

2018-2019 Combined Descriptive Report of Seafloor Mapping: Vicinity of Saco Bay to Monhegan Island, Gulf of Maine

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Maine Coastal Mapping Initiative, March 2020

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For an overview of the Maine Coastal Mapping Initiative (MCMI) information products, including maps, data, imagery, and reports visit: <u>https://www.maine.gov/dmr/mcp/planning/mcmi/index.htm</u>.

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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-Locality:	Vicinity of Saco Bay to Monhegan Island				
	2018-2019				
	CHIEF OF PARTY				
Benjamin Kra	un, Hydrographer, Contractor to the State of Maine				
	LIBRARY & ARCHIVES				
Date:					

	REGISTRY NUMBER:				
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State(s):	Maine				
General Locality:	Gulf of Maine				
Sub-Locality:	Vicinity of Saco Bay to Monhegan Island				
Scale:					
Dates of Survey:	08/01/2018 to 11/19/2018; and				
	04/12/2019 to 08/29/2019				
Instructions Dated:					
Project Number:					
Field Unit:	Amy Gale				
Chief of Party:	Benjamin Kraun, Hydrographer, Contract	or to the State of Maine			
Soundings by:	Multibeam Echo Sounder				
Imagery by:	Multibeam Echo Sounder Backscatter				
Verification by:					
Soundings in:	meters at Mean Lower Low Water				
Remarks:					

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ABSTRACT

During the 2018 survey season (July - November) and part of the 2019 field season (April - August), the Maine Coastal Mapping Initiative (MCMI) conducted hydrographic surveying using a multibeam echosounder (MBES) in the waters off southern and mid-coast Maine. The surveying was conducted in part to support the Federal Bureau of Ocean and Energy Management's (BOEM) efforts to enhance coastal resiliency through identification and characterization of potential sand and gravel resources on the outer continental shelf that may be used for beach nourishment. The surveys also coincide with state efforts to update coastal data sets and increase high resolution bathymetric coverage for Maine's coastal waters. A total of approximately 71 mi² (184 km²) of high-resolution multibeam data were collected in the surveyed areas. An additional 6.5 mi² were collected in nearshore waters for the purposes of assessing nearshore and riverine sand movement as well as mapping eelgrass beds. This work is summarized in separate reports.

1.0 Area Surveyed

The 2018 and 2019 mainscheme survey areas were located off Maine's southern and mid-coast regions in the Gulf of Maine, with sub-localities of the vicinity of Saco Bay and west of Monhegan Island as shown in Figure 1. The approximately 71 mi² (184 km²) mainscheme survey areas adjoin the eastern extent of the areas mapped by MCMI in 2014 and 2017 (both accepted by NOAA, who lists the surveys as W00289 and W00450, respectively) as well as areas mapped by NOAA in 2015 (surveys H12725 and H12726) (Figure 3). 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. The data for both survey seasons were combined, reprocessed, and analyzed for quality control as a single 2018-2019 surface for each sub-locality (Figure 2).

Mainscheme survey limits of each main sub-locality are listed in Table 1. Specific dates of data acquisition for the mainscheme survey are listed in Appendix A.

Table 1 – 2018-2019 mainscheme survey limits

Saco Bay

Southwest Limit	Northeast Limit
43° 22' 37.632'' N	43° 31' 32.664'' N
70° 13' 55.812" W	69° 57' 27.072" W

Monhegan Island

Southeast Limit	Northwest Limit
43° 39' 20.139" N	43° 44' 54.888" N
69° 20' 40.623" W	69° 23' 52.285" W

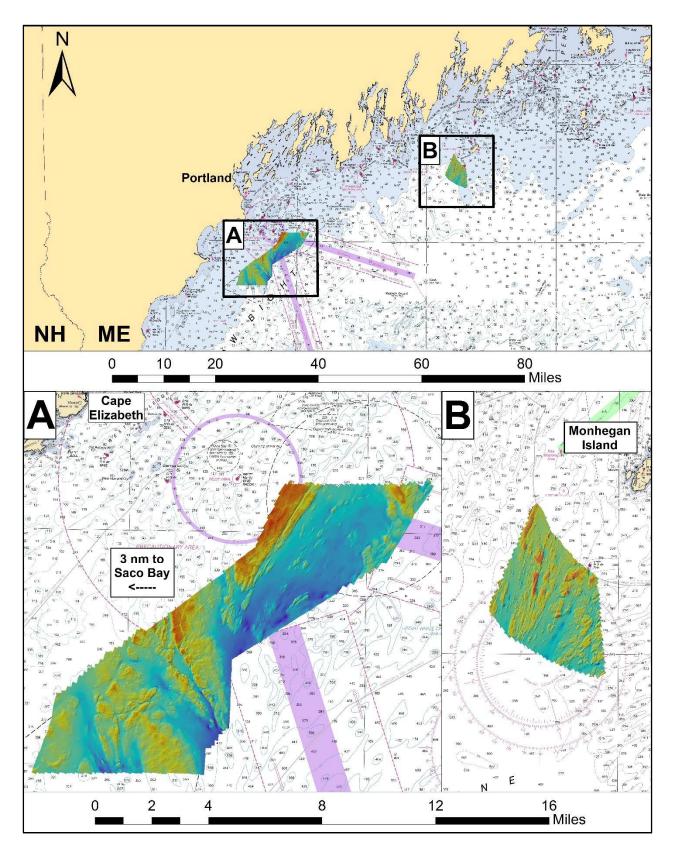


Figure 1 – General localities of 2018 - 2019 mainscheme survey coverage off southern and mid-coast Maine.

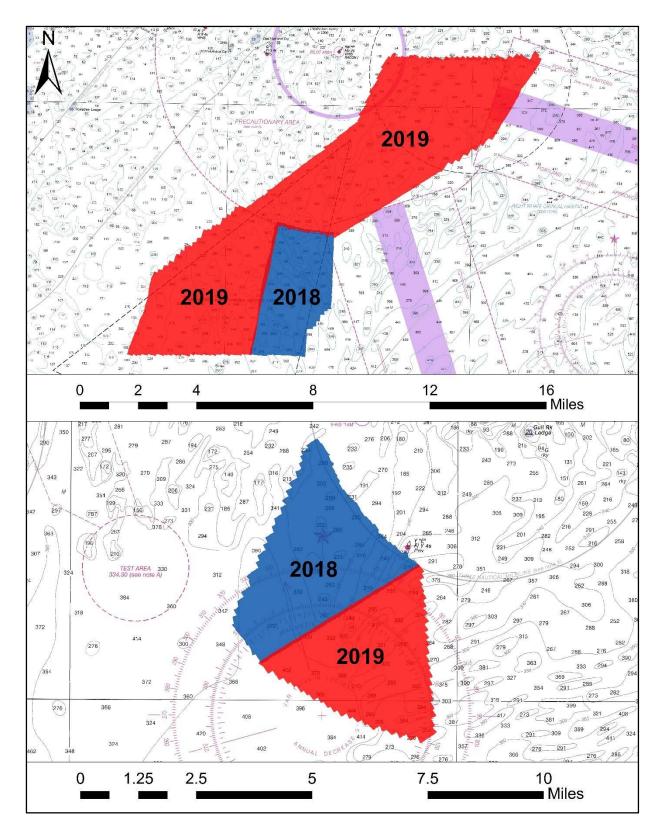


Figure 2 - 2018 - 2019 mainscheme survey coverage colored by year of data collection. The data for both survey seasons were combined, reprocessed, and analyzed for quality control as a single 2018-2019 surface for each sub-locality.

1.1 Survey Purpose

This survey was conducted by the Maine Coastal Program's Maine Coastal Mapping Initiative (MCMI) as part of a multi-agency cooperative agreement partially funded by the Bureau of Ocean and Energy Management (BOEM). The purpose of this project was to enhance coastal resiliency through identification and characterization of potential sand and gravel resources in waters of federal jurisdiction that may be used for beach replenishment. This project also coincides with state 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 13286, 13288, 13290, and 13301 in mid-coast and southern Maine. Additional objectives included habitat classification for planning purposes. 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

1.2 Survey Quality

The entire survey should be adequate to supersede previous data.

1.3 Survey Coverage

Numerous 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.

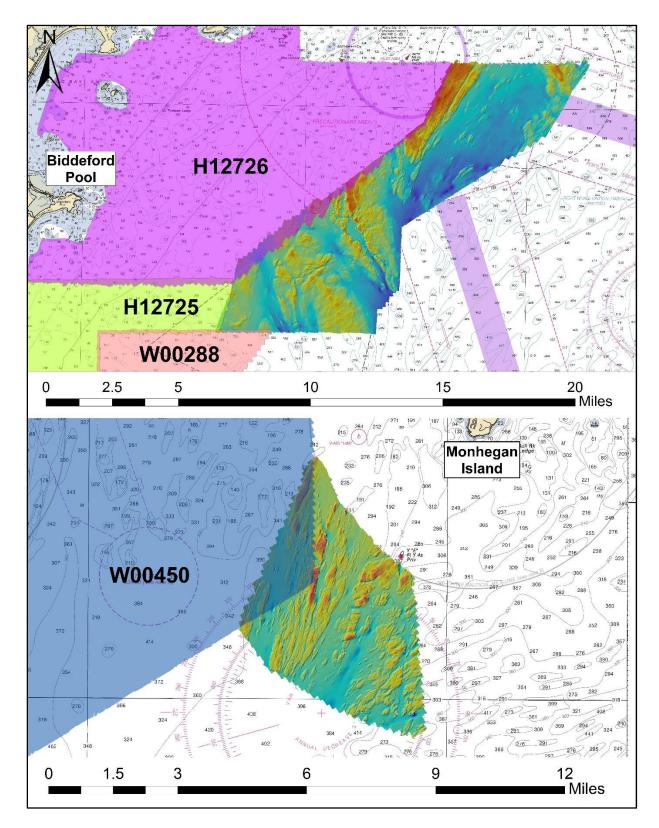


Figure 3 – 2018-2019 survey coverage relative to MCMI 2014 and 2017 surveys (NOAA survey IDs: W00288, W00450) and NOAA 2015 surveys (IDs: H12725 and H12726); plotted over RNCs 13288 and 13286, respectively

2.0 Data Acquisition

The following sub-sections contain a summary of the systems, software, and general operations used for acquisition and preliminary processing during the 2018 and 2019 survey seasons.

2.1 Survey Vessel

All data were collected aboard the Research Vessel (R/V) Amy Gale (length = 10.7 m, width = 3.81 m, draft = 0.93 m) (Figure 4), 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 based out of Boothbay Harbor, Maine and South Portland, ME. The EM2040C transducer, motion reference unit (MRU), AML Micro surface sound speed probe, and dual GNSS antennas were pole-mounted to the bow; pole raised (for transit) and lowered (for survey) via a pivot point at the edge of the bow. The main cabin of the vessel served as the data collection center and was outfitted with four display monitors for real time visualization of data during acquisition.



Figure 4 - R/V Amy Gale shown with pole-mounted dual GPS antennas, Kongsberg EM2040C multibeam sonar, 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 R/V Amy Gale during the 2018 and 2019 surveys are outlined in Table 2. Data acquisition was performed using the Quality Positioning Services (QPS) QINSy (Quality Integrated Navigation System; v.8.18.2) 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.

Table 2 – Major systems used	l aboard R/V Amy Gale
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Sub-system	Components
Multibeam Sonar	Kongsberg EM2040C and processing unit
Position, Attitude, and Heading Sensor	Seapath 330 processing unit, HMI unit, dual GPS/GLONASS antennas, MRU 5 motion reference unit (subsea bottle)
Acquisition Software and Workstation	QINSy software v.8.18.2 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 sound speed profiler
Ground-truthing/Sediment Sampling Platform	Ponar grab sampler, GoPro Hero 3+ video camera, dive light, dive lasers, YSI Exo I sonde

2.3 Vessel Configuration Parameters

In 2017, the MCMI contracted Doucet Survey, Inc. to perform high-definition (precision \pm 5mm) 3D laser scanning of the Amy Gale and all external MBES system components (e.g. MRU, GPS antennas, and EM2040C) (Figure 4). 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 5), 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 transducer (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 2018 or 2019 survey seasons. See appendices for specific settings as entered in the Seapath 330 Navigation Engine (Appendix B) and for the template database (Appendix C) used during data acquisition while online in QINSy. Configuration settings of the EM2040C were assigned in the EM Controller module of QINSy (Appendix D).

Table 3 – 2017 equipment reference frame measurements for Seapath 330

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

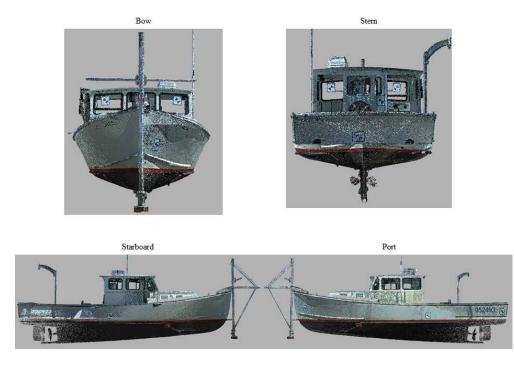


Figure 5 – Amy Gale RGB color images generated from 3D laser scan survey (GPS antennas and external cabling not included in survey) data (.pts file converted to .las for visualization)



Figure 6 – 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. Once 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 simultaneously used if any auxiliary equipment needed additional electricity. Immediately following power-up, all interfacing instruments were given time to stabilize (e.g. approximately 30-45 minutes for Seapath to acquire time tag for GPS). Next, the desired QINSy project (e.g. mainscheme, inshore, etc.) 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 a close match between the upcast and downcast data, the profile was applied to the sonar (EM2040C) in the QINSy Controller module. Data were gridded at 2-meters for real-time visualization. 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 the specifications set forth in the BOEM grant, but also met requirements for NOAA hydrographic standards (NOAA Field Procedures Manual, 2014). In the mainscheme area, parallel lines were mostly planned several days prior to surveying and run in a NE-SW or E-W pattern, depending on the location. Lines were spaced at consistent intervals to obtain a minimum of 20% 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 Quality Positioning Services 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 was acquired at approximately 6 - 6.5 knots, although some areas required slower speeds to ensure safe operation of the vessel around obstructions (e.g. fishing gear, docks, ledges, etc.).

2.6 Calibrations

Several patch tests were conducted aboard the R/V Amy Gale at the beginning of the 2018 and 2019 survey seasons to correct for alignment offsets. A second patch test was applied later in each season once verified tide data was available from NOAA. During the test, a series of lines were run to determine the latency, pitch, roll, and heading offset. The patch test data were processed using the Qimera (v.1.7.2) patch test tool. After calibration was complete, offsets (Tables 4 and 5) were entered into the template database in QINSy. Roll and heading offsets calculated for this patch test slightly differed from calibrations from each other but varied more greatly compared to previous seasons. Pitch offsets for 2019 varied significantly from previous seasons' values. 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 300KHz.

Table 4 - Initial and updated 2018 patch test calibration offsets for EM2040C

	7/30/2018	8/20/2018	
Latency (seconds)	0.06	0.01	
Roll (degrees)	-0.39	-0.39	
Pitch (degrees)	0.34	0.51	
Heading (degrees)	-0.15	-0.21	

Table 5 – Initial and updated 2019 patch test calibration offsets for EM2040C

	5/16/2019	5/28/2019
Latency (seconds)	0.01	0.01
Roll (degrees)	-0.35	-0.43
Pitch (degrees)	0.72	2.27
Heading (degrees)	-0.43	-0.30

3.0 Quality Control

3.1 Crosslines

Due to unforeseen scheduling conflicts, crosslines were not run in either mainscheme area during the 2018 field season. A late start to the field season resulting from the hire of a new hydrographer and poor weather conditions during the months of September through October were two major factors in the inability of the MCMI to conduct crosslines in 2018 survey areas. To meet the BOEM requirement, crosslines for the entire 2018 survey area were run during the 2019 season. Due to timing constraints, crosslines for the 2019 survey area were only run in areas of interest to BOEM (Figure 7).

Crosslines were run (staggered to save time on turns; in lieu of 900-meter BOEM requirement; U.S. Department of the Interior, 2014) to act as a data quality check over both years' coverage (Figure 7). Crosslines were filtered during post-processing to remove soundings greater than 45 degrees from the nadir. After filtering, the two-dimensional surface area of the crossline surfaces totaled approximately 20% of mainscheme acquisition. Crossline sounding agreement with mainscheme data was evaluated by using the crosscheck tool in Qimera v.2.1.1, which performs a beam-by-beam statistical analysis.

The mean difference between soundings was -0.006 meters with a standard deviation of 0.438 meters for the Saco Bay area and 0.071 meters with a standard deviation of 0.543 meters for the Monhegan Island area. Sounding agreement in both areas meet IHO Order 1 survey specifications according to the crosscheck tool.

95% of all differences for both survey areas were less than or equal to 1.15 meters from the mean (Figure 8). Summary statistics for this analysis are shown in Table 6 and Table 7. Additional statistical plots generated from this analysis are reported in Appendix E. Raw difference data, reference surfaces, and sonar files used for this analysis were submitted with the data in these surveys.

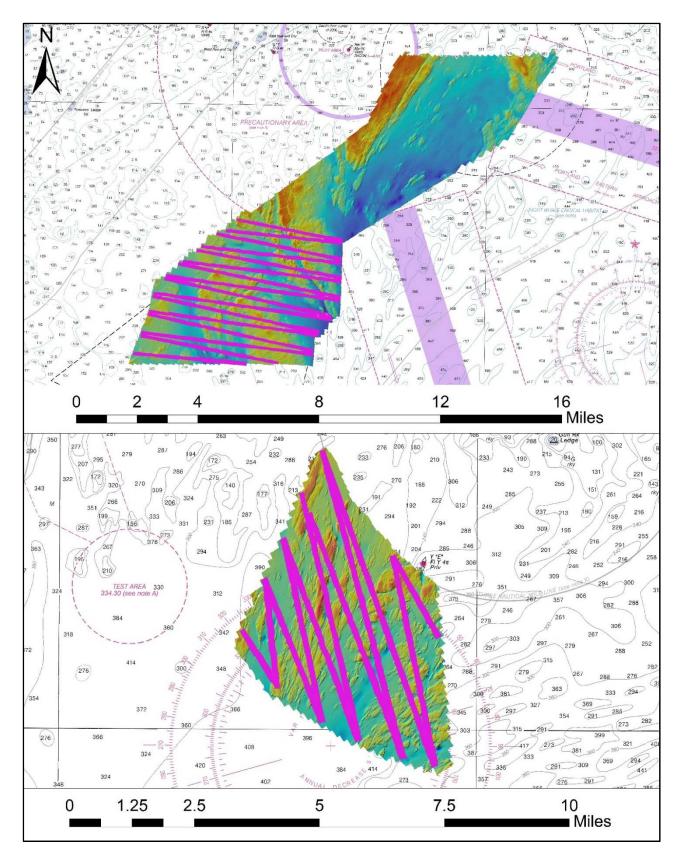
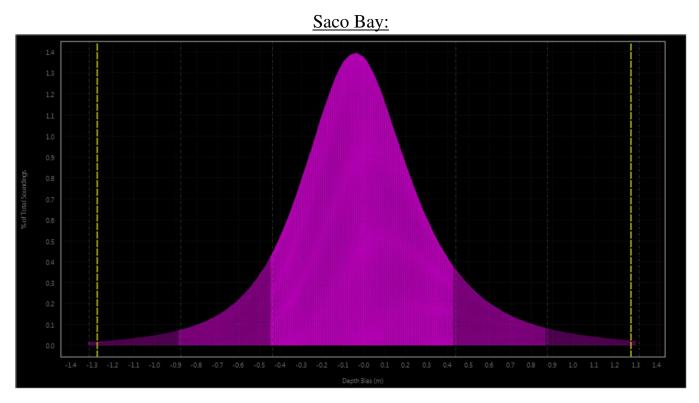


Figure 7 – Location of crosslines (shown in pink, beams filtered outside $\pm 45^{\circ}$) and mainscheme data.



Monhegan Island:

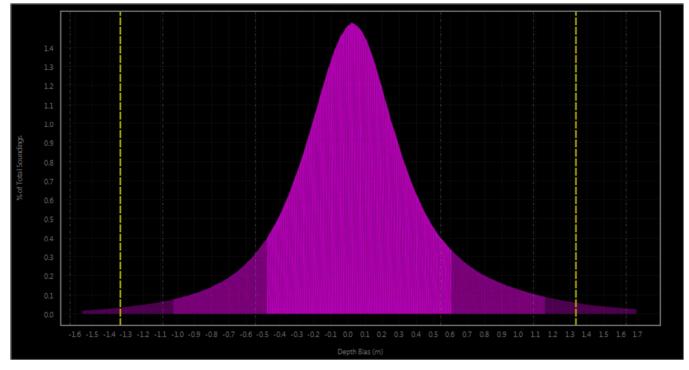


Figure 8 – 2018-2019 crosslines difference histogram; pink areas represent the 95% confidence interval based on normal distribution; yellow dashed lines represent limit of IHO Order 1 test vertical tolerance; gray dashed lines on histogram represent \pm sigma 1, 2, and 3

# of Points of Comparison	35,944,683
Data Mean	-90.286078 m
Reference Mean	-90.280010 m
Difference Mean	-0.006068 m
Difference Median	-0.026605 m
Std. Deviation	0.438126 m
Data Z - Range	-136.77 m to -47.96 m
Ref. Z - Range	-135.49 m to -48.39 m
Diff Z - Range	-16.94 m to 26.99 m
Mean + 2*stddev	0.882320 m
Median + 2*stddev	0.902857 m
Ord 1 Error Limit	1.275708 m
Ord 1 P-Statistic	0.017699 m
Ord 1 - # Rejected	636202
Order 1 Survey	ACCEPTED

Table 6 – Saco Bay survey area crossline difference (Qimera crosscheck) summary statistics

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

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Table 7 – Monhegan Island survey area crossline difference (Qimera crosscheck) summary statistics

# of Points of Comparison	20,298,902
Data Mean	-95.157647 m
Reference Mean	-95.229265 m
Difference Mean	0.071618 m
Difference Median	0.046148 m
Std. Deviation	0.543356 m
Data Z - Range	-131.56 m to -59.81 m
Ref. Z - Range	-132.11 m to -60.48 m
Diff Z - Range	-13.77 m to 17.87 m
Mean + 2*stddev	1.158330 m
Median + 2*stddev	1.132860 m
Ord 1 Error Limit	1.335139 m
Ord 1 P-Statistic	0.032928
Ord 1 - # Rejected	668410
Order 1 Survey	ACCEPTED

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

3.2 Junctions

The junctions shown in Table 8 were made with this survey. Survey W00450 was conducted by the Maine Coastal Program's Mapping Initiative aboard the Amy Gale in 2017. The areas of overlap between the 2018-2019 survey and the junction survey (NOAA survey ID W00450, currently in review) were evaluated for sounding agreement by performing surface (4-meter resolution) difference tests in Fledermaus (v.7.8.6, 64-bit), where the junctioning surface (2017) was subtracted from the new 2018-2019 surface. A summary of surface difference test results is shown in Table 9. The extent of overlap between the 2017 base surface and the corresponding 2018-2019 junction surface is illustrated in Figure 9. The surfaces used for these tests are submitted with the data in these surveys.

Survey W00288 was conducted by the Maine Coastal Program's Mapping Initiative aboard the Amy Gale in 2014. The areas of overlap between the 2018-2019 survey and the junction survey (NOAA survey ID W00288) were evaluated for sounding agreement by performing surface (8-meter resolution) difference tests in Fledermaus (v.7.8.6, 64-bit), where the junctioning surface (2014) was subtracted from the new 2018-2019 surface. A summary of surface difference test results is shown in Table 9. The extent of overlap between the 2014 base surface and the corresponding 2018-2019 junction surface is illustrated in Figure 10. The surfaces used for these tests are submitted with the data in these surveys.

Surveys H12725 and H12726 were conducted by NOAA aboard the Ferdinand R. Hassler in 2015. The areas of overlap between the 2018-2019 survey and the junction surveys (NOAA survey IDs H12725 and H12726) were evaluated for sounding agreement by performing surface (8-meter and 4-meter resolution, respectively) difference tests in Fledermaus (v.7.8.6, 64-bit), where the junctioning surfaces (2015) were subtracted from the new 2018-2019 surface. A summary of surface difference test results is shown in Table 9. The extent of overlap between the 2015 base surfaces and the corresponding 2018-2019 junction surface is illustrated in Figure 10. The surfaces used for these tests are submitted with the data in these surveys.

Registry Number	Grid Resolution	Mainscheme area	Year	Field Unit	Relative Location(s)
W00288	8 meters	Saco Bay	2014	AMY GALE	W and S
H12725	8 meters	Saco Bay	2015	FERDINAND R. HASSLER	W
H12726	4 meters	Saco Bay	2015	FERDINAND R. HASSLER	W and N
W00450	4 meters	Monhegan Island	2017	AMY GALE	W and N

Table 8 – 2018-2019 mainscheme survey junctions

Junction Surface ID	New Surface ID	Median (m)	Mean (m)	Std. Dev. (m)
W00288_MB_8m_MLLW_ Combined	MCMI_2018_2019_SacoBay_updated _8m_MLLW	-0.05	-0.04	0.25
H12725_MB_8m_MLLW_ Combined	MCMI_2018_2019_SacoBay_updated _8m_MLLW	0.04	0.02	0.37
H12726_MB_4m_MLLW_ Combined	MCMI_2018_2019_SacoBay_updated _4m_MLLW	0.03	0.04	0.42
MCMI_2017_mainscheme_ 4m_mllw	MCMI_2018_2019_Monhegan_4m_M LLW	0.00	0.01	0.55

Table 9 – Summary of surface difference test results for overlapping (junction) surveys

Several factors are thought to contribute to the high standard deviation in the overlapping Monhegan Island area surveys: poor agreement in rocky areas, filtering procedures, and survey conditions (e.g. weather and sea state). The most disagreement between surfaces was in areas with a steep, rocky seabed.

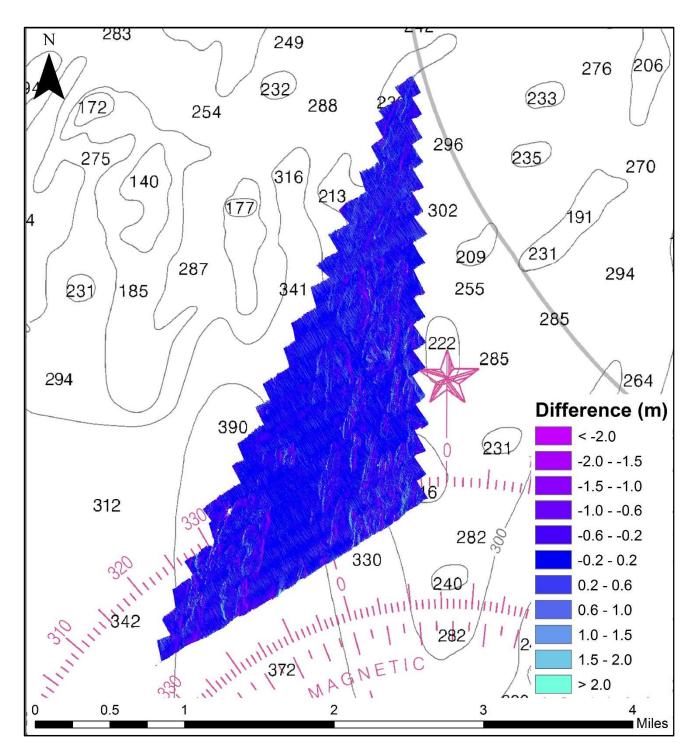


Figure 9 – Junctioning areas between W00450 and 2018-2019 Monhegan Island mainscheme survey (4-meter surfaces) shown as surface difference results; scale is 1:25,000.

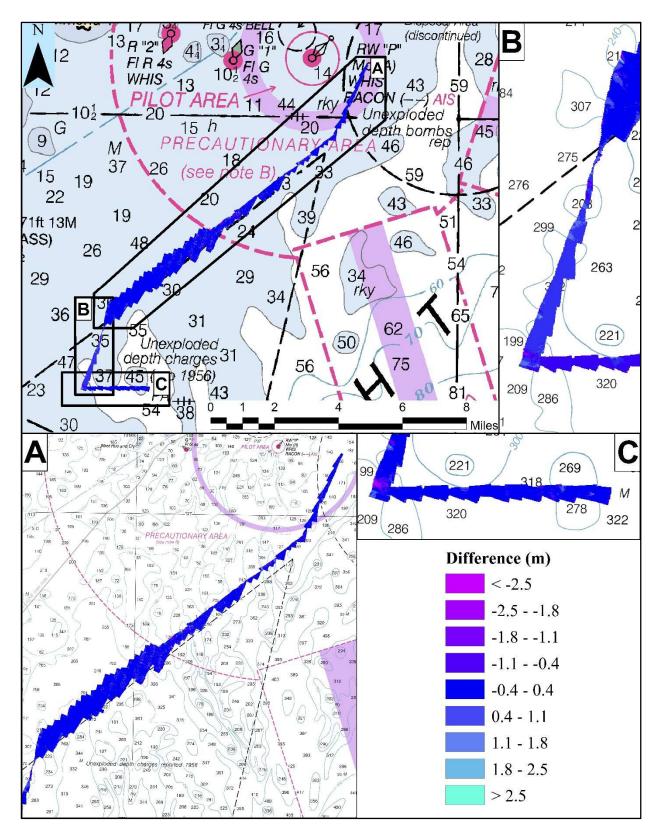


Figure 10 – Junctioning areas between H12726 (A), H12725 (B), W00288 (C), and 2018-2019 mainscheme survey; (4-meter and 8-meter surfaces) shown as surface difference results; scale in A is 1:30,000; scale in B and C is 1:10,000

3.3 Equipment Effectiveness

<u>Sonar</u>

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 year's 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 as per QPS recommendation), soundings greater than ± 60 degrees from the nadir were not included in final bathymetric surfaces.

Hydrographic Workstation

Prior to October 2018, a BIOS setting related to CPU power throttling on the hydrographic workstation PC created brief (<1 second) and semi-regular losses of QINSy's time sync status (e.g. PPS time tagging of incoming data) while recording data. Troubleshooting of this problem was successful prior to all surveying conducted in October 2018 and thereafter.

3.4 Sound Speed Methods

Sound speed cast frequency: A total of 70 sound speed casts were taken within the boundaries of the 2018 and 2019 mainscheme surveys. All sound speed cast measurements were collected using the Teledyne Odom Digibar S profiler. Sound speed casts were taken as needed throughout the survey, which was generally when the observed surface sound speed (monitored and visualized in real-time using the AML MicroX SV sensor) differed from the surface sound speed in the active profile by more than 2 meters per second. In certain instances, supplemental casts were taken when there was reason to suspect significant changes in the water column (e.g. change in tide, abrupt changes in seafloor relief, etc.). 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). Although sound speed data were recorded in raw sonar files, the raw sound velocity profiles (.csv) were also submitted with the survey data.

A quality comparison between the AML Micro X SV sensor and the Teledyne Odom Digibar S profiler 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 the Digibar S profile suggested these instruments were in agreement.

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.2.1.1, 64-bit edition) and Fledermaus (v.7.8.6, 64-bit edition) software.

4.1 Horizontal Datum

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

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 (.zdf; provided by NOAA CO-OPS) containing time and range corrections for verified data referenced from the Wells, ME (8419317) tide gauge was applied to all areas surveyed (Figure 11). Time corrections, tide height offsets, and tide scale (range) for each zone are listed in Table 10.

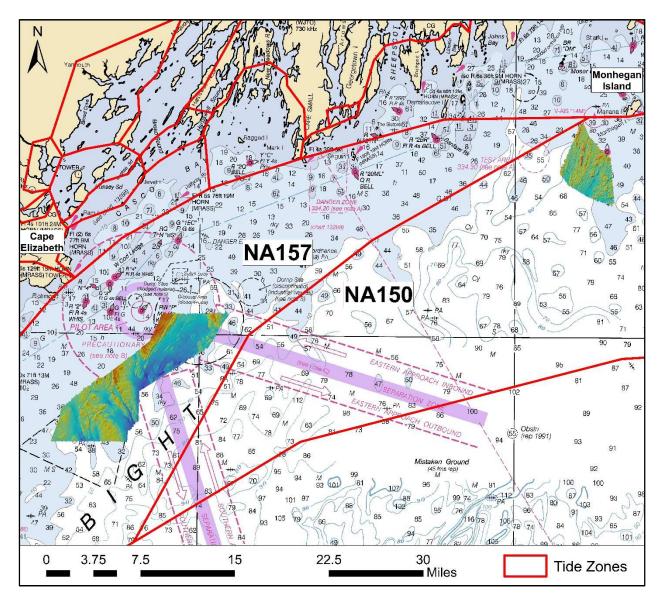


Figure 11 – Tide zones (outlined in red) relative to 2018-2019 mainscheme survey extent. Map scale 1:75,000.

Zone ID	Time Correction (mins.)	Tide Offset (m)	Tide Scale	Survey Area
NA150	-6	0	0.95	Mainscheme
NA157	-6	0	0.95	Mainscheme

Table 10 – Tide zones and corrections referenced to verified Wells (8419317)

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. Add tide zoning file (.zdf) and associated tide data and integrate into raw files
- 4. Create dynamic surface with NOAA_4m CUBE settings enabled
- 5. Review and edit soundings/clean surface with 3D editor tool
- 6. Duplicate surfaces at other grid sizes, if desired
- 7. Export final surface to .BAG file and CUBE surface
- 8. 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 'NOAA_4m' configuration (Figure 11) was selected for each surface. The mainscheme survey was gridded at 4 meters based on the average depth of the area and in accordance with NOAA's survey recommendations (NOAA, 2014).

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(Distance Mir	n: 2.828		
CUBE Hypothesis Resoluti	on Algorithm :	Number of Samples		
Estimate Offset:		4.00		
Horizontal Error Scale:		1.96		
Advanced < <				
Advanced << Distance Exponent:	2.00			
	2.00			
Distance Exponent:				
Distance Exponent: Queue Length:	11			
Distance Exponent: Queue Length: Quotient Limit:	11 255.00			

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

4.4 Final Surfaces

The following surfaces and BAGs were submitted with the survey data.

Surface Name	Resolution (m)	Depth Range (m)	Surface Parameter
MCMI_2018_2019_SacoBay_updated_2m_mllw	2	39 - 136	N/A
MCMI_2018_2019_SacoBay_updated_4m_mllw	4	38 - 136	N/A
MCMI_2018_2019_SacoBay_updated_8m_mllw	8	38 - 136	N/A
MCMI_2019_crosslines_SacoBay_4m_mllw	4	49 - 136	N/A
MCMI_2018_2019_Monhegan_2m_mllw	2	57 - 142	N/A
MCMI_2018_2019_Monhegan_4m_mllw	4	57 - 142	N/A
MCMI_2018_2019_Monhegan_8m_mllw	8	57 - 142	N/A
MCMI_2019_crosslines_Monhegan_4m_mllw	4	61 - 128	N/A

4.5 Backscatter

Backscatter was logged in the raw .db files. 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 v.2.1.1. in .GSF format. QPS Fledermaus Geocoder Toolbox (FMGT; v.7.8.6, 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 and AVG window size, which were set to 'Adaptive' and '100', respectively. Backscatter mosaics of the data were gridded at 4-meter resolution and exported in greyscale and floating-point GeoTIFF format. The mosaics are shown in Table 12 and Figure 13. The GSF files containing the extracted were submitted with the data in this survey. Processed mosaics (Table 12) were also saved in geoTiff format and submitted.

Table 12 - Backscatter mosaics submitted with 2018-2019 survey data

Mosaic Name	Pixel Size (m)
MCMI_2018_2019_mainscheme_SacoBay_backscatter_db_4m.tif	4
MCMI_2018_2019_mainscheme_Monhegan_backscatter_db_4m.tif	4
MCMI_2018_2019_mainscheme_all_backscatter_db_4m.tif	4
MCMI_2018_2019_mainscheme_SacoBay_backscatter_gs_4m.tif	4
MCMI_2018_2019_mainscheme_Monhegan_backscatter_gs_4m.tif	4
MCMI_2018_2019_mainscheme_all_backscatter_gs_4m.tif	4

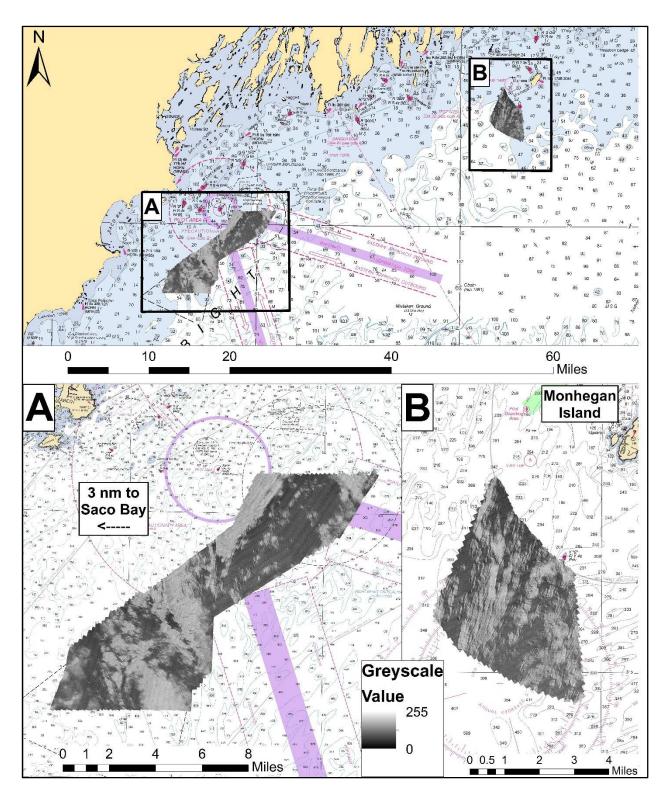


Figure 13 – Backscatter mosaic (4-meter pixel size) of 2018-2019 mainscheme surveys.

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 13. Prior hydrographic surveys in the vicinity were conducted by NOAA between 1888 and 1954 and consisted only of partial bottom coverage. These data were not compared with data collected by the MCMI.

Chart	Scale	Source Edition	Source Date	NTM Date
13301	1:40,000	22	12/11/2018	12/11/2018
13288	1:80,000	44	3/1/2016	2/20/2020
13290	1:40,000	41	10/9/2019	2/20/2020
13286	1:80,000	34	3/19/2019	1/9/2020

Table 13 – Largest scale raster charts in survey area

Chart 13301

A small portion of the Monhegan Island survey area coincides with chart 13301. Surveyed depths have good overall agreement with charted contours and soundings (Figure 14), although individual soundings may disagree at any given location.

Chart 13288

The entire Monhegan Island survey area and approximately one-third of the Saco Bay survey area coincide with chart 13288. Charts with scales 1:80,000 (and smaller) inherently contain very generalized contours. As shown in Figure 15 and Figure 17, the agreement between chart contours and new survey data (reclassified at 60 feet intervals; same as chart) is generally good at depths less than 240 feet (73.1 meters). Agreement becomes increasingly poor at depths beyond 240 feet throughout the surveyed area. This disagreement is likely due to the low resolution and lack of full bottom coverage during prior surveys rather than over generalization. It is recommended that contours within the survey area be revised.

Chart 13290

A small portion of the Saco Bay survey area coincides with chart 13290. Surveyed depths have good overall agreement with charted contours and soundings (Figure 16), although individual soundings may disagree at any given location.

Chart 13286

The entire Saco Bay survey area coincides with chart 13286. Charts with scales 1:80,000 (and smaller) inherently contain very generalized contours. As shown in Figure 18, the agreement between chart contours and new survey data (reclassified at 60 feet intervals; same as chart) is generally good at depths less than 420 feet (128 meters). However, since a relatively small total surface area deeper than 420 feet exists in the survey area, this disagreement could be considered negligible.

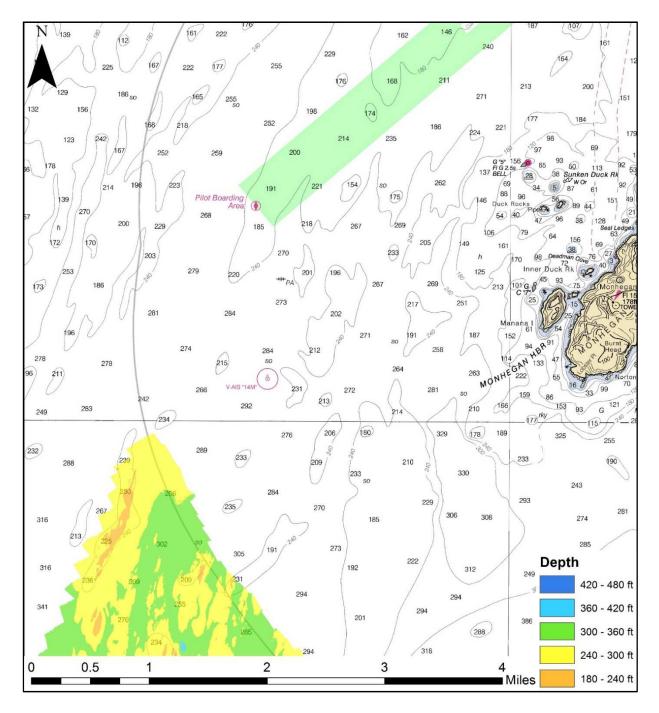


Figure 14 – Comparison between surveyed depth in Monhegan Island area (reclassified at 60-feet intervals) and chart 13301 (scale: 1:40,000, 60-feet contour intervals)

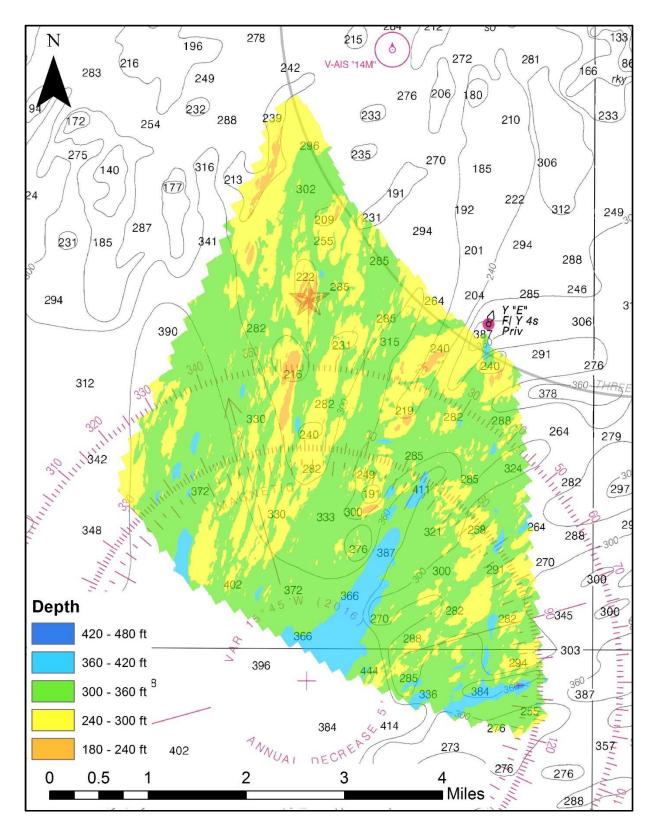


Figure 15 – Comparison between surveyed depth in Monhegan Island area (reclassified at 60-feet intervals) and chart 13288 (scale: 1:80,000, 60-feet contour intervals)

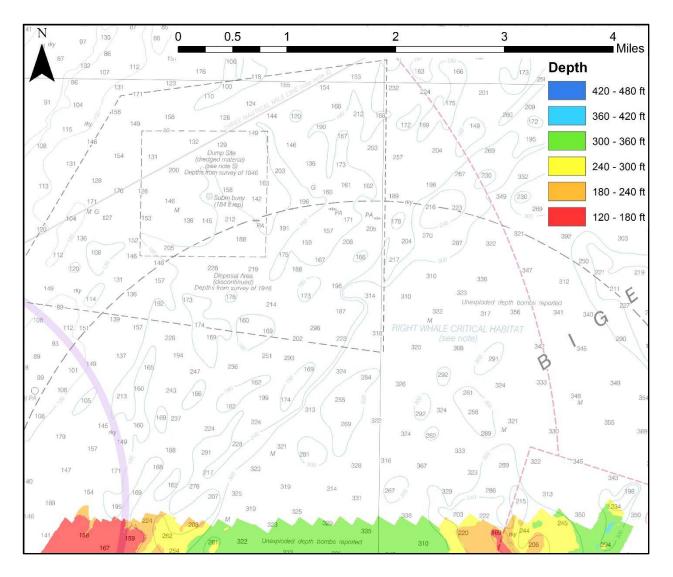


Figure 16 – Comparison between surveyed depth in Saco Bay area (reclassified at 60-feet intervals) and chart 13290 (scale: 1:40,000, 60-feet contour intervals)

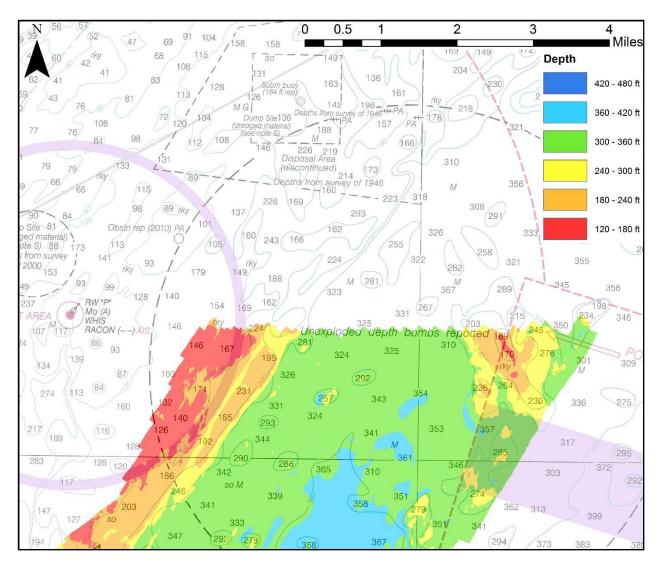


Figure 17 – Comparison between surveyed depth in Saco Bay area (reclassified at 60-feet intervals) and chart 13288 (scale: 1:80,000, 60-feet contour intervals)

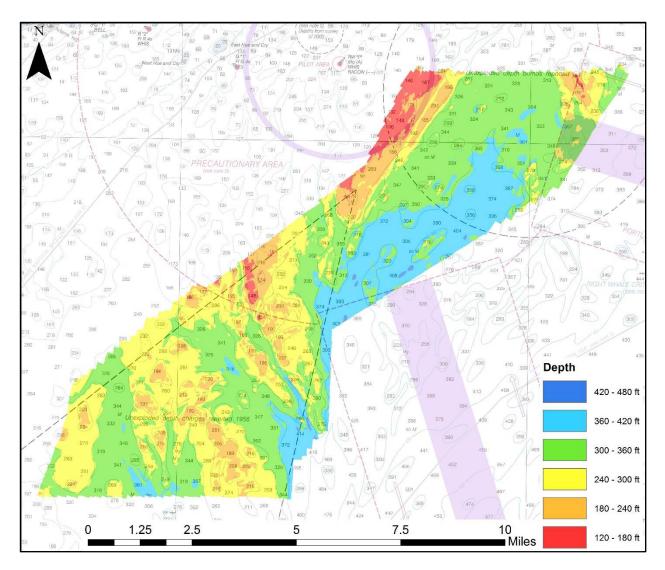


Figure 18 – Comparison between surveyed depth in Saco Bay area (reclassified at 60-feet intervals) and chart 13286 (scale: 1:80,000, 60-feet contour intervals)

6.0 Summary

A total of approximately 71 mi² (184 km²) of high-resolution multibeam data were collected in the mainscheme survey areas by MCMI from August to November of 2018 and April to August of 2019. Except for numerous small holidays, multibeam coverage was 100% in all areas surveyed. Survey data were processed with 4-meter grid resolution, although 2-meter and 8-meter surfaces were also generated for submission with this report. The consistency of hydrographic data collected aboard the R/V Amy Gale was reflected in the results of the surface difference tests between junction survey data, where mean vertical differences for all tests were less than 0.1 meters. Standard deviations of all tests were relatively low and comparable to those achieved by small NOAA vessels (e.g. *Ferdinand R. Hassler*) for similar surveys in Maine's coastal waters. Comparisons between these survey data and the largest scale nautical charts in the immediate vicinity show good overall agreement except for in surveyed areas at depths greater than 73 meters (locality off Monhegan Island) and 120 meters (locality off Saco Bay). Overall, these data are of sufficient quality to supersede previous data collected in the vicinity. It is recommended that the corresponding charts be updated to reflect these data.

MCMI has utilized final data products for high-resolution backscatter and bathymetry to refine existing seafloor sediment maps and determine the spatial extent of sand deposits within federal water. When combined with existing geophysical (e.g. seismic reflection profiles and side-scan sonar) data, these data may also be used to refine interpretations of coastal/nearshore geomorphology and three-dimensional assessments of potential sediment resources/valley fill in the region. In addition, these data are a critical component of benthic habitat classification and modeling performed by MCMI. Overall, these data have a variety of applications and are an invaluable resource to public and private agencies who wish to more effectively manage and understand coastal and marine resources.

These data were acquired and processed to meet Office of Coast Survey bathymetry standards as best as possible and were shared with the UNH-NOAA Joint Hydrographic Center / Center for Coastal and Ocean Mapping for review.

Please contact the Maine Coastal Mapping Initiative for additional information or data requests.

References

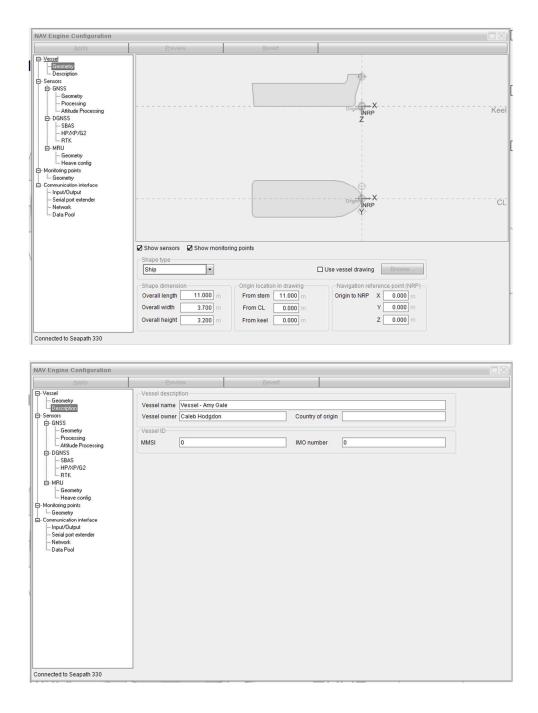
NOAA, 2014. NOS hydrographic surveys specifications and deliverables: U.S Department of Commerce National Oceanic and Atmospheric Administration. Page 89.

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 for mainscheme surveys

Mainscheme
08/01/18
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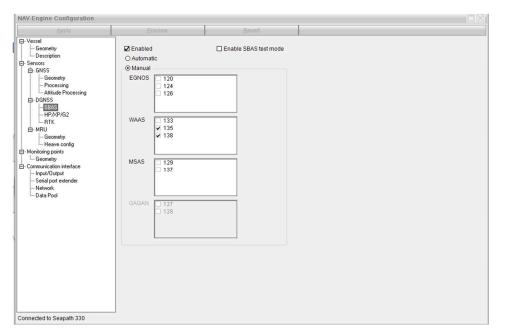
Appendix B – 2018-2019 Configuration settings for Sea path 330



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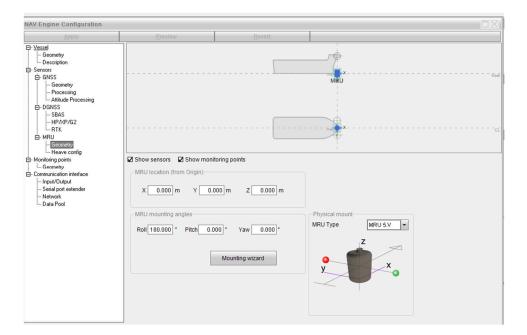
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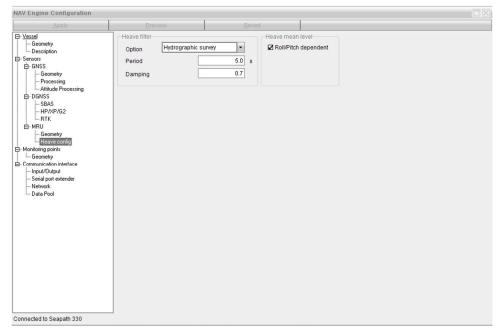
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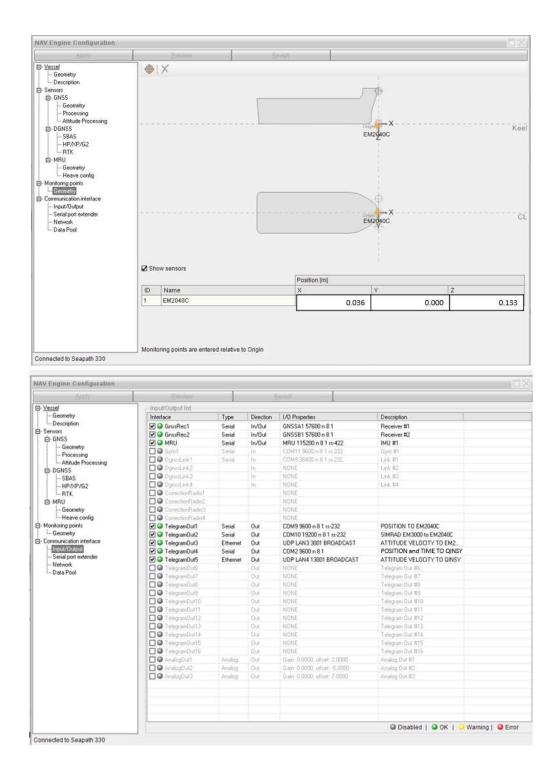


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Appendix C – Template database settings in QINSy (for acquisition)

Note: Only the 2019 template database is shown in this appendix. The 2018 and 2019 template databases are identical with the exception of EM2040C calibration offsets (e.g. pitch, roll, and heading). These differences and their historical values across the two years' survey seasons are summarized in table 4 of report's main text.

Template database name: AmyGale_2019.db

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

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AmyGale 2019.db - Database Setup Program ie Edit View Options Help Survey General Geodetic Codedtic Charl Datums Charl Datum / Vertical Datum Charl Daturs Digital Terrain Models Digital Terrain	System: AML Description: 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:	SV probe AML SV probe Underwater Sensor Sound Velocity - Smart SV (AML, ASCII) (Active) Dr.SoundVelocity-exe ACT 8 9600 8 1 1 None 10 bits (1.042 ms) 960 bytes / second 0.000 s 0.000 s [Directly into QINSy] (No additional time tags) N/A	
AmyGale_2019.db - Database Setup Program ite Edit View Options Help Survey General Geodetic Datums Chart Datum / Vertical Datum Heights Digital Terain Models Projections Universal Transverse Mercator (North Hemisphere) Local Construction Grid Digital Terain Models Digital Terain Model	System: AML Description: 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:	SV probe AML SV probe Underwater Sensor Sound Velocity - Smart SV (AML, ASCII) (Active) Dr.SoundVelocity-exe ACT 8 9600 8 1 1 None 10 bits (1.042 ms) 960 bytes / second 0.000 s 0.000 s [Directly into QINSy] (No additional time tags) N/A	
AmyGale 2019.db - Database Setup Program le Edit View Options Help Survey General General Charl Datum / Vertical Datum Men Water Level Model Digital Terrain Models Projections Universal Transverse Mercator (North Hemisphere) Cost Construction Grid Diriversal Transverse Mercator (North Hemisphere) Cost Construction Grid Surde Velocity Profile Sound Velocity Profile System System System System System Amilion Systems Amilion Systems Transverse Mercator System Statistic Rode RRU RX Amilion Systems Time Synce Amilion Systems Time Synce Market Systems Time Synce Market Systems Time Synce Market Systems Systems Time Synce Market Systems Systems Systems Time Synce Market Systems Systems Subale Node Systems Subale Node Systems Subale Node Systems Systems Subale Node Systems Subale Node Systems Systems Subale Node Systems Subale Node Systems	System: AML Description: 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:	SV probe AML SV probe Underwater Sensor Sound Velocity - Smart SV (AML, ASCII) (Active) Dr.SoundVelocity-exe ACT 8 9600 8 1 1 None 10 bits (1.042 ms) 960 bytes / second 0.000 s 0.000 s [Directly into QINSy] (No additional time tags) N/A	
AmyGale 2013.db - Database Setup Program E Edit View Options Help Survey General General General Heights Database Setup Program General General Database Setup Program Model Database Setup Program Digital Transverse Mercator (North Hemisphere) 	System: AML Description: 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:	SV probe AML SV probe Underwater Sensor Sound Velocity - Smart SV (AML, ASCII) (Active) Dr.SoundVelocity-exe ACT 8 9600 8 1 1 None 10 bits (1.042 ms) 960 bytes / second 0.000 s 0.000 s [Directly into QINSy] (No additional time tags) N/A	

🚱 🍉 🎾 🍗 🧰 🕍 🎯 🧠 🕅 👌 Survey	
🕜 General 🐔 Geodetic	Observation: Sound Velocity
G Datums G WGS84 ⊕-∰ Heights	Observation description: Sound Velocity Observation type: Sound Velocity 'At' node: Amy Gale MRU
- 🚁 Chart Datum / Vertical Datum	Measurement unit code: Meters / Second System description: AML SV probe
Digital Terrain Models Projections Suniversal Transverse Mercator (North Hemisphere) Leal Construction Grid Uric GPS Correction Sound Velocity Profile Object	Jystem Idextripuoli Amit. 29 proces (C-O) option; (C-O) option; Scale factor: 1.00000000000 Fixed system (C-O); 0.000000000 Variable (C-O); 0.00000000 Apriori SD; 0.0000000
Many Gale System Sound Velocity → & MM SV probe → & Sound Velocity → & WaddeC → & Gyro ↓ Pritch Roll Heave Sensor ↓ Porition Navigation System → Variable Node → Arm Gale MRU → RX ↓ RX	

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) 😂 🏓 🥍 🍗 🎰 🏏 🎯 🎭 🕅 🕴				
Urvey	System: EM2040C			
🗄 🔏 Geodetic	Description:	EM2040C		
Datums	Туре:	Multibeam Echosounder		
⊖ ∰ 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		
Projections	Update rate:	0.000 s		
	Acquired by:	[Directly into QINSy] (No additional time tags)		
- O UTC to GPS Correction	Observation time from:	N/A		
C Sound Velocity Profile	Number of slots:	1		
Object				
Amy Gale	Manufacturer:	Kongsberg		
🖨 🔚 System	Model:	EM2040C		
AML SV probe	Object location:	Amy Gale		
	Node name:	RX		
⊖ Ø Gyro	X (Stbd = Positive)::	0.000 m		
Gyro	Y (Bow = Positive)::	-0.045 m		
	Z (Up = Positive)::	0.006 m		
Position Navigation System	A-priori SD:	0.010 m		
G→ Variable Node	Roll offset:	-0.430		
	Pitch offset:	2.270		
	Heading offset:	-0.300		
- 8 Link	Unit is roll stabilized:	No		
Auxiliary Systems	Unit is pitch stabilized:	No		
Time Sync	Unit is heave compensated:	No		
EM2040C Controller D⇒ ASCII Logger	Beam steering (flat transducer):	No		
Fixed Node	Beam angle width along:	1.500 m		
4	Beam angle width across:	1.500 m		
	Maximum number of beams per ping:	800		
	Use sound velocity from unit:	Yes		
	Slot:	1		
	Sound velocity for beam angle:	Sound Velocity		
	SD type:	Pulse, Sampling		
	SD pulse length:	0.150 ms		
	SD sampling length:	0.050 m		
	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		

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Survey	System: Gyro			
a Geodetic	Description:	Gyro		
G Datums	Type:	Gyro Compass		
⊖ ∰ Heights	Driver:	Network - Seapath Binary Format 11 (Hdg) (With UTC)		
Chart Datum / Vertical Datum	Executable and Cmdline:	DrvQPSCountedUDP.exe SEAPATH_FMT11 PPS		
	Port:	13001		
📩 📩 Digital Terrain Models	Update rate:	0.000 s		
Projections	Latency:	0.010 s		
Universal Transverse Mercator (North Hemisphere) Local Construction Grid	Acquired by:	[Directly into QINSy] (No additional time tags)		
- UTC to GPS Correction	Observation time from:	N/A		
C Sound Velocity Profile	Number of slots:	0		
Object	Number of slots:	v		
Amy Gale				
System				
AML SV probe				
Sound Velocity MEM2040C				
E-Ø Gyro				
Gyro				
Pitch Roll Heave Sensor				
Position Navigation System				
□ ¥ Variable Node				
Amy Gale MRU				
@ RX				
⊚ TX				
B Link				
Auxiliary Systems				
- 💍 Time Sync				
EM2040C Controller				
- 🕩 ASCII Logger				
Fixed Node				

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Survey	Observation	: Gyro	
Geodetic	Observation description:		
🖶 🌗 Datums	Observation type:	Bearing (True)	
₩G584	2502		
🖻 🛣 Heights	'At' node:	Amy Gale MRU	
- 🛣 Chart Datum / Vertical Datum	Measurement unit code:		
Digital Terrain Models	System description:	Gyro	
Projections	(C-O) option:	(C-O) offsets applied first	
Universal Transverse Mercator (North Hemisphere)	Scale factor:	1.00000000000	
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			
B System AML SV probe			
Sound Velocity			
T EM2040C			
⊡ Ø Gyro			
Gyro			
Pitch Roll Heave Sensor			
2 Position Navigation System			
🖕 🔆 Variable Node			
- 🕀 Amy Gale MRU			
@ RX			
G TX ■ B Link			
Auxiliary Systems			
Ö Time Sync			
EM2040C Controller			
D+ ASCII Logger			
🗧 Fixed Node			

Survey	System: Pitch Roll	Heave Sensor
Geodetic	Description:	Pitch Roll Heave Sensor
Datums	Type:	Pitch Roll Heave Sensor
WG584	Driver:	Network - Seapath MRU Binary Format 11 (With UTC)
📄 🤹 Heights 🚔 🖄 Chart Datum / Vertical Datum	Executable and Cmdline:	DrvQPSCountedUDP.exe SEAPATH_FMT11 PPS
Mean Water Level Model	Port:	13001
🚁 Digital Terrain Models	service executive reservices	13001 0.000 s
Projections	Update rate:	
Universal Transverse Mercator (North Hemisphere)	Latency:	0.010 s
Local Construction Grid	Acquired by:	[Directly into QINSy] (No additional time tags)
👸 UTC to GPS Correction 	Observation time from:	N/A
Object	Number of slots:	0
Amy Gale	Object:	Amy Gale
System	PRH sensor reference number:	1
🖶 🧵 AML SV probe	Rotation convention pitch:	Positive bow up
Sound Velocity	Rotation convention roll:	Positive heeling to starboard
	Angular variable measured:	HPR (roll first)
i i i i i i i i i i i i i i i i i i i	Angular measurement units:	Degrees
Pitch Roll Heave Sensor	Sign convention heave:	Positive upwards
1 Position Navigation System	Measurement unit heave:	Meters
🖕 🏹 Variable Node	Conversion factor to degrees decimal:	N/A
Amy Gale MRU	Conversion factor to metres:	N/A
	Quality indicator type pitch and roll:	No quality info recorded
Link	Quality indicator type heave:	No quality info recorded
Auxiliary Systems	Description of quality indicator type:	
💍 Time Sync	Object location:	Amy Gale
EM2040C Controller	Node name:	Amy Gale MRU
	X (Stbd = Positive)::	0.000 m
- Fixed Node	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
	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:	0.50 *
	SD heave offset:	0.050 m
	SD neave onset:	11 000

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	Node: Am	ny Gale MRU
Geodetic	h	
🖨 🐠 Datums	Object location:	Amy Gale
	Node name:	Amy Gale MRU
🕀 🛣 Heights	X (Stbd = Positive)::	
🚽 Chart Datum / Vertical Datum	Y (Bow = Positive)::	
igital Terrain Models	Z (Up = Positive)::	
Projections	A-priori SD:	0.000 m
- 🔣 Universal Transverse Mercator (North Hemisphere)		
Local Construction Grid		
Sound velocity Profile Object		
Amy Gale		
🛓 🌆 System		
📄 🗓 AML SV probe		
Sound Velocity		
∰ EM2040C ⊟∲ Gyro		
i i i i i i i i i i i i i i i i i i i		
Hitch Roll Heave Sensor		
Position Navigation System		
A Variable Node		
e TX		
B Link		
Auxiliary Systems		
- 💩 Time Sync		
EM2040C Controller		
└──D→ ASCII Logger └──┬ Fixed Node		
	3	
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E-III General	Node: RX			1
E Geodetic	Constance in the second s			
Datums	Object location:	Amy Gale		
WG584	Node name:	RX		
🖻 🛣 Heights	X (Stbd = Positive)::			
- 🛣 Chart Datum / Vertical Datum	Y (Bow = Positive)::	-0.045 m		
	Z (Up = Positive)::	0.006 m		
	A-priori SD:	0.010 m		
Universal Transverse Mercator (North Hemisphere)				
Local Construction Grid				
O UTC to GPS Correction				
Cound Velocity Profile				
Barrier Constant State S				
System				
AML SV probe				
Sound Velocity				
i ⊕-Ø [®] Gyro ↓ ↓ ´ Gyro				
Pitch Roll Heave Sensor				
Position Navigation System				
⊢ ↓ Variable Node				
© IX				
Auxiliary Systems				
Time Sync				
D+ ASCII Logger				
Fixed Node				
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rorrep, press 12				

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Survey	Node: TX			
Geodetic		An and the		
🛓 💮 Datums	Object location:	Amy Gale		
	Node name:	TX		
🖻 🛣 Heights	X (Stbd = Positive)::	0.040 m		
- 🚖 Chart Datum / Vertical Datum	Y (Bow = Positive)::	0.004 m		
Digital Terrain Models	Z (Up = Positive)::	0.006 m		
Projections	A-priori SD:	0.010 m		
- 🔣 Universal Transverse Mercator (North Hemisphere)				
Local Construction Grid				
- O UTC to GPS Correction				
k∑ Sound Velocity Profile ⊟ +∄ Object				
🛓 🏭 System				
🚊 🕃 AML SV probe				
Sound Velocity				
⊡\$\$° Gyro └─↓` Gyro				
₩ Pitch Roll Heave Sensor				
Position Navigation System				
⊢				
• • • • • • • • • • • • • • • • • • •				
Auxiliary Systems				
Time Sync				
EM2040C Controller				
□→ ASCII Logger				
Fixed Node				
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i or neip, press ra				

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🖸 🎱 i 🦫 🎾 🍖 💼 🥍 🎯 🧠 i 🕅		
Gameral	System: Time Sync	
Geodetic	Description:	Time Sync
- 🚱 Datums	Type:	Time Synchronization System
	Driver:	NMEA ZDA
🖶 🏦 Heights 🗌 🚽 🏂 Chart Datum / Vertical Datum	Executable and Cmdline:	DrvPositionNMEA.exe
Mean Water Level Model		
Digital Terrain Models	Port:	2
🖨 🐻 Projections	Baud rate:	9600
- Universal Transverse Mercator (North Hemisphere)	Data bits:	8
Local Construction Grid	Stop bits:	1
0 UTC to GPS Correction	Parity:	None
Sound Velocity Profile	Byte frame length (time):	10 bits (1.042 ms)
🛓 📴 Amy Gale	Maximum data transfer rate:	960 bytes / second
System	Update rate:	0.000 s
🚊 🤰 AML SV probe	Latency:	0.000 s
Sound Velocity	Acquired by:	[Directly into QINSy] (No additional time tags)
	Observation time from:	N/A
i ∰ Gyro	Number of slots:	0
Pitch Roll Heave Sensor	Use QPS PPS Adapter:	On COM1
L Position Navigation System	PPS time tag pulse matching:	Automatic Matching
□-↓ Variable Node	Windows System Time Synchronization:	
	windows system time synchronization.	synchronization is enabled
Los TX - S Link		
- Ö Time Sync		
EM2040C Controller		
D+ ASCII Logger		
└_↓↓ Fixed Node		
For Help, press F1		

📢 AmyGale_2019.db - Database Setup Program		
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General General	System: EM	2040C Controller
E- 🐔 Geodetic	Description:	EM2040C Controller
WGS84	Туре:	Miscellaneous System
🕀 🛣 Heights	Driver:	Kongsberg EM2040 Compact (Single) Multibeam Controller
🚽 🚣 Chart Datum / Vertical Datum	Executable and Cmdline:	DrvKongsbergEMCtrl.exe 2040C
🔆 Mean Water Level Model	Update rate:	0.000 s
	Latency:	0.000 s
Universal Transverse Mercator (North Hemisphere)	Acquired by:	[Directly into QINSy] (No additional time tags)
Local Construction Grid	Observation time from:	N/A
- O UTC to GPS Correction	Number of slots:	0
Cound Velocity Profile		
📥 🏧 Amy Gale		
System		
👌 🗓 AML SV probe		
- 一続 Sound Velocity - 孫 EM2040C		
Gyro		
Pitch Roll Heave Sensor		
Position Navigation System		
— ⊛ TX		
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ASCII Logger		
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Condician	E- III Survey	System: ASC	II Logger		
Universe Update frame Update frame Update frame Update frame 1000 + Update frame 0	🚊 🔏 Geodetic	Description:	ASCII Logger		
Image: State Phone Image:		The second se			
Controlle and Condine		1913			
Man Wate Level Model Update role 100 s Dipate Irrain Model Undet setting: Enabled Dipate Irrain Model Update role 100 s Object Dipate role Directifying Orbole 0 Dipate Role Orror Patient Ministrie 0 Dipate Role Number of alots 0 0 Dipate Role Number of alots 0 0 Dipate Role Number of alots 0 <td>Chart Datum / Vertical Datum</td> <td>Executable and Cmdline:</td> <td></td> <td></td> <td></td>	Chart Datum / Vertical Datum	Executable and Cmdline:			
Le construction de la cons		Update rate:	CARL CARL		
I at a output etting: Lata output etting: <td></td> <td></td> <td>0.000 s</td> <td></td> <td></td>			0.000 s		
 Unclus 05 contraction Grid Object Object Anny Gale <	Projections Universal Transverse Mercator (North Hemisphere)	Data output setting:	Enabled		
Observation from N/A Sum diversion from N/A Observation time from N/A Number of slots: 0 Observation Narigetion System Sum diversion Narigetion Narigetion System Sum diversion Narigetion System Sum diversion Narigetion Narigetion Narigetion System Sum diversion Narigetion Nar	Local Construction Grid	Acquired by:	[Directly into QINSy] (No additional time tags)		
Coject 0 Anny Gale Image: State Image: State Image: State Image: St	👸 UTC to GPS Correction	100 000 000 000 000 000 000 000 000 000			
Molet Molet Molet System System For Gyro For Gyr	Sound Velocity Profile	Number of slots:	0		
Find Node Find Node	Diject				
Control Control Contr	Any one				
KOARDC Kore Fich Roll Have Sensor Ford Node Kall Ford Node Kall Ford Node	AML SV probe				
A Cyro A Picth Roll Have Sensor A Position Navigation System A ray Vale MRU A Riv Trained Node					
Control Roll Haves Sensor Distinon Nivitation System Roll Haves Sensor The Sync T					
House Sector Any Gale MRU Any Gale MRU K	i β ² Gyro				
Verial Note	→ Gyro				
Arry Gale MRU ● RX ● TX ● TM200C Controller ■ KM200C Controller ► KSCII Cogger ← Fixed Node					
■ Axiliary Systems ■ Multilary Systems ■ fixed Node					
▲ Wildy Systems ▲ Kin2040C Controller ► Kin2040C Controller ★ Fixed Node					
Mulliny Systems → Ime Sync → EX2300 Controller → Fixed Node Fixed Node					
Fixed Node					
L MAQAQC Controller □	Auxiliary Systems				
Fixed Node					
Trixed Node					
	£4				
	r Help, press F1	1			

Appendix D – Configuration settings for QINSy EM controller

PU Status				_
Status	Active		Stop	
Pinging	15308 @ 2.90	Hz		_
Clock Status	Ok		Pu Info	•
Errors	All Ok		Options.	-
			Options.	•••
Settings				
Head1 Port A	nale	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	pth	0.00		
Maximum De	pth	200.00		
Detector Mod	le	Normal	-	
Slope Filter		On	-	
Areation Filte	r	Off	-	
Interference F	ilter	Off	* * * * *	
Penetration F	ilter	Off	-	
Range Gate Si	ze	Normal	<u>-</u>	
Spike Filter St	rength	Medium	-	
Phase Ramp		Normal	-	
Special Amp I	Detect	Off	-	
Special TVG		Off	-	
Normal Inci.	-	10		
Lambert's law	for intensity	Off	-	
Ping Mode		300 KHz		
Pulse Type		Auto		
Transmit Pow	er Level	Maximum FM Fachlad		
FM Enable	Casa Chara	FM Enabled	<u> </u>	~
1.0				
Apply	Settings 🔻	Force Vog Events		
Events				
	PU Clock is syn			~
	Connection to I Set Initial Setti	PU (157.237.20.40) Established		

🔣 EM Controller -	EM2040C C	ontroller -	- 🗆 ×
PU Status			
Status Act	ive		Stop
	46 @ 2.70 H	z	
Clock Status Ok	Ed	-	Pu Info 🔻
Errors All			
			Options
Settings			
Penetration Filter		Off	T
Range Gate Size		Normal	
Spike Filter Strengt	th	Medium	
Phase Ramp	ui	Normal	<u> </u>
Special Amp Deter	rt	Off	<u> </u>
Special TVG		Off	
Normal Inci. Secto	Angle	10	<u> </u>
Lambert's law for		Off	-
Ping Mode	incensity	300 KHz	<u> </u>
Pulse Type		Auto	
Transmit Power Le	avel	Maximum	
FM Enable	.vei	FM Enabled	
3D Scanning - Sca	n Sten	0.0	
3D Scanning - Mir		-5	
3D Scanning - Ma		5	
Dual Swath Mode	ar angle	Off	-
Min. Swath Distan	ce	0.0	
Yaw Stabilization		Off	•
Yaw Manual Angle		0.0	
Heading Filter	-	Medium	•
WCD Sonar Mode		Off	
WCD Passive Mod		Off	
WC TVG LOG R		30.0	
WC TVG dB		20.0	
Special amplitude	detection	Off	•
Sound Velocity Up		3.0	
Sound Velocity Mi		0.5	
			×
Apply	igs 🔻 🛛 i	Force 🔽 Log Events	
Events			
10:00:53.105 PU	Clock is synch	ronized	^
10:00:53.963 Con	nection to PL	J (157.237.20.40) Established	
10:00:53.963 Set 10:00:55.073 Con			
			×

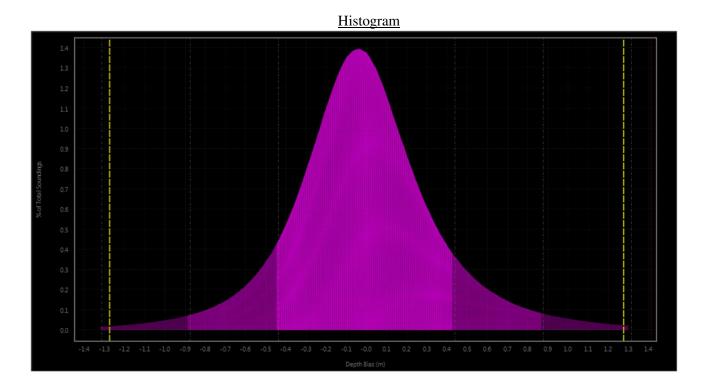
System Type (from DbSetup) Pu Ip Address Simulation Mode	EM2040		_
	LIVILOVO	C Single Transducer 🛛 👱	
Simulation Mode	157.237	20.40	
Simulation would	Off		
External Triggering	Off	1	
Control Port	2000		
Enabled Output Ports	Output	Port 1,2,3 🔄	
Output Port 1 (Bathy)	2001	19.04	
Output Port 2 (Bathy)	2002		
Output Port 3 (Sidescan)	2003		
ZDA/GGA Serial Port	Port1 (default) 🔄 🚬	
Use GGA	On	-	1
Baudrate ZDA/GGA	9600		1
Motion Serial Port	Port 2 (lefault) 🔻	1
Program Options			_
Start Pinging when QINSy Starts		Pinging On Startup	+
Synchronize Clock Interval(min.)		60	
· · · · · · · ·			
Sound Velocity Mode		From SoundVelocity C	•
Sound Velocity Mode Sound Velocity Observation			
Sound Velocity Mode Sound Velocity Observation Popup window when error occurs		From SoundVelocity C Sound Velocity On	
Sound Velocity Observation	Data	Sound Velocity	
Sound Velocity Observation Popup window when error occurs Allow HD beamspacing with Water Column Installation Parameters	1.4	Sound Velocity On	
Sound Velocity Observation Popup window when error occurs Allow HD beamspacing with Water Column Installation Parameters RX1 Gain Offet	0	Sound Velocity On	
Sound Velocity Observation Popup window when error occurs Allow HD beamspacing with Water Column Installation Parameters RX1 Gain Offet RX2 Gain Offet	0	Sound Velocity On Not Allowed	
Sound Velocity Observation Popup window when error occurs Allow HD beamspacing with Water Column Installation Parameters RX1 Gain Offet RX2 Gain Offet Head1 Installation angles from	0 0 EM20	Sound Velocity On Not Allowed 40C	
Sound Velocity Observation Popup window when error occurs Allow HD beamspacing with Water Column Installation Parameters RX1 Gain Offet RX2 Gain Offet Head1 Installation angles from Head2 Installation angles from	0 0 EM20 Not U	Sound Velocity On Not Allowed 40C Jsed	
Sound Velocity Observation Popup window when error occurs Allow HD beamspacing with Water Column Installation Parameters RX1 Gain Offet RX2 Gain Offet Head1 Installation angles from Head2 Installation angles from Velocity Sensor Number	0 0 EM20 Not U	Sound Velocity On Not Allowed 40C	
Sound Velocity Observation Popup window when error occurs Allow HD beamspacing with Water Column Installation Parameters RX1 Gain Offet RX2 Gain Offet Head1 Installation angles from Head2 Installation angles from Velocity Sensor Number Velocity Sensor UDP Port	0 0 EM20 Not U Motio 3001	Sound Velocity On Not Allowed 40C Jsed on Sensor 1	
Sound Velocity Observation Popup window when error occurs Allow HD beamspacing with Water Column Installation Parameters RX1 Gain Offet RX2 Gain Offet Head1 Installation angles from Head2 Installation angles from Velocity Sensor Number Velocity Sensor UDP Port Velocity Sensor Ethernet Port	0 0 EM20 Not U Motio 3001 Ether	Sound Velocity On Not Allowed 40C Jsed on Sensor 1 net Port 2 (if available)	
Sound Velocity Observation Popup window when error occurs Allow HD beamspacing with Water Column Installation Parameters RX1 Gain Offet RX2 Gain Offet Head1 Installation angles from Head2 Installation angles from Velocity Sensor Number Velocity Sensor UDP Port	0 0 EM20 Not U Motio 3001 Ether 192.1	Sound Velocity On Not Allowed 40C Jsed on Sensor 1	

Appendix E – Mainscheme crossline surface difference test statistical plots

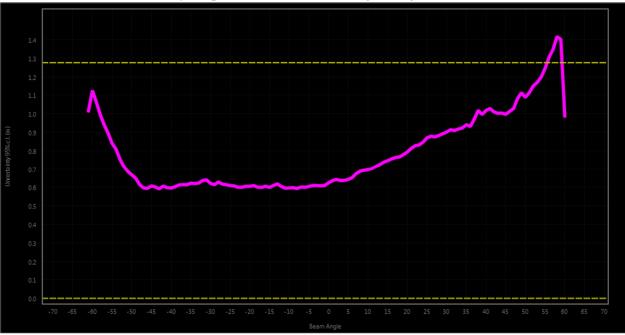
Plots (histogram, scatter, and uncertainty)

Key for plots:

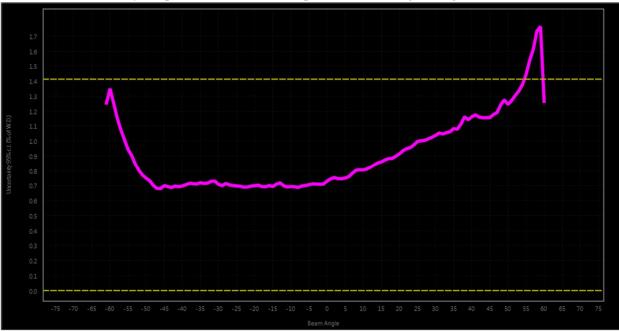
- Gray dots represent difference in depth between the crossline and the reference surface for individual beam angles or beam numbers
- Purple areas represent the 95% confidence interval (2 standard deviations) based on normal distribution (see histogram)
- Yellow dashed lines represent limit of IHO Order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



Saco Bay Crossline Plots:

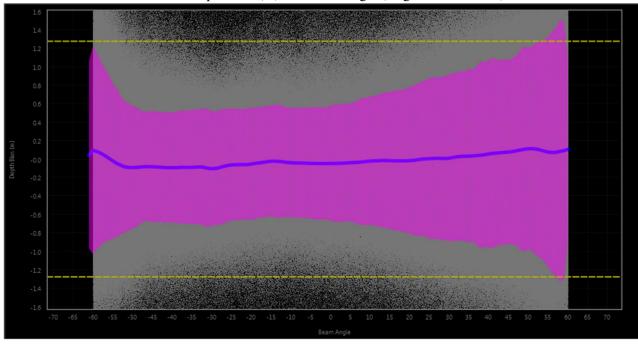


Uncertainty: Depth Bias (m) vs. Beam Angle (Degrees from nadir)

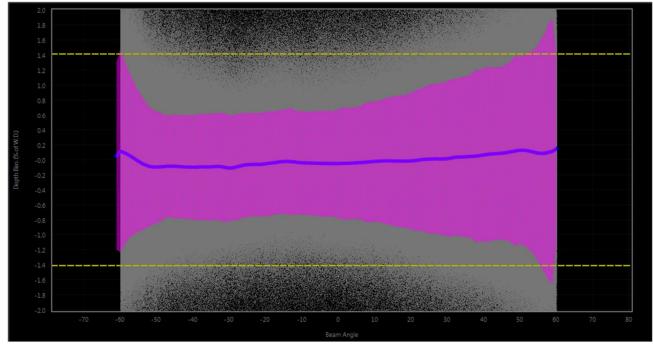


Uncertainty: Depth Bias (% of water depth) vs. Beam Angle (Degrees from nadir)

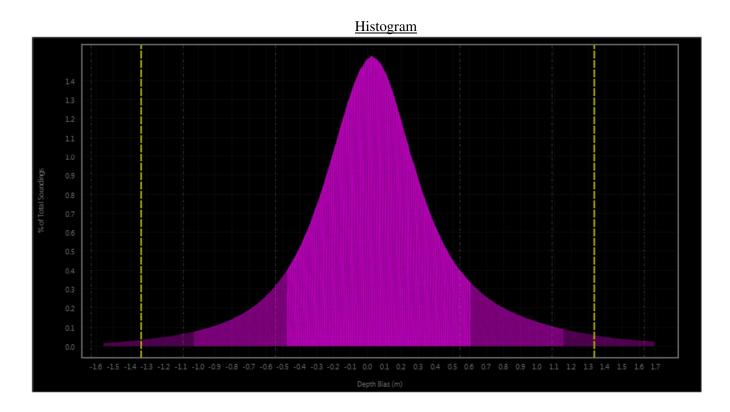
Scatter: Depth Bias (m) vs. Beam Angle (Degrees from nadir)



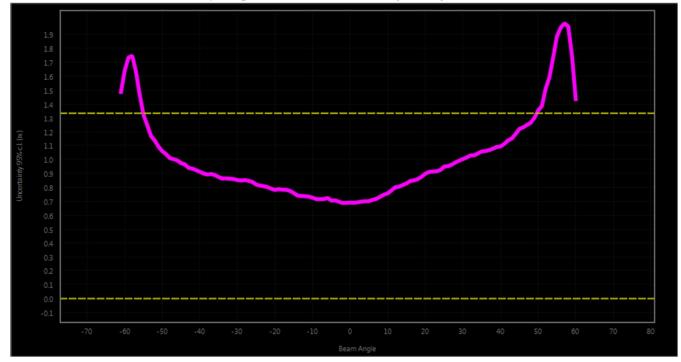
Scatter: Depth Bias (% of water depth) vs. Beam Angle (Degrees from nadir)

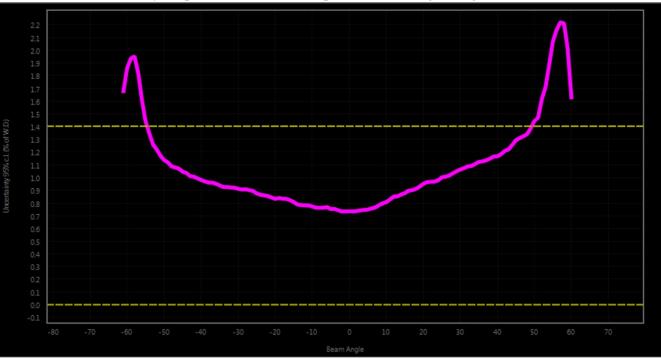


Monhegan Island Crossline Plots:



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





Uncertainty: Depth Bias (% of water depth) vs. Beam Angle (Degrees from nadir)

Scatter: Depth Bias (m) vs. Beam Angle (Degrees from nadir)

