2023 Descriptive Report of Seafloor Mapping: Vicinity of Mistaken Ground

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Maine Coastal Mapping Initiative, December 2024

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Maine Coastal Mapping Initiative Maine Coastal Program Department of Marine Resources				
	DESCRIPTIVE REPORT			
Type of Survey:	Navigable Area			
Registry Number:				
	LOCALITY			
State(s):	Maine			
General Locality:	Gulf of Maine			
Sub-Localities:	Vicinity of Mistaken Ground			
	2023			
	CHIEF OF PARTY			
Peyton	Benson, Lead Hydrographer, State of Maine			
	LIBRARY & ARCHIVES			
Date:				

	MAINE COASTAL MAPPING INITIATIVE	REGISTRY NUMBER:			
	MAINE COASTAL PROGRAM				
HYDR	HYDROGRAPHIC TITLE SHEET				
INSTRUCTIONS: The hy	ydrographic sheet should be accompanied by this form, filled in as completely as possible, v	when the sheet is forwarded to the Office.			
State(s):	Maine				
General Locality:	Gulf of Maine				
Sub-Locality:	Vicinity of Mistaken Ground				
Scale:					
Dates of Survey:	04/21/2023 to 10/28/2023				
Instructions Dated:					
Project Number:					
Field Unit:	Amy Gale				
Chief of Party:	Peyton Benson, Lead Hydrographer				
Soundings by:	Kongsberg EM2040C (MBES)				
Imagery by:	Kongsberg EM2040C (MBES Backscatter)				
Verification by:					
Soundings in:	meters at Mean Lower-Low Water				
Remarks:					

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ABSTRACT

From April 21 through October 28, 2023, the Maine Coastal Mapping Initiative (MCMI) conducted hydrographic surveys using a multibeam echosounder (MBES) in federal marine waters in regions lacking high-resolution bathymetry adjacent to previously-mapped areas. The survey area lies approximately 35 miles south of Pemaquid Point and 45 miles east of Wells, Maine and is bounded to the north by survey H13333 and to the south by survey W00195. The surveying efforts were conducted to support endeavors to enhance coastal resiliency through identification and characterization of seafloor habitat to provide information necessary to managing the marine environment and economy. The survey also coincides with state and federal efforts to update coastal data sets and increase high resolution bathymetric coverage for Maine's coastal and marine waters. This report serves as a comprehensive summary of the mainscheme survey efforts conducted by MCMI throughout the 2023 survey season. In total, this survey effort collected approximately 35.92 mi² (93.03 km²) of high-resolution multibeam data in the target area and conducted sediment sampling at 25 sites to aid in seafloor characterization. At all sediment sampling sites, MCMI also collected water column data and underwater video, which are utilized to improved classification of substrate and modeling of benthic communities.

1.0 Area Surveyed

The survey area collected throughout the span of the 2023 season is situated in the vicinity of Mistaken Ground in the Gulf of Maine, as shown in Figure 1. The approximately 35.92 mi² survey area consists of all navigable waters within the survey bounds between adjoining H13333 to the north and W00195 to the south (Figure 2).

These data were not collected in direct accordance with the *NOS Hydrographic Surveys Specifications and Deliverables* and the *Field Procedures Manual* requirements; however, both documents were referenced during acquisition for guidance.

Mainscheme survey limits are listed in Table 1. Specific dates of data acquisition for the mainscheme survey are listed in Appendix A.

Table 1 – Survey Limits

2023 Mainscheme Survey Limits

Southwest Limit	Northeast Limit
43° 14' 50.64" N	43° 19' 34.14" N
69° 42' 36.25" W	69° 27' 21.94" W

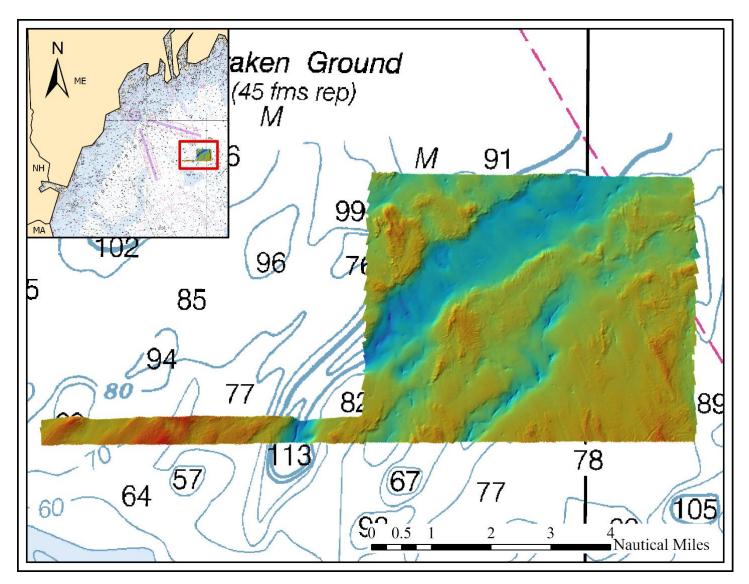


Figure 1 – General locality of mainscheme survey coverage, plotted over NOAA chart 13260.

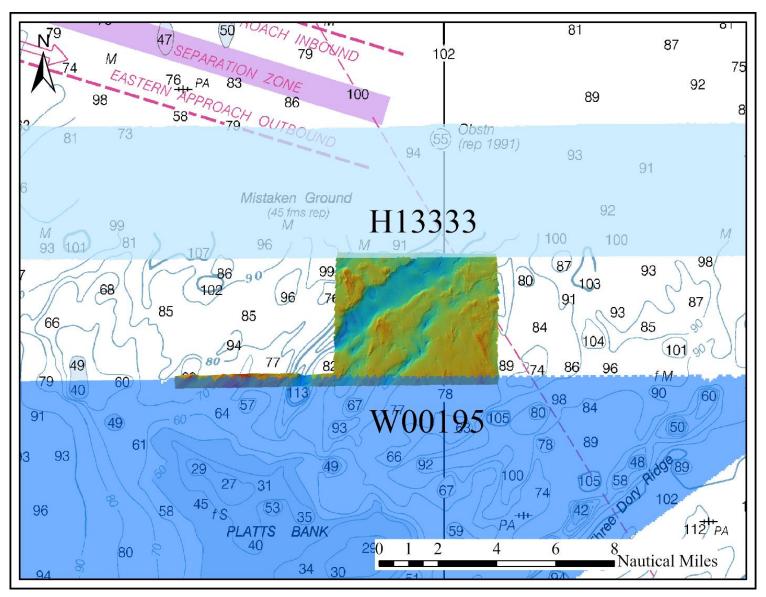


Figure 2 – General locality of mainscheme survey coverage relative to overlapping datasets in the region.

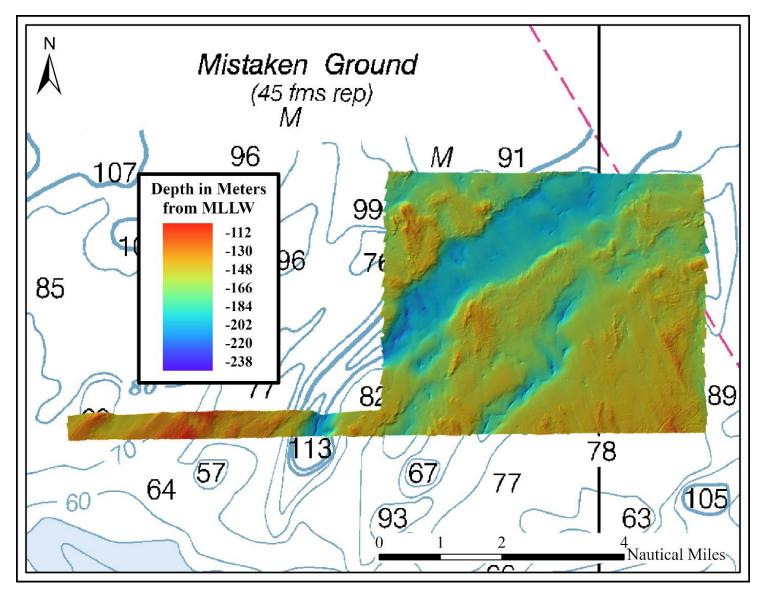


Figure 3 – Shaded relief image of mainscheme bathymetry data gridded at 4-meter resolution and colored by depth. Data overlay on NOAA chart 13260.

1.1 Survey Purpose

This survey was conducted by the Maine Coastal Mapping Initiative (MCMI) as part of a multi-agency cooperative agreement partially funded by the National Oceanic and Atmospheric Administration (NOAA) Office of Coastal Management (OCM), the Coastal States Stewardship Foundation/Northeast Regional Ocean Council, and The Nature Conservancy (TNC). The purpose of this project is to help inform policy decision-making related to Maine's coastal waters by increasing the volume of available high-quality bathymetric, benthic habitat, geochemical, and geologic data in the Gulf of Maine. This project also coincides with state and federal efforts to update coastal data sets for Maine's coastal waters and provides new data in the areas covered by National Oceanic and Atmospheric Administration (NOAA) nautical charts 13260 in the vicinity of Mistaken Ground, Gulf of Maine. These data were acquired and processed to meet Office of Coast Survey bathymetry standards as best as possible and are shared with the NOAA Office of Coast Survey for review.

1.2 Survey Quality

The entire survey should be adequate to supersede previous data.

1.3 Survey Coverage

Select few small holidays (gaps in MBES coverage) exist within the surveyed area, and normally occurred as sonic shadows in areas of locally high relief and/or highly irregular bathymetry. Analyses of bathymetric data show that the least depths were achieved over all features, and that holidays have not compromised data integrity.

2.0 Data Acquisition

The following sub-sections contain a summary of the systems, software, and general operations used for acquisition and preliminary processing throughout the 2023 survey season.

2.1 Survey Vessel

All data were collected aboard the Fishing Vessel (F/V) Amy Gale (length = 10.95 m, width = 3.81 m, draft = 0.93 m) (Figures 4, 5, and 6), a former lobster boat converted to a survey vessel and contracted to the MCMI. The vessel was captained by Caleb Hodgdon of Hodgdon Vessel Services. Surveys were based out of ports in Boothbay Harbor, ME. The EM2040C multibeam echosounder, Seatex MRU-5 motion reference unit (MRU), AML MicroX surface sound speed probe, dual GNSS antennas, and Fugro corrections antenna were pole-mounted to the vessel's bow; pole raised (for transit) and lowered (for survey) via a pivot point at the prow. The main cabin of the vessel served as the data collection center and was outfitted with four display monitors for real-time data visualization during acquisition.



Figure 4 - F/V Amy Gale shown with pole-mounted dual GPS antennas, Fugro AD-341 antenna, Kongsberg EM2040C multibeam sonar (not visible), MRU (not visible), and surface sound speed probe (not visible) in acquisition mode.

2.2 Acquisition Systems

The real-time acquisition systems used aboard the F/V Amy Gale during the reported surveys are outlined in Table 2. Data acquisition was performed using the Quality Positioning Services (QPS) Qinsy (Quality Integrated Navigation System; v.9.5.4) acquisition software. The modules within Qinsy integrated all systems and were used for real-time navigation, survey line planning, data time tagging, data logging, and visualization.

Sub-system	Components		
Multibeam Echosounder	Kongsberg EM2040C and processing unit		
Position, Attitude, and Heading Sensor	Seapath 330 processing unit, HMI unit, dual GPS/GLONASS antennas, MRU 5-V motion reference unit (subsea bottle), Fugro 3610 Receiver and AD-341 antenna		
Acquisition Software and Workstation	Qinsy software v.9.5.4 and 64-bit Windows 10 PC console		
Surface Sound Velocity (SV) Probe	AML Micro X with SV Xchange		
Sound Velocity Profiler (SVP)	Teledyne Odom Digibar-S and Valeport SWiFT SVP		
Ground-truthing/Sediment Sampling Platform	van Veen grab sampler, GoPro Hero 3+ video camera, GoPro Hero 5 Black video camera, dive lights, dive lasers, YSI Exo I sonde		

Table 2 – Major systems used aboard F/V Amy Gale

* See Appendix B for a diagram overview of survey systems aboard the F/V Amy Gale.

2.3 Vessel Configuration Parameters

In 2017, MCMI contracted Doucet Survey, Inc. to perform high-definition (precision \pm 5mm) 3D laser scanning of the F/V Amy Gale and all external MBES system components (e.g. MRU, GPS antennas, and EM2040C) (Figures 5 and 6). The purpose of the laser scan survey was to refine and or verify the precision of hand-made vessel reference frame measurements for future surveys. All points were referenced to the center point of the base of the MRU (mounted inside the pole and directly atop the EM2040C transducer) (Figure 7), which served as the origin (e.g. 0,0,0), where 'x' was positive forward, 'y' was positive starboard, and 'z' was positive down. The laser scan survey results only differed from hand-made measurements by \leq 3mm for all nodes of interest. Reference measurements for each component were entered into the Seapath 330 Navigation Engine (Table 3) and converted so all outgoing datagrams would be relative to the location of the EM2040C (e.g. EM2040C was used as the monitoring point for all outgoing datagrams being received by Qinsy during acquisition). Additional configuration and interfacing of all systems were established during the creation of a template database in the Qinsy console.

These offset values were not changed for the reported survey effort. Additional vessel configuration diagrams can be found in the appendices: settings as entered in the Seapath 330 Navigation Engine (Appendix C), template database in Qinsy (Appendix D), and Qinsy online computation settings (Appendix F). Configuration settings of the EM2040C were assigned in the EM Controller module of Qinsy (Appendix E).

Equipment	x (m)	y (m)	z (m)
MRU	0.000	0.000	0.00
Antenna 1 (port)	0.158	-1.245	-3.000
Antenna 2 (starboard)	0.158	1.252	-3.035
EM2040C	0.036	0.000	0.133

Table 3 – 2017 equipment reference frame measurements for Seapath 330

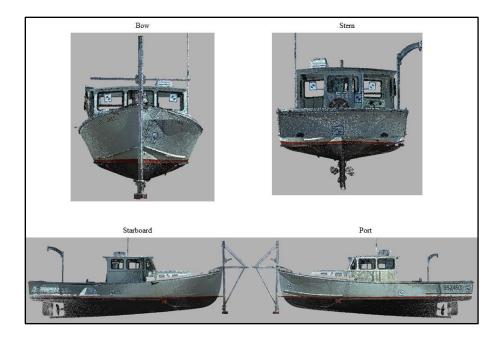


Figure 5 - F/V Amy Gale RGB color images generated from 3D laser scan survey (GPS antennas and external cabling not included in survey) data (.pts file converted to .las for visualization)

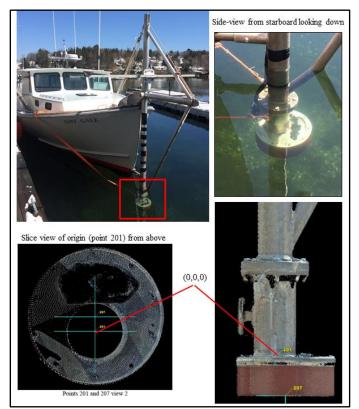


Figure 6 – F/V Amy Gale origin (point 201 in RGB images) for vessel reference frame(s); origin is center point within the base of the pole (center point of base within internally-mounted motion reference unit (MRU) point 201 in images above)

2.4 Survey Operations

The following is a general summary of daily survey operations. When the survey destination was reached, the sonar pole mount was lowered into survey position and its bracing rods were fastened securely to the hull of the ship via heavy-duty ratchet straps. Electric power to all systems was provided by a 2000-watt Honda eu2000i generator. Occasionally, two eu2000i generators were used simultaneously if additional auxiliary equipment needed electricity. Immediately following power-up, all interfacing instruments were given time to stabilize (e.g. approximately 30-45 minutes for Seapath to acquire accurate positioning). Next, the desired Qinsy project was selected for data acquisition. All files (e.g. raw sonar files, sound speed profiles, grid files, etc.) were recorded and stored within their respective project subfolders on a local drive. Prior to surveying, a sound speed cast was taken and imported into the 'imports' folder of the current project. After confirming agreement between the surface probe reading and the downcast data and visually inspecting cast values for abnormal profile/readings, the profile was applied to the sonar (EM2040C) in the Oinsy Controller module. Regular sound speed casts were collected throughout the survey day when necessitated by changing tide, location, or upon disagreement with the surface probe measurement (exceeding +/-2.0 m/s difference). Data were gridded at 0.5 to 4 meters for real-time visualization, depending on expected water depth range. Raw sonar files were logged in the Qinsy Controller module in .db format and saved directly onto the hydrographic workstation computer. All data were backed up daily on an external hard drive. At the end of each day's survey, sonar and navigation systems were powered down and the pole mount was raised and fastened for transit back to port. Upon arriving at the dock, all external instruments/hardware were visually inspected and rinsed with freshwater to prevent corrosion.

2.5 Survey Planning

Line planning and coverage requirements were designed to meet requirements for NOAA hydrographic standards and in accordance with IHO S-44 6th Edition Order 1a survey (International Hydrographic Organization, 2022 & NOAA Office of Coast Survey, 2021). Throughout the survey area, parallel lines were planned several days prior to surveying. Survey lines generally run along channel orientation or in alignment with coastal geometry, but variation was necessary for highly dynamic areas such as over ledges and scours. Lines were spaced at consistent intervals to obtain a minimum of 30% overlap between full swaths. Soundings from beam angles outside of ± 60 degrees from the nadir were blocked from visualization during acquisition, thus increasing the true minimum full-swath overlap. This online blocking filter was recommended by QPS field engineers with the intent of eliminating noisy outer beams from the final product, thereby increasing the overall contribution of higher quality soundings. All data were acquired at approximately 6.5-7 knots, although some areas required slower speeds to ensure safe operation of the vessel around obstructions, fishing operations, or in especially rough conditions.

2.6 Calibrations

Patch tests were conducted aboard the F/V Amy Gale at the beginning of the survey season as well as throughout data collection periods to correct for alignment offsets. For each patch test, a series of lines were run to determine the latency, pitch, roll, and heading offset following standard protocol (NOAA Office of Coast Survey, 2021). The patch test data were processed using the Qimera (v.2.5.4) patch test tool. After calibration was complete, offsets (Table 4) were entered into the template database in Qinsy. Additional patch tests were conducted any time a system was removed or reinstalled throughout the survey season or if data disagreements were noticed between lines. Full built-in self-tests (BIST) were performed at semi-

regular intervals throughout the season to determine if any significant deviations in background noise were present at the chosen survey frequency of 300 kHz.

Calibration	Offsets 04/21/23	Offsets 05/09/23
Roll (degrees)	-0.060	0.000
Pitch (degrees)	0.609	0.511
Heading (degrees)	0.695	1.091

Table 4 – 2023 Mainscheme Patch test calibration offsets for EM2040C

3.0 Quality Control

3.1 Crosslines

Due to difficulty in deploying the survey platform to the survey site throughout the season, dedicated crosslines were not completed for this survey effort. However, a portion of an adjacent investigative survey effort overlaps with the eastern edge of the 2023 mainscheme coverage. The orientation of the adjacent survey effort meets BOEM and NOAA requirements of intersecting mainscheme coverage between 60° and 90°, so the overlapping lines can be used to conduct a crosscheck analysis (U.S. Department of the Interior, 2014 & NOAA Office of Coast Survey, 2021). The findings of this analysis are somewhat limited, as crossline coverage does not meet linear mileage requirements, totaling 1.97% of mainscheme linear mileage versus the ideal 4% outlined by the NOAA HSSD (NOAA, 2022). Crosslines are also poorly distributed geographically and only cover the easternmost portion of the dataset (Figure 7).

Crossline sounding agreement with mainscheme data was evaluated using the crosscheck tool in Qimera version 2.5.4, which performs beam-by-beam statistical analysis.

Results of the statistical analysis showed the mean difference between soundings was 0.188 meters with a standard deviation of 0.304 meters; 95% of all differences were less than 0.796 meters from the mean (Figure 8). Summary statistics for this analysis are shown in Table 5. Additional statistical plots are reported in Appendix G. Raw difference data, reference surfaces, and sonar files used for this analysis were submitted with the data in this survey package.

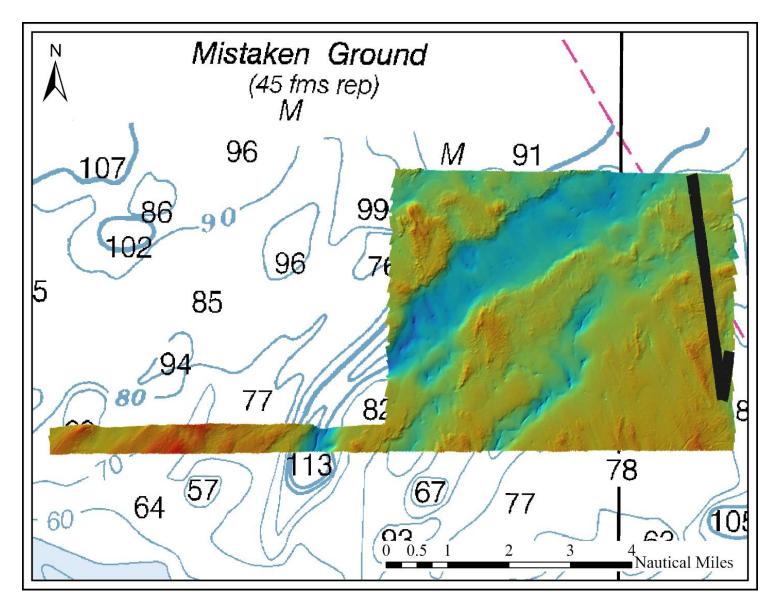


Figure 7 – Location of crosslines (depicted in black, with beams filtered outside $\pm 45^{\circ}$) atop bathymetry data.

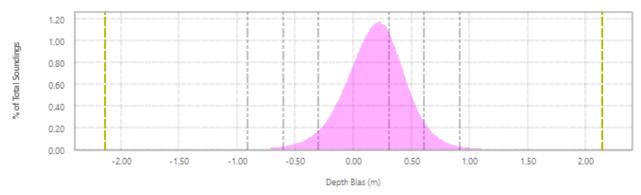


Figure 8 – 2023 mainscheme crosslines difference histogram; pink areas represent the 95% confidence interval based on normal distribution; yellow dashed lines represent limit of IHO Order 1 test vertical tolerance; gray dashed lines on histogram represent \pm sigma 1, 2, and 3

# of Points of Comparison	1483391
Data Mean	-159.880018 m
Reference Mean	-160.068789 m
Difference Mean	0.188771 m
Difference Median	0.195886 m
Std. Deviation	0.303568 m
Data Z - Range	-193.24 m to -127.51 m
Ref. Z - Range	-176.10 m to -141.17 m
Diff Z - Range	-26.83 m to 32.34 m
Mean + 2*stddev	0.795907 m
Median + 2*stddev	0.803022 m
Order 1a Error Limit	2.140122 m
Order 1a P-Statistic	0.000120
Order 1a - # Rejected	178
Order 1a Survey	ACCEPTED
Order 1a parameters: $a = 0.25$ a	nd h = 0.013

Table 5 – 2023 Mainscheme crossline difference (Qimera crosscheck) summary statistics

*Order 1a parameters: a = 0.25 and b = 0.013

3.2 Junctions

2023 mainscheme survey coverage was planned such that data would sufficiently overlap to the north and to the south with existing surveys in the region. The junctions shown in Table 6 are the result of overlap between the 2023 mainscheme survey and these existing surveys. The areas of overlap between the mainscheme and the junction surfaces (H13333 and W00195) were evaluated for sounding agreement by performing surface difference tests in Fledermaus (v.8.5.3), where existing surfaces were subtracted from the newly collected 2023 surface. A summary of surface difference test results is shown in Table 7.

The extent of overlap between the newly collected surface and the existing survey areas are illustrated in Figures 2 & 9. For all regions, junctions meet or exceed the requirement to overlap at least one full swath width at the nominal depth, as set out by the NOAA HSSD (NOAA, 2022). Detailed junction surfaces can

be seen in Figure 9. The surfaces used for these tests are submitted with the data package accompanying this report.

Registry Number	Resolution (m)	Year	Field Unit	Relative Location(s)
H13333	VR	2019	Ferdinand R. Hassler	Ν
W00195	VR	2005	M/V Atlantic Surveyor	S

Table 6 – 2023 Mainscheme survey junctions

Table 7 – Summary of surface difference test results for overlapping (junction) surveys

Junction Surface ID	New Surface ID	Mean (m)	Median (m)	Std. Dev. (m)
H13333_MB_VR_MLLW	MCMI_2023_Offshore_4m_ MLLW	1.44	0.12	1.49
W00195_MB_VR_MLLW	MCMI_2023_Offshore_4m_ MLLW	2.36	0.52	2.31

Notable differences between overlapping surveys are most frequently found in rocky areas or evidenced from motion artifacts induced by rough survey conditions during acquisition. The greatest disagreement between surfaces is seen in areas of steep, rocky relief where dynamic features and dramatic changes in depth and substrate are present.

Generally, newly acquired data agrees with overlapping survey coverages, with average difference values falling to 1.44m and 2.36m when compared against H13333 and W00195, respectively. Standard deviation for each respective surface is 1.49m and 2.31m. Junction agreement is stronger with survey H13333, which could be attributed to the more recent acquisition which included more advanced system capabilities and more stringent operating protocols versus the W00195 survey conducted 14 years prior. Despite small discrepancies across the compared datasets, these results indicate good agreement given the depths of survey and verify system accuracy to within desired survey parameters in accordance with Order 1a and NOAA HSSD for this region (International Hydrographic Organization, 2022 & NOAA, 2022).

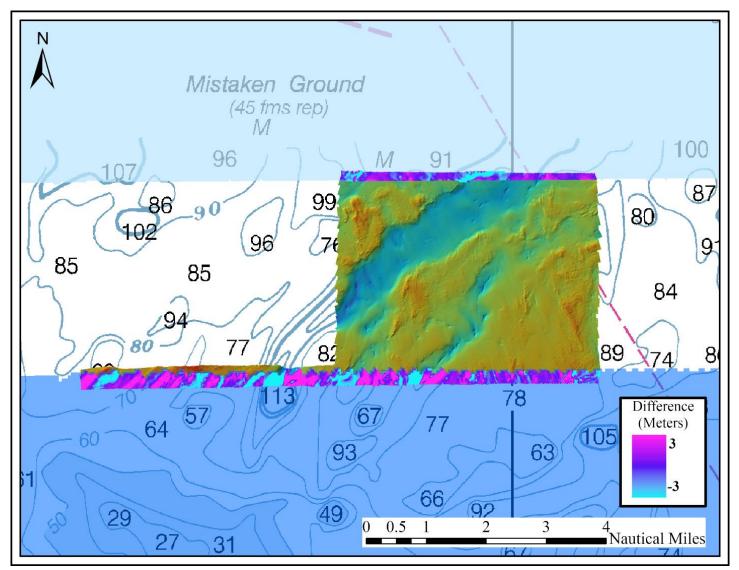


Figure 9 – Overview of resulting junction surfaces atop 2023 mainscheme survey.

3.3 Uncertainty

HydrOffice QC Tools v.3.10.10 Grid QA feature was used to analyze the highest resolution surface for compliance with NOAA allowable uncertainty standards. 99.99% of all nodes in the surface met uncertainty specifications which passes allowable TVU for the given survey. Detailed results from the analysis are shown in Figure 10 below.

CUBE uncertainty surface layers are provided with all BAG files submitted with this report.

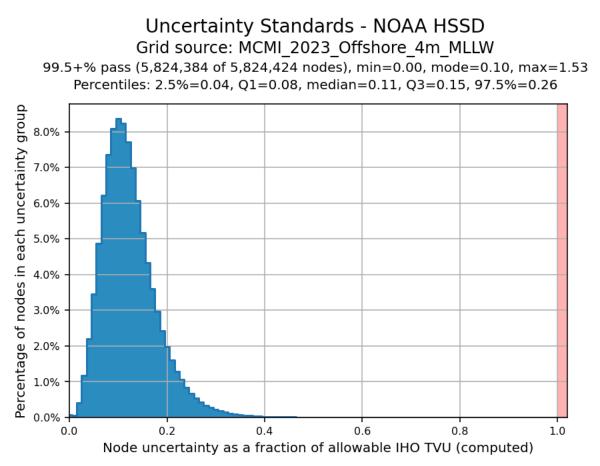


Figure 10 - Allowable uncertainty statistics for 2023 mainscheme data

3.4 Equipment Effectiveness

Survey Platform

The location of the survey area caused great difficulty in safely deploying the contracted survey platform to the survey site. Sea state was frequently too large for surveying with a platform of F/V Amy Gale's dimensions, and conditions would often shift dramatically and swiftly during acquisition, shortening select mapping days. The limited number of successful dates of acquisition are largely attributable to the

disproportionate scale of weather conditions compared against the stability of the survey platform in use. Future survey efforts will deploy a larger vessel to regions at similar distance or greater from shore.

Sonar

Sonar data were acquired with a Kongsberg EM2040C set to a survey frequency of 300 kHz, high-density beam forming, with 400 beams per ping. Although the EM2040C allowed full swath widths at this frequency, lines from previous years' survey run at comparable depths contained considerable noise in outer beams (> ± 60 degrees from the nadir as identified by QPS engineers). As a result (and per QPS recommendation), soundings greater than ± 60 degrees from the nadir were not included in final bathymetric surfaces.

Lambert's Law for Intensity

Prior to January 25, 2023, the setting in EM Controller for Lambert's Law was set to OFF (Default). Following discussions with Kongsberg engineers regarding the mechanics of this setting and after a test comparing data in an area when OFF versus when ON, the setting was changed permanently to ON (Appendix E). This has allowed for more accurate backscatter returns which enables better substrate modeling and more refined sediment characterization efforts. Datasets after changing the setting maintain agreement with older data collected by the program but show improved definition of substrate transitions and throughout regions of uniform substrate.

All systems performed normally throughout the survey season and no significant failures are worthy of note for the duration of this survey.

3.5 Sound Speed Methods

Sound speed cast frequency: A total of 41 sound speed casts were taken within the boundaries of the survey area throughout the survey effort. A single sound speed cast was collected using a Teledyne Odom Digibar-S profiler, while the remaining 40 sound speed casts were collected with a Valeport SWiFT SVP. The program transitioned to the Valeport SWiFT just after the survey effort had begun to improve the effectiveness of absorption characterization of the water column, and to subsequently increase the accuracy and reliability of sounding data.

Sound speed casts were taken frequently throughout the survey, which was when one of the three following conditions were met: 1) When the observed surface sound speed (monitored and visualized in real-time using the AML Micro X SV sensor) differed from the surface sound speed in the active profile by more than 2 meters per second. 2) When there was reason to suspect significant changes in properties of the water column (e.g. change in tide/riverine input, abrupt changes in seafloor relief, geographic position, etc.). 3) When more than ninety minutes had elapsed since the most recent sound velocity cast was taken.

During the collection of sound speed casts, logging was stopped to download and apply the new cast and was resumed when the boat circled around and came back on the survey line. Throughout the duration of the survey, the surface sound speed was observed in real-time (by the AML Micro X SV probe). Sound speed data are recorded and included in raw sonar files submitted with this data package.

A quality comparison between the AML Micro X SV sensor and the Teledyne Odom Digibar-S or the Valeport SWiFT SVP was not performed. However, real-time comparisons between surface sound speed observed by the AML Micro X SV and the surface sound speed entry in all profiles suggested these instruments agreed. Additionally, annual calibrations were conducted for all sensors by original manufacturers to ensure performance within manufacturer defined standards.

4.0 Data Post-processing

The following is a summary of the procedures used for post-processing and analysis of survey data using Qimera (v.2.5.4, 64-bit edition) and Fledermaus (v.8.5.3, 64-bit edition) software.

4.1 Horizontal Datum

The horizontal datum for these data is WGS 84 projected in UTM zone 19N (meters) (EPSG 32619).

4.2 Vertical Datum and Water Level Corrections

The vertical datum for these data is mean lower-low water (MLLW) level in meters. A tidal zoning file ("ME23A_ZDF.zdf") containing time and range corrections for verified tide station data was provided by NOAA OCS to MCMI in July 2023. This file was used to apply time corrections, tide height offsets, and tide scale (range) for collected data in each zone listed in Table 8 and shown in Figure 11.

A small portion of the mainscheme coverage extends beyond the bounds of the NA11 zone as provided by NOAA OCS. There are no provided polygons which extend further east from NA11, so the processing team elected to expand this zone to cover the bounds of the survey. If new zones are published in the future, this portion of the dataset will be reprocessed and all submitted surfaces will be updated as an addendum to this submission.

Table 8 - Tide zones and corrections referenced to verified Seavey Island, ME (8419870) tide station data

Survey Area	Tide Station	Zone ID	Time Correction (mins.)	Tide Offset (m)	Tide Scale
MCMI 2023 Mainscheme	8419870	NA11	-36	0	1.04

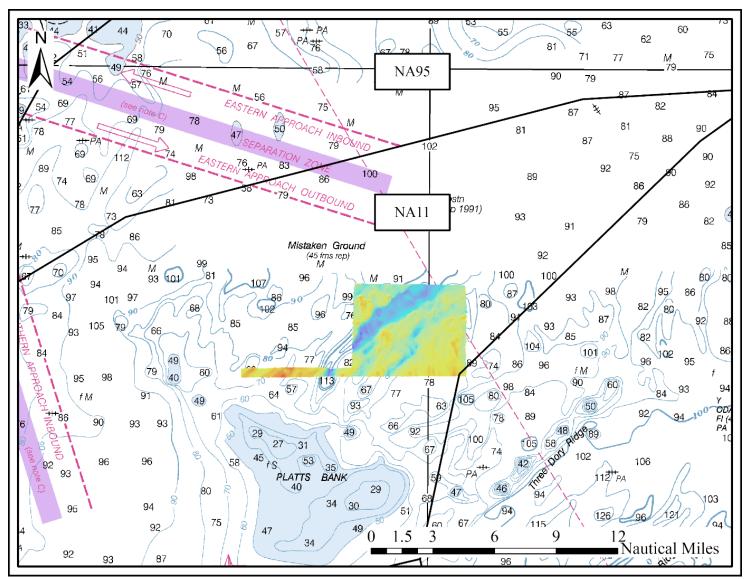


Figure 11 - Tide zones (outlined in black) relative to survey extent.

4.3 Processing Workflow

The general post-processing workflow in Qimera was as follows:

- 1. Create project
- 2. Add raw sonar files (e.g. metadata extracted and processed bathymetry data converted to .qpd, including vessel configuration and sound velocity)
- 3. Apply sound velocity profiles via real-time scheduling or by distance/time, contingent upon region surveyed and local conditions
- 4. Add tide zoning file (.zdf) and associated tide data and integrate into raw files
- 5. Create dynamic surface with NOAA CUBE settings enabled for desired resolution (e.g. 2-meter, 4 meter)
- 6. Review and edit soundings/clean surface with slice editor tool, 3D editor tool, and available filters
- 7. Duplicate surfaces at other grid sizes, if desired
- 8. Export final surface to .BAG surface
- 9. Export processed data in .GSF format for backscatter processing

<u>CUBE</u>

A CUBE (Combined Uncertainty and Bathymetry Estimator) surface was created for editing and as a starting point for final products. The corresponding NOAA CUBE setting (e.g. "NOAA_4m" configuration, Figure 12) was selected for each surface depending on the grid size of the surface.

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Configuration NOAA_4m					
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Figure 12 - CUBE settings parameters window shown with settings for NOAA 4-meter grid resolution

4.4 Final Surfaces

The following surfaces were submitted with the survey data. Each BAG file contains the CUBE-processed sounding surface layer and a CUBE uncertainty layer.

Naming conventions of these surfaces adhere to the following format:

Program which collected and processed the data (MCMI = Maine Coastal Mapping Initiative), year of last date of data acquisition (2023), the general locus of the survey effort (Inshore or Offshore), the grid resolution of the output product (1m = 1 meter, etc.), and the vertical datum the data is reduced to (MLLW = Mean Lower-Low Water).

Table 9 – Bathymetry surfaces submitted for 2023 mainscheme	survey data
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Surface Name	Resolution (m)	Depth Range (m)
MCMI_2023_Offshore_4m_MLLW	4	112 - 219
MCMI_2023_Offshore_8m_MLLW	8	112 - 219
MCMI_2023_Offshore_16m_MLLW	16	112 - 219

4.5 Backscatter

Backscatter data were logged in raw .db files during acquisition. The .db files also hold the navigation record and bottom detections for all lines of surveys. Processed sonar files containing multibeam backscatter data (snippets and beam-average) were exported from Qimera in .GSF format. QPS Fledermaus Geocoder Toolbox (FMGT; v.7.10.3, 64-bit edition) was used to import, process, and mosaic time-series backscatter data. Default backscatter processing settings were used to create the mosaic, except for the Angle Varied Gain (AVG) filter which was adjusted to 'Flat' or 'Trend' as the topography necessitated, and the AVG window size, which was adjusted to '100 pings' to improve resulting surfaces. Backscatter mosaics of the data were gridded at 1-meter, 2-meter, and 4-meter resolutions. Mosaics were exported in floating-point GeoTIFF format. The mosaics are shown in Table 10 and Figure 13.

Naming conventions of these surfaces adhere to the following format:

Program which collected and processed the data (MCMI = Maine Coastal Mapping Initiative), year of last date of data acquisition (2023), the general locus of the survey effort (Inshore or Offshore), the type of multibeam data contained within the surface (BS = backscatter), and the grid resolution of the output product (1m = 1 meter, etc.).

Table 10 – Backscatter mosaics submitted for 2023 m	nainscheme survey data
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Mosaic Name	Pixel Size (m)
MCMI_2023_Offshore_BS_4m	4
MCMI_2023_Offshore_BS_8m	8
MCMI_2023_Offshore_BS_16m	16

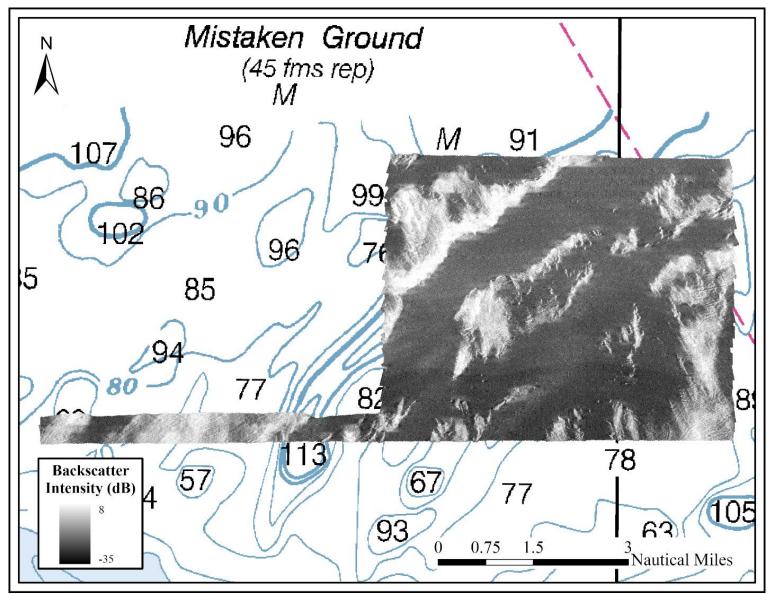


Figure 13 – Backscatter mosaic (4-meter pixel size) of 2023 mainscheme coverage atop NOAA chart 13260.

5.0 Results

5.1 Charts Comparison

The hydrographer conducted a qualitative comparison of reclassified bathymetry data and depth contours from the surveyed area to the charted soundings and contours. The largest-scale raster navigational charts which cover the survey areas are listed in Table 11. Prior hydrographic surveys in the vicinity were conducted by NOAA in 1940 but consisted only of partial bottom coverage. These data were not compared with data collected by the MCMI. No existing surveys with digital sounding data was available for reference for much of the survey area.

Chart	Scale	Source Edition	Source Date	NTM Date
 13260	1:378,838	44	11/01/2020	10/30/2023

Chart 13260

Surveyed depths show relatively poor agreement overall with charted contours throughout the survey area (Figure 14). While regions of select existing contours do align with surveyed depths, such as the deeper region in the southern extent of the survey area, the great majority of the defined bounds are inconsistent with newly surveyed findings. The proposed reason for this discrepancy is the dramatic difference in sounding density and more advanced acquisition methods of the 2023 mainscheme effort compared to the 1940 survey data which informed much of the charted features in this region. It is recommended that the charted contours in this region be revised based on the findings of this report, following appropriate investigation by the reviewing office.

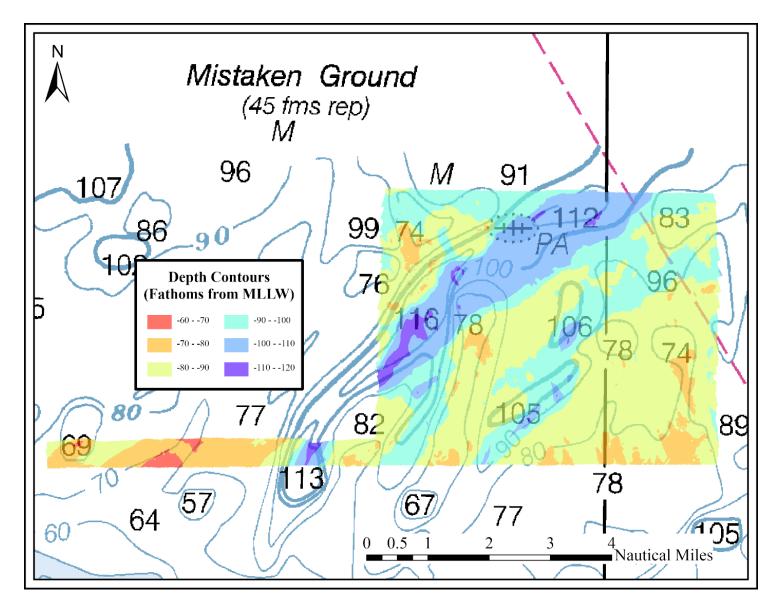


Figure 14 – 2023 Mainscheme data comparison between surveyed depth (re-classified at 10-fathom intervals) and chart 13260.

5.2 Bottom Samples

A grab sampling campaign was planned following the bathymetry and backscatter acquisition effort, which provided the required inputs for a textural classification model used to guide site selection to ensure that representative depths and substrates were sampled (Figure 15). A total of 25 sites were successfully completed, with all 25 retrieving sediment samples for analysis. A subset of 12 sites also had CTD casts. The results of grain-size and video analyses will be used to calibrate, refine, and digitize interpretations of seafloor substrate. These data are also used to investigate how bathymetric and backscatter findings relate to benthic infauna in the survey area.

Additional details on the bottom samples are provided in Table 12. More detailed analysis of grain size composition of these samples and benthic fauna composition will be determined after laboratory processing is complete for the collected samples. Metadata sheets for all bottom samples are provided as part of the submitted data package accompanying this report.

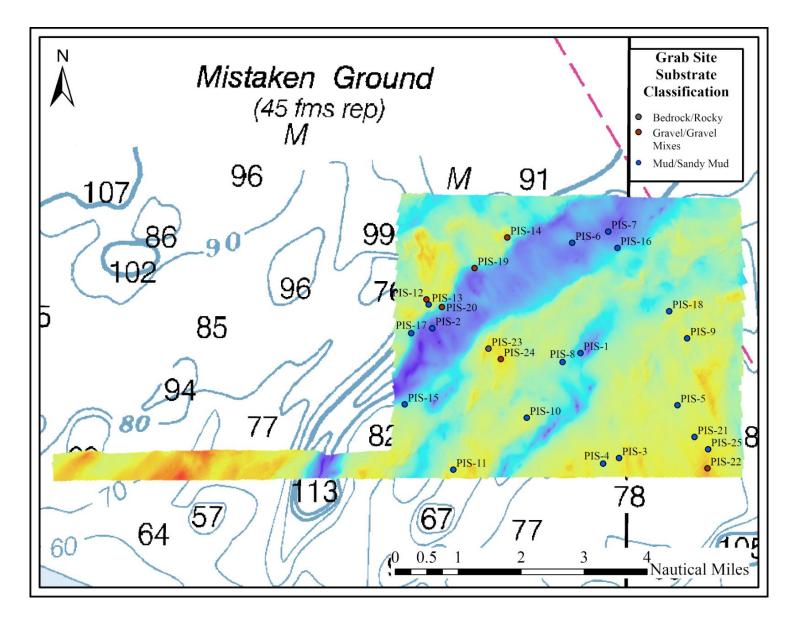


Figure 15 – Bottom sample locations collected over the course of the 2023 season in and around the survey area. Sites classified via modified CMECS 7-class scheme from field observations (Appendix H).

Site Name	Date	Latitude (Decimal Degrees N)	Longitude (Decimal Degrees W)	Depth (m)	Grain Size (Field Observation)	CMECS Class (from Field Observation)	Backscatter Intensity (dB)
PIS-1	8/7/2024	43.28386667	-69.51686667	188	silty mud	Mud	-18.04
PIS-2	8/7/2024	43.29016667	-69.57066667	212	silty mud	Mud	-15.52
PIS-3	8/7/2024	43.25608333	-69.5027	152	muddy silt	Mud	-19.93
PIS-4	8/7/2024	43.25458333	-69.50845	155	silty mud	Mud	-18.98
PIS-5	8/7/2024	43.27016667	-69.48166667	155	silt/mud	Mud	-18.35
PIS-6	8/7/2024	43.3130777	-69.5201111	199	silty clay/ mud	Mud	-18.35
PIS-7	8/7/2024	43.31608333	-69.50708333	204	mud	Mud	-16.78
PIS-8	8/7/2024	43.28146667	-69.5234	171	silty mud	Mud	-16.78
PIS-9	8/7/2024	43.28795	-69.47825	151	silt/mud	Mud	-10.79
PIS-10	8/7/2024	43.26661667	-69.53621667	156	silty mud	Mud	-20.24
PIS-11	8/7/2024	43.25273333	-69.56273333	150	silty mud	Mud	-12.05
PIS-12	8/7/2024	43.29781667	-69.57288333	157	silty clay mud with trace gravel	Gravel Mixes	-10.16
PIS-13	8/7/2024	43.29646667	-69.57205	156	muddy sand	Sandy Mud	-9.22
PIS-14	8/7/2024	43.3144	-69.54368333	160	muddy sandy gravel	Gravel Mixes	-0.4
PIS-15	8/7/2024	43.26995	-69.58048333	177	clayey mud	Mud	-17.72
PIS-16	8/7/2024	43.31178333	-69.50375	187	mud/clay	Mud	-16.15
PIS-17	8/7/2024	43.28883333	-69.57831667	183	silty mud	Mud	-11.11
PIS-18	8/7/2024	43.2951	-69.48481667	165	silt	Mud	-15.2
PIS-19	8/7/2024	43.30616667	-69.55548333	186	sandy mud w/ trace gravel	Gravel Mixes	-4.81
PIS-20	8/7/2024	43.2958	-69.56726667	182	muddy sand w/ trace gravel and cobble	Gravel Mixes	-3.55
PIS-21	8/7/2024	43.261767	-69.475417	147	silt/mud	Mud	-12.05
PIS-22	8/7/2024	43.2535	-69.47066667	134	muddy sandy gravel w/ rocks	Gravel Mixes	-5.75
PIS-23	8/7/2024	43.28485	-69.55025	138	two large rocks	Bedrock/Rocky	-2.92
PIS-24	8/7/2024	43.28211667	-69.54575	145	muddy silt, cobbles	Gravel	-9.85
PIS-25	8/7/2024	43.25853333	-69.47045	143	sandy mud, trace gravel	Sandy Mud	-10.16

Table 12 – Grab Sample Information

6.0 Summary

A total of 35.92 mi² (93.03 km²) of high-resolution multibeam data were collected throughout the 2023 mainscheme area, located in the vicinity of the Mistaken Ground, Maine from April to October 2023. Except for select few small holidays due to seafloor elevation-induced sonic shadows, multibeam coverage was 100% in all areas surveyed.

Bathymetry and backscatter data products were produced at 4-meter, 8-meter, and 16-meter grid resolution. The bathymetry and backscatter information for the survey area are supplemented by seafloor surficial sediment samples, water column data, video, and benthic fauna collection in 25 locations.

Consistency of hydrographic data collected aboard the F/V Amy Gale was reflected in the results of the surface difference tests for crosslines and junction survey data, which all fell within allowable tolerances for IHO and NOAA specifications at the ensonified depths. Crossline analysis yielded a mean difference of 18.8 cm across all transects with a standard deviation of 30.4 cm, while junction comparisons found mean differences of 1.44 m and 2.36 m with standard deviations of 1.49 m and 2.31 m for H13333 and W00195, respectively. Statistical results of all differencing tests were relatively low and comparable to those achieved by small vessels in similar surveys of the area (e.g. *Ferdinand R. Hassler* and *Atlantic Explorer*). Total vertical uncertainties for all areas surveyed were within tolerances for IHO and NOAA specifications at all depths, where 99.99% of all nodes fell within the allowable range.

Comparisons between survey data and the largest scale nautical chart in the vicinity showed poor agreement with charted contours throughout the survey area. Newly collected bathymetry and backscatter in this submission provides high resolution data throughout the region where poor and outdated data were the best existing sources. As such, the refined feature depths and positions found in this survey provide additional information where no published soundings previously existed. It is recommended that the corresponding charts be updated in this area to reflect these data, and that contours be adjusted throughout the survey area to the refined values delivered in these updated datasets.

These data were acquired and processed to meet Office of Coast Survey bathymetry standards as best as possible and were shared with the NOAA Office of Coast Survey for review.

Please contact the Maine Coastal Mapping Initiative's lead hydrographer or program lead for additional information or data requests.

References

International Hydrographic Organization (2022) IHO Standards for Hydrographic Surveys, Edition 6.1.0, September 2022. Monaco, International Hydrographic Organization, 52pp. (International Hydrographic Organization Special Publication, S-44). DOI: https://doi.org/10.25607/OBP-1354.3

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U.S. Department of the Interior (2014). Proposed geophysical and geological activities in the Atlantic OCS to identify sand resources and borrow areas north Atlantic, mid-Atlantic, and south Atlantic-Straits of Florida planning areas, *final environmental assessment*. OCS EIS/EA BOEM 2013-219 U.S. Department of the Interior Bureau of Ocean Energy Management Division of Environmental Assessment Herndon, VA, January 2014.

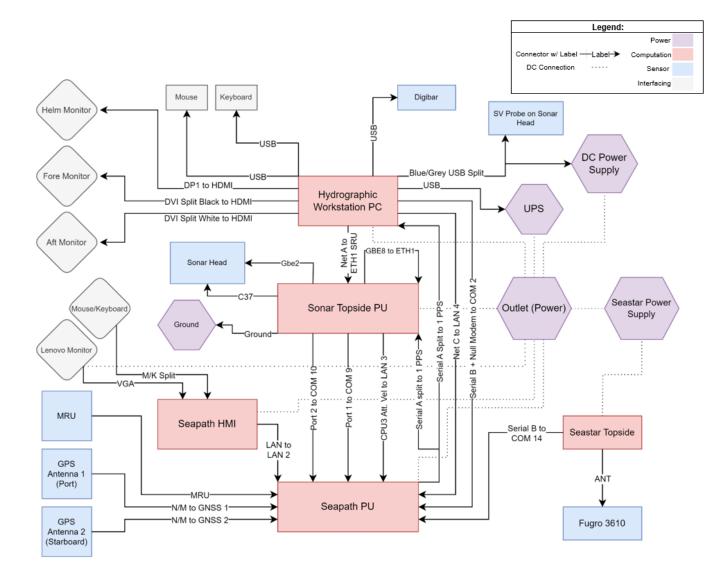
Appendix A – Specific dates of data acquisition

Dates (mm-dd-yyyy) of Data Acquisition for 2023 Mainscheme Surveys*

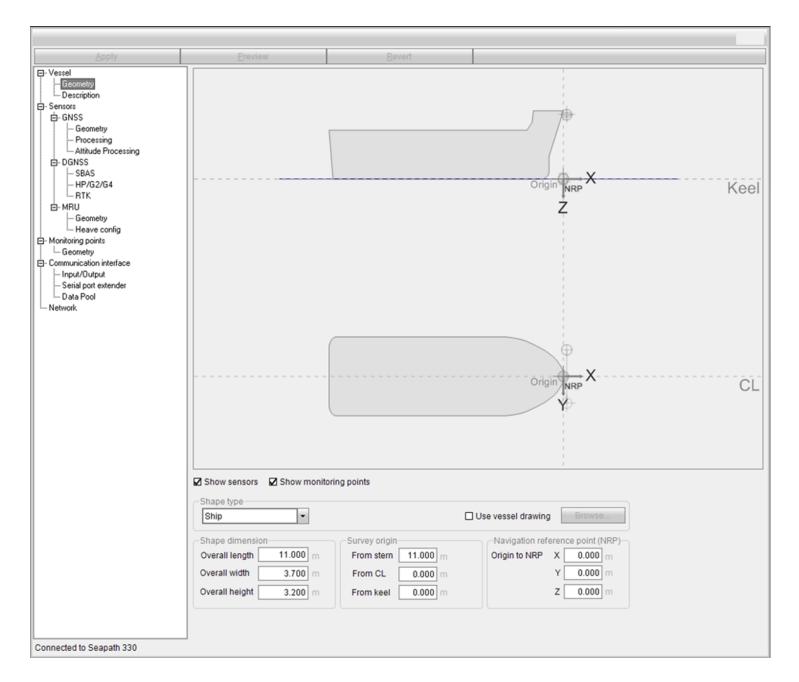
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07-31-2023	
09-07-2023	
09-11-2023	
09-28-2023	
10-28-2023	

*Dates of surveys not summarized in this report not listed

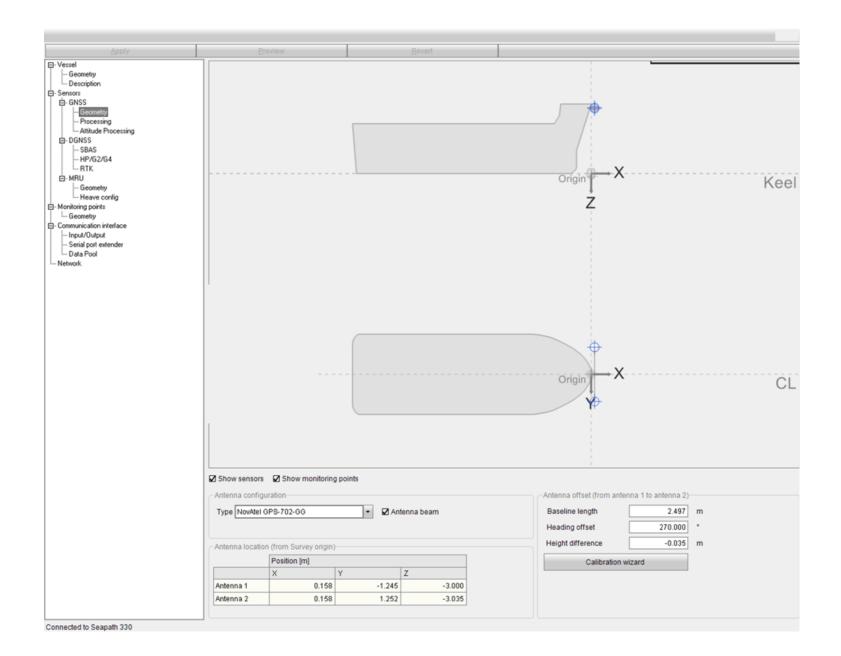








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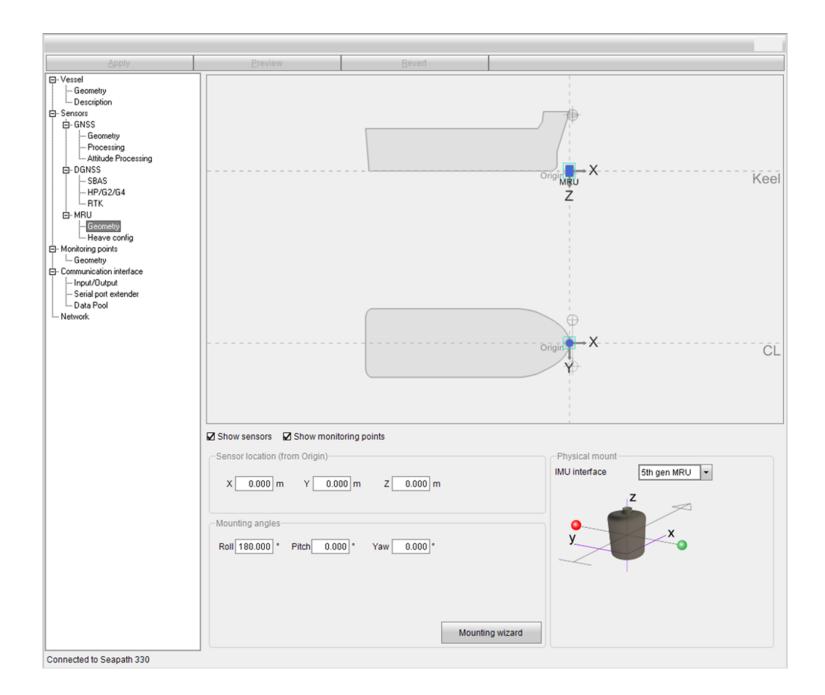
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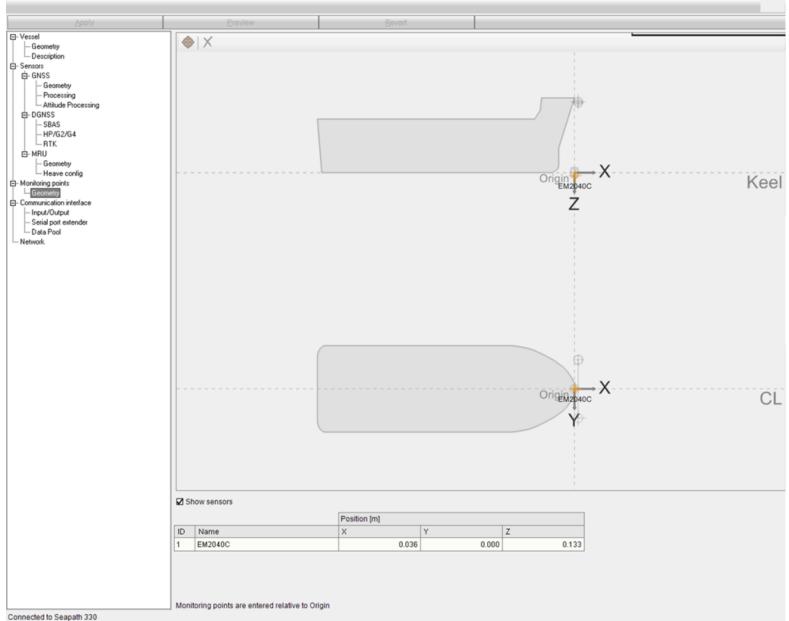
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Appendix D – **Template database settings in Qinsy (for acquisition)**

Note: Depicted Qinsy template settings show configuration from a 2020 survey project. All settings remain the same for the seasons described in this report apart from changes to pitch, roll, heading for EM2040C from patch test results (Table 4), as well as latency offsets applied to Position Navigation Systems and Motion Reference output values.

Qinsy uses the following reference frame conventions (these differ from those used by Seapath 330):

Pitch rotation: + bow up Roll rotation: + heeling to starboard Heave: + upwards

X: + to starboard Y: + towards bow Z: + up

	Information: General
- III General - 🖉 Geodetic	
Datums	Line name: No line name
G WGS84	Line sequence number: 1
⊟ <u>≭</u> Heights	Line description: N/A
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		SPHEROID["WGS 1984", 6378137, 298.2572235
Ø UTC to GPS Correction		UNIT["meter", 1, AUTHORITY["EPSG", "9001"]]]],
C Sound Velocity Profile		PRIMEM["Greenwich", 0, AUTHORITY["EPSG",
Object		"8901"]],
📲 Amy Gale		UNIT["degree", 0.0174532925199433, AUTHORITY["EPSG", "9102"]]],
🖨 🔚 System		PROJECTION_NAME["Universal Transverse Mercator
		(North Hemisphere)", AUTHORITY["EPSG", "9807"]],
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└─┴ Position Navigation System		PARAMETER["central_meridian", -69, UNIT["degree"
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		PARAMETER["false_easting", 500000, UNIT["meter",
● TX		AUTHORITY["EPSG", "9001"]]],
B Link		PARAMETER["false_northing", 0, UNIT["meter", 1, AUTHORITY["EPSG", "9001"]]],
Auxiliary Systems		PARAMETER["scale_factor", 0.9996, UNIT["unity", 1,
🗝 🕉 Time Sync		AUTHORITY["EPSG", "9201"]]],
EM2040C Controller		UNIT["meter", 1, AUTHORITY["EPSG", "9001"]]],
		METADATA["WGS84",
Fixed Node		PARAMETER["version", 2], PARAMETER["timestamp",
		"20210225T035001.424000"]]

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V Survey	Object: Amy Gale		
	Object: Amy Gale Object reference number: Object type: Description of reference point: Height above draft reference: Squat model: SD draft: SD squat: SD load: SD tide: Time latency navigation: Time correction to GMT (UTC): Time correction to master vessel's time:	1 Vessel Amy Gale MRU 0.000 m Not Defined 0.050 m 0.050 m 0.050 m 0.050 m 0.050 m 0.000 m 0.025 s 0.000 h 0.000 s	

e Edit View Options Help	1 2				
General	System: EM2040C				
Geodetic	Description:	EM2040C			_
🛱 🌗 Datums		Multibeam Echosounder			
G WGS84	Type:				
🖨 🚖 Heights	Driver:	Kongsberg EM2040/EM710/EM302/EM122			
🚽 🛣 Chart Datum / Vertical Datum	Executable and Cmdline:	DrvKongsbergEM.exe			
📥 Mean Water Level Model	Driver specific settings:	MANUFACTURER=2;MODEL=2045;RAW_BATHY=1;RAW_SNIP=1;RAW_WCD=1;			_
🚽 📩 Digital Terrain Models	Port:	2001			
E Projections	Update rate:	0.000 s			
题 Universal Transverse Mercator (North Hemisphere) 	Acquired by:	[Directly into Qinsy] (No additional time tags)			-
-@ UTC to GPS Correction	Observation time from:	N/A			
Sound Velocity Profile	Number of slots:	1			-
Object					
Amy Gale	Manufacturer:	Kongsberg			
🛓 🔚 System	Model:	EM2040C			_
EM2040C	Object location:	Amy Gale			
⊨ Ø Gyro	Node name:	RX			
La Gyro	X (Stbd = Positive)::	0.000 m			
-# Pitch Roll Heave Sensor	Y (Bow = Positive)::	-0.045 m			
La Position Navigation System	Z (Up = Positive)::	0.006 m			
□ ¥ Variable Node	A-priori SD:	0.010 m			
	Roll offset:	0.332			-
	Pitch offset:	0.279			
© TX ■S Link	Heading offset:	-0.181			
Auxiliary Systems	-				_
- Time Sync	Unit is roll stabilized:	No			
EM2040C Controller	Unit is pitch stabilized:	No			
- ASCII Logger	Unit is heave compensated:	No			
Fixed Node	Beam steering (flat transducer):	No			
	Beam angle width along:	1.500 m			
	Beam angle width across:	1.500 m			
	Maximum number of beams per ping:	800			
	Use sound velocity from unit:	Yes	<i>.</i>	-	
	Slot:	1			-
	SD type:	Pulse, Sampling			-
	SD pulse length:	0.150 ms			
	SD puise length: SD sampling length:	0.050 m			

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Survey	Update rate:	0.000 s	
II General	Acquired by:	[Directly into Qinsy] (No additional time tags)	
Teodetic	Observation time from:	N/A	
Datums	Number of slots:	1	
G WGS84	Manufacturer:		
自	Model:	Kongsberg	
	The second secon	EM2040C	
ż Digital Terrain Models	Object location:	Amy Gale	
Projections	Node name:	RX.	
- 🔄 Universal Transverse Mercator (North Hemisphere)	X (Stbd = Positive)::	0.000 m	
Local Construction Grid	Y (Bow = Positive)::	-0.045 m	
💩 UTC to GPS Correction	Z (Up = Positive)::	0.006 m	
C Sound Velocity Profile	A-priori SD:	0.010 m	
Object	Roll offset:	0.332	
Amy Gale	Pitch offset:	0.279	
	Heading offset:	-0.181	
B Ø Gyro	Unit is roll stabilized:	No	
↓ Gyro	Unit is pitch stabilized:	No	
- 😾 Pitch Roll Heave Sensor	Unit is heave compensated:	No	
- A Position Navigation System	Beam steering (flat transducer):	No	
ia .∓ Variable Node	Beam angle width along:	1.500 m	
	Beam angle width across:	1.500 m	
• • RX • • TX	Maximum number of beams per ping:	800	
Link	Use sound velocity from unit:	Yes	
Auxiliary Systems	Slot:	1	
Ö Time Sync	SD type:	Pulse, Sampling	
 EM2040C Controller ASCII Logger 	SD pulse length:	0.150 ms	
Fixed Node	SD sampling length:	0.050 m	
nice node	SD roll offset:	0.050 °	
	SD pitch offset:	0.050 °	
	SD heading offset:	0.500 °	
	SD roll stabilization:	0.000 °	
	SD pitch stabilization:	0.000 °	
	SD heave compensation:	0.000 m	
	SD sound velocity:	0.050 m/s	

AmyGale_2020_Patch1_nonverified_tides_2.db - Database Setup Pro	gram		20 3	×
File Edit View Options Help				
E ¼ 📕 🙏 💿 🖉 🛛 🔢 📟 🛃 📟 🔒	1			
□ III Survey	System: Gyr	0		
Geodetic				
Datums	Description:	Gyro		
WGS84	Туре:	Gyro Compass		
Heights	Driver:	Network - Seapath Binary Format 11 (Hdg) (With UTC)		
🚽 🛣 Chart Datum / Vertical Datum	Executable and Cmdline:	DrvQPSCountedUDP.exe SEAPATH_FMT11 PPS		
🚽 🛓 Mean Water Level Model	Port:	13001		
🚽 🛓 Digital Terrain Models	Update rate:	0.000 s		
🖨 🐻 Projections	Latency:	0.000 s		
- 🔁 Universal Transverse Mercator (North Hemisphere)	Acquired by:	[Directly into Qinsy] (No additional time tags)		
Local Construction Grid	and the second sec			
- O UTC to GPS Correction	Observation time from:	N/A		
Sound Velocity Profile	Number of slots:	0		
H Object				
🖨 🏧 Amy Gale				
EM2040C				
Gyro				
→ Pitch Roll Heave Sensor				
L Position Navigation System				
□ Y Variable Node				
- Amy Gale MRU				
- • RX				
B Link				
- 🛄 Auxiliary Systems				
💩 Time Sync				
EM2040C Controller				
- D→ ASCII Logger				
- 🔆 Fixed Node				
nsy 9 For Help, press F1	1			

AmyGale_2020_Patch1_nonverified_tides_2.db - Database Setup Provided - Database Provided - Database Setup Provided - Database Provided	ogram		22 3	×
File Edit View Options Help	1		 	
E W Survey	Observation	Gyro		
- 🖪 General	Observation	aylo		
🖨 🔏 Geodetic	Observation description:	Gyro		
Datums	Observation type:	Bearing (True)		
GS84	'At' node:	Amy Gale MRU		
er Heights → ☆ Chart Datum / Vertical Datum	Measurement unit code:	 There is a state of the state o		
Mean Water Level Model	10 72 80	Gyro	 	
Digital Terrain Models	System description:		 	
	(C-O) option:	(C-O) offsets applied first		
- Superior States - S	Scale factor:	1.0000000000		
Local Construction Grid	Fixed system (C-O):	0.000000000		
- 💩 UTC to GPS Correction	Variable (C-O):	0.0000000		
Sound Velocity Profile	A-priori SD:	0.5000		
🕀 🚼 Object			 	 -
📥 🏧 Amy Gale				
🖨 🚟 System				
⊟ \$° Gyro				
L. Gyro				
-# Pitch Roll Heave Sensor				
L⊥ Position Navigation System				
Amy Gale MRU				
- • RX				
o TX				
S Link				
Auxiliary Systems				
- 💩 Time Sync				
EM2040C Controller				
→ ASCII Logger				
└────────────────────────────────────				
Qinsy 9 For Help, press F1				

AmyGale_2020_Patch1_nonverified_tides_2.db - Database Setup Pro	ogram			
				_
Survey	System: Pitch Roll	Heave Sensor		
- 🕼 General	System. Then non			_
Datums	Description:	Pitch Roll Heave Sensor		
WGS84	Туре:	Pitch Roll Heave Sensor		
⊟ ± Heights	Driver:	Network - Seapath MRU Binary Format 11 (With UTC)		
Chart Datum / Vertical Datum	Executable and Cmdline:	DrvQPSCountedUDP.exe SEAPATH_FMT11 PPS		
Mean Water Level Model	Port:	13001		
🛓 🛓 Digital Terrain Models	Update rate:	0.000 s		
Projections	Latency:	0.000 s		
- 🔁 Universal Transverse Mercator (North Hemisphere)	Acquired by:	[Directly into Qinsy] (No additional time tags)		-
Local Construction Grid	and the second			
💩 UTC to GPS Correction	Observation time from:	N/A		_
Sound Velocity Profile	Number of slots:	0		
Object	Object:	Amy Gale		
🔤 Amy Gale	PRH sensor reference number:	1		
EM2040C	Rotation convention pitch:	Positive bow up		
B Ø Gyro	Rotation convention roll:	Positive heeling to starboard		
Gvro	Angular variable measured:	HPR (roll first)		
→ Hitch Roll Heave Sensor	Angular measurement units:	Degrees		
L Position Navigation System	Sign convention heave:	Positive upwards		
⊨ X Variable Node	Measurement unit heave:	Meters		
Amy Gale MRU	Conversion factor to degrees decimal:			
® RX	Conversion factor to metres:	N/A		
E © TX	A RECORD AND A CONTRACTOR OF A CONTRACT AND A CONTRACT AND	All the test of the second s		
Link	Quality indicator type pitch and roll:	No quality info recorded		
Auxiliary Systems	Quality indicator type heave:	No quality info recorded		
Time Sync	Description of quality indicator type:	N/A		_
 EM2040C Controller ASCII Logger 	Object location:	Amy Gale		
Fixed Node	Node name:	Amy Gale MRU		
HAEU NOUE	X (Stbd = Positive)::	0.000 m		
	Y (Bow = Positive)::	0.000 m		
	Z (Up = Positive)::	0.000 m		
	A-priori SD:	0.000 m		
	(C-O) roll offset:	0.000 °		-
	(C-O) pitch offset:	0.000 °		
	(C-O) heave offset:	0.000 m		
	Heave time delay:	0.000 s		-
	ricave time delay.	0.000 3		

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V Survey	Latency:	0.000 s	
- III General	Acquired by:	[Directly into Qinsy] (No additional time tags)	
	Observation time from:	N/A	
Datums	Number of slots:	0	
Heights	Object:		
🖉 🚽 🖉 Chart Datum / Vertical Datum	PRH sensor reference number:	Amy Gale	
🚽 📥 Mean Water Level Model	10 Year of Construction and the second strength of the twee strength of the	2	
🚽 🛣 Digital Terrain Models	Rotation convention pitch:	Positive bow up	
E Projections	Rotation convention roll:	Positive heeling to starboard	
Universal Transverse Mercator (North Hemisphere)	Angular variable measured:	HPR (roll first)	
└॔ Local Construction Grid -ॐ UTC to GPS Correction	Angular measurement units:	Degrees	
Sound Velocity Profile	Sign convention heave:	Positive upwards	
Object	Measurement unit heave:	Meters	
🔤 Amy Gale	Conversion factor to degrees decimal:	N/A	
🛓 📒 System	Conversion factor to metres:	N/A	
	Quality indicator type pitch and roll:	No quality info recorded	
⊜ Ø Gyro	Quality indicator type heave:	No quality info recorded	
	Description of quality indicator type:	N/A	
-# Pitch Roll Heave Sensor	Object location:	Amy Gale	
└─_⊥ Position Navigation System	Node name:	Amy Gale MRU	
Amy Gale MRU	X (Stbd = Positive)::	0.000 m	
-	Y (Bow = Positive)::	0.000 m	
TX	Z (Up = Positive)::	0.000 m	
S Link	A-priori SD:	0.000 m	
Auxiliary Systems	(C-O) roll offset:	0.000 °	
- Ö Time Sync	(C-O) pitch offset:	0.000 °	
EM2040C Controller	(C-O) heave offset:	0.000 m	
- D+ ASCII Logger Fixed Node	Heave time delay:	0.000 s	
Fixed Node	Heave filter length:	N/A	
	SD roll and pitch:	0.050 °	
	SD heave (fixed):	0.050 m	
	SD heave (variable):	5.000 %	
	SD roll offset:	0.050 °	
	SD pitch offset:	0.050 °	
	SD heave offset:	0.050 m	

E 🎢 🔜 🙏 💿 🖉 🔢 🕎 🔤 🔤 🛛 🔒		
Survey	System: Pos	ition Navigation System
 Survey General Geodetic WGS84 ★ Heights Chart Datum / Vertical Datum Mean Water Level Model Digital Terrain Models Projections Universal Transverse Mercator (North Hemisphere) Local Construction Grid UTC to GPS Correction Sound Velocity Profile Object Many Gale System Yeniable Node RX TX Kulliary Systems Time Sync EM2040C Controller ACCII Logger Fixed Node 	System: PosiDescription:Type:Driver:Executable and Cmdline:Port:Update rate:Latency:Acquired by:Observation time from:Number of slots:Satellite system name:Horizontal datum:Vertical datum:Vertical datum:Height file:Height file:Height offset:SD latitude:SD longitude:SD height:Measurement unit:Receiver description:Receiver number:Object location:Node name:X (Stbd = Positive)::Y (Bow = Positive)::Z (Up = Positive)::Z (Up = Positive)::A-priori SD:	ition Navigation System Position Navigation System Position Navigation System Network - Seapath Binary Format 11 (With UTC) DrvQPSCounted/UDP.exe SEAPATH_EMT11 PPS 13001 0.000 s 0.000 m 0.00

AmyGale_2020_Patch1_nonverified_tides_2.db - Database Setup Pro	ogram	- 🗆 X
File Edit View Options Help ■ ½ ■ ↓ ● ∅ □		
Survey	Node: Amy Gale MRU	
Geodetic Geodetic Geodetic Geodetic WGS84 Chart Datum / Vertical Datum Mean Water Level Model Digital Terrain Models Digital Terrain Models Digital Terrain Models Digital Terrain Models Construction Grid Colocat Construction	Object location: Amy Gale Node name: Amy Gale MRU X (Stbd = Positive): 0.000 m Y (Bow = Positive): 0.000 m Z (Up = Positive): 0.000 m A-priori SD: 0.000 m	
Qinsy 9 For Help, press F1		

AmyGale_2020_Patch1_nonverified_tides_2.db - Database Setup Progr	am	– 🗆 X
File Edit View Options Help		
E W Survey	Node: RX	
	Node: KX Object location: Amy Gale Node name: RX X (Stbd = Positive):: 0.000 m Y (Bow = Positive):: 0.006 m A-priori SD: 0.010 m	
Qinsy 9 For Help, press F1		
consy s Torrieb, press ri		

AmyGale_2020_Patch1_nonverified_tides_2.db - Database Setup Progr	am	– 🗆 X
File Edit View Options Help		
Emeral	Node: TX	
⊟ a Geodetic		
Datums	Object location: Amy Gale	
- WGS84	Node name: TX	
⊖ ★ Heights	X (Stbd = Positive):: 0.040 m	
└ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓	Y (Bow = Positive):: 0.004 m	
Mean Water Level Model	Z (Up = Positive):: 0.006 m	
🚖 Digital Terrain Models	A-priori SD: 0.010 m	
Projections		
Universal Transverse Mercator (North Hemisphere)		
Local Construction Grid		
- Ö UTC to GPS Correction		
Sound Velocity Profile		
e 🗄 Object		
🖻 🏧 Amy Gale		
System ▲ ▲ EM2040C		
⊢ ∰ Gyro		
l ↓ Gyro		
₩ Pitch Roll Heave Sensor		
L Position Navigation System		
Amy Gale MRU		
e RX		
Link		
🕀 🔚 Auxiliary Systems		
- 💩 Time Sync		
EM2040C Controller		
ASCII Logger		
→ Fixed Node		
Qinsy 9 For Help, press F1	*	

E % 🔜 🙏 💿 🖉 🔢 层 📟 🛃 😫 🔒	8 8		
- III General	System: Time Sync		
	System: Time SyncDescription:Type:Driver:Executable and Cmdline:Port:Baud rate:Data bits:Stop bits:Parity:Byte frame length (time):Maximum data transfer rate:Update rate:Latency:Acquired by:Observation time from:Number of slots:Use QPS PPS Adapter:PPS time tag pulse matching:Windows System Time Synchronization:	Time Sync Time Synchronization System NMEA ZDA DrvPositionNMEA.exe 2 9600 8 1 1 None 10 bits (1.042 ms) 960 bytes / second 0.000 s 0.000 s 0.000 s (Directly into Qinsy] (No additional time tags) N/A 0 On COM1 Automatic Matching Synchronization is enabled	

Geodetic □ Image: Datums □ Imag	
Geodetic Description: WGS84 Type: ★ Heights Driver: ★ Chart Datum / Vertical Datum Executable and Cmdline ★ Mean Water Level Model Update rate: ★ Digital Terrain Models Latency: ★ Digital Terrain Models Update rate: ▲ Digital Terrain Models Universal Transverse Mercator (North Hemisphere) ▲ Local Construction Grid Observation time from: Number of slots: Number of slots: Object Mary Gale ▲ Amy Gale System ★ Position Navigation System Yariable Node ▲ RX TX ● Link Maxiliary Systems ▲ Tx Time Sync ▲ EM2040C Controller ● ACIL Logger	2040C Controller
Image: Source Controller Type: Image: Source Controller Diver: Image: Source Controller Executable and Cmdline Image: Source Controller Digital Terrain Models Image: Source Control Control Control Update rate: Image: Source Control Control Latency: Image: Source Control Control Acquired by: Image: Source Control Control Distribution Grid Image: Source Control Control Control Number of slots: Image: Source Control Control Control Control Number of slots: Image: Source Control Control Control Control Control Number of slots: Image: Source Control Cont	
→ WigS84 Driver: ★ Heights Executable and Cmdline ★ Mean Water Level Model Update rate: ▲ Digital Terrain Models Update rate: ■ Projections Cost Construction Grid ▲ Utiversal Transverse Mercator (North Hemisphere) Observation time from: Number of slots: Number of slots: ▲ Object Amy Gale ■ Amy Gale System → Position Navigation System → Yoriable Node → Amy Gale MRU ● RX ● Time Sync ■ Tx ● Link Auxiliary Systems → ASCII Logger ■ Ascil Logger	EM2040C Controller
Arreights Action Ac	Miscellaneous System
↓ Chain Datanny Vertical Datanny ↓ Mean Water Level Model ↓ Digital Terrain Models ↓ Local Construction Grid ↓ Local Construction Grid ↓ Local Construction Grid ↓ Sound Velocity Profile ↓ Object ↓ Number of slots: ↓ System ↓ ↓ ↓ May Gale ↓ ↓ ↓ Yeitch Roll Heave Sensor ↓ ↓ ↓ ♥ ↓ ♥ ↓ ♥ ↓ ♥ ↓ ♥ ↓ ♥ ↓ ♥ ↓ ♥ ↓ ♥ ↓ ♥ ↓ ♥ <td>Kongsberg EM2040 Compact (Single) Multibeam Controller</td>	Kongsberg EM2040 Compact (Single) Multibeam Controller
Digital Terrain Models Digital Terrain Models Digital Terrain Models Latency: Latency: Acquired by: Observation time from: Number of slots: Diservation Navigation System Position Navigation System Position Navigation System Position Navigation System TX Number of Slots: Diservation time from: Number of slots: Diservation time from: Number of slots:	: DrvKongsbergEMCtrl.exe 2040C
 Projections Cuckery: Acquired by: Observation time from: Number of slots: Number of slots: Sound Velocity Profile Object Amy Gale System EM2040C \$ Gyro Y Prich Roll Heave Sensor Position Navigation System Y variable Node Amy Gale MRU RX TX Link Auxiliary Systems Time Sync EM2040C Controller ASCII Logger 	0.000 s
▲ Cquired by: Observation time from: ▲ Local Construction Grid Observation time from: ▲ UTC to GPS Correction Number of slots: ▲ Object Amy Gale ▲ May Gale ▲ EM2040C ▲ Pitch Roll Heave Sensor ▲ Position Navigation System ▲ Variable Node ▲ Amy Gale MRU ● TX ● Link ▲ Auxiliary Systems ● TX ● Link EM2040C Controller ● ASCII Logger ● ASCII Logger	0.000 s
Observation time from: Image: Sound Velocity Profile Object Image: System Image: Syst	[Directly into Qinsy] (No additional time tags)
→ B Local Construction Grid → © UTC to GPS Correction ↓ Sound Velocity Profile ↓ Object ↓ May Gale ↓ System ↓ Gyro ↓ Gyro ↓ Position Navigation System ↓ Variable Node ↓ Number of slots: ↓ Yariable Node ↓ RX ● RX ● TX ⑧ Link ▲ Auxiliary Systems ▲ SCII Logger	N/A
Sound Velocity Profile Object Amy Gale System KeM2040C System Position Navigation System Position Navigation System Amy Gale MRU RX TX Link Auxiliary Systems Axiliary System Axiliary Sys	
Object Amy Gale System Amy Controller Mathematical System According to the sensor System Amy Gale MRU Amy Gale MRU Amy Gale MRU Systems Trx Link Mathematical System According to the sensor	0
Amy Gale System EM2040C Sy or System Position Navigation System Position Navigation System Amy Gale MRU Systems TX TX TX Success Time Sync EM2040C Controller PostIl Logger	
 System Method System System Systems Time Sync EM2040C Controller ASCII Logger 	
 It has been been been been been been been bee	
Position Navigation System Amy Gale MRU Stress TX Time Sync Million Systems Million Systems Marcologer Solution System Solution	
Variable Node Amy Gale MRU O RX O TX O TX O TX O Time Sync EM2040C Controller D ASCII Logger	
Amy Gale MRU O RX O TX O TX O Time Sync EM2040C Controller DF ASCII Logger	
• RX • TX • TX • Time Sync • EM2040C Controller • ASCII Logger	
TX Stink Sinc Muxiliary Systems Muxiliary Systems Ascription of the sync Mathematical System of the sync Mathematical System of the sync Mathematical System of the system of t	
Link Auxiliary Systems	
Auxiliary Systems O Time Sync EM2040C Controller ASCII Logger	
 ─Õ Time Sync ✓ EM2040C Controller □→ ASCII Logger 	
ASCII Logger	
ASCII Logger	
→ Fixed Node	

AmyGale_2020_Patch1_nonverified_tides_2.db - Database Setup Prog	ram		20 3	×
File Edit View Options Help				
E 26 🖪 🙏 💿 🖉 🛛 🔢 📟 😰 😫 💷 🔒 (8			
Emeral General	System: ASC	II Logger		
Geodetic	Description: Type:	ASCII Logger Output System		
日本 Heights 一立 Chart Datum / Vertical Datum	Driver: Executable and Cmdline:	33		
	Update rate: Latency: Data output setting:	1.000 s 0.000 s Enabled		
Universal Transverse Mercator (North Hemisphere) Local Construction Grid $-$ UTC to GPS Correction	Acquired by: Observation time from:	[Directly into Qinsy] (No additional time tags) N/A		
└─└ Sound Velocity Profile	Number of slots:	0		
Amy Gale System Amy Gale System Amy Gale System Amy Gale System Amy Gale MRU System Yariable Node Amy Gale MRU SRX TX Link Sinc Amy Gale MRU Systems Sinc Fixed Node				
Qinsy 9 For Help, press F1				

Appendix E – Configuration settings for Qinsy EM controller

PU Status			
Status	Active		 Char
Pinging	15308 @ 2.90	47	 Stop
Clock Status	Ok		Pu Info
Frors	All Ok		
			Options.
Settings			·
Head1 Port Ar	ade	65	
Head1 Starbo		65	
Max. Port Cov		300	
Max. Starboar		300	
Angular Cove		Auto	 •
Beam Spacing		High Density	 -
Pitch Stabiliza		On	•
Max. Ping Fre	q.(Hz)	50.00	
Transmit Ang	le (deg)	0.0	
Minimum De	oth	0.00	
Maximum De	pth	200.00	
Detector Mod	e	Normal	-
Slope Filter		On	-
Areation Filter	r	Off	•
Interference F	ilter	Off	•
Penetration Fi	lter	Off	-
Range Gate Si	ze	Normal	-
Spike Filter Str	rength	Medium	T
Phase Ramp		Normal	-
Special Amp [Detect	Off	-
Special TVG		Off	-
Normal Inci. S	ector Angle	10	
Lambert's law	for intensity	Off	-
Ping Mode		300 KHz	-
Pulse Type		Auto	• • •
Transmit Power Level		Maximum	 -
FM Enable		FM Enabled	<u> </u>
3D Scanning -	Scan Step	0.0	
Apply	Settings 🔻	Force V Log Events	
Events			
	PU Clock is synd	thronized PU (157.237.20.40) Established	1
	Set Initial Settin		

📶 EM Contro		×			
-PU Status					
Status	Active			Stop	
Pinging	18646 @ 2.70 H	łz		3.00	
Clock Status	Ok			Pu Info	-
Errors	All Ok				=
				Options	····
Settings				·	
Penetration F	ülter	Off		-	
Range Gate S		Normal		- -	<u> </u>
Spike Filter St		Medium			
Phase Ramp	arengen	Normal		-	
Special Amp	Detect	Off		-	
Special TVG	Delett	Off		+ + + + + + + + + + + + + + + + + + + +	
Normal Inci.	Sector Angle	10			
Lambert's lav		Off		-	
Ping Mode		300 KHz			
Pulse Type		Auto		- - -	
Transmit Pov	ver Level	Maximum		-	
FM Enable		FM Enabled		-	
3D Scanning	- Scan Step	0.0			
3D Scanning	- Min Angle	-5			
3D Scanning		5			
Dual Swath N	/lode	Off		-	
Min. Swath D	listance	0.0			
Yaw Stabilizat	tion Mode	Off		-	
Yaw Manual	Angle	0.0			
Heading Filte	er	Medium		-	
WCD Sonar N	/lode	Off		-	
WCD Passive	Mode	Off		-	
WC TVG LOG	R	30.0			
WC TVG dB		20.0			
Special ampl	itude detection	Off		-	
Sound Veloci	ty Update Rate	3.0			
Sound Veloci	ty Min Change	0.5			~
Apply	Settings 🔻	Force 🔽 Log Events			
		I♥ Log Events			
Events					_
	PU Clock is synd Connection to P	hronized U (157.237.20.40) Established			^
10:00:53.963	Set Initial Settin	gs			
10:00:55.073	Command Accep	oted			¥
,					

Lambert's law for intensity was turned ON starting 01/25/23. No notable disagreements were found across backscatter datasets collected before and after the change was implemented.

System Type (from DbSetup) EM2040C Single Transducer Pu Ip Address 157.237.20.40 Simulation Mode Off External Triggering Off Control Port 2000 Enabled Output Ports Output Port 1,2,3 Output Port 1 (Bathy) 2001 Output Port 2 (Bathy) 2002 Output Port 3 (Sidescan) 2003 ZDA/GGA Serial Port Port 1 (default)	* * *
Simulation Mode Off External Triggering Off Control Port 2000 Enabled Output Ports Output Port 1,2,3 Output Port 1 (Bathy) 2001 Output Port 2 (Bathy) 2002 Output Port 3 (Sidescan) 2003	•
External Triggering Off Control Port 2000 Enabled Output Ports Output Port 1,2,3 Output Port 1 (Bathy) 2001 Output Port 2 (Bathy) 2002 Output Port 3 (Sidescan) 2003	•
Control Port 2000 Enabled Output Ports Output Port 1,2,3 Output Port 1 (Bathy) 2001 Output Port 2 (Bathy) 2002 Output Port 3 (Sidescan) 2003	
Enabled Output Ports Output Port 1,2,3 Output Port 1 (Bathy) 2001 Output Port 2 (Bathy) 2002 Output Port 3 (Sidescan) 2003	•
Output Port 1 (Bathy) 2001 Output Port 2 (Bathy) 2002 Output Port 3 (Sidescan) 2003	_
Output Port 2 (Bathy) 2002 Output Port 3 (Sidescan) 2003	
Output Port 3 (Sidescan) 2003	
ZDA/GGA Senal Port	-
Use GGA On	
Baudrate ZDA/GGA 9600	
Motion Serial Port Port 2 (default)	
Program Options	_
Start Pinging when QINSy Starts Pinging On Start	up _
Synchronize Clock Interval(min.) 60	
Sound Velocity Mode From Sound Velocity	city C
Sound Velocity Observation Sound Velocity Popula window when error occurs On	-
Popup window when error occurs On Allow HD beamspacing with Water Column Data Not Allowed	-
Installation Parameters	
RX1 Gain Offet 0	
RX2 Gain Offet 0	_
Head1 Installation angles from EM2040C	
Head2 Installation angles from Not Used	_
Head2 Installation angles from Not Used Velocity Sensor Number Motion Sensor 1	
Head2 Installation angles from Not Used Velocity Sensor Number Motion Sensor 1 Velocity Sensor UDP Port 3001	- 1
Head2 Installation angles from Not Used Velocity Sensor Number Motion Sensor 1	- 1

Appendix F – Computation Settings for Qinsy Online

Computation Setup

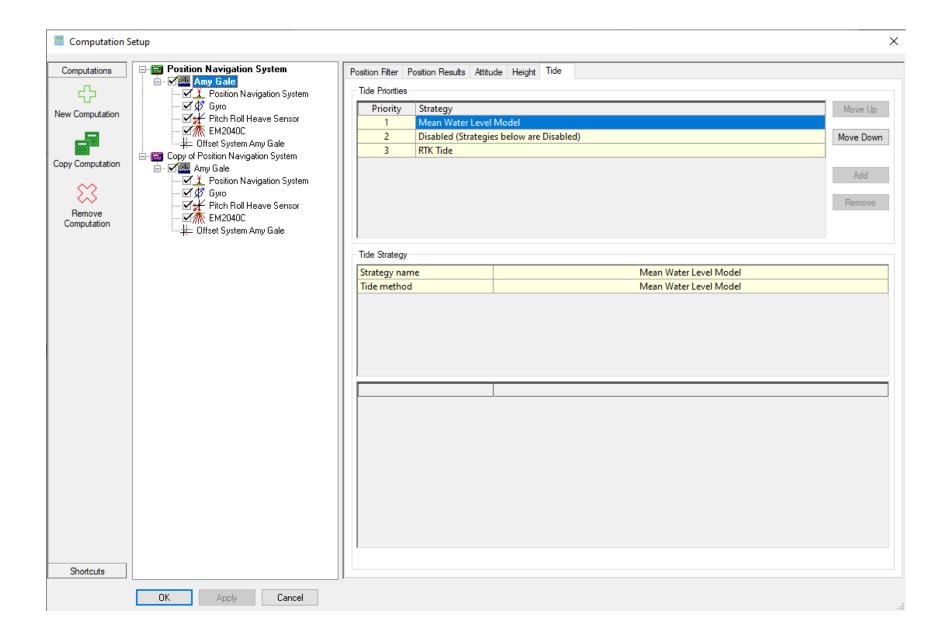
Position Navigation System Computations Computation Parameters 🖮 🗹 🛄 Amy Gale ÷ Computation name Position Navigation System 🗹 🧵 Position Navigation System 🗹 🗭 Gyro Position Navigation System • • Triggering system New Computation Pitch Roll Heave Sensor Max. triggering rate 50 [Hz] ☑ ★ EM2040C P Iteration threshold 5 📥 Offset System Amy Gale Statistical testing Separate Objects ▼ E Gopy of Position Navigation System Enabled • Copy Computation Data snooping 🖮 🗹 🛄 Amy Gale Redundancy minimum 1 🗹 🏌 Position Navigation System £3 Level of significance 1% 🗹 🗭 Gyro 80 % Pitch Roll Heave Sensor Power of test Remove ☑ ★ EM2040C Lower limit max. ages 0.0 [s] Computation 👍 Offset System Amy Gale Approximate Position Coordinate system Geographical • 52;06;10.800 N Latitude 5;15;25.560 E Longitude 0.0 Height **Computation Priority** Priority Status Heights Computation Move Up 1 Enabled Tide (Unrelial Copy of Position Navigation System RTK (Accurat Position Navigation System 2 Enabled Move Down Shortcuts ΟK Apply Cancel

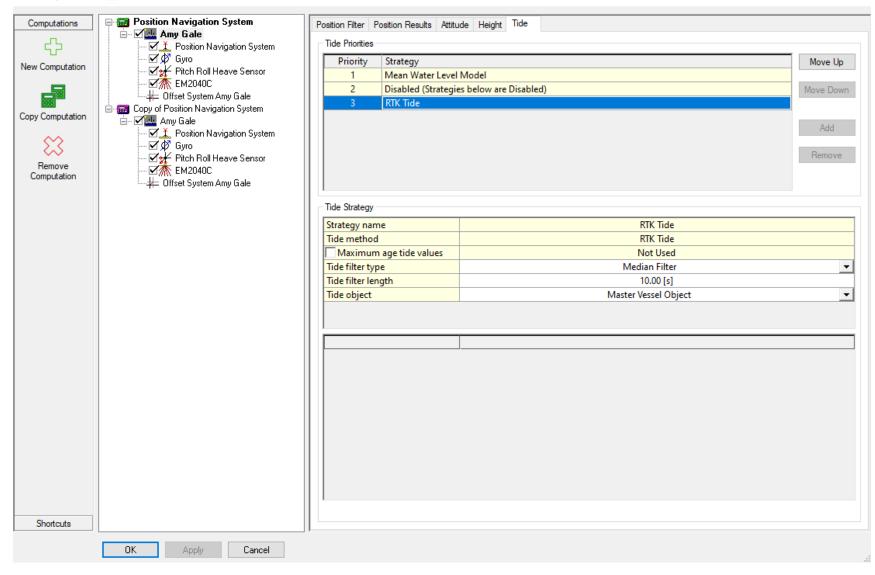
Computations	Position Navigation System	Position Filter Position Results Attitud	de Height Tide	
- cp	Amy Gale	Filter Parameters		
¹ 0 ²	Gyro	General Parameters	C. 11	
New Computation			Settin	
	EM2040C	Dynamic model	None	
		Height model	None	•
888	🚍 📷 Copy of Position Navigation System			
Copy Computation	🖮 🗹 🛄 Amy Gale			
	🔤 🗹 🌋 Position Navigation System			
1 X3	— 🗹 🗭 Gуго	Extended Parameters	Noise SD	Time Constant
Remove	Pitch Roll Heave Sensor			
Computation				
		Observations	Setting	SD
		Observation Parameters	Settin	g
		1 ·		
		Filter Thresholds		
		Reset Parameters	Settin	a
				· · · · · · · · · · · · · · · · · · ·
		Threshold Parameters	Maximum	Time Factor
Shortcuts				
]]		
	OK Apply Cancel			

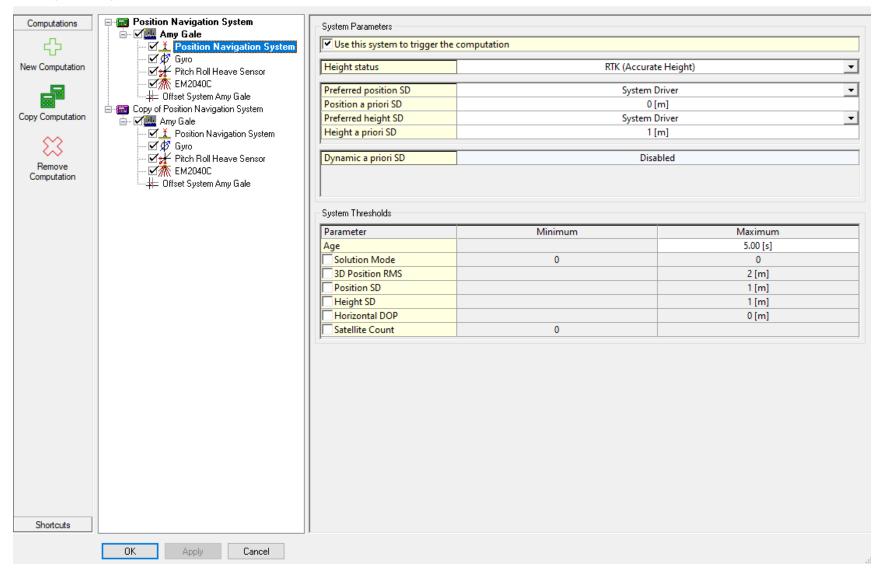
Computations	Position Navigation System	Position Filter Position Results Attitu	ude Height Tide	
-c-	ian ⊻ III Amy Gale ✓ III Position Navigation System			
- ⁶ 0	Gyro	Parameters	C-Hin -	
New Computation	Pitch Roll Heave Sensor	COG value	Setting	
_	- ☑ EM2040C		Position Updates	-
	Offset System Amy Gale	SOG value	Position Updates	-
	E- 🗃 Copy of Position Navigation System	Position count	10	
Copy Computation	🖮 🗹 🛄 Amy Gale	Position threshold	0.05 [m]	
23	ー・ビ 👗 Position Navigation System ー・ビ 🖉 Gyro			
Remove		Rate-Of-Tum		
Computation	Offset System Amy Gale	Parameters	Setting	
		Rate-Of-Turn value	Rotation Updates	-
		Rate-Of-Turn count	5	
		Par (Patri		
		Positions / Prediction		
		Parameters	Setting	
		Position results	Computation	-
		Height results	Computation	–
		Parameters	Setting	
		Prediction	Disabled	-
		Maximum position age	5.0 [s]	
		Snap to Survey Line / Node Track -		
		Parameters	a w	
			Setting	_
		Snap option	Disabled	
Shortcuts		J		
	OK Apply Cancel			

Computations Image Destition Navigation System New Computation Postion Navigation System Copy Computation Postion Navigation System Copy Computation Postion Navigation System Copy Computation Postion Navigation System Pennove Computation Pennove Computation Pennove Computation Pennove Postion Navigation System Pennove Postion Navigation Pennove Postion Navigation Navigation Pennove Postion Navigation Navigati		Position Navigation System					
Wet Computation Wethod Max Age Skew Move Upin Wet Computation Wethod Max Age No Move Upin Coop Computation Wethod Max Age No Move Upin Coop Computation Wethod Max Age No Move Upin Wethod Wethod Max Age No Move Upin Wethod Wethod No No Move Upin Wethod Wethod Move Upin No Move Upin Wethod Wethod Move Upin Move Upin Move Upin Wethod Wethod Move Upin Move Upin Move Upin Pich - Roll Wethod No No Move Upin Stotcats Wethod No </td <td>Computations</td> <td></td> <td>Position Filter</td> <td>Position Results Attitude Height Tie</td> <td>de</td> <td></td> <td></td>	Computations		Position Filter	Position Results Attitude Height Tie	de		
New Computation M & Bylo Copy Computation M & Bylo Copy Computation M & Bylo M & Diffield System Amy Gale M ore Data M & Diffield System Amy Gale M ore Data M & Diffield System Amy Gale M ore Data M & Diffield System Amy Gale M ore Data M & Diffield System Amy Gale M ore Data M & Diffield System Amy Gale M ore Data M & Diffield System Amy Gale M ore Data M & Diffield System Amy Gale M ore Data M & Diffield System Amy Gale M ore Data M & Diffield System Amy Gale M ore Data M & Diffield System Amy Gale M ore Data M & Diffield System Amy Gale M ore Data M & Diffield System Amy Gale M ore Data M & Diffield System Amy Gale M ore Data M & Diffield System Amy Gale M ore Data M & Diffield System Amy Gale M ore Data M & Diffield System Amy Gale M ore Data M & Diffield System Amy Gale M ore Data M & Diffield System Amy Gale M ore Data M ore Data M ore Data	<u>5</u>	✓ I Position Navigation System	Heading				
Shotcuts		- 🗹 🕸 Gyro	Priority	Method	Max Age	Skew	Move Up
Copy Computation With Muddle Intel System Any Gale Not Used N/A More Down Computation With Pointon Navigation System With Pointon Navigation System Intel System Any Gale N/A More Down Remove Computation With Pointon Navigation System With Pointon Navigation System Intel System Any Gale N/A More Down Price Nation With Pointon Navigation System With Pointon Navigation System Intel System Any Gale Intel System Any Gale Price Nation Price Nation With Pointon Navigation System With Pointon Navigation System Intel System Any Gale Intel System Any Gale Price Nation Stortcuts Stortcuts Stortcuts Not Used N/A More Down		Pitch Roll Heave Sensor				No	
Copy Computation Image Sales Image Sales<			2			N/A	Move Down
Copy Computation Image: Second Se		······≄⊏ Utrset System Amy Gale		-	·		
Shotcuts	Copy Computation						
Shotcuts	~ ~	Position Navigation System					
Nemove Computation Image: Max Age Skew Move Up Pich - Roll Image: Max Age Skew Move Up 2 Disabled Not Used N/A Move Down Image: Max Age Skew Move Up Shotcuts Shotcuts Image: Max Age Skew Move Up	- ES						
Computation Introduce Image: Computation Image: Computation Image: Computation	Remove	Pitch Roll Heave Sensor					
Pitch - Roll Pitch Roll Heave Sensor 1.00 [s] No 2 Disabled Not Used N/A Move Down Image: Sensor Image: Sensor Image: Sensor Shotcuts Shotcuts Image: Sensor Image: Sensor Image: Sensor	Computation	■ M EM2040C					
Priority Method Max Age Skew Move Up 1 Pitch Roll Heave Sensor 1.00 [s] No 2 Disabled Not Used N/A		Criset System Amy Gale					
1 Pitch Roll Heave Sensor 1.00 [s] No 2 Disabled Not Used N/A Move Down			Pitch - Roll				
1 Pitch Roll Heave Sensor 1.00 [s] No 2 Disabled Not Used N/A Move Down			Priority	Method	May Age	Skew	Maya Ha
Shortcuts			·		-		Move op
Shotcuts							Move Down
				bibbled	Horosca		MOVE DOWN
	Shortoute						
OK Apply Cancel	Shoricuis		J				
		OK Apply Cancel					

Computations	Position Navigation System Amy Gale		Position Results Attitude	Height Tide			
New Computation	Position Navigation System System Amy Gale Gyro G	-Height Interp	Method Heave Pitch Roll Heave		Max Age 1.00 [s]	Skew No	Move Up Move Down
	└	Draft and Squ Draft meth Manual dra Squat meth	ft		Manual 0.8 Disab	350	
Shortcuts	OK Apply Cancel						







Computation S	Setup					×
Computations	Position Navigation System	Heading				
- c	Amy Gale	Priority	Method	Max Age	Skew	Move Up
		1	Gyro	5.00 [s]	No	more op
New Computation	Pitch Roll Heave Sensor	2	COG Amy Gale	Not Used	N/A	Move Down
Copy Computation				1		
Remove Computation	⊡ ∲ Gyro ⊡ ∲ Pitch Roll Heave Sensor ⊡ ☆ EM2040C					
	Offset System Amy Gale	Pitch - Roll —				
		Priority	Method	Max Age	Skew	Move Up
		1	Pitch Roll Heave Sensor	1.00 [s]	No	
		2	Disabled	Not Used	N/A	Move Down
Shortcuts						
	OK Apply Cancel					

Computations	Position Navigation System					
	🖮 🗹 🛄 Amy Gale	Heading				_
- c	- 🗹 👗 Position Navigation System	Priority	Method	Max Age	Skew	Move Up
New Computation	- ∀ Ø Gyro	1	Gyro	5.00 [s]	No	
	Pitch Roll Heave Sensor EM2040C	2	COG Amy Gale	Not Used	N/A	Move Down
888	E-E-Copy of Position Navigation System					
Copy Computation	🖮 🗹 🛄 Amy Gale					
\sim	- 🗹 🁗 Position Navigation System					
2,3	Gyro					
Remove	🗹 🖌 Pitch Roll Heave Sensor ☑ 🎢 EM2040C					
Computation	Offset System Amy Gale					
		Pitch - Roll				
		Priority	Method	Max Age	Skew	Move Up
		1	Pitch Roll Heave Sensor	1.00 [s]	No	
		2	Disabled	Not Used	N/A	Move Down
Shortcuts						
	L]]				
	OK Apply Cancel					

×

Computations	Position Navigation System My Gale	Refraction			^
	- V Any Gale	Velocity profile		Enabled	
_	- ØØ Gyro	Add sound velocity from	system to velocity profile		
New Computation					
	EM2040C Gale Gifset System Amy Gale	Flag Data When			
222	Copy of Position Navigation System	ltem	Min	Max	
Copy Computation	E ✓ May Gale	Cepth outside	1	500	
	Position Navigation System	Range outside	2	50	
53	🗹 🖉 Gyro	Sector outside	-60	60	
~~		Intensity outside	0	0	
Remove Computation	🗹 🥂 EM2040C	Quality outside	0	0	
comparation	Offset System Amy Gale	Heave above		5	
		Height outside	0	0	
		Inside / outside polygon	<none> 👻</none>	<none> 👻</none>	
		TPU exceeds			
		<u>'</u>			
		Exclude beams			
		Despike Data			
		Despike method	Disabl	ed 🔹	
		Data Reduction			
		Reduction method	Disabl	ed 🔹	
			Disabi		
Shortcuts					~
Chortouto		1.1			
	OK Apply Cancel				
					.:

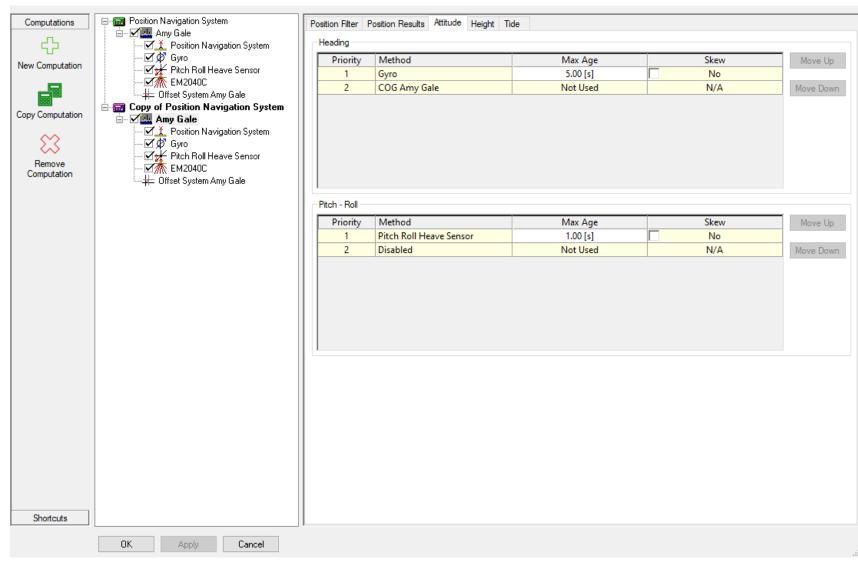
Computation S	Setup		×
Computations	🖃 🗃 Position Navigation System	System Parameters	
- c	Amy Gale	Use a common A priori SDs for all offsets	
_	Gyro		
New Computation	Pitch Roll Heave Sensor	Node Offsets	
	- M EM2040C	Offset	A priori SD
		🕂 X-offset Amy Gale MRU to TX	0 [m]
Copy Computation	i i i i i i i i i i i i i i i i i i i	✓ Y-offset Amy Gale MRU to TX	0 [m]
	Siny Gold	Z-offset Amy Gale MRU to TX	0 [m]
	Gyro	🚽 X-offset Amy Gale MRU to RX	0 [m]
Remove		Y-offset Amy Gale MRU to RX	0 [m]
Computation	☑ 🛣 EM2040C # Offset System Amy Gale	🚽 Z-offset Amy Gale MRU to RX	0 [m]
Shortcuts			
	OK Apply Cancel		

×

Computations	Position Navigation System	- Computation P	arameters			
{}	Amy Gale	Computation	n name		Copy of Position Navigation System	
~~~		Triggering system			Position Navigation System	
Computation	Pitch Roll Heave Sensor	Max. triggering rate			50 [Hz]	
	🗹 🥂 EM2040C	Iteration thre			5	
		Statistical tes	ting		Separate Objects	
omputation	Copy of Position Navigation System	Data snoopir	ng		Enabled	
	Amy Gale	Redundancy	minimum		1	
2		Level of sign	ificance		1 %	
>		Power of test	t		80 %	
e tion	Z M EM2040C	Lower limit n	nax. ages		0.0 [s]	
	Offset System Amy Gale	Approximate P	osition			
		Coordinate s			Geographical	
		Latitude	ystem		52;06;10.800 N	
		Longitude			5;15;25.560 E	
		Height			0.0	
		Priority 1			Computation Copy of Position Navigation System	Move Uj
		2	Enabled 🔹	RTK (Accurat	Position Navigation System	Move Dov

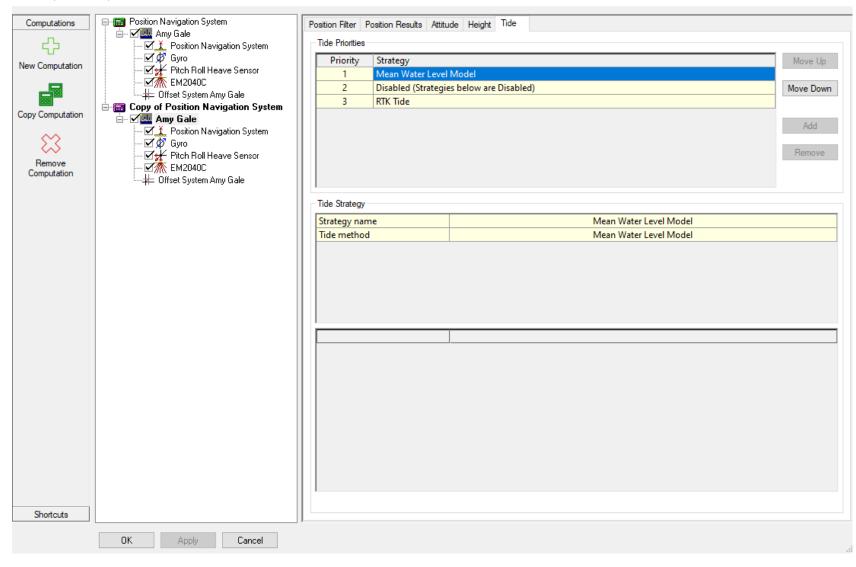
Computations	🖃 📾 Position Navigation System	Position Filter Position Results Attitu	ide Height Tide	
	🖮 🗹 🛄 Amy Gale	Filter Parameters		
÷	ー・ビ 👗 Position Navigation System ー・ビ 🛱 Gyro	General Parameters	C.u.	
New Computation	Pitch Roll Heave Sensor	Dynamic model	Settir None	-
	🗹 🥂 EM2040C	Height model	None	
	Offset System Amy Gale     Gale     Gopy of Position Navigation System		1	
Copy Computation	Amy Gale			
$\sim$		Extended Parameters	Nuiter CD	TracConstant
225	⊠Ø Gyro Ø☆ Pitch Roll Heave Sensor	Extended Parameters	Noise SD	Time Constant
Remove Computation	27 EM2040C			
Computation	🕂 Offset System Amy Gale			
		Observations	Setting	SD
			Setting	30
		, Observation Parameters	Settir	
			Setti	'Y
		Filter Thresholds		
		Reset Parameters	Settir	ng
		Threshold Parameters	Maximum	Time Factor
Shortcuts				
	OK Apply Cancel			

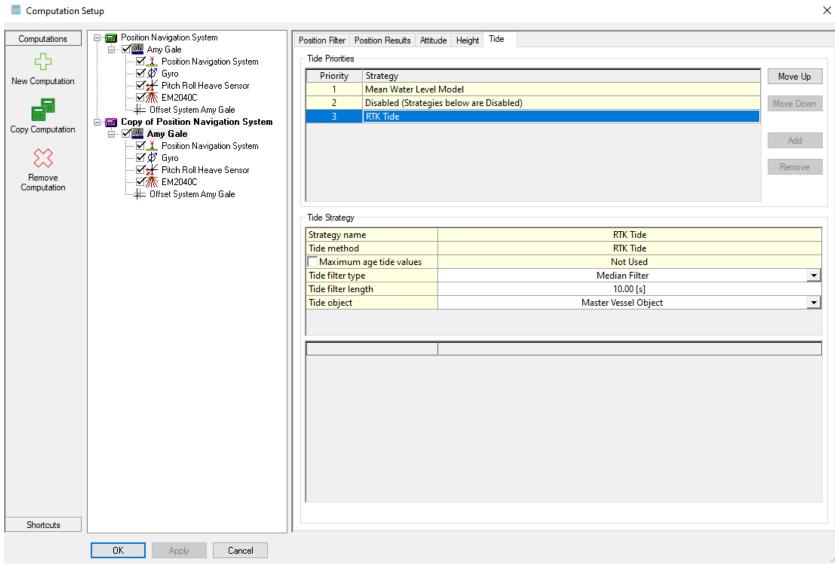
<b>0</b>	Position Navigation System			
Computations	E V Amy Gale	Position Filter Position Results Attitu	ide Height Tide	
4 <u>2</u>	- V Any date - V Any date - V Any date	COG / SOG		
_		Parameters	Setting	
New Computation	- 🗹 👷 Pitch Roll Heave Sensor	COG value	Position Updates	-
		SOG value	Position Updates	-
	□ In the system Amy Gale	Position count	10	
Copy Computation	E Gopy of Position Navigation System	Position threshold	0.05 [m]	
	Position Navigation System			
53				
Remove	Pitch Roll Heave Sensor	Rate-Of-Tum		
Computation	☑ 🎢 EM2040C #= Offset System Amy Gale	Parameters	Setting	
		Rate-Of-Turn value	Rotation Updates	-
		Rate-Of-Turn count	5	
		F		
		Positions / Prediction		
		Parameters	Setting	
		Position results	Computation	-
		Height results	Computation	-
		Parameters	Setting	
		Prediction	Disabled	-
		Maximum position age	5.0 [s]	
		Maximum position age	2.0 [2]	
		Snap to Survey Line / Node Track -		
			6 w	
		Parameters	Setting Disabled	
		Snap option	Disabled	
Shortcuts				
Shortcuts		1		
	OK Apply Cancel			



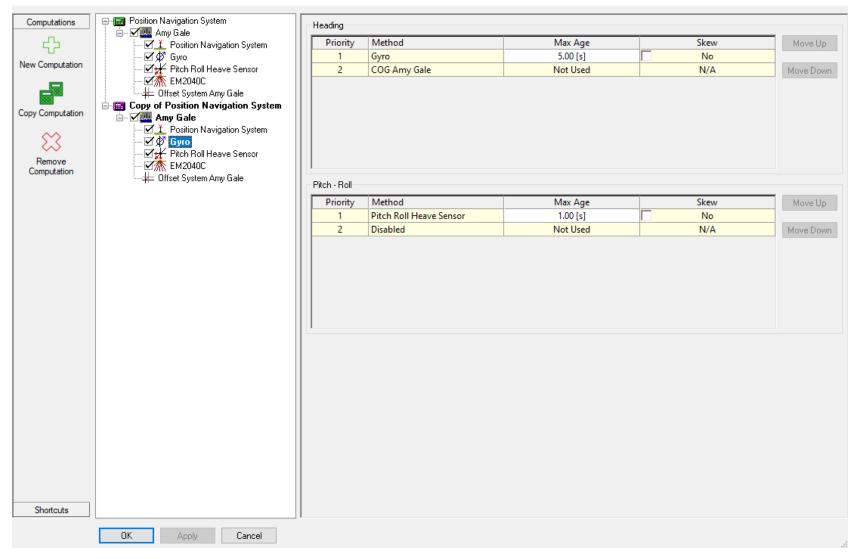
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Computation S	Setup				×
Computations		Position Filter Position Results Attitu	de Height Tide		
6		Height Interpolation			
	⊡Ø Gyro	Priority Method	Max Age	Skew	Move Up
New Computation	Pitch Roll Heave Sensor	1 Heave Pitch Roll H		No No	
	EM2040C			I	Move Down
Copy Computation	E				
8	⊠⊥ Position Navigation System ⊡ØØ Gyro				
Remove Computation					
Comparation	Offset System Amy Gale				
		Draft and Squat Parameters			
		Draft method		Manual Draft	•
		Manual draft		0.850	
		Squat method		Disabled	<u>•</u>
Shortcuts					
	OK Apply Cancel				





omputations	Position Navigation System	System Parameters			
÷	✓ ✓ ✓ Ally date ✓ ✓ Position Navigation System ✓ Ø Gyro	Use this system to trigger the compu	itation		
v Computation		Height status	Tide (Unreliab	le Height)	•
	III IIII EM2040C IIII Offset System Amy Gale	Preferred position SD	System [	Driver	
888	Copy of Position Navigation System	Position a priori SD	0 [	m]	
Computation		Preferred height aiding SD	Database	Setup	•
83	<mark>✓</mark> ¥ Position Navigation System <b>✓</b> Ø Gyro	Height aiding a priori SD	Auto	matic	
× •	- Itch Roll Heave Sensor	Dynamic a priori SD	Disa	bled	
Remove	🗹 🥂 EM2040C				
		System Thresholds			
		Parameter	Minimum	Maximum	
		Age		5.00 [s]	
		Solution Mode	0	0	
		3D Position RMS		2 [m]	
		Position SD		1 [m]	
		Height SD		1 [m]	
		Horizontal DOP		0 [m]	
		Satellite Count	0		



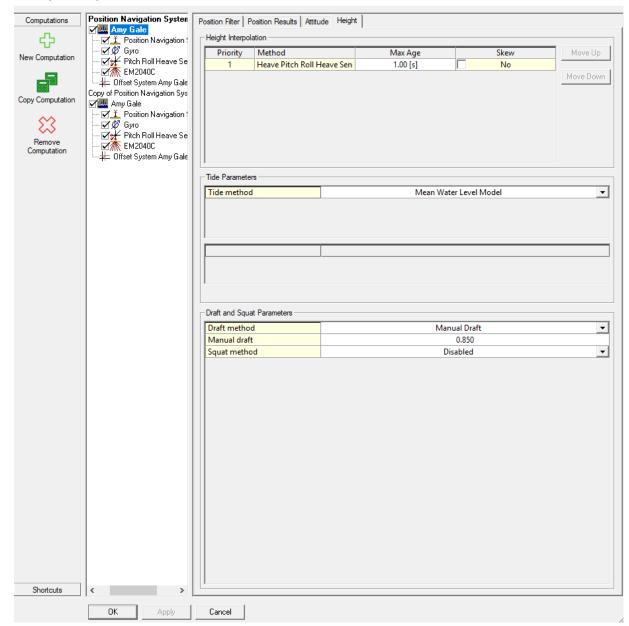
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Computation S	etup					×
Computations	Position Navigation System	Heading				
-c-	Mily Gale	Priority	Method	Max Age	Skew	Move Up
		1	Gyro	5.00 [s]	No	
New Computation		2	COG Amy Gale	Not Used	N/A	Move Down
	☑ 🛣 EM2040C Offset System Amy Gale					
Copy Computation	Copy of Position Navigation System					
$\sim$	I I I I I I I I I I I I I I I I I					
Remove	- 🗹 📈 Pitch Roll Heave Sensor					
Computation	☑ 🦟 EM2040C #= Offset System Amy Gale					
		Pitch - Roll				
		Priority	Method	Max Age	Skew	Move Up
		1	Pitch Roll Heave Sensor	1.00 [s]	No	
		2	Disabled	Not Used	N/A	Move Down
Shortcuts						
	OK Apply Cancel					.:

×

	ı					
Computations	E- 📰 Position Navigation System È ☑ 🛄 Amy Gale	Refraction				^
4 <u>2</u>	- Supervision Navigation System	Velocity profile			Enabled	-
_		Add sound velocity from	system to velocity profile			
New Computation				1		
	☑ 🦟 EM2040C 🛱 Offset System Amy Gale	Flag Data When				_
	Copy of Position Navigation System	ltem	Min		Max	
Copy Computation	🖮 🗹 🛄 Amy Gale	Depth outside		1		00
~~		Range outside		2		i0
53	<b>⊡</b> Ø Gyro	Sector outside		-60		50
Remove		Intensity outside		0		0
Computation	- M EM2040C	Quality outside		0		0
		Heave above				5
		Height outside		0		0
		Inside / outside polygon		<none> 💌</none>	<none></none>	-
		TPU exceeds				
		in o exceeds				_
						_
		Exclude beams				
		Despike Data				_
		Despike method		Disable	d	-
		L				
		Data Reduction				_
		Reduction method		Disable	d	-
Shortcuts						~
	OK Apply Cancel					

Computations	Position Navigation System	System Parameters	
4D	🖮 🗹 🛄 Amy Gale	Use a common A priori SDs for all offsets	
_			
New Computation	Pitch Roll Heave Sensor	Node Offsets	
	🗹 🎢 EM2040C Offset System Amy Gale	Offset	A priori SD
222	Copy of Position Navigation System	X-offset Amy Gale MRU to TX	0 [m]
Copy Computation	🖮 🗹 🛄 Amy Gale	Y-offset Amy Gale MRU to TX	0 [m] 0 [m]
$\sim$	Position Navigation System	X-offset Amy Gale MRU to RX	0 [m]
~~~	⊠∯ Gyro ⊡∰ Pitch Roll Heave Sensor	Y-offset Amy Gale MRU to RX	0 [m]
Remove	EM2040C	Z-offset Amy Gale MRU to RX	0 [m]
Computation	Offset System Amy Gale		0 [m]
Shortcuts			
Shortcuts]]	
	OK Apply Cancel		



 \times

¢		System Parameters		
52	✓ May Gale ✓ May Gale ✓ May Control	Use this system to trigger the co	mputation	
w Computation	⊠Ø Gyro ⊡¥ Pitch Roll Heave Se	Height status	RTK (Accurat	te Height)
_	EM2040C			-
	🚽 🕂 Offset System Amy Gale	Preferred position SD	System	
	Copy of Position Navigation Sys	Position a priori SD		5 [m]
y Computation	Amy Gale	Preferred height SD	System	
\sim	Position Navigation !	Height a priori SD	0.50)[m]
\sim	⊡Ø Gyro ⊡∰ Pitch Roll Heave Se	Dynamic a priori SD	Disz	abled
Remove Computation	EM2040C	by harme a prior ob		
		System Thresholds		
		Parameter	Minimum	Maximum
		Age		5.00 [s]
		Solution Mode	0	0
		3D Position RMS		1.73 [m]
		Position SD		1.00 [m]
		Height SD		1.00 [m]
		Horizontal DOP		0.00 [m]
		Satellite Count	0	

Position Navigation	Use this system to trigger the com	putation	
omputation	Height status	Tide (Unreliab	le Height)
Pitch Roll Heave Se	Preferred position SD	System E	Driver
Offset System Amy Gale	Position a priori SD	0.25	
Copy of Position Navigatio omputation Image: Copy of Position Navigatio Image: Copy of Positio<	Preferred height aiding SD	Database	
Position Navigati	Height aiding a priori SD	Autor	•
C Gyro			
move	Dynamic a priori SD	Disa	bled
putation EM2040C			
	System Thresholds		
	Parameter	Minimum	Maximum
	Age		5.00 [s]
	Solution Mode	0	0
	3D Position RMS		1.73 [m]
	Position SD		1.00 [m]
	Height SD		1.00 [m]
	Horizontal DOP		0.00 [m]
	Satellite Count	0	
ottcuts			

Computations	Position Navigation System	Computation Pa	arameters			
÷	Position Navigation !	Computation	name		Position Navigation System	
-	Gyro	Triggering sy			Position Navigation System	
omputation	Pitch Roll Heave Se	Max. triggerin		20 [Hz]		
-		Iteration thre	-		5	
	👘 🚈 Offset System Amy Gale	Statistical tes			Separate Objects	
Computation	Copy of Position Navigation Sys	Data snoopin			Enabled	
computation	Amy Gale	Redundancy	-		1	
\sim	Position Navigation ! $\nabla \phi$ Gyro	Level of signi			1 %	
\sim	- ₩ ₩ Gyro - ₩ ₩ Pitch Roll Heave Se	Power of test			80 %	
emove	EM2040C	Lower limit max. ages			0.0 [s]	
outation	Gifset System Amy Gale		,		••	
		Approximate Po	osition			
		Coordinate s	ystem		Grid	
		Easting			4840352.1	
		Northing			8669036.1	
		Height			0.0	
		-				
		Computation Pr	-			
		Priority	Status	Heights	Computation	Move U
		1	Enabled • Enabled •		Copy of Position Navigation System Position Navigation System	Move Do
Shortcuts	<					

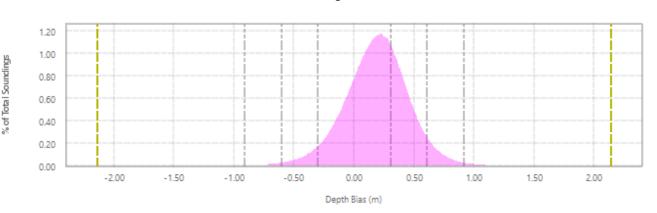
Appendix G – Crossline surface difference test statistical plots

Plots (histogram, scatter, and uncertainty)

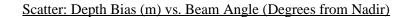
Key for plots:

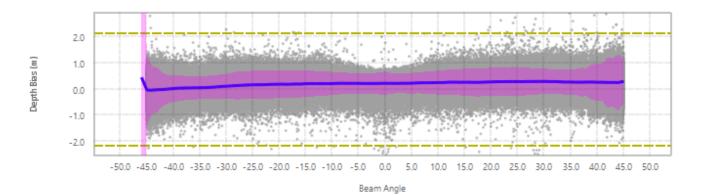
- Gray dots represent difference in depth between the crossline and the reference surface for individual beam angles or beam numbers
- Purple areas represent the 95% confidence interval (2 standard deviations) based on normal distribution (see histogram)
- Yellow dashed lines represent limit of IHO Order 1 test vertical tolerance
- Gray dashed lines on histogram represent ±sigma 1, 2, and 3
- Blue lines represent the mean value

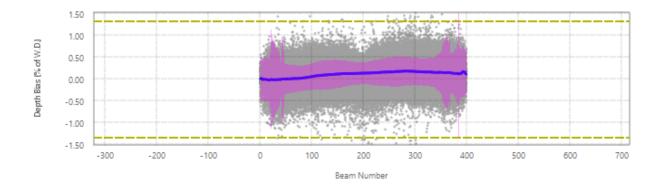
SECTION 1: Crossline statistical plots for 2023 Mainscheme



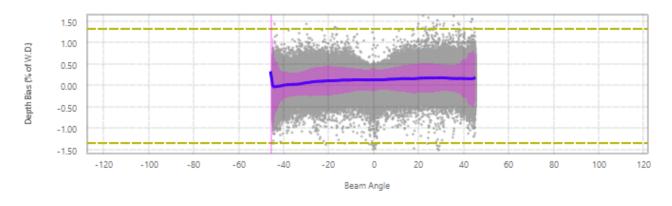
Histogram



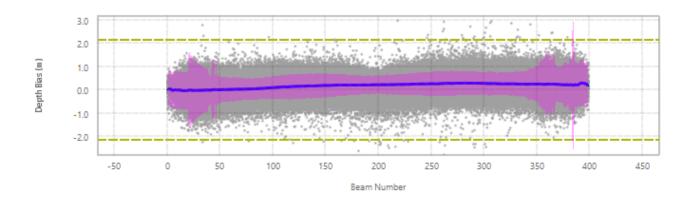




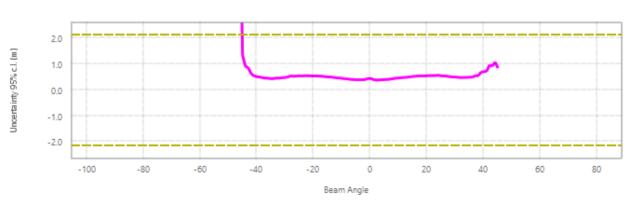
Scatter: Depth Bias (% Water Depth) vs Beam Angle (Degrees from Nadir)



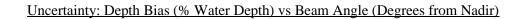
Scatter: Depth Bias (m) vs Beam Number

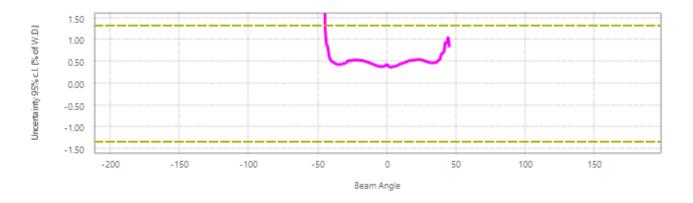


Scatter: Depth Bias (% Water Depth) vs Beam Number

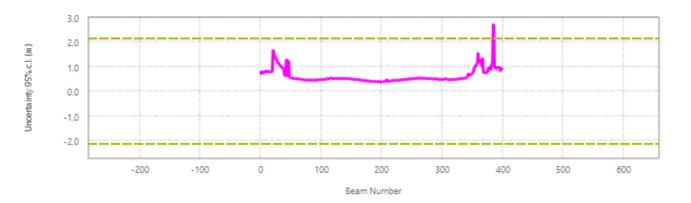


Uncertainty: Depth Bias (m) vs Beam Angle (Degrees from Nadir)

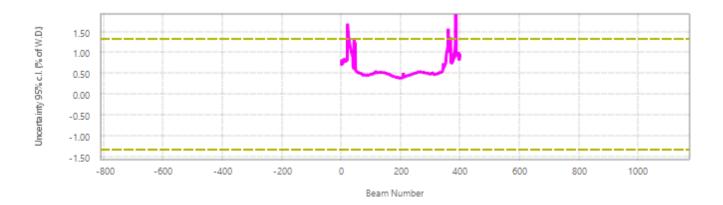




Uncertainty: Depth Bias (% Water Depth) vs Beam Number



Uncertainty: Depth Bias (m) vs Beam Number



Appendix H – Modified CMECS Classification Scheme Used by MCMI

Modified CMECS Substrate Group	CMECS Substrate SubGroup	Modified CMECS Substrate Groups for 7-Class Textural Model	Modified CMECS Substrate Groups for 4-Class Textural Model	
Bedrock/rocky		Bedrock/rocky (confirmed with video)	Bedrock/rocky	
	Boulder			
Gravel	Cobble			
Giavei	Pebble	Consultaneouslavinus (complete		
	Granule	Gravel/gravel mixes (samples containing ≥ 30% gravel)		
	Sandy Gravel			
Gravel Mixes	Muddy Sandy Gravel		Gravel/gravel mixes/gravelly/slightly gravelly	
	Muddy Gravel			
	Gravelly Sand		Bravery	
Gravelly	Gravelly Muddy Sand	Gravelly medium-coarse sand		
	Gravelly Mud	(includes samples with 5-30% gravel and samples with >90% sand with a		
	Very Coarse Sand	mean phi size < 2, even if gravel		
	Coarse Sand	content is up to 5%)		
Sand	Medium Sand			
	Fine Sand	Fine sand (samples having 0-5%		
	Very Fine Sand	gravel, ≥ 90% sand, and a mean phi size between 2 and 4)		
	Silty Sand		Fine and (fine sand + muddy sand)	
Muddy Sand	Silty-Clayey Sand	Muddy sand (silty sand + clayey sand + muddy sand; Folk, 1974)		
	Clayey Sand	sand + muddy sand, Polk, 1974)		
	Sandy Silt			
Sandy Mud	Sandy Silt-Clay			
	Sandy Clay	Nord (can de med + cit+ class)	Mud	
	Silt	Mud (sandy mud + silt + clay)	Mud	
Mud	Silt-Clay			
	Clay			
	Slightly Gravelly Sand			
Slightly Gravelly	Slightly Gravelly Muddy Sand	Slightly gravelly sand-mud mixtures (0.01-5% gravel, excluding samples	Gravel/gravel mixes/gravelly/slightly	
Singinuy Gravelly	Slightly Gravelly Sandy Mud	(0.01-5% graver, excluding samples) with > 90% sand)	gravelly	
	Slightly Gravelly Mud			