Final Report

REACH-6629-SR-001

Final Report

MV ESTONIA High Resolution Seabed Imaging Survey

Republic of Estonia
Safety Investigation Bureau

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REVISIONS

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ABBREVIATIONS

Abbreviation	Definition
AOB	Any Other Business
ATTU	EIVA Accurate Time Tagging Unit
CR	Company Representative
CTD	Conductivity, Temperature, Depth (Sampler)
DPR	Daily Progress Report
ESIB	Estonia Safety Investigation Bureau
GIS	Geographic Information System
HSVA	Hamburgische Schiffbau Versuchsanstalt
INS	Inertial Navigation System
JAIC	Joint Accident Investigation Commission

Abbreviation	Definition
LWD/LWH	Length, Width, Height/Depth
MAS	Multi Aperture Sonar
MBE / MBES	Multibeam Echosounder
MoD	Ministry of Defence
MOM	Minutes of Meeting
MSL	Mean Sea Level
NTM	Notice To Mariners
OM	Offshore Manager
PPP	Precise Point Positioning
QC	Quality Control
QHSE	Quality, Health, Safety and Environment
RS	Reach Subsea
RTK	Real-Time Kinematic positioning
SHE	Safety, Health and Environment
SHK	Statens Haverikommission (Sweden)
SSDM	Seabed Survey Data Model (GIS Delivery format)
SSS	Sidescan Sonar
SVP	Sound Velocity Profile
TBA	To Be Agreed
TBC	To Be Confirmed
USBL	Ultra Short Baseline System
UTC	Coordinated Universal Time
UTM	Universal Transverse Mercator
VORF	Vertical Offshore Reference Frame
WGS84	World Geodetic System 1984
WOW	Waiting on Weather

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1 SUMMARY

Reach Subsea AS was contracted by Estonia Safety Investigation Bureau (ESIB) to perform a high resolution seabed imaging site survey at the location of the wreck of MV ESTONIA. The survey was performed between 22 and 29 November 2023 with the vessel R/V Skagerak.

The main objective of the site survey was to map debris from the wreck and the Client's aim is to improve the reconstruction of the ship's track by usage of debris findings. The second objective of the survey was to map the anchoring wires of the geotextiles installed in 1996.

The survey was conducted in an area of app 4 km^2 with hull mounted Multibeam Echo Sounder (MBES), Kongsberg 2040 and a towed Equinox system from EIVA. The Equinox consists of platform of a Scanfish III equipped with an Aperture Sonar (MAS), manufactured by Solstice, with USBL/INS positioning. The Equinox system was the primary system and all data acquired was of good to very good quality.

The bathymetrical data was processed with the aim to get an overview of the area by bathymetrical and backscatter data.

The acquired MAS data was processed with main aim to select targets on the seafloor and to create a seabed sediment interpretation. A total of 296 items were selected and divided into six classes whereof parts could be interpreted as life raft boxes and similar items. In Figure 1-1 the pattern of targets is shown, with most of the targets found in the area south-west of the wreck. However, a relatively large number of targets is scattered in the large remain of the survey area west of the wreck. Approximately 30 targets are interpreted to likely originate from the cargo of the vessel. All have a similar straight shape of circa 3 m long.

In the vicinity of the wreck a few targets are interpreted and classified as anchor chains, these were installed in 1996 as attempt to stabilize the area.

Note that all targets from the MAS data shall be handled as an interpretation until visual inspection has been performed.

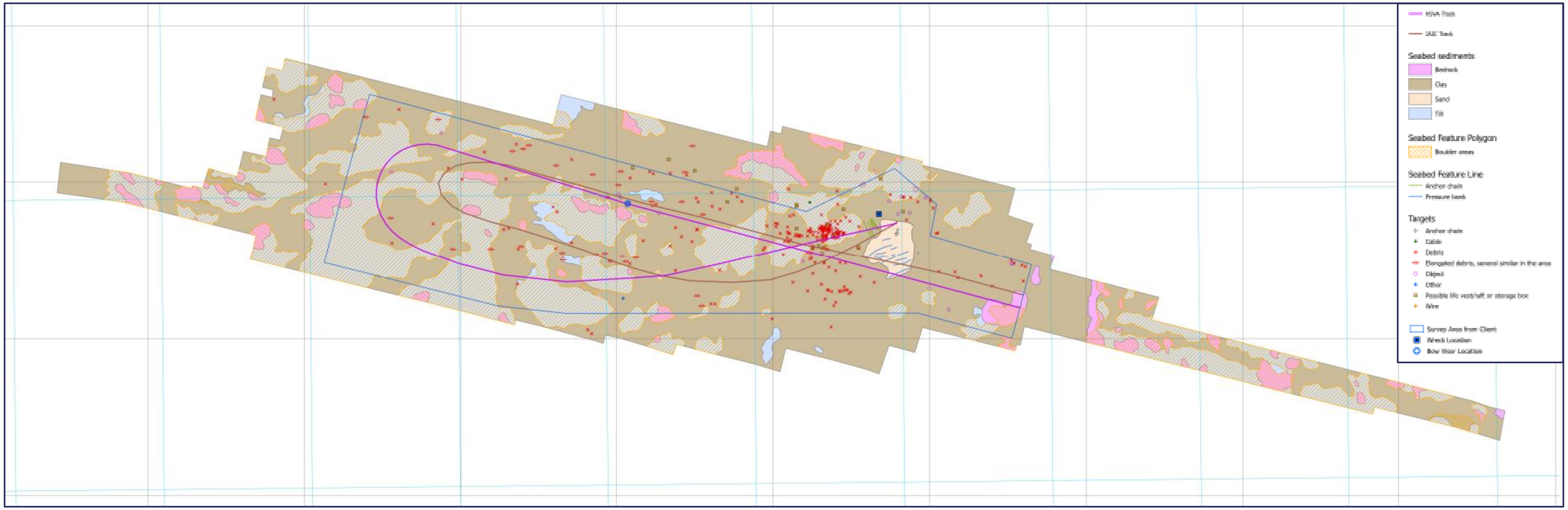


Figure 1-1 Overview of the result from the survey, seabed sediment interpretation chart. Targets marked in red dots, planned survey area in blue polygon, modelled tracks of the sinking path in magenta from HSVA and red from JAIC and the official wreck location marked with blue dot. 1 km between scale lines.

2 INTRODUCTION AND SCOPE OF WORK

Reach Subsea AS was contracted by ESIB to perform a high resolution seabed imaging site survey at the location of the wreck of MV ESTONIA.

The cruise ferry MV ESTONIA sank during a cruise from Tallinn to Stockholm 28 September 1994, a disaster that resulted in 852 lost lives.

The wreck site has as per today two modelled tracks for the ships path from the start of sinking to the place of rest on the seafloor (Figure 2-1). Numerous objects are expected to have entered the water column from the time the ship started taking in water until the ship rested on the seafloor.

The area has been mapped previously in several projects, by geophysical, geotechnical, laser and video surveys since the sinking. Reach Subsea was provided with MBES data, from 2006 and 2021, by ESIB.

The main objective of the site survey was to map the debris and the Client's aim is to improve the reconstruction of the ship's track by usage of debris findings. The second objective of the survey was to map the anchoring wires of the geotextiles installed in 1996 as an attempt to stabilize the site.

The survey was conducted with hull mounted MBES Kongsberg 2040 and a towed Equinox system from EIVA consisting of platform of a Scanfish III equipped with a MAS manufactured by Solstice. The Equinox system was the primary system and data.

This project utilized the research vessel R/V Skagerak and the operational phase was carried out from 22 November to 29 November 2023.

This report specifies the performed survey and the interpreted results of the data in acquired in the project.

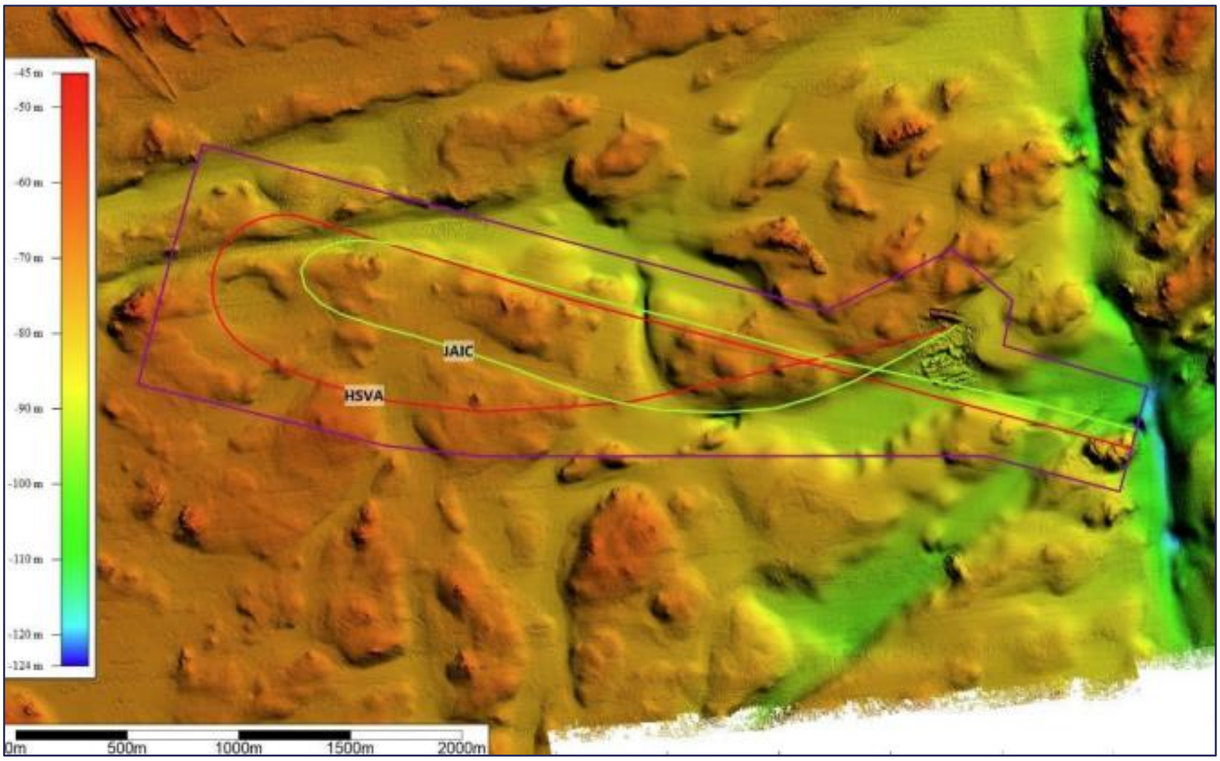


Figure 2-1 Planned survey area as red polygon with the two modelled tracks and backgound data MBES

2.1 LINE PLANNING

The line spacing was 25 m with a mean flight altitude of 7.5 m and the typical survey speed was 4.5 to 5 knots (Figure 2-2). The centre line in the area was named CL, the lines towards the north was named P (port) with start P1 closest to the CL and increasing number finishing on P31. The lines towards south from the CL was named S (starboard) starting on S1 with increasing number ending with S27.

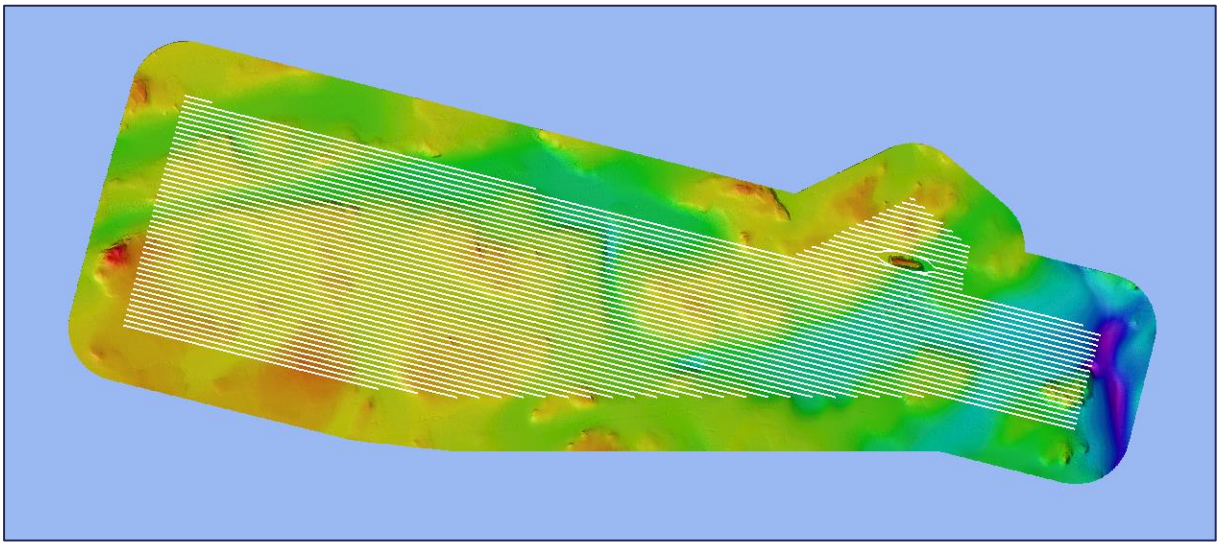


Figure 2-2 Line plan on top of background MBES data from 2006

2.2 CHANGES TO SCOPE OF WORK

Two additional survey lines were added to the scope towards the end of the survey; from the eastern end of the area one line extended further east approximately 3000 m and an adjacent line was surveyed adjacent in opposite direction.

In the same area, the easternmost, a rapid change in bathymetry made the movement of the Scanfish a potential risk, as well as the data insufficient. Due to this, the 600 m eastern part of lines P2 to P12 were resurveyed in eastward direction with acceptable data result.

2.3 BACKGROUND DATA

ESIB provided Reach Subsea with background data from surveys performed in 2006 and 2021. The dataset from 2006 included MBES data in 1-m resolution, origin from Finnish Transport Agency, and was used during the planning phase of the survey. The set from 2021 also included MBES data, in 2 m resolution and the resolution was considered too low for usage of the dataset.

2.4 PROJECT REFERENCE DOCUMENTS

- REACH-6629-SEP-001 Survey Execution Plan
- REACH-6629-MAC-002 Mobilisation & Calibration Report
- REACH-6629-FOR-001 Field Operations Report
- REACH-6629-RA-001 Project Risk Opportunity Register
- REACH-6629-RE-001 Project HAZOP Report
- REACH-6629-SCH-001 Project Schedule
- Geophysical Surveys: Level 1 procedure
- Sidescan Sonar Procedure, adjusted for MAS data
- Multibeam Echo Sounder Acquisition & Processing Procedure
- Method of Calibrations and Verifications Procedure

2.5 SURVEY PARAMETERS

The MV ESTONIA high resolution wreck site survey comprised survey in app. 4 km^2 area and the line spacing was set to 25 m to fulfil the criteria for high resolution MAS. The datasets were acquired simultaneously with the MAS as primary instrument.

2.5.1 GEODETIC INFORMATION

The project datums are:

Horizontal: Universal Transverse Mercator, Zone 34 North, WGS84, meters.

Vertical reference: RH2000, meters which in practical terms is similar to Mean Sea Level (MSL) in this area.

Geoid model: Swen17_RH2000

EPSG code: 32634

3 INSTRUMENTATION

The vessel utilized in the project was the research vessel R/V Skagerak (Figure 3-1), owned by University of Gothenburg and operated by Northern Offshore Services. The vessel specifications are summarized in Table 3-1.

Figure 3-1 Vessel R/V Skagerak

Table 3-1 Vessel Specifications

Measure	Specifications/Type
Length overall	49.2 m
Width	11.2 m
Draft	3.9 m
Gross Tonnage	916 Te
Year Built	2014-2021
Net deck area (available for project)	130 m^2
Service speed	11 kn
Crane & A-frame	2 tonnes at 10 m/4 tonnes at 6 m & 8 tonnes at 7 m
Accommodation	21 persons
USBL system	Kongsberg HiPAP 501
Gyro	MRU 5+ Seapath 330
MBES	Kongsberg 2040 hull mounted

3.1 EQUIPMENT

The survey was conducted with hull mounted MBES, Kongsberg 2040 and a towed Equinox system from EIVA consisting of platform of a Scanfish III equipped with a MAS manufactured by Solstice, Table 3-2 and Table 3-3.

Table 3-2 Survey Sensor Specifications

System	Type	S/N	Supplied by
GNSS	1×Seatex Seapath 330		Vessel
Gyro	1×Seatex Seapath 330		Vessel
MRU position/motion	MRU5+		Vessel

System	Type	S/N	Supplied by
Underwater positioning system	Kongsberg Hipap 501 incl. Cnode mini transponders		Vessel
EIVA Equinox system	Solstice MAS, Scanfish III, Sonardyne Sprint INS		Reach Subsea
MBES	Kongsberg 2040		Vessel
Kongsberg cNode	MiniS 34-180 Cymbal	23452 23449 31914	Reach Subsea
C-Nav	C-nav 3050	13097	Reach Subsea
CTD	Sea-Bird SBE 9	-	Vessel
SVS	Valeport MiniSVS	40035	Reach Subsea
Online System	EIVA NaviPac	-	Reach Subsea
Data acquisition	EIVA NaviScan	-	Reach Subsea
Offline Suite	EIVA NaviModel, Janus, ArcGIS	-	Reach Subsea
Time Tagging	EIVA ATTU	-	Reach Subsea

Table 3-3 Geophysical Survey Requirement

System	Description
MBES	0.25m bin size where gaps is accepted Acceptance is one hit per cell
MAS	200% coverage, within specification / Adjacent line overlap: 100%. Resolution: 0.05m Along Track × 0.05m Across Track

3.2 MULTIBEAM ECHO SOUNDER

MBES data was acquired using a hull mounted multibeam Kongsberg EM2040 0.4×0.7 degree dual RX/single swath, frequency 400kHz, detailed in Table 3-4.

The purpose of the MBES was to map the seabed surface and give detailed information about the general topography, structures and to correlate findings in the MAS data.

Speed of sound in water corrections for any bathymetric survey using acoustic instruments is critical. Since the speed of sound is not constant throughout the water column, a correction needs to be applied to ensure that the soundings are correct.

A sound velocity profile was acquired at the start of the MBES survey and when the survey recommenced after a longer stop, to provide the MBES with sound velocity data. A total of 14 SVP casts was performed during the survey, whereof four with the CTD Seabird and 10 with the miniSVS.

During acquisition the data was quality controlled by Online personnel, the data was thereafter controlled by Offline personnel in EIVA software. After the fieldwork was completed the data processing and reporting took place in REACH offices in the EIVA software.

Table 3-4 Kongsberg EM2040 MBES setup

Parameter	Comment
Acquisition Software	SIS – Seafloor Information System
Configuration	Dual head – Dual swath
Frequency	400kHz
Swath	±40° relative to nadir for a total of +80°
Processing Software	EIVA NaviSuite (Edit & Model)
Max ping rate	N/A
Horizontal Resolution	0.25m (target but may have gaps)
Sound Velocity Probe	Sea-Bird SBE 9 CTD

3.3 MULTI APERTURE SONAR

The Equinox system is a towed sidescan sonar solution that utilizes a Solstice MAS in combination with the EIVA scanfish 3D steering (Figure 3-2). The system was used with the purpose to detect and position objects and features within the survey area as well as enable a classification of seafloor conditions. The so was tightly integrated with INS navigation to provide real-time motion compensation and it is fitted with underwater positioning capable to provide positional accuracy better that 0.5% of the slant range. The MAS is a system that provides a high-resolution image by using a back-projection beamforming technique to extend the focus along the whole swath.

Figure 3-2 EIVA Equinox

The Equinox system covered approximately 100 m per side, gaining >200% coverage. The Solstice MAS produces along-track resolution of 0.15° and a constant across track resolution of 37.5 mm. The MAS setup is detailed in Table 3-5.

Table 3-5 MAS Setup

Parameter	Comment
Acquisition Software	Solstice
Data Interface	Navigation information (raw easting & northing) received from EIVA NaviPac
Frequency	Band 725 – 775 kHz
Recording Range	100m to each side
Processing Range	25m
Fly Height	~7.5m above the seabed
File Output	.SWF8 primary format (used in post-processing) .XTF secondary format (deliverable)
Processing Software	SonarWiz

4 DATA PROCESSING

4.1 MULTIBEAM ECHO SOUNDER

The MBES data was acquired using a dual head Kongsberg EM2040 and was recorded in Kongsberg SIS (Seafloor Information System).

The MBES was run in equidistant mode with a swath angle of around 40° for each head, using a fixed short pulse at 400 kHz, giving a swath width of approximately 120-130 m for 80 m water depth.

The recorded depth data was loaded and processed with EIVA NaviEdit and NaviModel. The point data was reduced to RH2000 heights/depths using the Swen17_RH2000 model. In the survey area this can be considered almost mean sea level.

The MBES data was cleaned using automated methods and, if required, edited using manual methods for final cleaning to remove any erroneous data from the swaths before merging the data into the digital terrain model DTM (Figure 4-1, Figure 4-2, Figure 4-3).

A difference model was made between the onboard Preliminary and the Final data to highlight areas with changes in the data. These areas were then further quality controlled and edited manually.

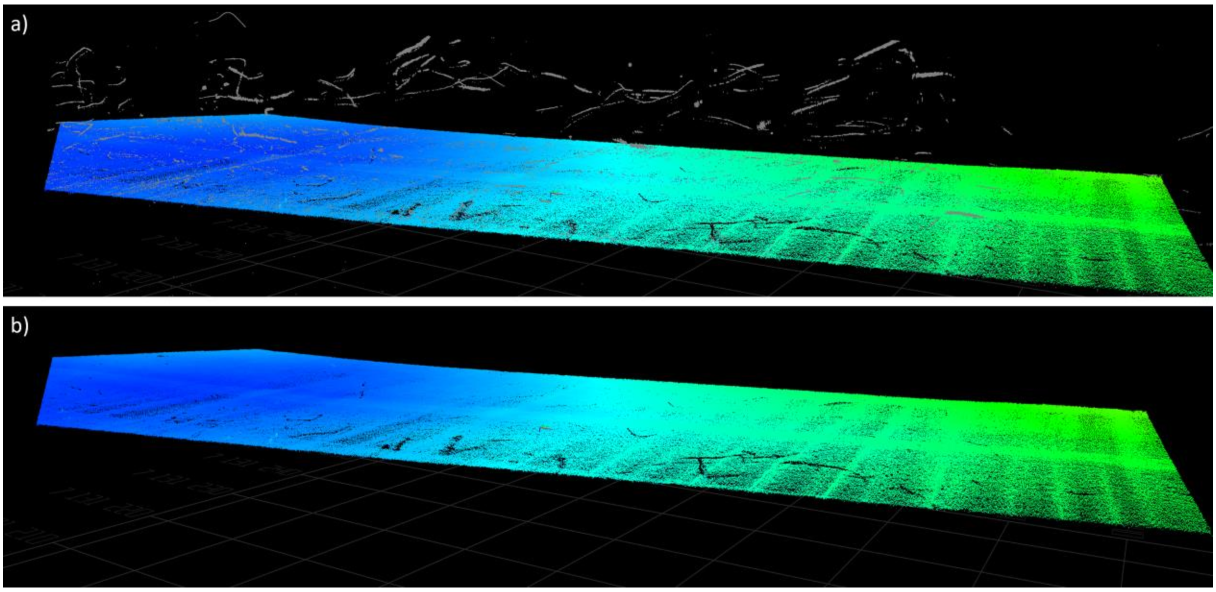


Figure 4-1 Data example showing MBES data processing in EIVA NaviModel, a) pre clean and b) post-clean

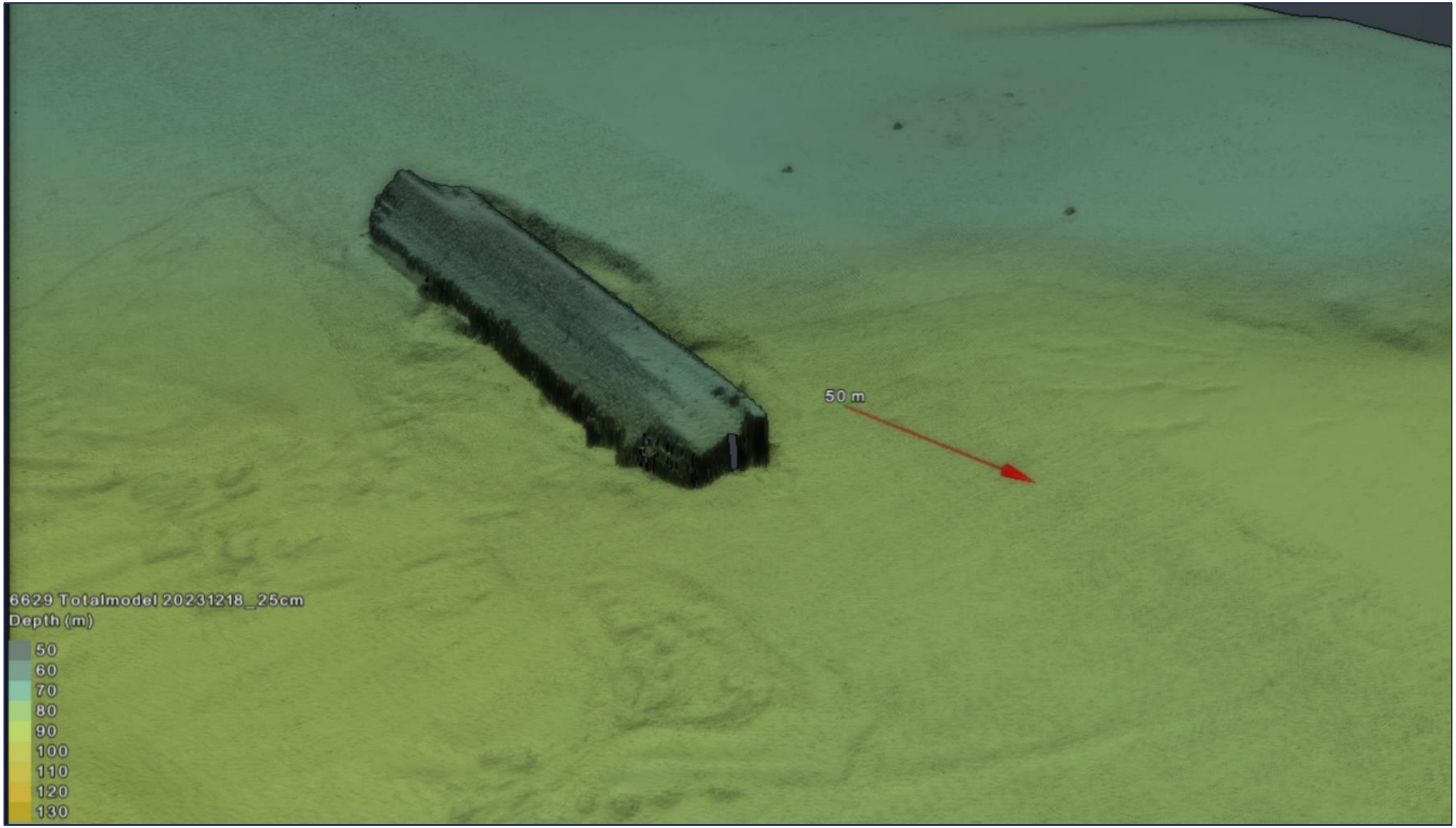


Figure 4-2 Data example showing MBES data of the MV ESTONIA

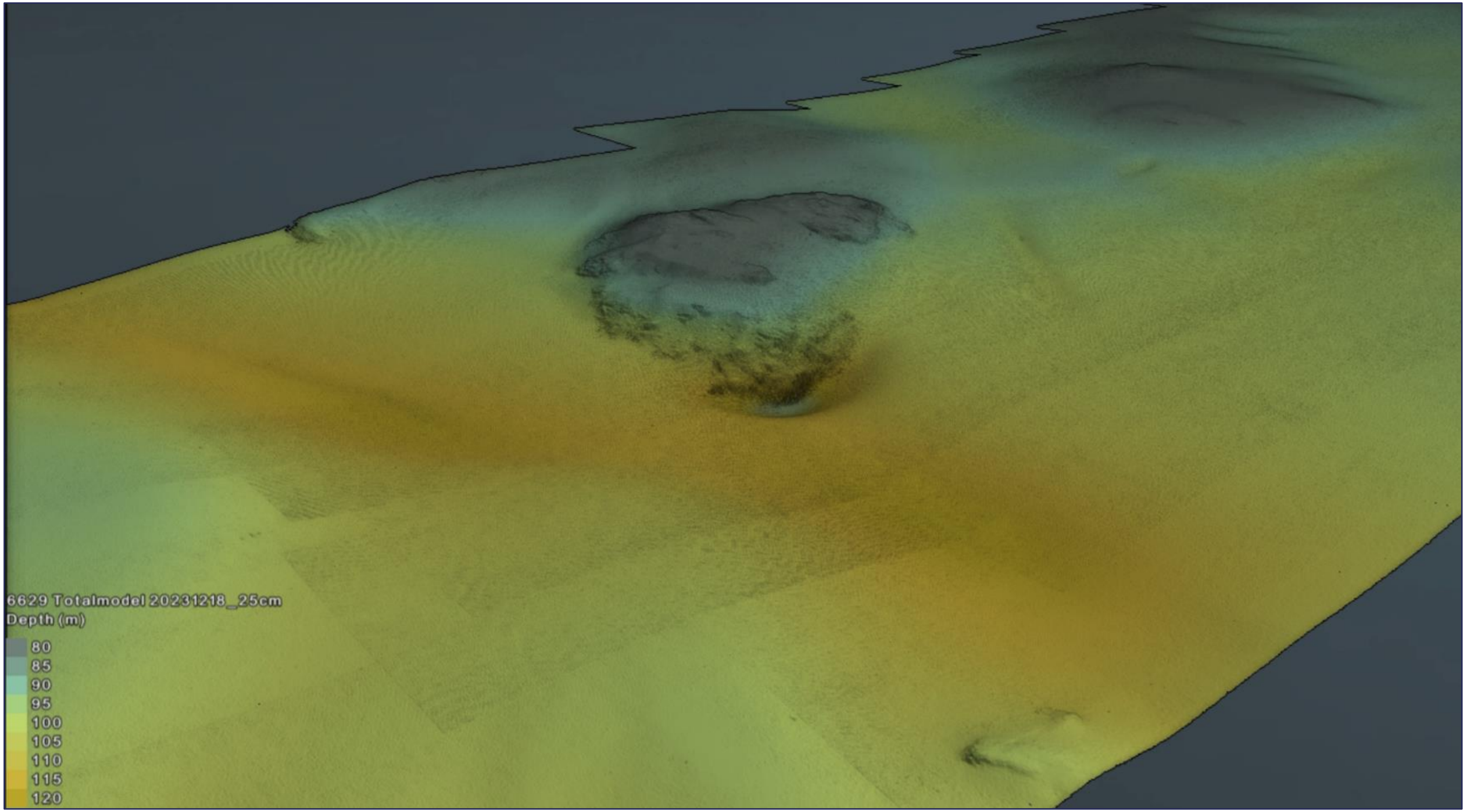


Figure 4-3 Data example showing MBES data of the steep slopes in the eastern part of the survey area

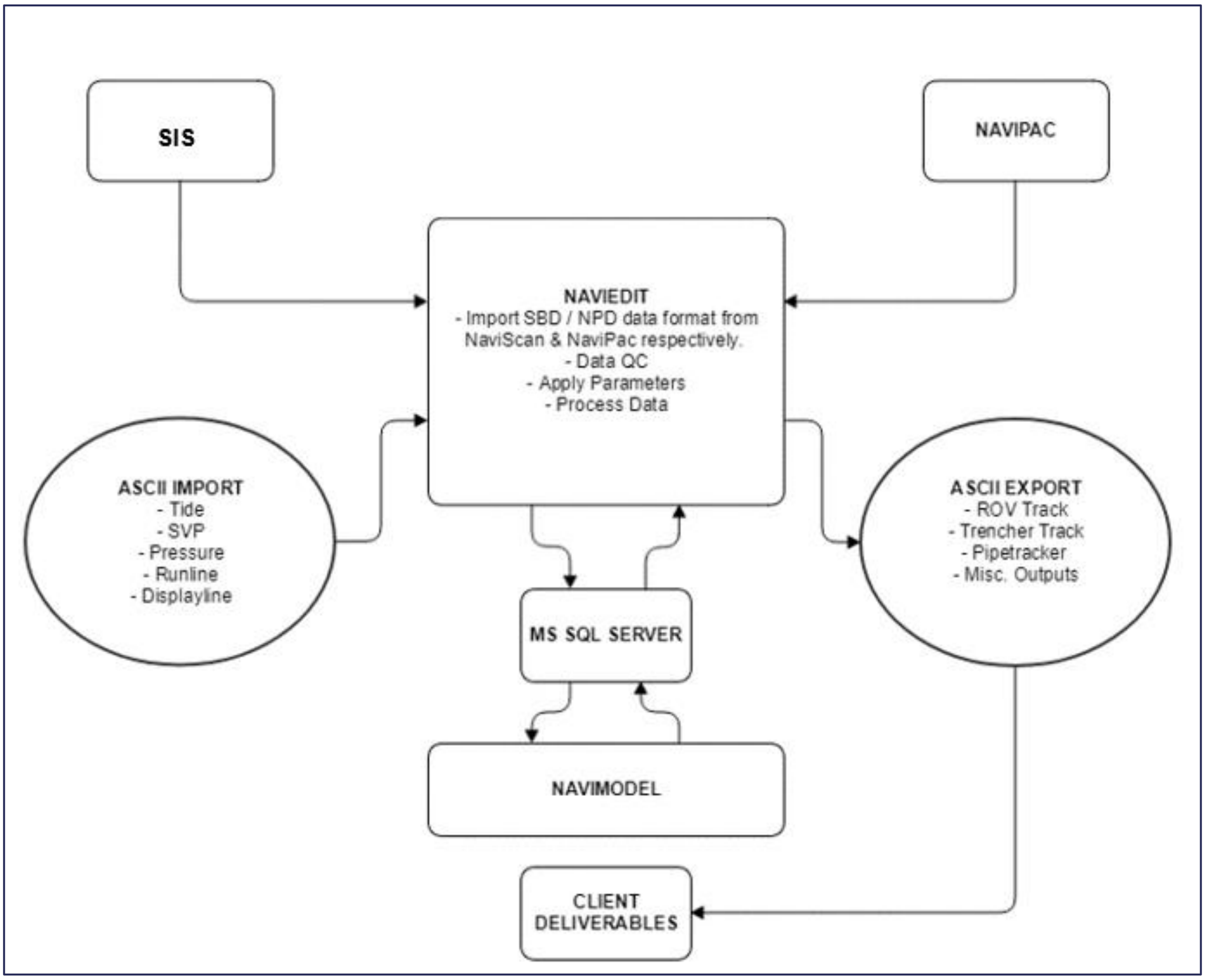


Figure 4-4 MBES processing workflow

4.2 BACKSCATTER

Backscatter data was produced from the collected multibeam data using QPS FMGT. The data was merged into grayscale GeoTiffs, one for each required resolution.

Backscatter processing workflow presented in Figure 4-5.

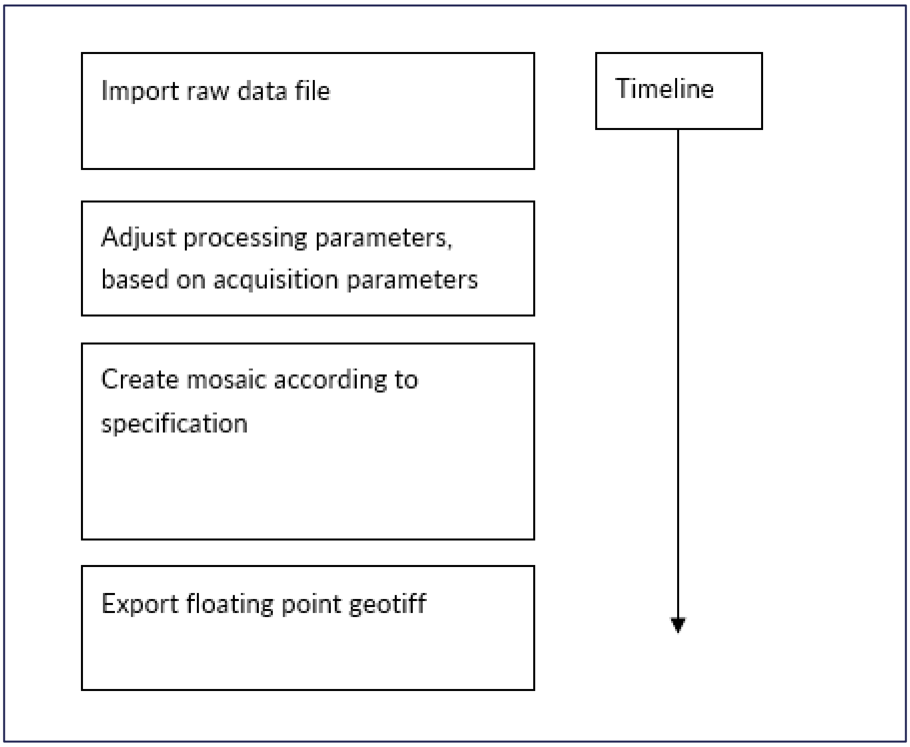


Figure 4-5 Backscatter processing workflow

4.3 MULTI APERTURE SONAR

The data quality was checked by Online personnel during acquisition and the Geophysical QC Log kept updated. The MAS data was checked as soon as possible for quality and position by the Offline personnel. Lines with poor quality data or gaps were highlighted and added to the re-run list. In the easternmost part of the area, sections of six lines were rerun from east to west. This was done to improve the Equinox system steering, as the system handles decreasing water depth better than increasing depths. The MAS data is slant range corrected in the acquisition phase.

The SWF8 data format was imported to SonarWiz (Figure 4-6), and the processed for each survey line:

a) Load *.swf8 raw files into project
b) Quality control file (accept/reject), bottom track and gain normalisation
c) Position control with MBES tiff and adjacent lines ran in same and opposite direction, apply processed navigation where deemed necessary (Figure 4-9, Figure 4-10)
d) Target selection using the waterfall display, all files checked for targets but no duplicates selected (Figure 4-7).
e) Target classification and length, width and shadow measured, all targets interpreted as boulders have not been selected.
f) Quality control of selected targets and check towards mosaic
g) Calculation of target height from the shadow, altimeter and offset to nadir
h) Exporting processed data:
   - MAS sonar mosaic exported in grey and copper scale
   - MAS stripes exported in grey and copper scale
   - Target listing exported and edited

The MAS data workflow is presented in Figure 4-8.

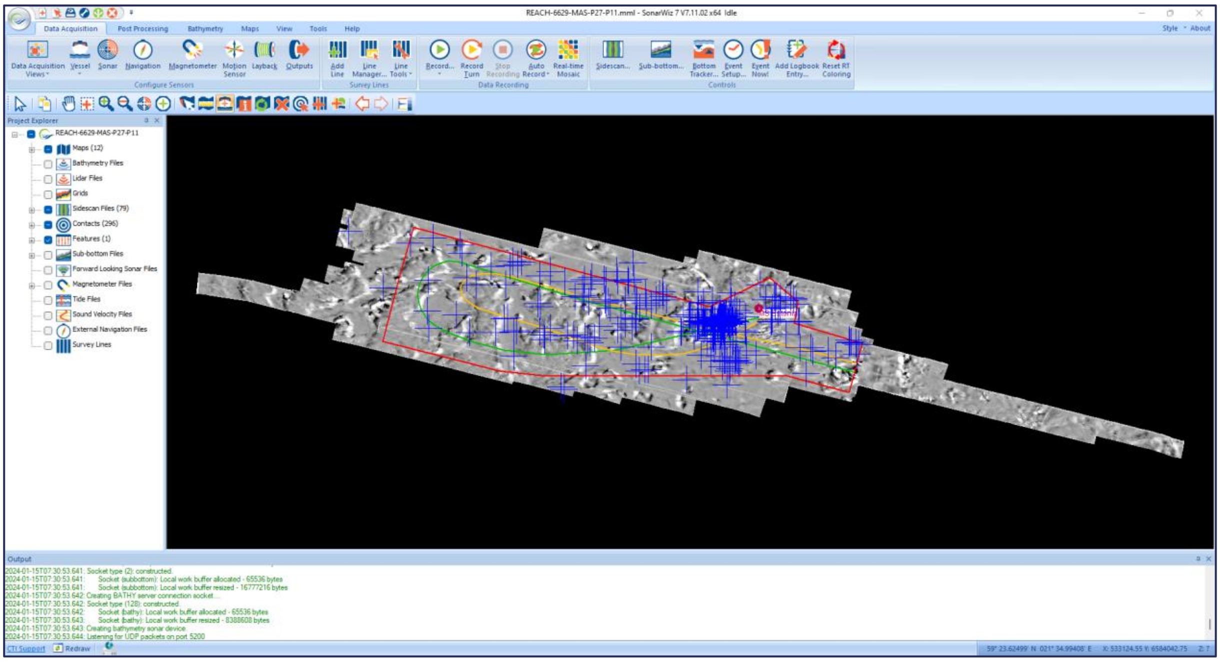


Figure 4-6 SonarWiz main window showing MAS data in grey scale with MAS targets marked as blue crosses, planned survey area in red polygon, modelled tracks of the sinking path in green from HSVA and yellow from JAIC and the official wreck location marked with red dot.

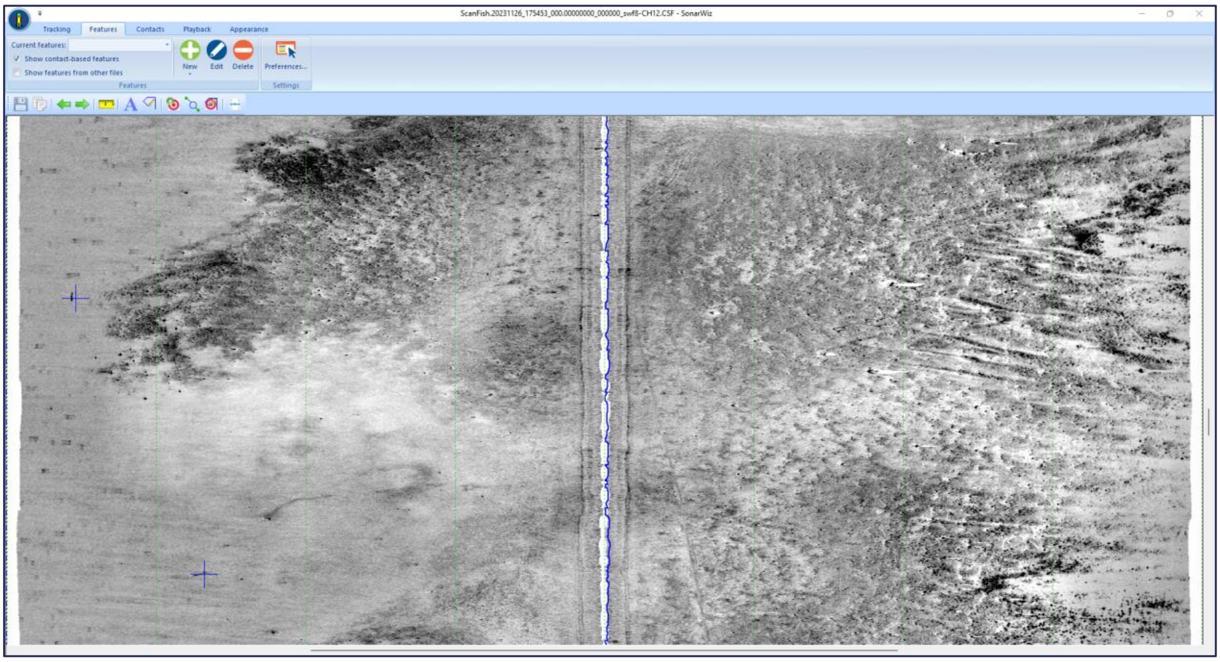


Figure 4-7 MAS data example showing SonarWiz waterfall window, total data width 200m, 25 m between green lines.

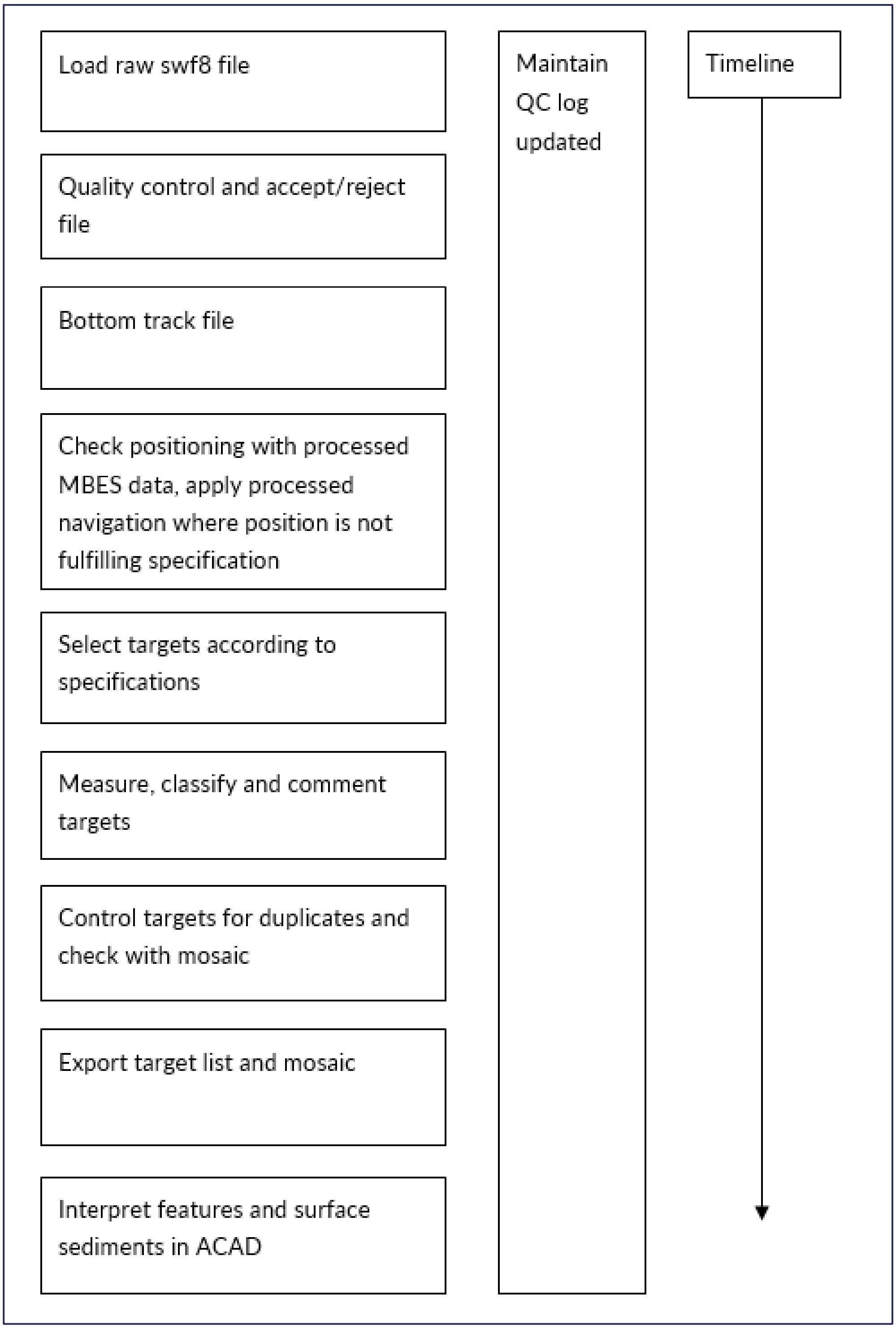


Figure 4-8 MAS data workflow

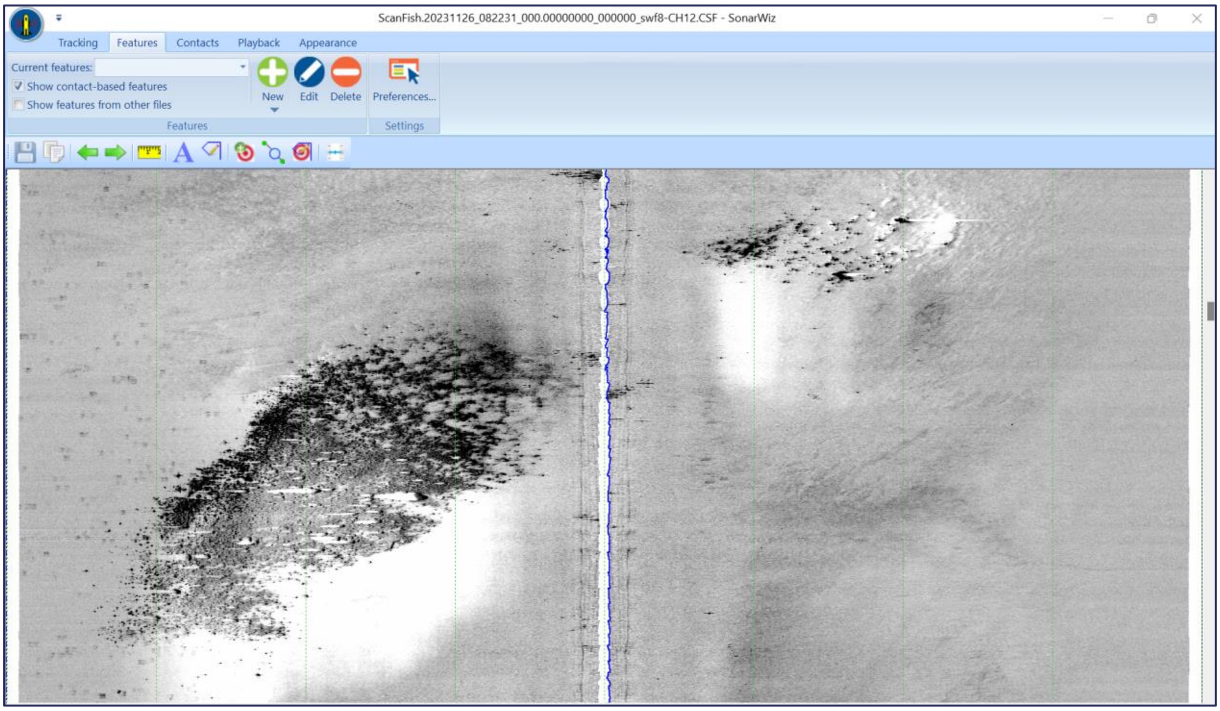


Figure 4-9 SonarWiz example pre navigation proscessing

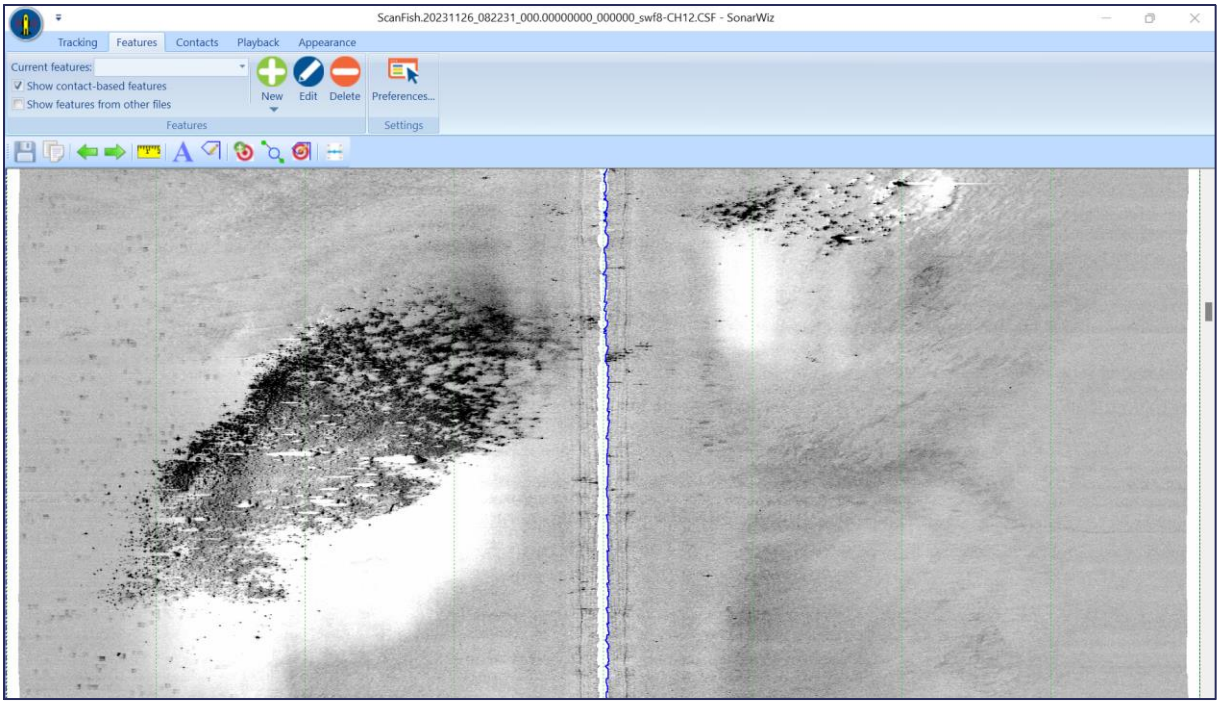


Figure 4-10 SonarWiz example post navigation proscessing

5 DATA QUALITY

5.1 LIMITING FACTORS

The limiting environmental factors during the survey included pycnocline, that comprises differences in salinity and temperature. The pycnocline is mostly pronounced in the outer range of the data and varied locally both in vertical and horizontal scale. The linespacing at 25 m gives overlapping data and the limiting factor was not considered an issue, further discussed in 5.4.

In the operational phase the weather, mainly the large wave height, halted the operation from 09.00 UTC 20231127 to 15.00 UTC 20231128.

5.2 POSITIONING

The GNSS vessel positions had good quality throughout the survey operations which is evident from the high quality of the geophysical data. The GNSS corrections were supplied to the system using the Veripos network (Ultra^2). The system broadcasts differential corrections via a communications satellite downlink to the field receiver, which on Skagerak is the Seapath 330 system. The differentially corrected position from the Seapath system was passed to all onboard acquisition systems.

The ROTV was equipped with an Sonardyne Sprint INS system, which supplements the USBL system. The Sonardyne Sprint INS system was stable throughout the project. The USBL positions for the ROTV were stable in general with few spikes.

5.3 BATHYMETRY

The multibeam data acquired during the survey was of good quality. The data was acquired at 400kHz and a short CW pulse throughout the survey work. The pycnocline was found as expected in the Baltic in late autumn and did not affect the data quality. The difference in the CTD and miniSVS values were consistent and did not prove major changes in the water mass in the area.

The vertical accuracy of the MBES data is approximately 0.2 m and an object of 0.5 m in any direction is possibly visible in the MBES data, an object of 1 m in any direction is visible.

5.4 MULTI APERTURE SONAR

The overall quality of the MAS data was average to very good and met the criteria for target selection, as discussed below.

The sensor achieved 100 m coverage on each side whereof approximately the inner half on both sides were of excellent quality. The high quality of the vessel surface positioning coupled with very good USBL/INS data from the ROTV resulted in above average quality of the sonar data positioning.

In the outermost half of the data on the port side disturbances occurred with somewhat regular pattern, visible in data example in Figure 5-1. As the survey was performed with multiple lines on the same area the disturbances were not considered to affect the result of the target selection. Six lines were rerun because of poor data quality caused by rapid change in the bathymetry in the easternmost part of the area, as described in section 2.1.

A pycnocline was present in some parts of the survey area but did not affect the data to any greater extent except for the additional survey lines in the easternmost area, visible in Figure 5-1.

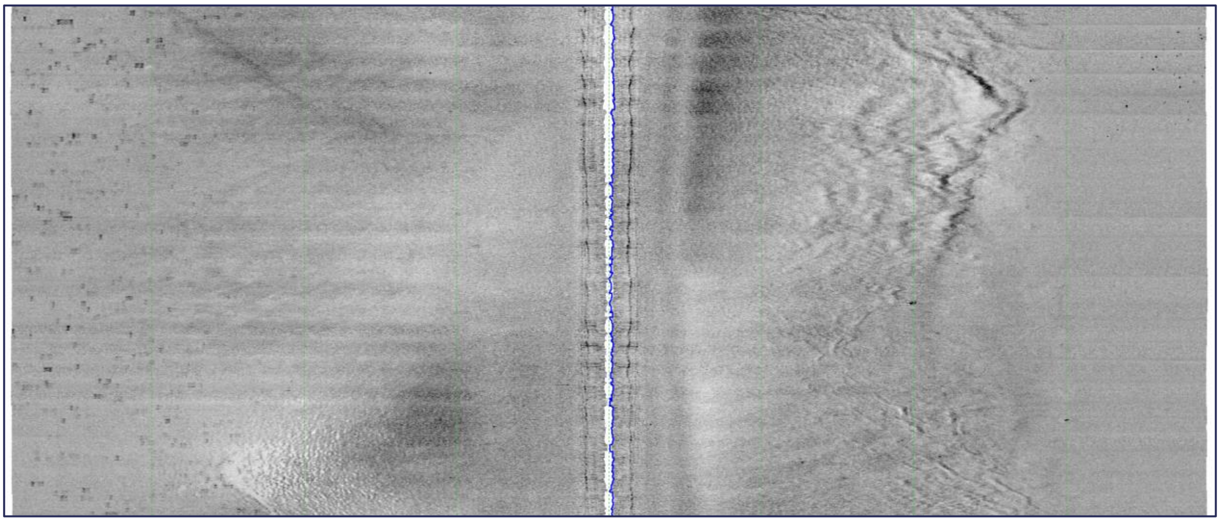


Figure 5-1 MAS data example, noise in data on the left hand side and pycnocline present on the right hand side, 25m between green lines

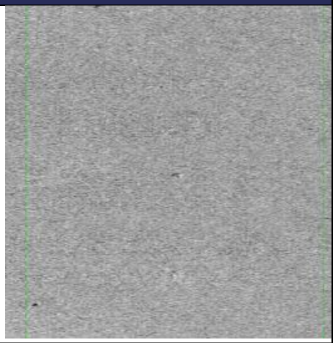
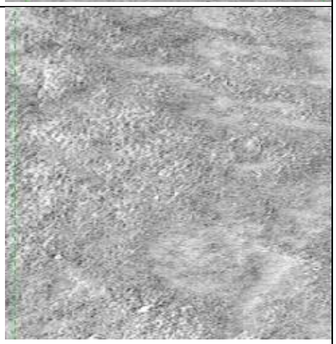
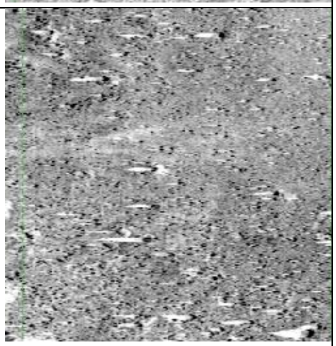
6 GEOLOGICAL SETTINGS AND CLASSIFICATIONS

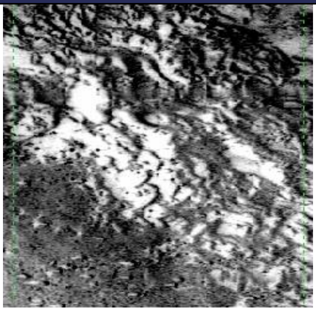
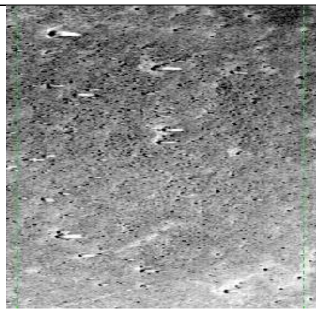
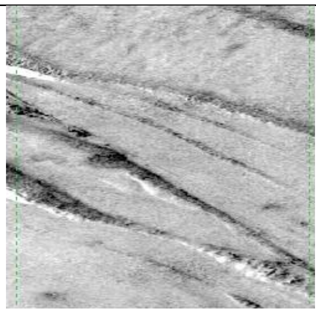
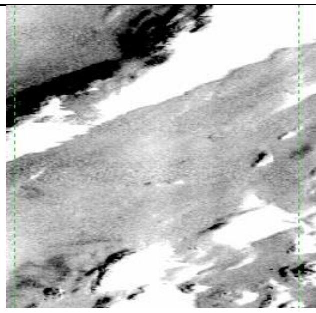
The geological setting in the area is of typical kind of the Baltic Sea with glacial and postglacial clays deposited on till and bedrock. The till was deposited during the latest glaciation, with maximum extend around 20 000 years ago. During the ice retreat, glacial clays was deposited on the till and the bedrock. Thereafter the deeper basins were filled with postglacial clay, with high organic content at locations. Due to erosion caused by bottom currents the till and bedrock is present in surface at locations, and in the deeper areas the clay is the dominant surface sediment.

6.1 SEABED SEDIMENT AND FEATURE CLASSIFICATION

The MAS mosaic was interpreted in ACAD civil 3D together with MBES data to provide a seabed sediment classification. The sediments were divided into four categories together with three feature classes. Descriptions along with MAS sonar data examples of the observed morphological features are detailed in Table 6-1.

Table 6-1 Surface Sediment Classification

Lithological Interpretation	Acoustic Description	MAS Example Image
CLAY	Glacial/Postglacial CLAY. Low to medium acoustic reflectivity. Smooth and even texture. At locations few occasional boulders (glacial CLAY). 25 m between green lines.	
SAND	Medium and even acoustic reflectivity. Grainy texture. This sediment type is present south of the MV ESTONIA wreck after dumping. 25 m between green lines.	
TILL	High acoustic reflectivity. Grainy to coarse texture with frequent acoustic shadows. 25 m between green lines.	

Lithological Interpretation	Acoustic Description	MAS Example Image
BEDROCK	Igneous BEDROCK. High acoustic reflectivity. Hard textures and large acoustic shadows. 25 m between green lines.	
Boulder field	Area with high density of boulders, >30 boulders per 25×25 m and the boulders are >0.2 m. 25 m between green lines.	
Mass waste scar	Scars from mass waste. Present south-west on the MV ESTONIA wreck. 25 m between green lines.	
Pressure banks	Pressure bank installed to stabilize the wreck area, Present south of the MV ESTONIA. 25 m between green lines.	

6.2 TARGET CLASSIFICATION

The targets/contacts were selected from SonarWiz waterfall window and divided into six classes:

a) Debris, interpreted to be of origin from the wreck, manmade items
b) Object, the source of the item is difficult to interpret, can be manmade or natural
c) Other, one depression from the bow visor and one possible drag mark
d) Wire
e) Anchor chain, from installation of geo textiles
f) Cable

See section 7.3 for further description.

In addition, a confidence level of 1 or 2 were given, where class 1 is an object that can be interpreted with higher certainty. No targets interpreted as boulders were selected from the data. In cases where the interpretation of boulder or target was difficult, a target was selected.

7 RESULTS

The main objective of the site survey was to map debris from the MV ESTONIA and the second objective of the survey was to map the anchoring wires of the geotextiles. Reach Subsea consider both the objectives fulfilled as debris and the geo textiles could be recognized from the dataset.

7.1 SEABED DEPTH, GRADIENT AND MORPHOLOGY

The area is characterized of an undulating seafloor where a few broad heights are separated by deeper narrower valleys. The depths vary between 52 and 125 m (vertical reference RH2000) and the largest depth is found in a channel in the easternmost part of the area (Figure 7-1).

The gradient is quantified as the calculated rate of change of depth with respect to horizontal distance. The seabed in the survey area is characterised as very gentle to gentle with steeper gradients associated with valleys, till and outcropping bedrock. The gradients vary between 0 to about 65 degrees (Figure 7-2).

In Figure 7-3 the result from backscatter data is presented, with softer sediments in light grey and harder surfaces in darker grey.

7.2 SEABED FEATURES AND SEABED SEDIMENTS

7.2.1 BOULDER FIELDS

Areas with a density of >30 boulders per 25x25 m were marked as a feature in the surface sediment chart (Figure 7-4).

7.2.2 LINEAR FEATURES

South -west of the MV ESTONIA seven scars from mass waste has been marked as features (Figure 7-4). South of the MV ESTONIA ten ridges of pressure banks have been marked as feature (Figure 7-4).

7.2.3 SEABED SEDIMENTS

The seabed sediments are displayed in Figure 7-4, with Bedrock in red colour, Till in grey and Clay in yellow.

7.3 SEABED TARGETS

The total number of 296 targets/contacts were selected from the MAS data and divided into six classes (Table 7-1 Overview of Identified Targets).

Table 7-1 Overview of Identified Targets

Type	Number	Comment
Debris	273	Interpreted to be of origin from the wreck, manmade items
Object	15	The source of the item is difficult to interpret, can be manmade or natural
Other	2	One depression from the bow visor and one possible drag mark
Wire	1	Possible wire
Anchor chain	4	Anchor chains from the geo textiles
Cable	1	Possible cable

The main quantity of targets is located in the vicinity of the wreck. However, several targets are found scattered in the area. The pattern of targets is shown in Figure 7-5.

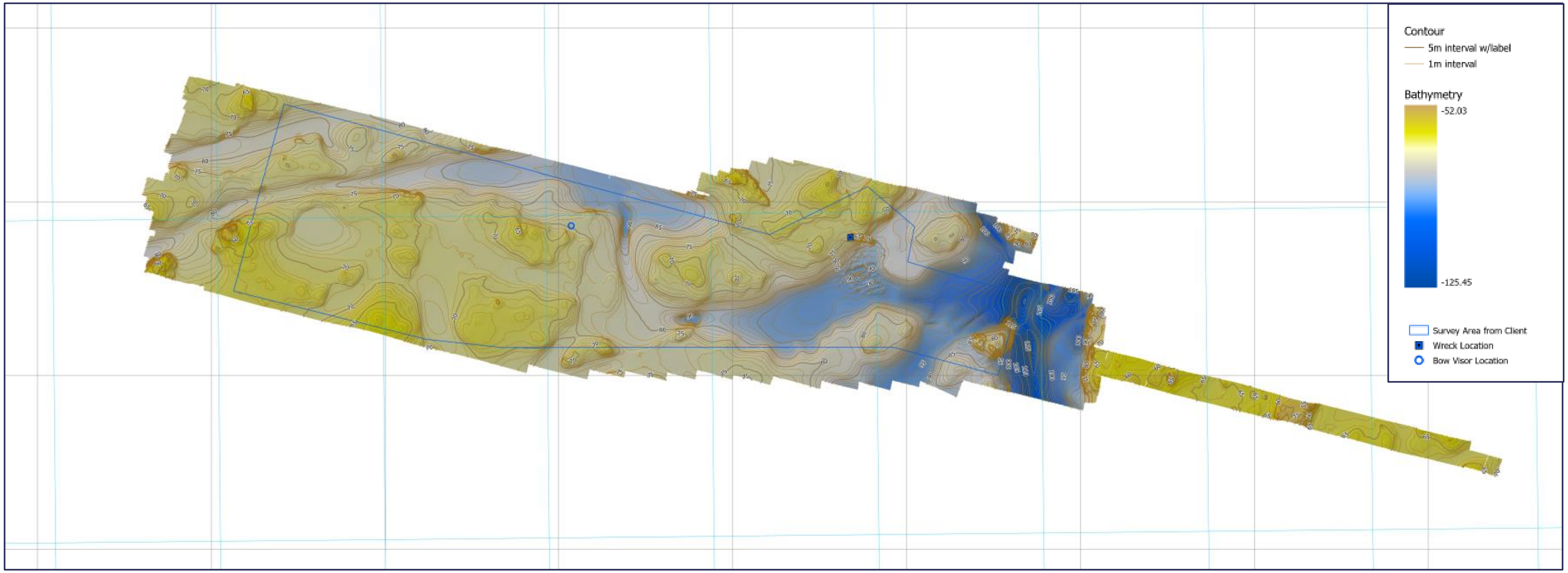


Figure 7-1 Bathymetry, 1km between scale lines

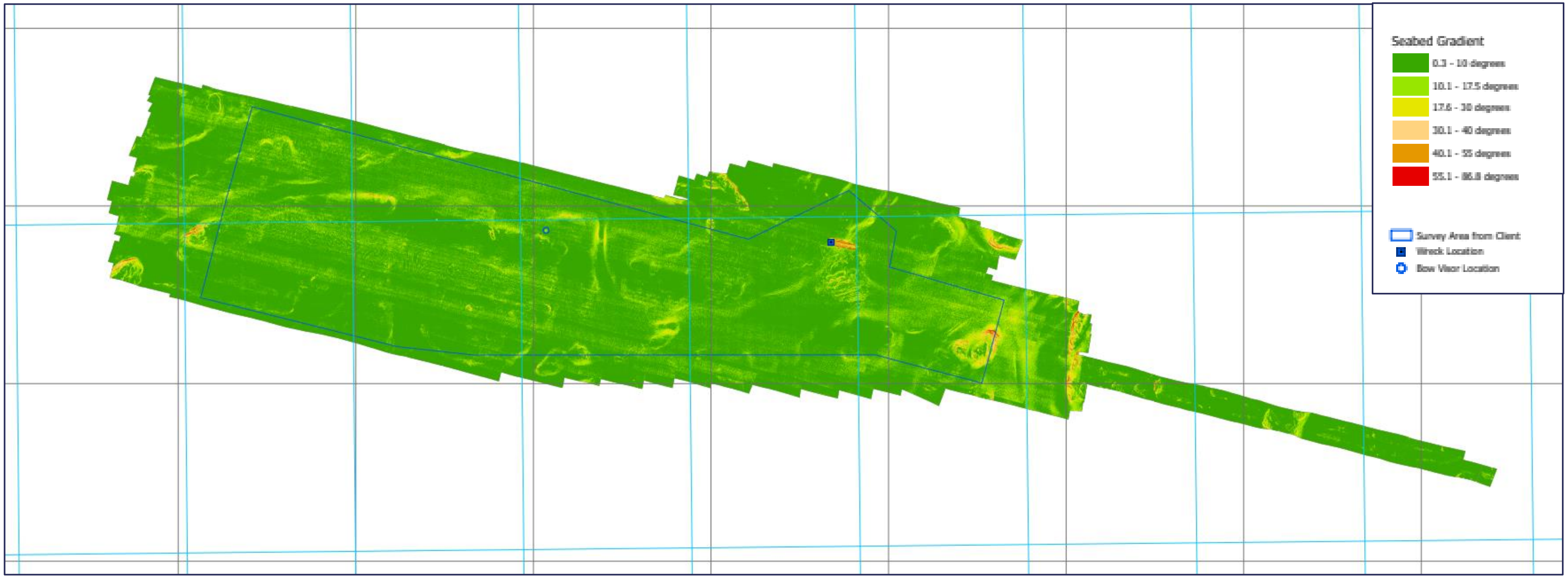


Figure 7-2 Seabed gradient, 1km between scale lines

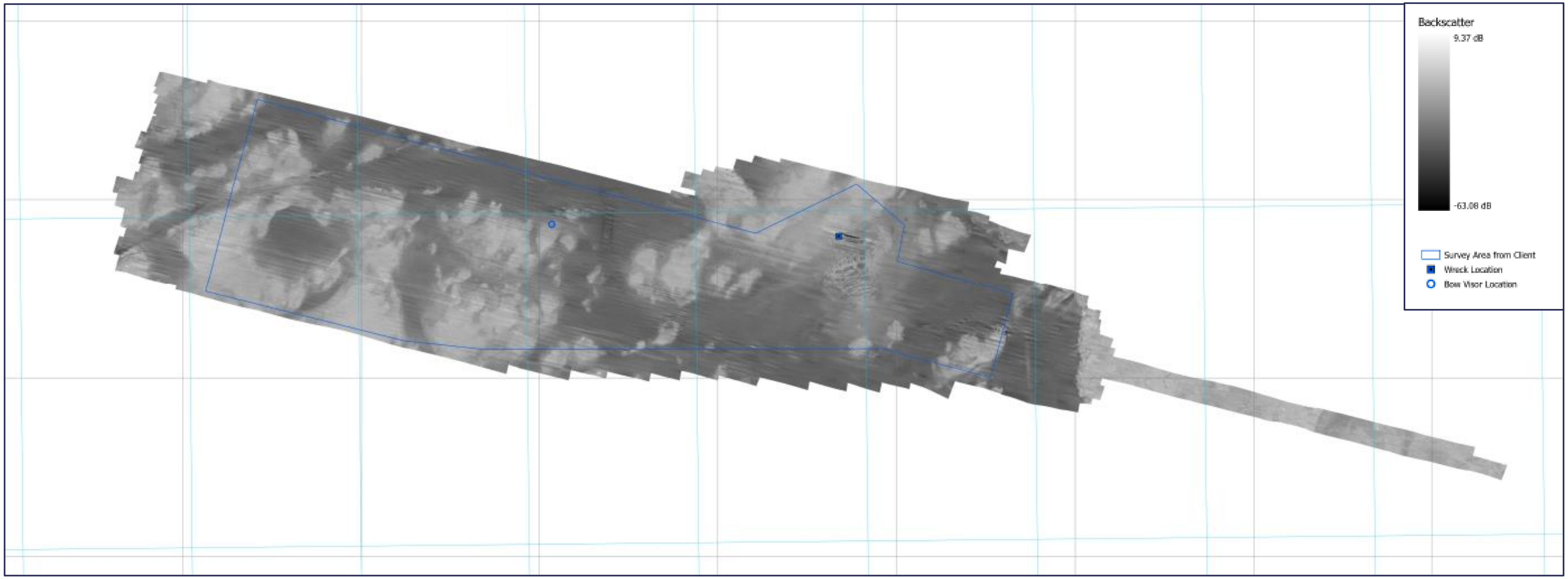


Figure 7-3 Backscatter mosaic, 1km between scale lines

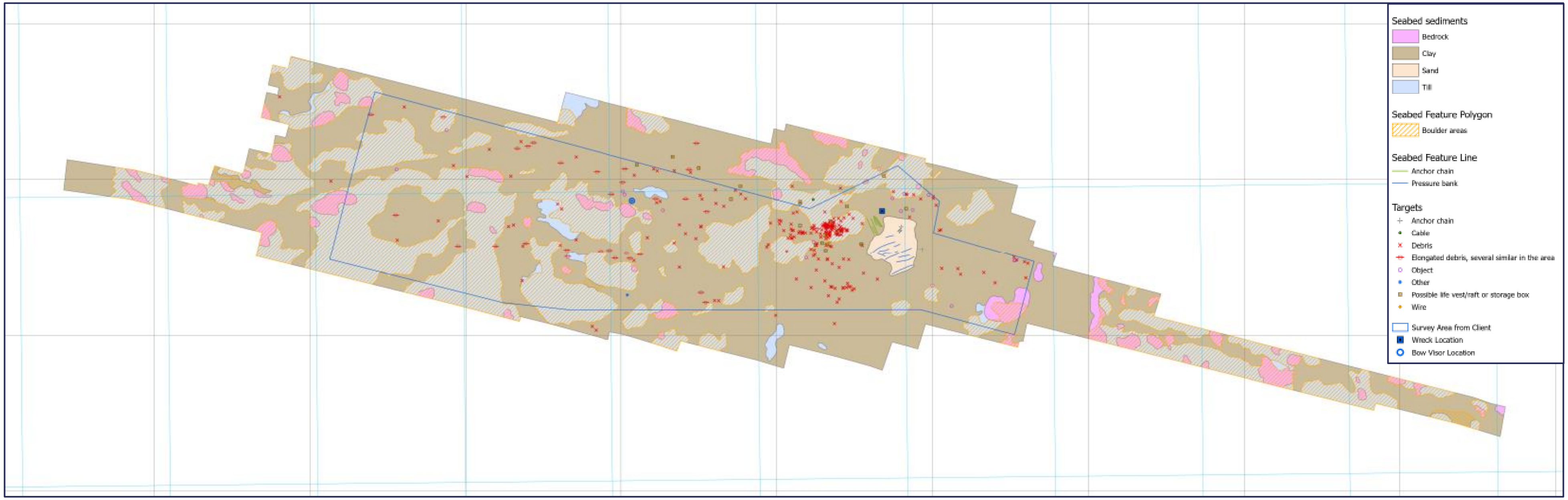


Figure 7-4 Seabed sediment and feature classification, 1 km between scale lines.

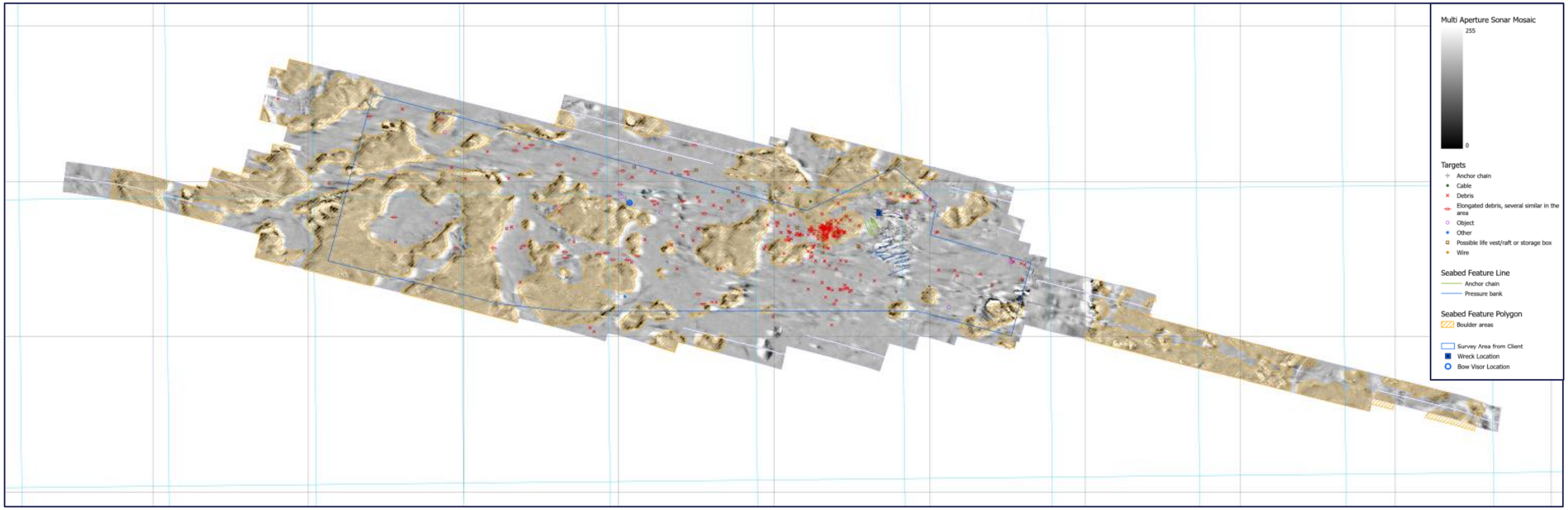


Figure 7-5 MAS mosaic with targets and features, 1 km between scale lines.

A total number of 19 targets in the class Debris are interpreted as possible life raft/vest or storage boxes, example in Figure 7-6 to Figure 7-8.

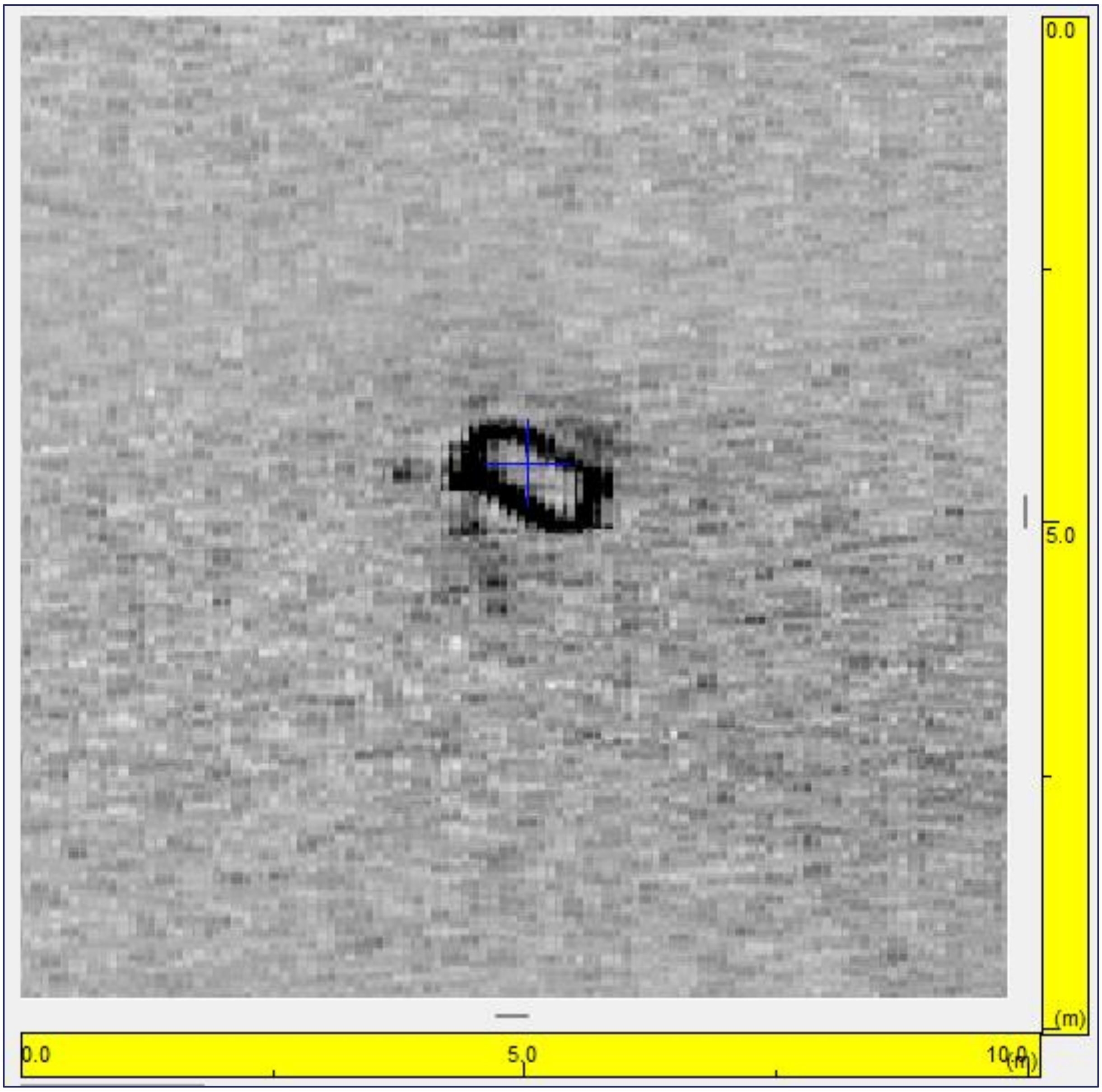


Figure 7-6 Target in MAS data, possible life raft box, picture 10x10 m

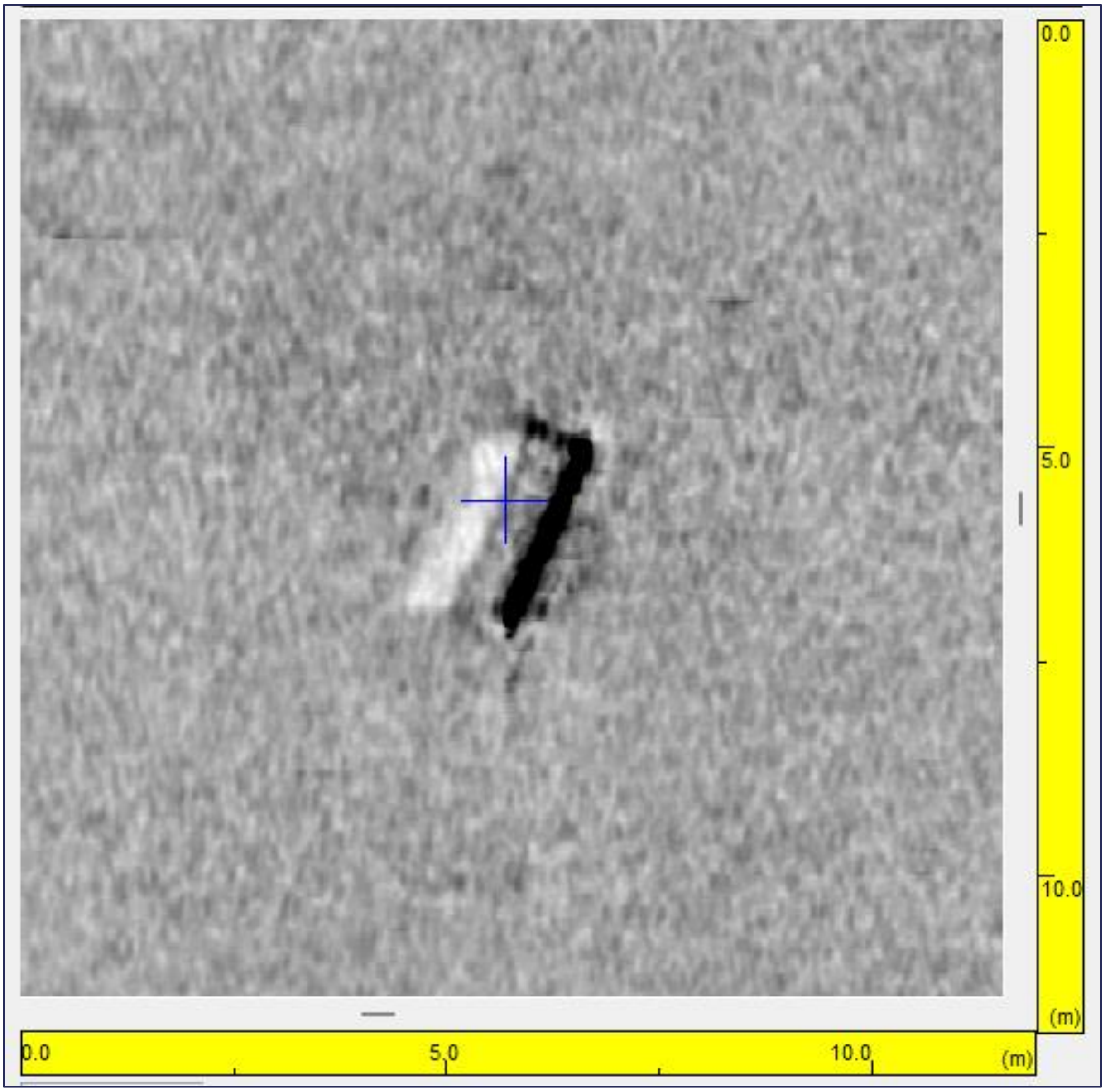


Figure 7-7 Target in MAS data, possible life vest box, picture 10x10 m

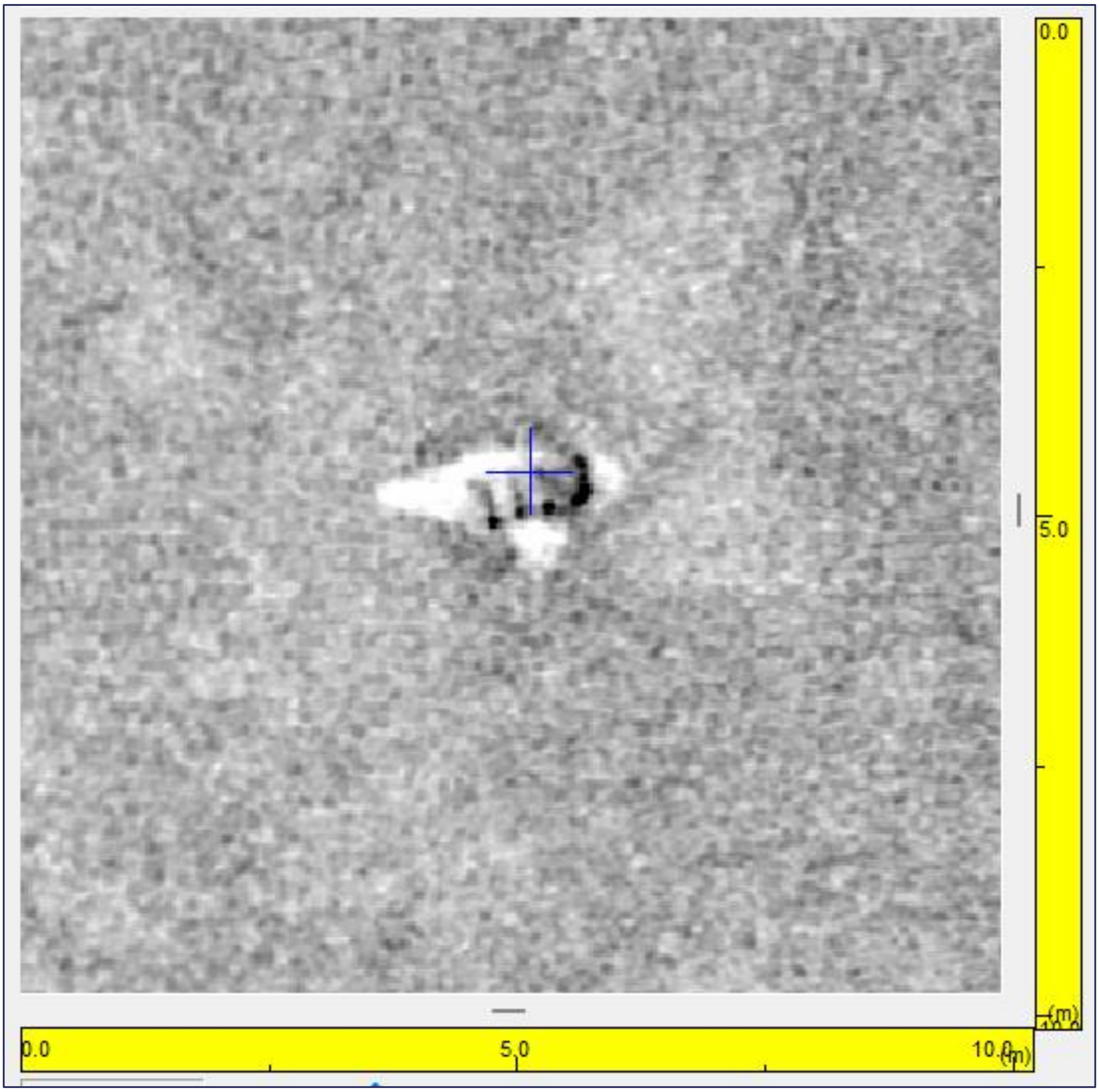


Figure 7-8 Target in MAS data, possible life raft box, picture 10x10m

A total of 33 items in the class Debris is very similar to each other and can be of origin from the cargo on MV ESTONIA. These items are elongated straight objects with length between 2.2 to 3.5 m and a width of about 0.3m. Example in Figure 7-9.

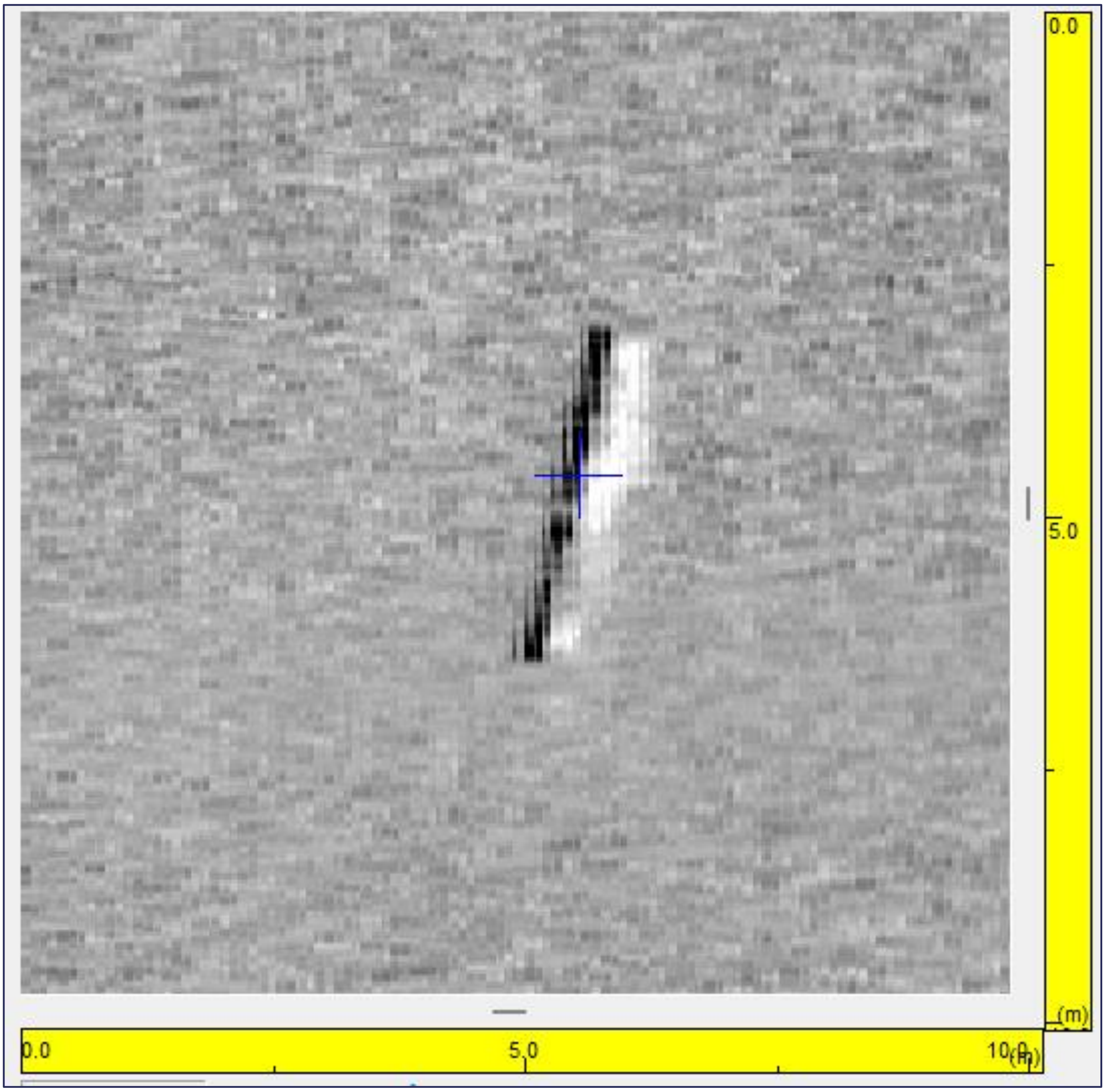


Figure 7-9 Target in MAS data interpreted as Debris, possible item from MV ESTONIA cargo, picture 10x10 m

In the area close to the wreck a number of 4 targets were classified as anchor chains, origin from the installation of geo textiles in 1996 Figure 7-10.

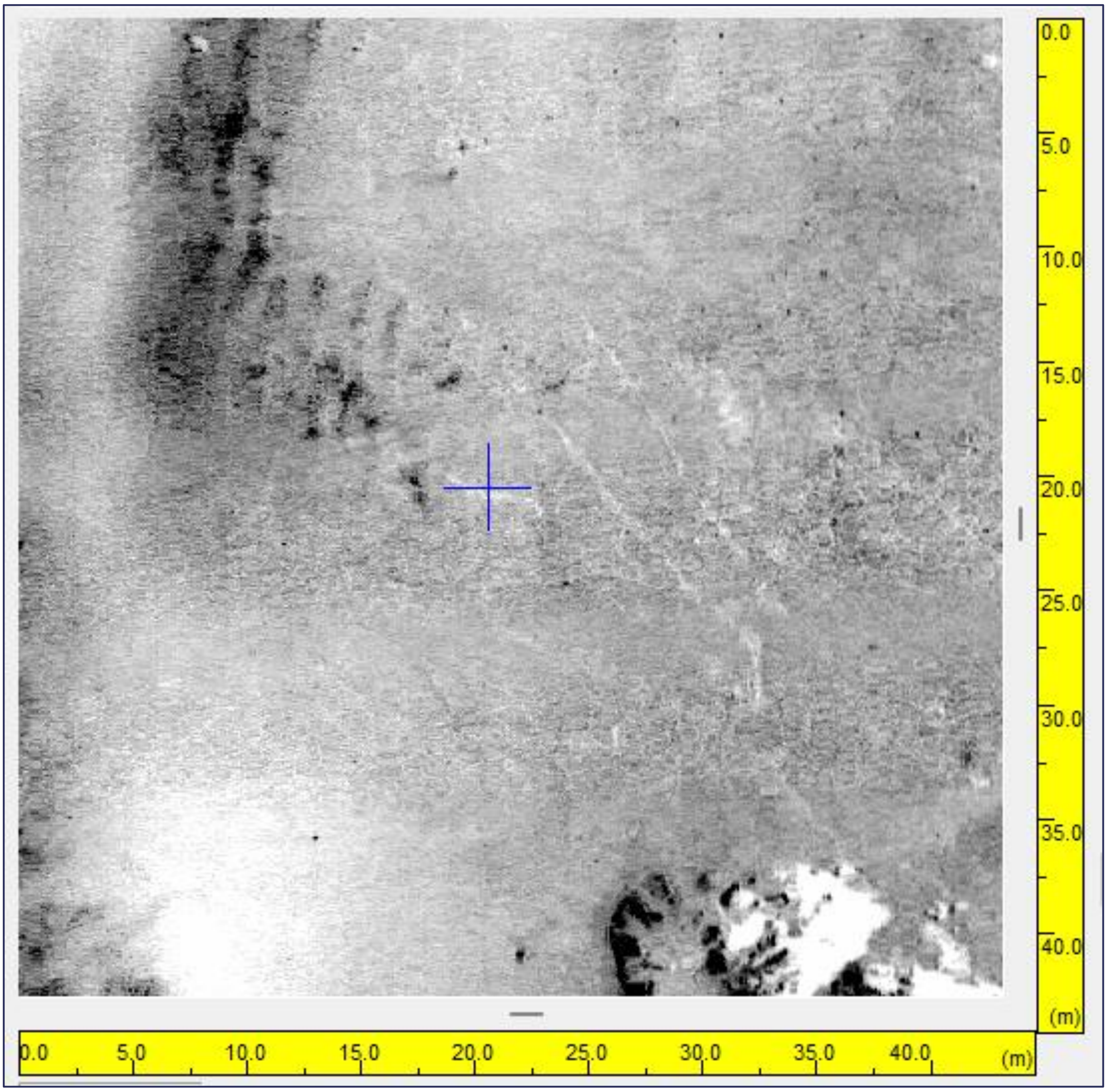


Figure 7-10 Target in MAS data, possible anchor chains from geo textiles, picture 50x50 m

North of the wreck, three items are classified as fundaments to underwater positioning, origin from the work to stabilize the wreck in 1996.

A total of 15 targets are classified as objects, this type of item is difficult to interpret and may be of either manmade or natural items.

It must be noted that the targets have been detected and interpreted but are not confirmed. To confirm the interpretation of a target, a visual inspection of still camera or preferably video must be performed. However, the high-quality MAS data has given a possibility to make a classification of higher certainty compared to conventional SSS data.

8 FINAL DELIVERY

Charts delivered with this report;

Table 8-1 Final chart delivery

Chart	Format, Scale	Content
MBES	A0, 10000	MBES data grid, survey boundary, wreck position, bow visor position
Backscatter	A0, 10000	Backscatter geotiff, survey boundary, wreck position, bow visor position
Gradient	A0, 10000	Inclination of seafloor, survey boundary, wreck position, bow visor position
MAS	A0, 10000	MAS geotiff, features, survey boundary, wreck position, bow visor position
Seabed sediments	A0, 10000	Seabed sediments, features, targets, survey boundary, wreck position, bow visor position
Interpreted wreck conditions	A0, 10000	Seabed sediments, features, targets, survey boundary, wreck position, bow visor position, modelled sinking tracks

A database, according to Technical Specification provided by ESIB, have also been delivered.