-axis:	Mean Value
Left:	-18.52
Right:	-17.85
Y-axis:	Number of cells
Top:	506
Bottom:	0
S-Curve:	Cumulative Fraction

Cursor	
X-Axis:	-18.21
Y-Axis:	2
S-Curve:	77.8%

Hotspot	
X-Axis:	-18.10
Y-Axis:	73
S-Curve:	95.3%
Left:	9529
Right:	471



95.29% have a mean depth deeper than -18.10, so 4.71% are shallower

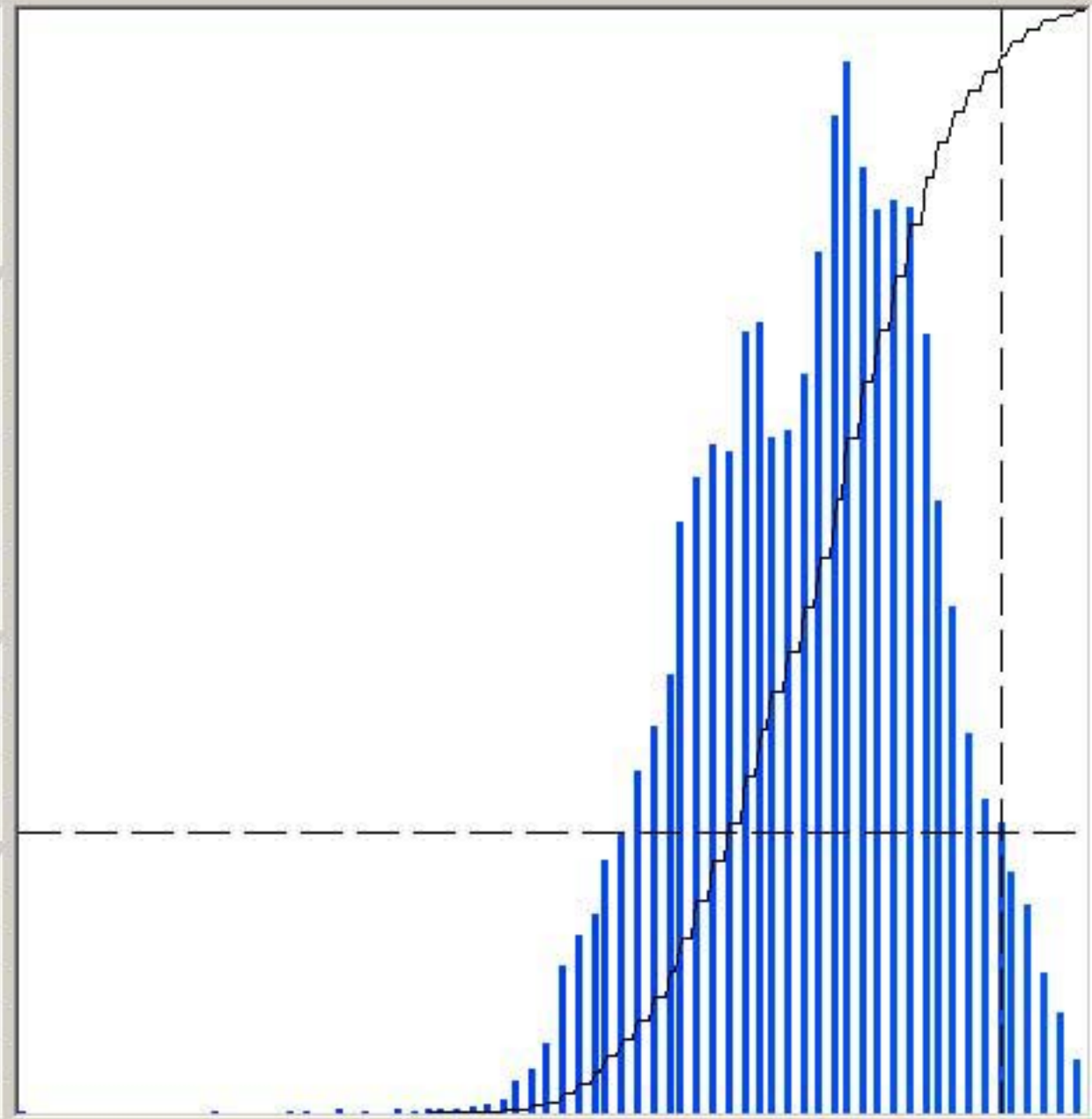
Close | Help | Capture... | ☑ Show Histogram | ☑ Show S-Curve

Grid Area	Level 0
Total Cells:	10000
Filled Cells:	10000
Attribute:	Mean Value
Min:	-16.75
Max:	-16.04

Graph Area	Bathymetric data
X-axis:	Mean Value
Left:	-16.75
Right:	-16.04
Y-axis:	Number of cells
Top:	584
Bottom:	0
S-Curve:	Cumulative Fraction

Cursor	
X-Axis:	-16.40
Y-Axis:	12
S-Curve:	1.1%

Hotspot	
X-Axis:	-16.10
Y-Axis:	149
S-Curve:	96.0%
Left:	9599
Right:	401



95.99% have a mean depth deeper than -16.10, so 4.01% are shallower

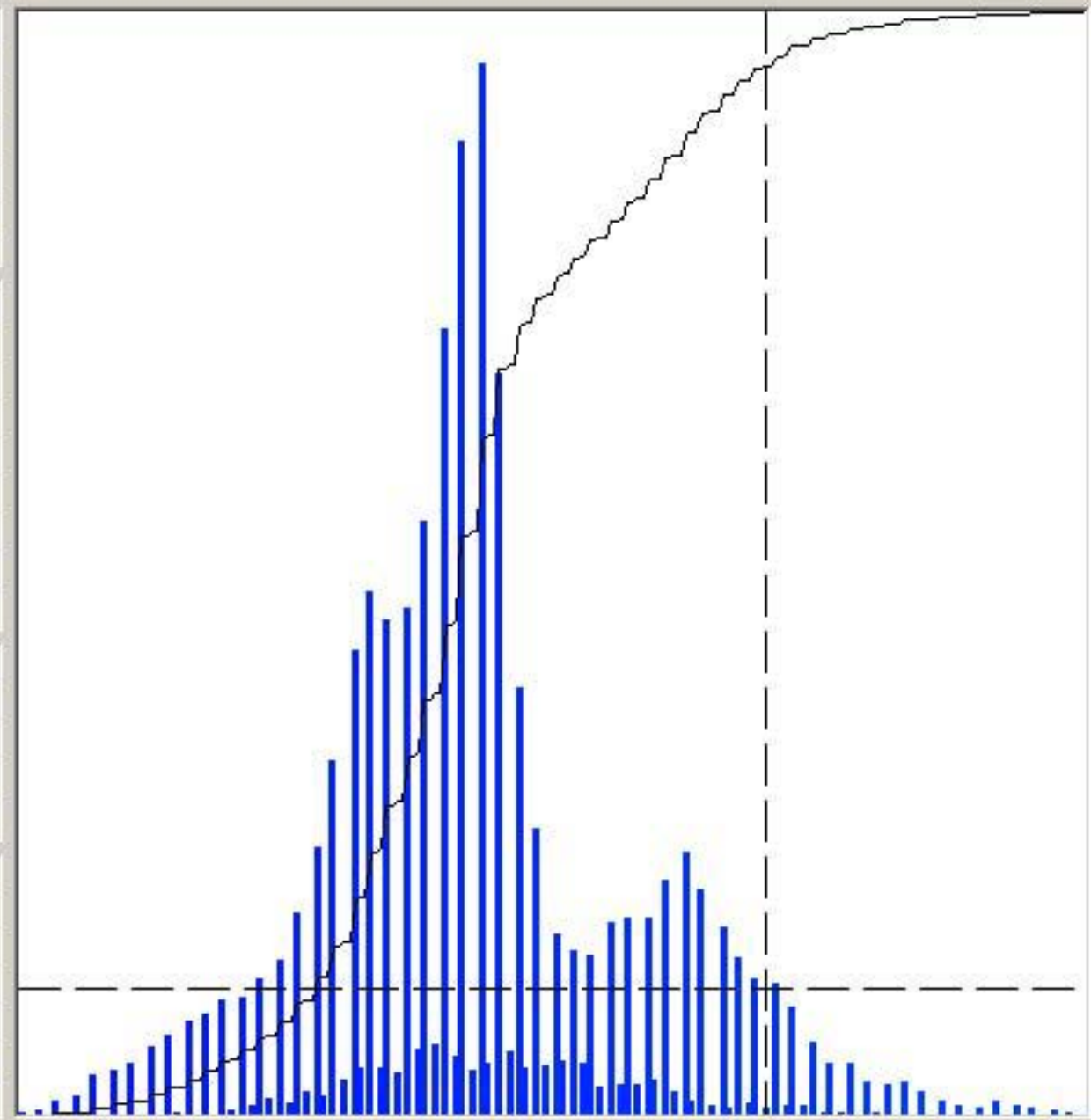
Close | Help | Capture... | ☑ Show Histogram | ☑ Show S-Curve

Grid Area	Level 0
Total Cells:	10000
Filled Cells:	10000
Attribute:	Mean Value
Min:	-16.95
Max:	-16.37

Graph Area	Bathymetric data
X-axis:	Mean Value
Left:	-16.95
Right:	-16.37
Y-axis:	Number of cells
Top:	872
Bottom:	0
S-Curve:	Cumulative Fraction

Cursor	
X-Axis:	-16.79
Y-Axis:	1
S-Curve:	10.3%

Hotspot	
X-Axis:	-16.55
Y-Axis:	100
S-Curve:	95.0%
Left:	9502
Right:	498



95.02% have a mean depth deeper than -16.55, so 4.98% are shallower

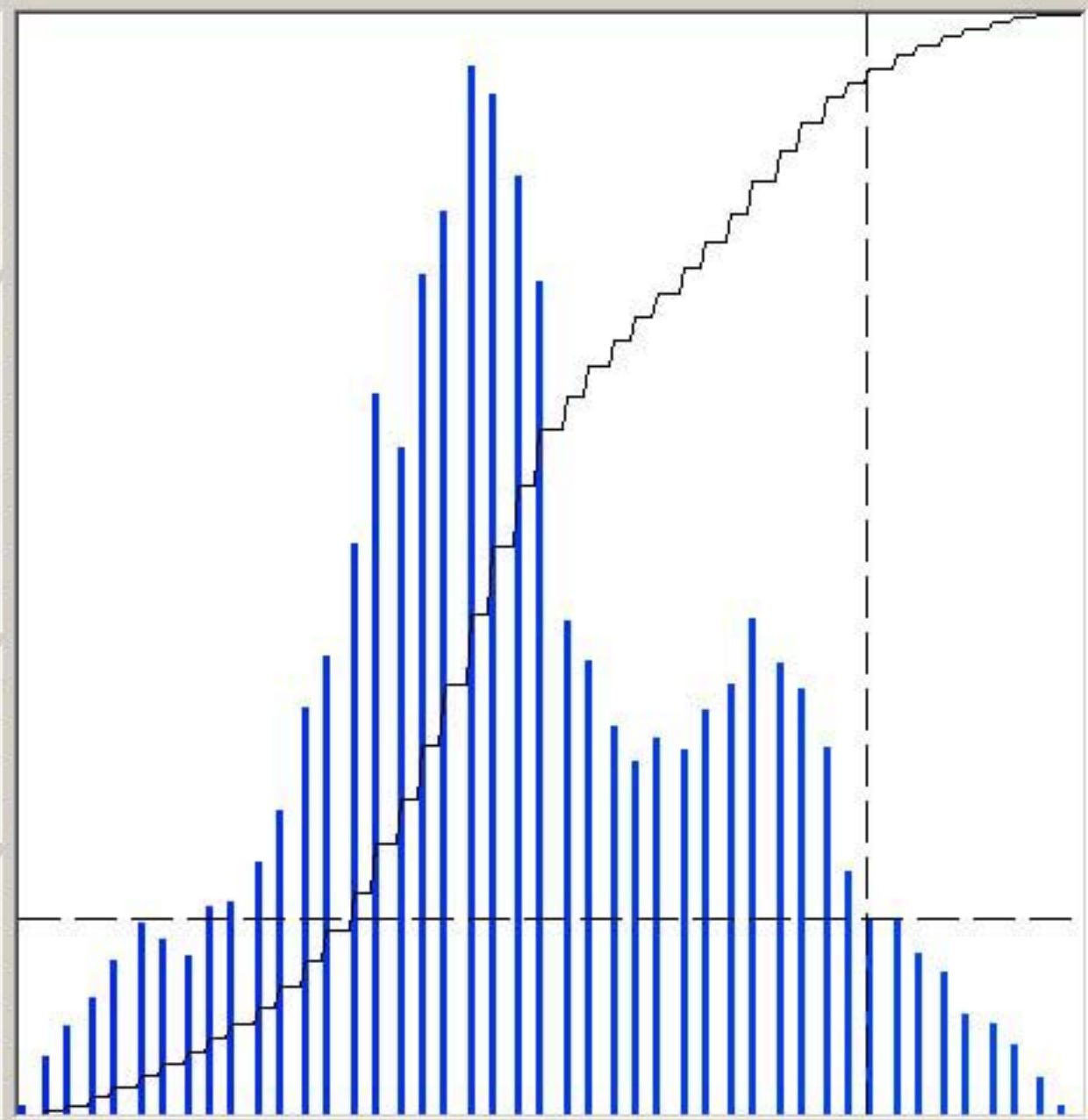
Close | Help | Capture... | ☑ Show Histogram | ☑ Show S-Curve

Grid Area	Level 0
Total Cells:	10000
Filled Cells:	10000
Attribute:	Mean Value
Min:	-16.71
Max:	-16.26

Graph Area	Bathymetric data
X-axis:	Mean Value
Left:	-16.71
Right:	-16.26
Y-axis:	Number of cells
Top:	663
Bottom:	0
S-Curve:	Cumulative Fraction

Cursor	
X-Axis:	-16.71
Y-Axis:	253
S-Curve:	0.1%

Hotspot	
X-Axis:	-16.35
Y-Axis:	118
S-Curve:	95.1%
Left:	9511
Right:	489



95.11% have a mean depth deeper than -16.35, so 4.89% are shallower

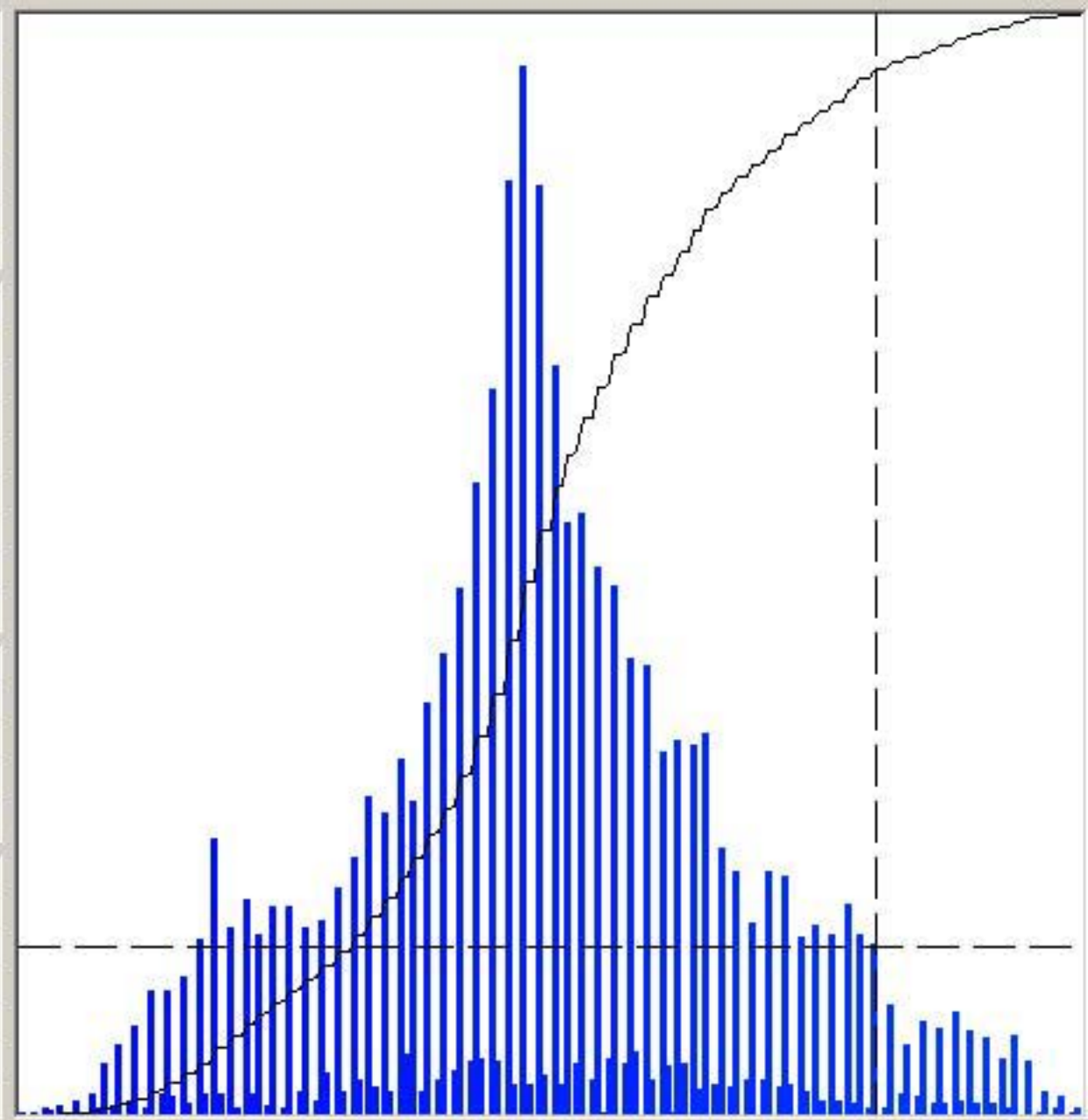
Close | Help | Capture... | ☑ Show Histogram | ☑ Show S-Curve

Grid Area	Level 0
Total Cells:	10000
Filled Cells:	10000
Attribute:	Mean Value
Min:	-17.11
Max:	-16.41

Graph Area	Bathymetric data
X-axis:	Mean Value
Left:	-17.11
Right:	-16.41
Y-axis:	Number of cells
Top:	546
Bottom:	0
S-Curve:	Cumulative Fraction

Cursor	
X-Axis:	-16.84
Y-Axis:	8
S-Curve:	25.5%

Hotspot	
X-Axis:	-16.55
Y-Axis:	83
S-Curve:	95.1%
Left:	9508
Right:	492



95.08% have a mean depth deeper than -16.55, so 4.92% are shallower

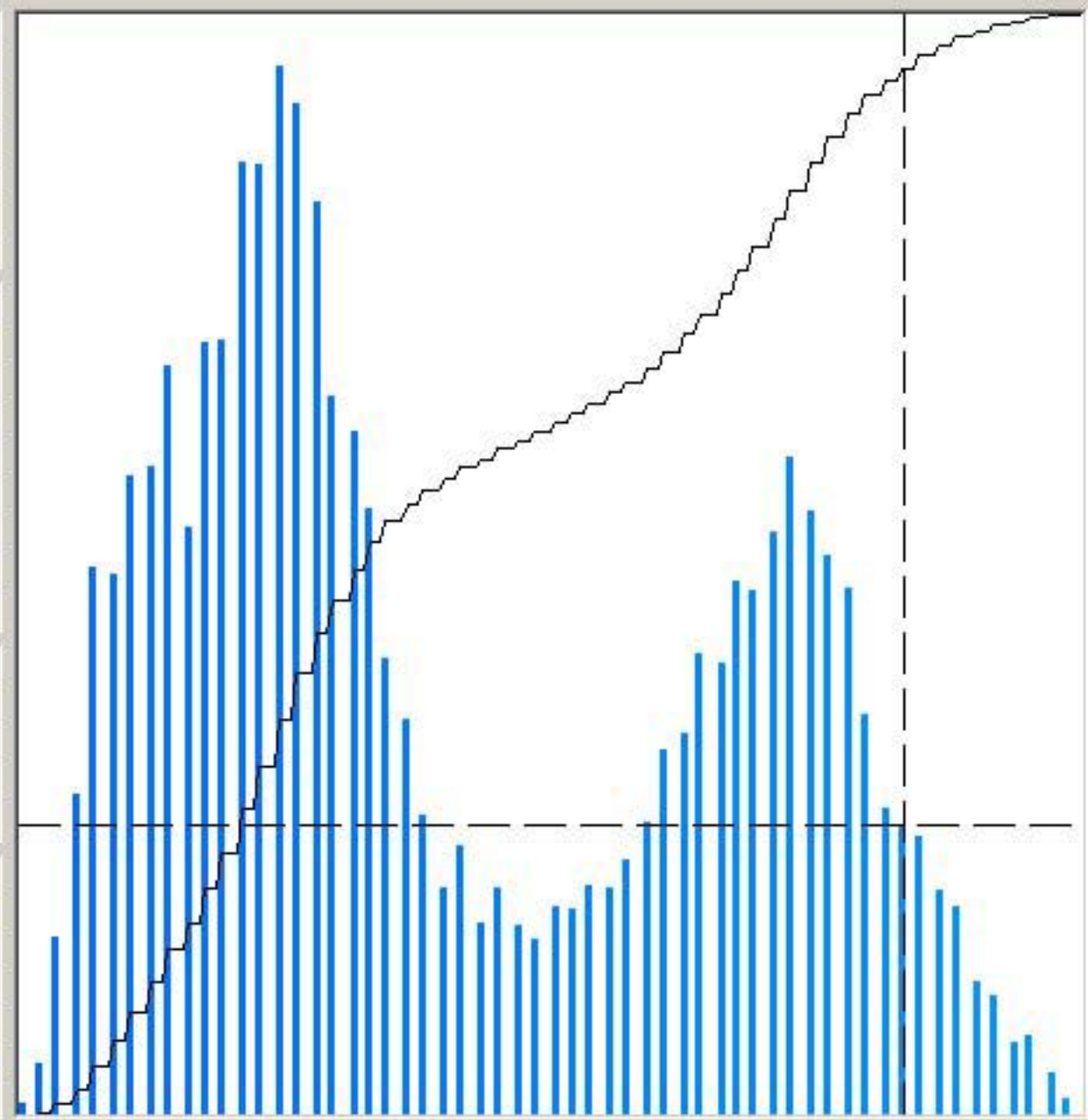
Close | Help | Capture... | ☑ Show Histogram | ☑ Show S-Curve

Grid Area	Level 0
Total Cells:	10000
Filled Cells:	10000
Attribute:	Mean Value
Min:	-15.82
Max:	-15.24

Graph Area	Bathymetric data
X-axis:	Mean Value
Left:	-15.82
Right:	-15.24
Y-axis:	Number of cells
Top:	451
Bottom:	0
S-Curve:	Cumulative Fraction

Cursor	
X-Axis:	-15.78
Y-Axis:	1
S-Curve:	4.5%

Hotspot	
X-Axis:	-15.34
Y-Axis:	118
S-Curve:	95.2%
Left:	9515
Right:	485



95.15% have a mean depth deeper than -15.34, so 4.85% are shallower

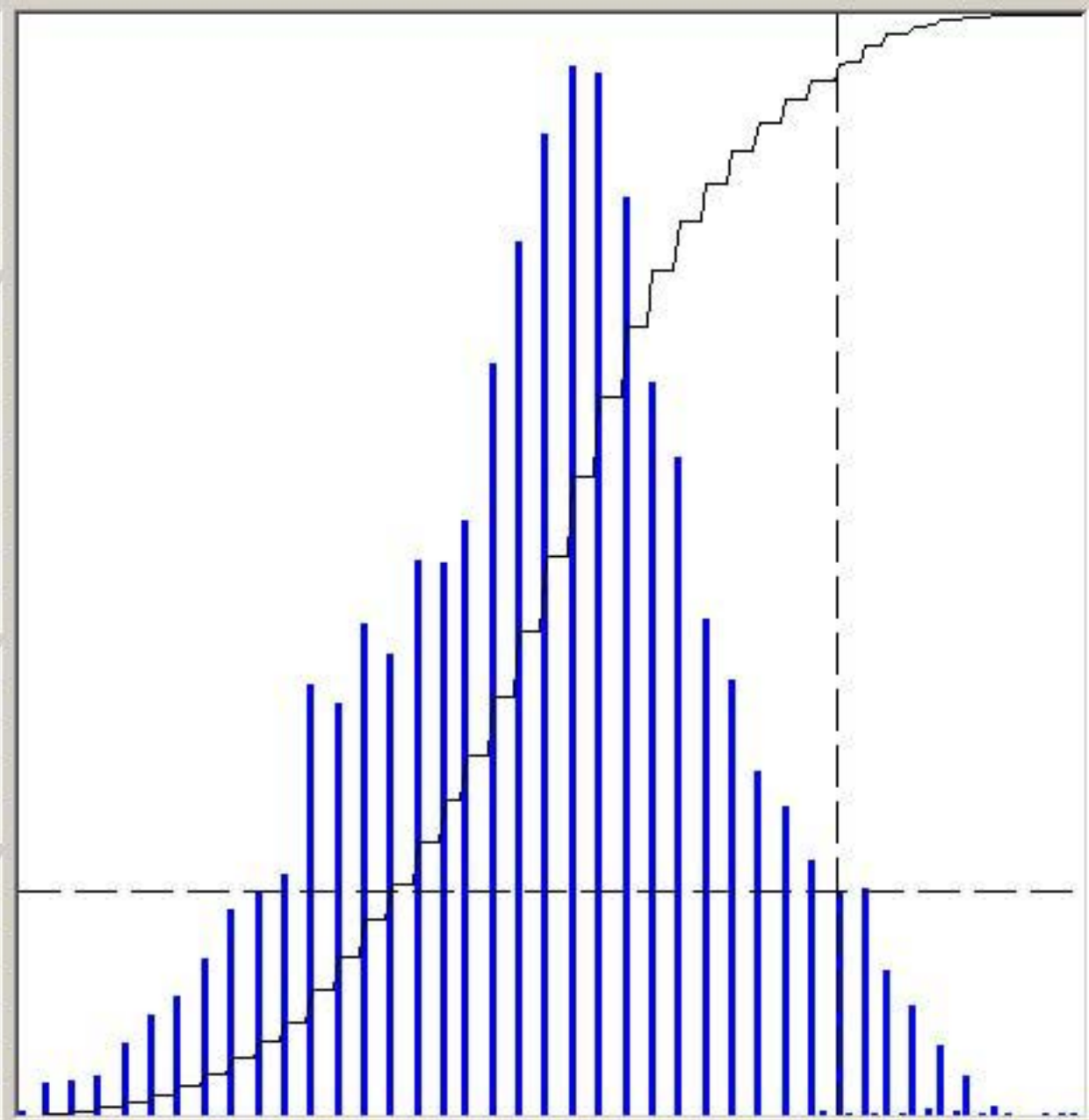
Close | Help | Capture... | Show Histogram | Show S-Curve

Grid Area	Level 0
Total Cells:	10000
Filled Cells:	10000
Attribute:	Mean Value
Min:	-17.45
Max:	-17.05

Graph Area	Bathymetric data
X-axis:	Mean Value
Left:	-17.45
Right:	-17.05
Y-axis:	Number of cells
Top:	762
Bottom:	0
S-Curve:	Cumulative Fraction

Cursor	
X-Axis:	-17.33
Y-Axis:	1
S-Curve:	14.4%

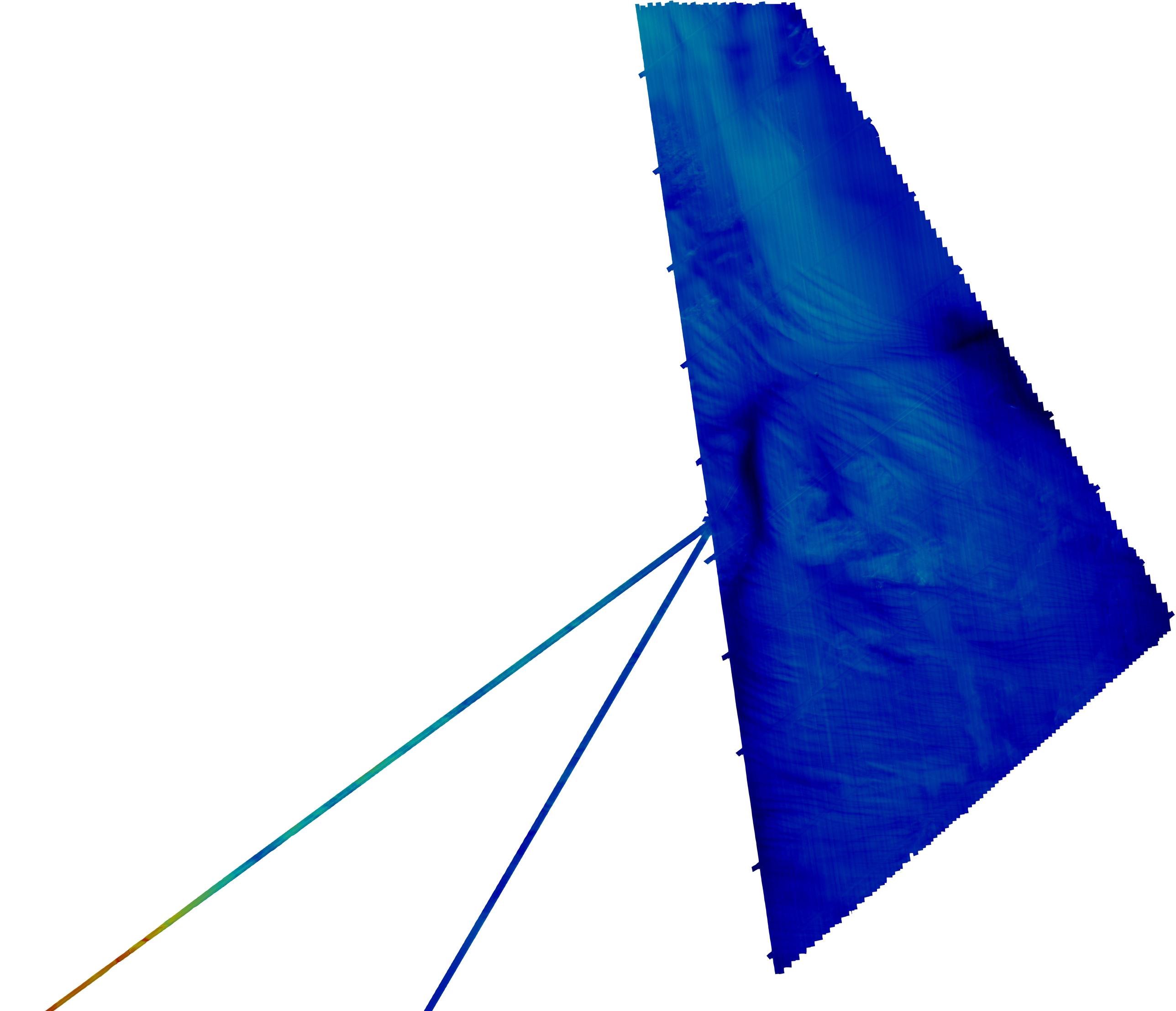
Hotspot	
X-Axis:	-17.14
Y-Axis:	155
S-Curve:	95.6%
Left:	9562
Right:	438

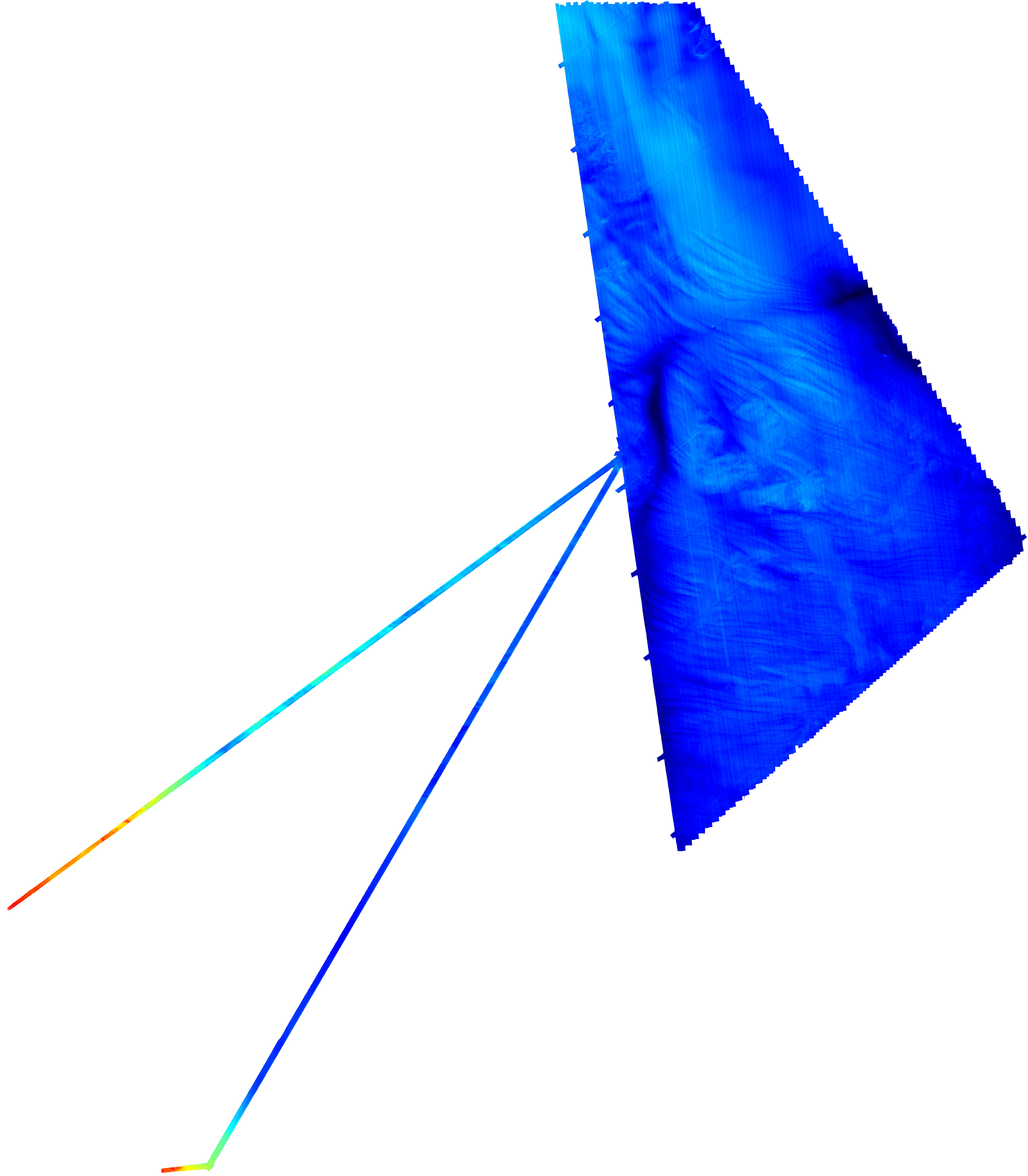


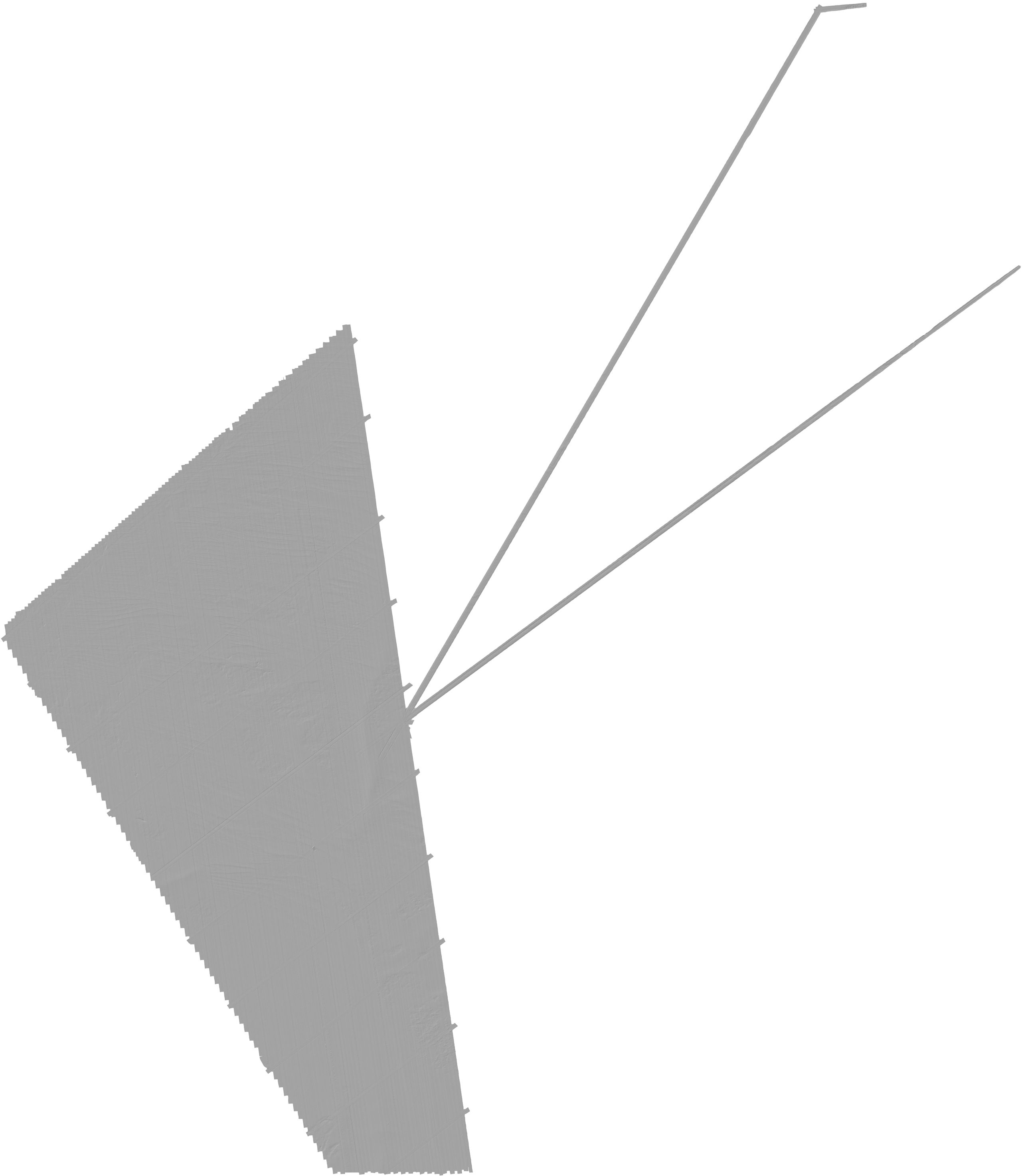
95.62% have a mean depth deeper than -17.14, so 4.38% are shallower

Close | Help | Capture... | ☑ Show Histogram | ☑ Show S-Curve

Appendix 13
Geo-referenced shaded relief images







Appendix 14
Colour plots of the bathymetric data