U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Ocean Service

Data Acquisition & Processing Report

Type of Survey:	Navigable Area
Project Number:	OPR-W386-TJ-22
Time Frame:	May - October 2022

LOCALITY

State(s):	New York Ohio Pennsylvania
General Locality:	Lake Erie

2022

CHIEF OF PARTY
Matthew J. Jaskoski, CDR/NOAA

LIBRARY & ARCHIVES

Date:

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NOAA Ship *Thomas Jefferson*
Chief of Party: Matthew J. Jaskoski, CDR/NOAA
Year: 2022
Version: 1.3
Publish Date: 2022-08-08

A. System Equipment and Software

A.1 Survey Vessels

A.1.1 NOAA Ship THOMAS JEFFERSON (WTEA)

<table>
<tr><td>Vessel Name</td><td colspan="2">NOAA Ship THOMAS JEFFERSON (WTEA)</td></tr>
<tr><td>Hull Number</td><td colspan="2">S222</td></tr>
<tr><td>Description</td><td colspan="2">S222 is a steel hulled hydrographic survey ship built by Halter Marine, Inc., Moss Point, MS.</td></tr>
<tr><td rowspan="3">Dimensions</td><td>LOA</td><td>63.4m</td></tr>
<tr><td>Beam</td><td>13.7m</td></tr>
<tr><td>Max Draft</td><td>4.6m</td></tr>
<tr><td rowspan="2">Most Recent Full Static Survey</td><td>Date</td><td>2016-09-01</td></tr>
<tr><td>Performed By</td><td>The IMTEC Group, Ltd.</td></tr>
<tr><td rowspan="2">Most Recent Partial Static Survey</td><td>Date</td><td>2020-11-12</td></tr>
<tr><td>Performed By</td><td>Kevin Jordan, National Ocean Service - National Geodetic Survey (NGS) - Field Operations Branch</td></tr>
</table>

Figure 1: THOMAS JEFFERSON underway from the starboard view.

A.1.2 Hydrographic Survey Launch 2903 (HSL 2903)

<table>
<tr><td>Vessel Name</td><td colspan="2">Hydrographic Survey Launch 2903 (HSL 2903)</td></tr>
<tr><td>Hull Number</td><td colspan="2">2903</td></tr>
<tr><td>Description</td><td colspan="2">HSL 2903 is an aluminum hulled hydrographic survey launch built in 2017 by Willard Marine, Inc. HSL 2903 is equipped to collect bathymetric data, side scan imagery, and water column profiles.</td></tr>
<tr><td rowspan="3">Dimensions</td><td>LOA</td><td>8.5m</td></tr>
<tr><td>Beam</td><td>3m</td></tr>
<tr><td>Max Draft</td><td>1.2m</td></tr>
<tr><td rowspan="2">Most Recent Full Static Survey</td><td>Date</td><td>2020-01-28</td></tr>
<tr><td>Performed By</td><td>Kevin Jordan, National Ocean Service - National Geodetic Survey (NGS) - Field Operations Branch</td></tr>
</table>

Figure 2: 2903 and 2904 returning to S222

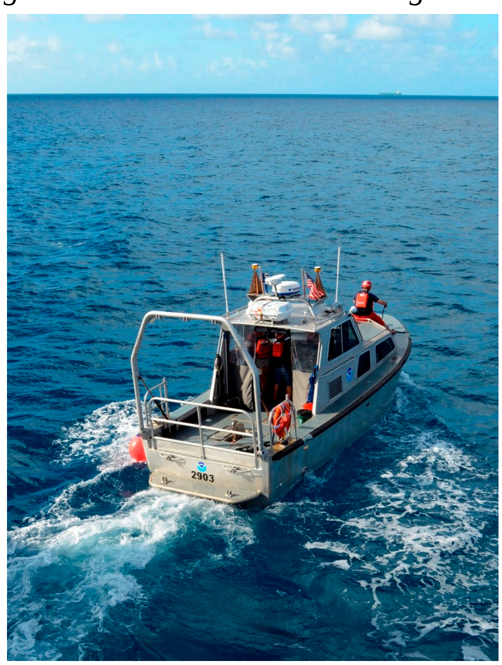

Figure 3: 2903 heading out for survey operations.

Figure 4: 2903 from starboard view.

A.1.3 Hydrographic Survey Launch 2904 (HSL 2904)

Vessel Name	Hydrographic Survey Launch 2904 (HSL 2904)	
Hull Number	2904	
Description	HSL 2904 is an aluminum hulled hydrographic survey launch built in 2017 by Willard Marine, Inc. HSL 2904 is equipped to collect bathymetric data, side scan imagery, and water column profiles.	
Dimensions	*LOA*	8.5m
	Beam	3m
	Max Draft	1.2m
Most Recent Full Static Survey	*Date*	2020-01-28
	Performed By	Kevin Jordan, National Ocean Service - National Geodetic Survey (NGS) - Field Operations Branch

Figure 5: 2904 from port view.

A.2 Echo Sounding Equipment

A.2.1 Multibeam Echosounders

A.2.1.1 Kongsberg EM2040

The Kongsberg EM2040 is a high resolution shallow water multibeam echosounder system (MBES). The system is capable of operating at 200, 300, or 400 kHz frequencies, can provide across-track swath width up to 5.5 times water depth, provides single or multi-sector modes of operations, and can be used in depths up to 600 meters.

For hydrographic survey collection, the EM2040 swath width is set up to an angle of 70 degrees off-nadir with angular coverage set to Auto. The beam spacing is set to high definition equal distant to obtain max swath width when operating in any depth. Dual swath mode is set to Dynamic. Dynamic mode is selected because it allows the along side angle between the two transmit fans to be determined based on the vessel speed, ping rate, and depth in order to provide a uniform along ship sampling of the sea floor. The frequency of the EM2040 is typically set to 300 kHz for normal survey operations, and will shift to 400 kHz for shallow water data collection. Pulse type set to auto with FM disabled. Pulse type is changed by the operator to vary primarily between FM and very short CW depending on the depth of the water, to obtain maximum coverage available.

Components of the EM2040 include a sonar head, a processing unit, and a hydrographic workstation. Motion sensor and positioning data from the POSMV system, with sound speed profile data being input to the EM 2040 via separate sound speed profiling equipment. All echo sounder electronics are contained in the sonar head which is interfaced to the processing unit via GBit Ethernet. The processing unit also supplies 48 VDC power via the same cable. Operator control, data quality inspection, and data storage is handled by the hydrographic workstation running SIS software.

The Sonar Acceptance Reports for the EM2040s on NOAA Ship THOMAS JEFFERSON and both Hydrographic Survey Launches can be found in the appendices. 2903, 2904, and S222 are equipped with hull mounted EM2040 systems.

Manufacturer	Kongsberg					
Model	EM2040					
Inventory	*S222*	*Component*	Processing Unit	Work Station	Transducer	Receiver
		Model Number	EM2040	EM2040	EM2040	EM2040
		Serial Number	40072	CZC3410L1L	236	334
		Frequency	200-400 kHz	200-400 kHz	200-400 kHz	200-400 kHz
		Calibration	2021-04-19	2021-04-19	2021-04-19	2021-04-19
		Accuracy Check	2021-04-20	2021-04-20	2021-04-20	2021-04-20
	2903	*Component*	Processing Unit	Work Station	Transducer	Receiver
		Model Number	EM2040	EM2040	EM2040	EM2040
		Serial Number	40143	CZC746864F	281	363
		Frequency	200-400 kHz	200-400 kHz	200-400 kHz	200-400 kHz
		Calibration	2022-04-08	2022-04-08	2022-04-08	2022-04-08
		Accuracy Check	2022-04-22	2022-04-22	2022-04-22	2022-04-22
	2904	*Component*	Processing Unit	Work Station	Transducer	Receiver
		Model Number	EM2040	EM2040	EM2040	EM2040
		Serial Number	40139	CZC7468666	282	393
		Frequency	200-400 kHz	200-400 kHz	200-400 kHz	200-400 kHz
		Calibration	2022-04-11	2022-04-11	2022-04-11	2022-04-11
		Accuracy Check	2022-05-30	2022-05-30	2022-05-30	2022-05-30

Figure 6: Hull mounted Kongsberg EM2040 onboard 2903.

Figure 7: Location of the hull mounted EM2040 onboard S222.

A.2.2 Single Beam Echosounders

No single beam echosounders were utilized for data acquisition.

A.2.3 Side Scan Sonars

A.2.3.1 Edgetech 4200

The EdgeTech 4200 system is comprised of a rack-mounted topside system and a stainless steel towfish. The towfish contains the sonar transducer arrays and the electronics required to transmit and receive the sonar signals; to receive the downlink commands from the topside processor; and to provide the uplink side scan data, sensor data, and status information to the topside processor. The rack mount interfaces with a user supplied computer over a 10/100BaseT Ethernet connection.

Frequencies are transmitted as linearly-swept, wide-band, high energy acoustic pulses, and the received echoes are processed into high signal-to-noise (SNR) images that can be directly displayed as shades of gray color. The towfish is a dual frequency 300/600 kHz capable of simultaneous acquisition in both frequencies. The towfish is fitted to either 2903 and 2904 in a hull-mounted configuration: The 4200 "towfish" depth is restricted to the draft of the survey launch.

The EdgeTech 4200 uses Multi-Pulse (MP) technology to enable survey speeds up to 10 knots while maintaining 100% bottom coverage. When operated in simultaneous dual frequency acquisition mode, speed must be reduced since the frequencies alternate between 300 and 600 kHz.

<table>
<tr><td>Manufacturer</td><td>Edgetech</td></tr>
<tr><td>Model</td><td>4200</td></tr>
<tr><td>Inventory</td><td><table><tr><td>2903</td><td><table>
<tr><td>Component</td><td>TPU</td><td>Towfish</td></tr>
<tr><td>Model Number</td><td>4200</td><td>4200</td></tr>
<tr><td>Serial Number</td><td>50423</td><td>40423</td></tr>
<tr><td>Frequency</td><td>300kHz-600kHz</td><td>300kHz-600kHz</td></tr>
<tr><td>Calibration</td><td>2022-05-05</td><td>2022-05-05</td></tr>
<tr><td>Accuracy Check</td><td>2022-05-05</td><td>2022-05-05</td></tr>
</table></td></tr></table></td></tr>
</table>

Figure 8: Hull mounted Edgetech 4200 onboard 2903.

A.2.3.2 Klein 5000V2

The Klein 5000V2 Side Scan Sonar (SSS) system is a beam-forming acoustic imagery device. The system includes a Klein 5000V2 towfish, a Transceiver/Processing Unit (TPU), and a computer for user interface. Stern-towed units also include a tow cable telemetry assembly. The towfish operates at a frequency of 455kHz and a vertical beam angle of 40°, and can resolve up to 5 discrete received beams per transducer stave. The system is capable of ranges of up to 250 meters. The Klein 5000V2 is deployed in a stern-towed configuration on S222.

The Klein 5000V2 has a set range scale of 50 meters, 75 meters, 100 meters, and 150 meters. The range scale is determined by the depth of the water and the type of survey conducted for best results as determined by the HSSD 2022, the hydrographer sets the range scale before surveying. During acquisition the hydrographer controls the depth of the fish from the acquisition station, keeping the 5000V2 at an altitude between 8%-20% of the range scale.

All Klein systems were updated with new TPUs in 2017.

<table>
<tr><td>Manufacturer</td><td colspan="4">Klein</td></tr>
<tr><td>Model</td><td colspan="4">5000V2</td></tr>
<tr><td rowspan="6">Inventory</td><td rowspan="6">S222</td><td>Component</td><td>TPU</td><td>Towfish</td></tr>
<tr><td>Model Number</td><td>5000</td><td>5000v1</td></tr>
<tr><td>Serial Number</td><td>008</td><td>280</td></tr>
<tr><td>Frequency</td><td>455kHz</td><td>455kHz</td></tr>
<tr><td>Calibration</td><td>2022-05-08</td><td>2022-05-08</td></tr>
<tr><td>Accuracy Check</td><td>2022-05-08</td><td>2022-05-08</td></tr>
</table>

Figure 9: Deployment of Klein 5000V2 from S222 fantail.

A.2.4 Phase Measuring Bathymetric Sonars

No phase measuring bathymetric sonars were utilized for data acquisition.

A.2.5 Other Echosounders

No additional echosounders were utilized for data acquisition.

A.3 Manual Sounding Equipment

A.3.1 Diver Depth Gauges

No diver depth gauges were utilized for data acquisition.

A.3.2 Lead Lines

No lead lines were utilized for data acquisition.

A.3.3 Sounding Poles

No sounding poles were utilized for data acquisition.

A.3.4 Other Manual Sounding Equipment

No additional manual sounding equipment was utilized for data acquisition.

A.4 Horizontal and Vertical Control Equipment

A.4.1 Base Station Equipment

No base station equipment was utilized for data acquisition.

A.4.2 Rover Equipment

No rover equipment was utilized for data acquisition.

A.4.3 Water Level Gauges

No water level gauges were utilized for data acquisition.

A.4.4 Levels

No levels were utilized for data acquisition.

A.4.5 Other Horizontal and Vertical Control Equipment

No other equipment were utilized for data acquisition.

A.5 Positioning and Attitude Equipment

A.5.1 Positioning and Attitude Systems

A.5.1.1 Applanix Corporation POS MV 320 Version 5

The Applanix POS MV 320 Version 5 (Position and Orientation System for Marine Vessels, hereafter POS MV v5 or simply POS MV) is a GNSS (Global Navigation Satellite System)-aided inertial navigation system that provides high frequency and highly accurate vessel trajectory (both position and attitude) data. The system incorporates data from an Inertial Measurement Unit (IMU) and dual multi-constellation GNSS receivers. The IMU and GNSS receivers are complementary sensors. Data from one are used to filter and constrain errors from the other: The IMU data is precise and the GNSS data is accurate. Advanced proprietary Kalman Filtering techniques are used to provide a blended navigation and trajectory solution in real-time that is both highly accurate and reliable. The POS MV is equipped with the Applanix GNSS Azimuth Measurement Subsystem (GAMS). GAMS forms a precise baseline vector between the POS MV dual GNSS receivers/antennas to determine accurate heading after being blended with the inertial navigation solution. The POS MV v5 also computes vessel heave (both instantaneous and filtered values). The POS MV v5 system is integrated with all platform acquisition systems. Data from the POS MV v5 is applied to echosounder data in real-time and logged for post-processing and data archive.

The POS MV generates attitude data (roll, pitch, and heading) to an accuracy of 0.02° or better. Real-time heave measurements from the POS/MV maintain an accuracy of 5% of the measured vertical displacement or 5 cm (whichever is greater) for vertical motions within a high-pass, frequency-limited band. THOMAS JEFFERSON configures the Heave Bandwidth filter with a damping coefficient of 0.707 based on the manual's recommendations. This value is determined by estimating the swell period encountered on survey grounds; they ranged from 8 seconds (flat water) to 20 seconds (long period swell), with values of 8 or 12 seconds normally. The standard practice is to apply a high pass filter that is determined by the longest swell period encountered on the survey grounds.

The POS MV V5 filtered heave is called TrueHeave by Applanix. The TrueHeave algorithm uses a delayed filtering technique to eliminate many of the artifacts present in real time heave data. Applanix delayed heave measurements maintain an accuracy of 2% of the measured vertical displacement or 2 cm (whichever is greater) for vertical motions less than approximately 20 seconds in period. POS MV TrueHeave measurements are logged and applied to MBES data in post processing as CARIS HIPS "Delayed Heave".

A graphical user interface provides visual representations and summary statistics of data quality in real-time. Attitude accuracies are monitored by the crew and survey operations are temporarily halted if the uncertainty in any component (roll/pitch or heading) continuously exceeds 0.08 degrees, root mean square (RMS). Accuracy is usually regained through a calibration procedure, where the vessel must prescribe a loose figure eight track to improve the inertial navigation figure of merit.

Position and trajectory data from the POS MV v5 system is applied in both real-time and post-processed applications. Navigation and attitude data is supplied to the MBES in real-time via serial connection at 2 Hz and 100 Hz, respectively, to compensate for the effects of heave, pitch, roll, and heading. The POS

MV navigation solution and "raw" IMU data are recorded at sample rates of 50 Hz and 200 Hz (default), respectively, for post-processing. Data is logged in 20 minute file increments throughout acquisition via POS MV Ethernet connection. Inertially-aided post-processed kinematic (PPK) GNSS procedures are documented elsewhere in this document.

Manufacturer	Applanix Corporation			
Model	POS MV 320 Version 5			
Inventory	*S222*	*Component*	IMU	PCS
		Model Number	LN200 (IMU2)	V5
		Serial Number	5760	6497
		Calibration	2019-10-17	2019-10-17
	2903	*Component*	IMU	PCS
		Model Number	LN200 (IMU2)	V5
		Serial Number	131	3245
		Calibration	2021-03-02	N/A
	2904	*Component*	IMU	PCS
		Model Number	LN200 (IMU2)	V5
		Serial Number	293	8959
		Calibration	2019-09-26	2019-09-26

Figure 10: GNSS Antennas set up on the forward mast of S222

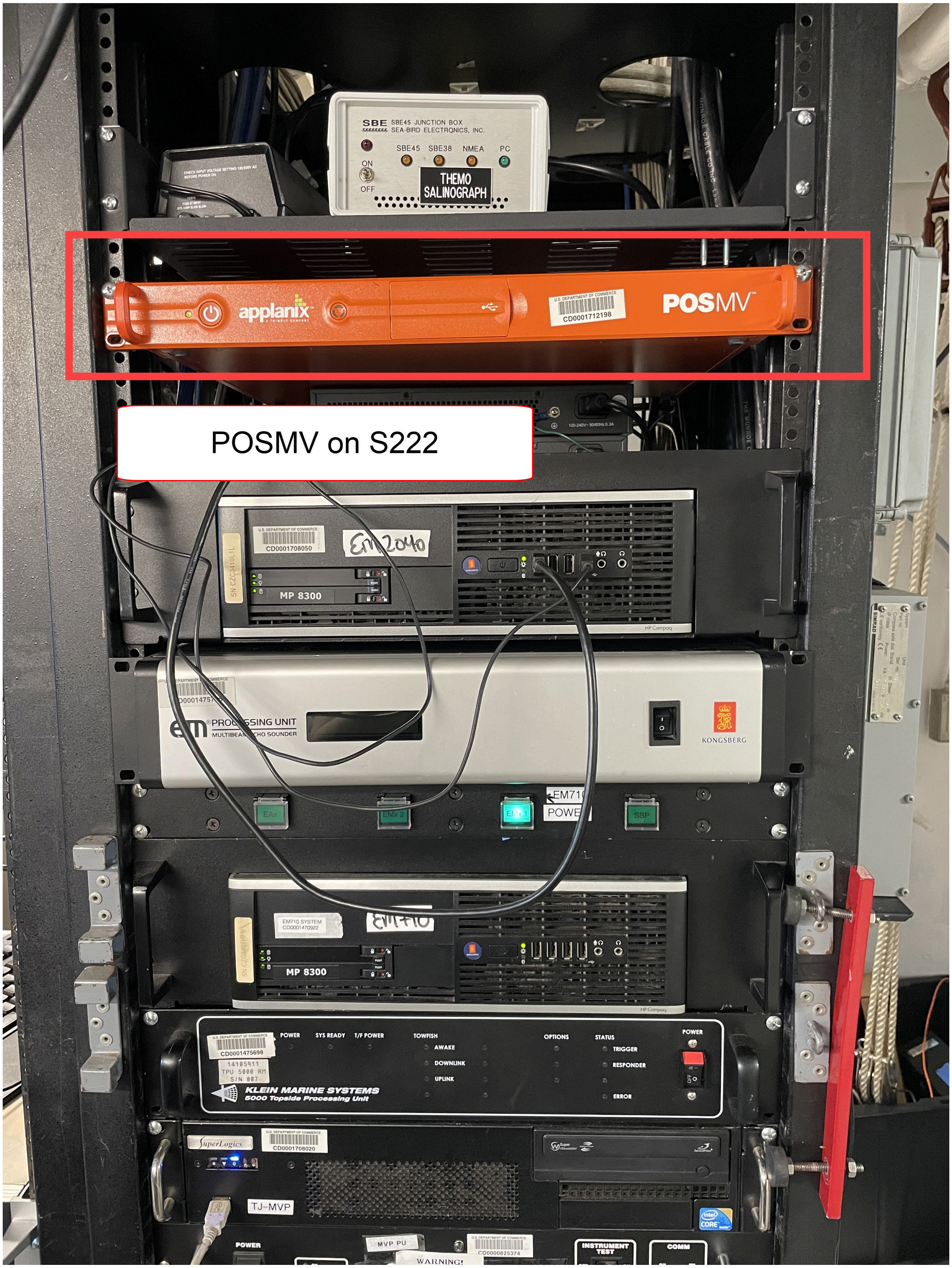

Figure 11: POSMV installed in the server rack of S222

Figure 12: GNSS Antennas set up on 2903

A.5.2 DGPS

DGPS equipment was not utilized for data acquisition.

A.5.3 GPS

Additional GPS equipment was not utilized for data acquisition.

A.5.4 Laser Rangefinders

Laser rangefinders were not utilized for data acquisition.

A.5.5 Other Positioning and Attitude Equipment

No additional positioning and attitude equipment was utilized for data acquisition.

A.6 Sound Speed Equipment

A.6.1 Moving Vessel Profilers

A.6.1.1 AML Oceanographic MVP200 Moving Vessel Profiler (MVP)

S222 is equipped with a Rolls-Royce Group Brooke Ocean MVP200 Moving Vessel Profiler (MVP) that is now owned by AML Oceanographic. The MVP system consists of a sensor towfish, a conductor/tow cable, a computer-controlled high-speed hydraulic winch, and a cable metering system. A Conductivity-Temperature-Depth (CTD) sensor, AML Oceanographic MVP-X instrument package, is housed in the towfish and interfaced with the ship acquisition system via the conductor/tow cable. The MVP system provides a means of collecting full water-column data while S222 remains underway. The MVP system on S222 has 320m of cable and can be used to take water-column profiles up to 150m in depth at speeds of approximately 10 kts. To conduct deeper SV casts and take full advantage of all the cable on the drum, the ship must come to a complete stop. MVP system is continuously monitored by survey personnel during acquisition watches. A cast is taken at least every four hours but may be done more often when working in areas with high water column variability in temperature and salinity.

<table>
<tr><td>Manufacturer</td><td colspan="3">AML Oceanographic</td></tr>
<tr><td>Model</td><td colspan="3">MVP200 Moving Vessel Profiler (MVP)</td></tr>
<tr><td rowspan="4">Inventory</td><td rowspan="4">S222</td><td>Component</td><td>MVP System</td></tr>
<tr><td>Model Number</td><td>MVP 200</td></tr>
<tr><td>Serial Number</td><td>M12981</td></tr>
<tr><td>Calibration</td><td>2022-03-04</td></tr>
</table>

Figure 13: MVP 200 on the fantail

Figure 14: Towfish for the MVP 200

A.6.2 CTD Profilers

A.6.2.1 AML Oceanographic AML MVP-X

The AML MVP-X is a multi-parameter sensor designed specifically for use with the AML Moving Vessel Profiler (MVP) models. The MVP-X is highly configurable and is compatible with all AML Xchange (tm) oceanographic sensors. The MVP-X configuration used on S222 includes conductivity, temperature and pressure sensors with the following accuracies and resolutions: the conductivity sensors provide a sensor range of 0-90 mS/cm, a resolution of 0.001 mS/cm, with an accuracy of plus/minus 0.01 mS/cm; the temperature sensors provide a sensor range of -5 to +45 Deg C, a resolution of 0.001 Deg C, with an accuracy of plus/minus 0.005 Deg C; the pressure sensors provide a sensor range of 0 to 1000 dBar, a resolution of 0.02% of measurement, with an accuracy of 0.05% of measurement. The main instrument housings on the MVP-X units are rated for operation at pressures up to 6000 dBar.

These sensors are sent to AML annually for calibration and testing.

<table>
<tr><td>Manufacturer</td><td>AML Oceanographic</td></tr>
<tr><td>Model</td><td>AML MVP-X</td></tr>
<tr><td>Inventory</td><td><table>
<tr><td>Component</td><td>Probe</td></tr>
<tr><td>Model Number</td><td>AML MVP-X</td></tr>
<tr><td>Serial Number</td><td>9001</td></tr>
<tr><td>Calibration</td><td>2021-02-08</td></tr>
</table></td></tr>
</table>

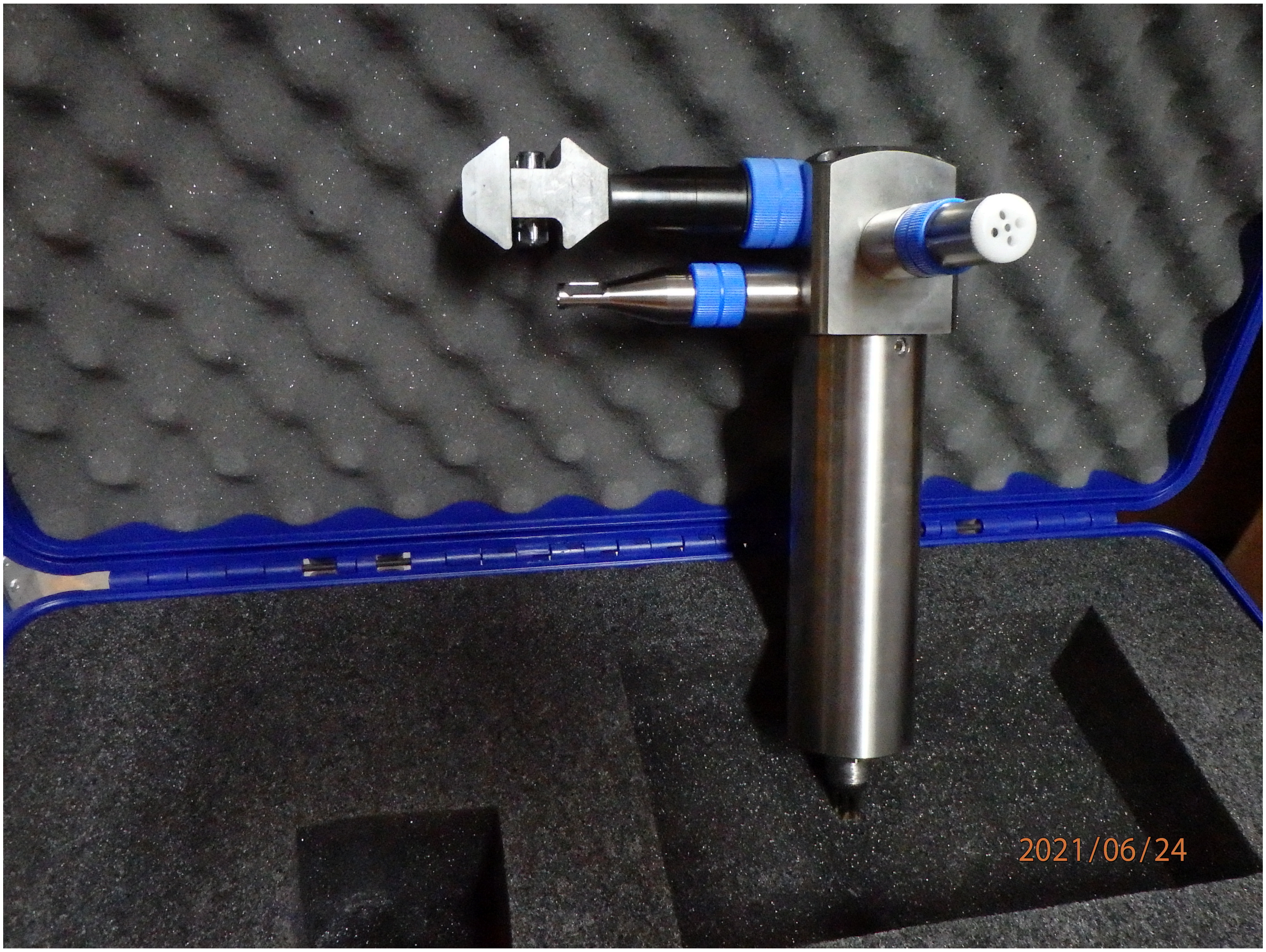

Figure 15: AML MVP-X with conductivity, temperature, and pressure sensors

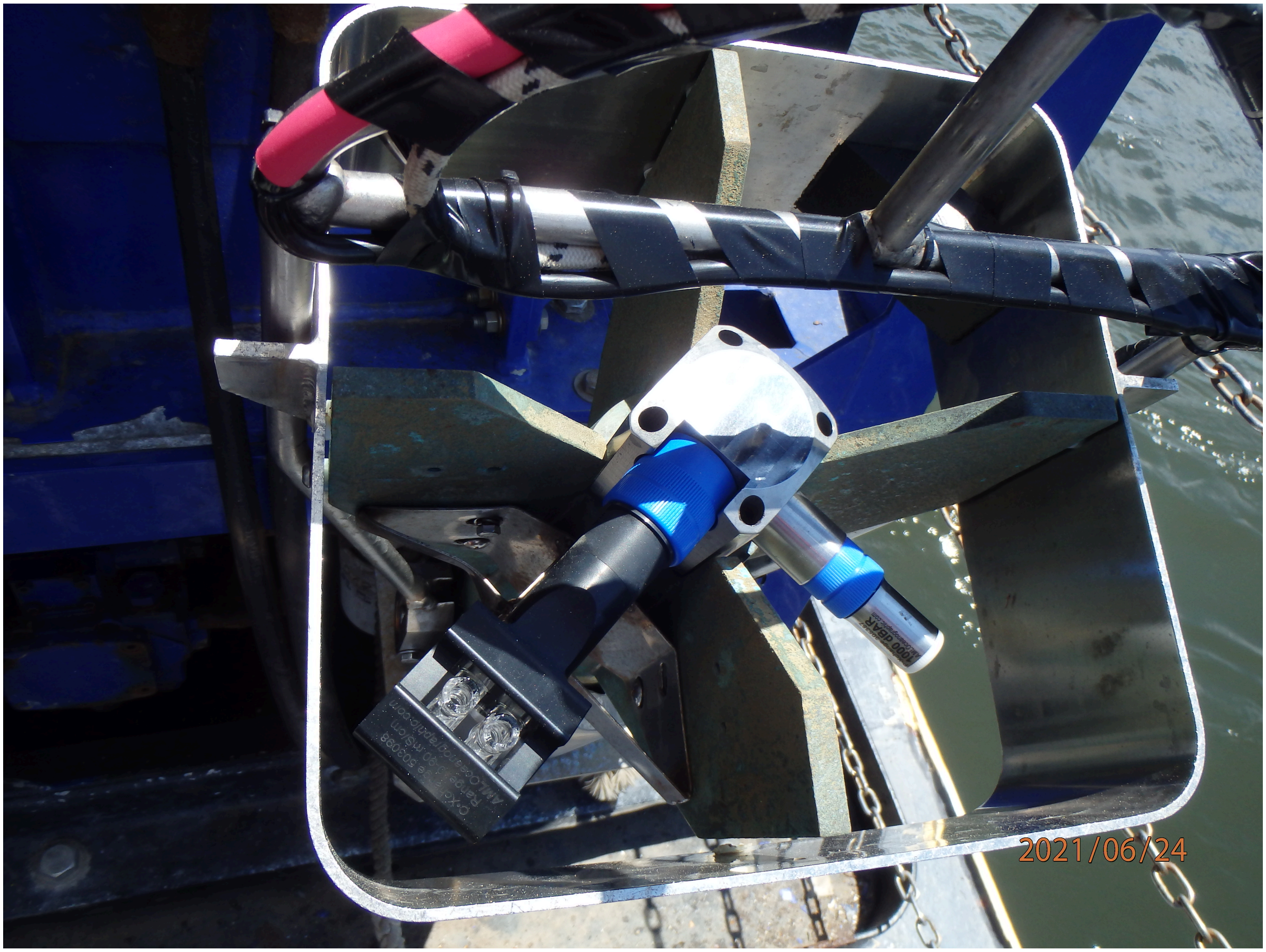

Figure 16: AML MVP-X installed in MVP towfish

A.6.2.2 Sea-bird Electronics SBE 19plus

The Sea-Bird Electronics SBE 19plus SeaCAT profiler measures conductivity, temperature, and depth (CTD) in marine and/or freshwater environments. The SBE 19plus is rated for use at depths of up to 600 meters and is capable of sampling at a rate of 4 measurements per second. CTD values are used to calculate the speed of sound through the water column.

Sea-Bird Electronics SBE 19plus CTD profilers are used on HSL 2903 and HSL 2904 to collect vertical sound speed profiles. In the event of an MVP failure, the SBE 19plus can also be used to collect profiles from the ship. The speed of sound is calculated from temperature, salinity, and pressure measurements. Temperature is measured directly, salinity is calculated from measured electrical conductivity, and depth is calculated via strain gauge pressure sensor. The system is configured for a sampling rate of 0.5 seconds. The CTD is deployed over the side of the launches or the THOMAS JEFFERSON and is held just below the water line at the cast location for approximately two minutes before the device is lowered to the bottom and promptly recovered, at a travel rate of approximately 1 meter per second. As a back up to the MVP, the SBE19Plus can also be used from S222 to take CTD measurements.

At the end of each field season, any CTD that was put in use is sent to Sea-Bird Electronics for annual testing and calibration. Calibration certificates for each CTD can be found in the appendices.

Manufacturer	Sea-bird Electronics		
Model	SBE 19plus		
Inventory	*Component*	CTD	
	Model Number	19plus	
	Serial Number	19P33589-4487	
	Calibration	2021-12-01	
	Component	CTD	
	Model Number	19plus	
	Serial Number	19P33072-4472	
	Calibration	2021-12-01	
	Component	CTD	CTD
	Model Number	19plus V2	19plus
	Serial Number	19P60744-6667	19P36399-4630
	Calibration	2021-12-03	2021-12-03

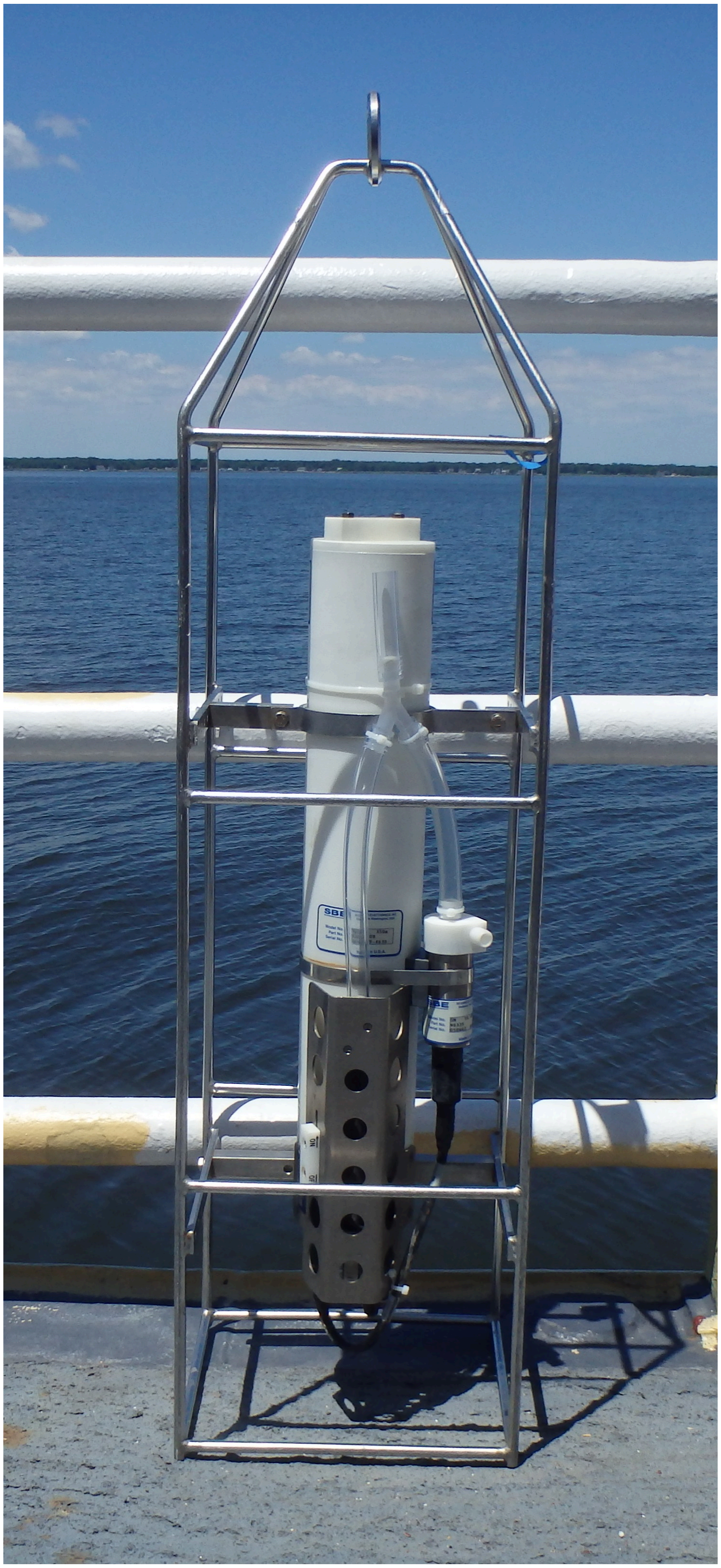

Figure 17: Sea-Bird Electronics SBE 19plus SeaCAT CTD profiler

A.6.3 Sound Speed Sensors

A.6.3.1 Teledyne Reson Reson SVP-70

The Reson SVP-70 is a direct-read sound velocity measurement devices. The SVP 70 obtains sound speed measurements by directly measuring the travel time of sound pulses along a set 125 mm transmission path. The SVP systems are capable of reading sound speeds from 1350 to 1800 m/s with a resolution of 0.01 m/s (±0.15m/s) at a sampling rate of 20 Hz.

Reson SVP-70 sensors collect the speed of sound at the face of the Kongsberg EM2040 transducers on HSL 2903 and HSL 2904. The sensors are bolted in the mounting boxes near the face of the transducer on each launch. The speed of sound is measured directly using an ultrasonic sensor (2 MHz) with automatic compensation for temperature and pressure. The SVP-70 is integrated with the Kongsberg EM2040 and provides sound velocity measurements which are critical for beam steering from a flat-face transducer. The output of the sensor is monitored in real-time during acquisition and compared against the interpolated sound speed determined from the loaded CTD cast profile at an equivalent depth. Appreciable differences between the matched SVP-CTD values prompts the acquisition of another CTD profile, inside the nominal cast frequency of every four hours or otherwise at a new location about the survey area.

The SVP-70 sensors are returned to the manufacturer annually for testing and calibration. Calibration certificates can be found in the Appendices.

<table>
<tr><td>Manufacturer</td><td colspan="3">Teledyne Reson</td></tr>
<tr><td>Model</td><td colspan="3">Reson SVP-70</td></tr>
<tr><td rowspan="8">Inventory</td><td rowspan="4">2903</td><td>Component</td><td>Probe</td></tr>
<tr><td>Model Number</td><td>SVP-70</td></tr>
<tr><td>Serial Number</td><td>1013077</td></tr>
<tr><td>Calibration</td><td>2019-01-16</td></tr>
<tr><td rowspan="4">2904</td><td>Component</td><td>Probe</td></tr>
<tr><td>Model Number</td><td>SVP-70</td></tr>
<tr><td>Serial Number</td><td>0217007</td></tr>
<tr><td>Calibration</td><td>2020-01-30</td></tr>
</table>

Figure 18: Location of the SVP-70 onboard 2903

A.6.3.2 Valeport Limited MODUS SVS Thruhull

The Valeport MODUS SVS is a direct-read 'time of flight' sound speed sensor. The Valeport instrumentation used aboard S222 is equipped with a 100mm measurement path and includes temperature sensing. The sound speed sensor can measure sound in fresh water or marine environments with a measurement range of 1400-1600 m/s, at a resolution of 0.001 m/s, with an accuracy of ± 0.03 m/s. The thru-hull port where the sound speed sensor is deployed is located adjacent and aft of the transducer fairing. The Valeport is integrated with the Kongsberg EM2040 and EM710 to provide sound velocity measurements at the transducer faces for beam steering. The output of the sensor is monitored in real-time during acquisition and compared against the interpolated sound speed at an equivalent depth determined by the most recent MVP cast. Appreciable differences between the matched SVP-CTD values prompts the acquisition of another CTD profile, inside the nominal cast frequency of every four hours or otherwise at a new location about the survey area.

The Valeport sensors are returned to the manufacturer annually for testing and calibration. Calibration certificates can be found in the Appendices.

Manufacturer	Valeport Limited		
Model	MODUS SVS Thruhull		
Inventory	*S222*	*Component*	Probe
		Model Number	065101
		Serial Number	33747
		Calibration	2019-12-27

Figure 19: Valeport SVS installed in thru-hull fitting in the 'recovered' position

A.6.4 TSG Sensors

No TSG sensors were utilized for data acquisition.

A.6.5 Other Sound Speed Equipment

No other surface sound speed sensors were utilized for data acquisition.

A.7 Computer Software

Manufacturer	*Software Name*	*Version*	*Use*
Caris	HIPS AND SIPS	11.4.6	Processing
Caris	BASE Editor	5.4	Processing
NOAA	Pydro (ie: Charlene, QC tools, XmlDR, SHAM, transmission letter, Sound Speed Manager)	19.4	Processing
HYPACK - A Xylem Brand	HYPACK	2021 Q3	Acquisition
Applanix Corporation	POSPac MMS	8.7	Processing
Applanix Corporation	POSView	10.21	Acquisition
ESRI, Inc.	ArcGIS Pro	2.8.0	Processing
Kongsberg	Seafloor Information System (SIS)	4.2.3 build 32	Acquisition
Edgetech	Discover 4200-MP	37.0.1.111	Acquisition
Klein Marine Systems, Inc	SonarPro	14.1	Acquisition
QPS, Inc	FMGT	7.8.10	Processing
QPS, Inc	Qimera	2.1.1	Acquisition

A.8 Bottom Sampling Equipment

A.8.1 Bottom Samplers

A.8.1.1 Ponar Wildco Model #1728

The Ponar Wildco is a winch-deployed bottom sampler used aboard S222. This grab sampler is in common use to sample a wide variety of sediment types. The sampler design uses self-tripping center hinged jaws and a spring loaded trigger pin that releases when the sampler makes impact with the bottom. The sampler's jaws are closed by the scissor action of the lever arms when the sampler is retrieved. The sampling area is 6" x 6"—the Petite Ponar.

For deployment, the bottom sampler is secured to a sturdy line or winch wire and deployed over the side of a launch or ship. The descent of the sampler is controlled until the sampler impacts the bottom. Once the line goes slack, the operator tugs on the line to lift the sampler ensuring that the jaws have closed around a sample. The bottom sampler is then hauled to the surface and the sample is inspected and compared to sediment color and size cards. Images of the sample are taken on deck, to be included in the Final Feature File of the survey. If no sample was obtained, the process is completed twice more in accordance with the 2020 FPM.

Figure 20: Petite Ponar bottom sampler in open position

Figure 21: Petite Ponar bottom sampler in the closed position

A.8.1.2 Kahlisco Mud Snapper 214WA100 (AKA 'The Nibbler')

The Kahlisco Mud Snapper is a compact bottom sampler deployable from the ship or launches. The Mud Snapper is a foot-trip model clam shell style bottom sampler. This sampler is designed to collect unconsolidated sediments up to the size of small pebbles. The sampler is fabricated from sturdy bronze and stainless steel materials for trouble-free service in a marine environment. The unit consists of a long threaded post surrounded by a strong compression spring that presses against the jaws at one end and an adjustable screw cap at the upper end. By turning this threaded cap the spring-compression is adjusted, changing the strength at which the jaws close.

For deployment, the bottom sampler is secured to a sturdy line or winch wire and deployed over the side of a launch or ship. The descent of the sampler is controlled until the sampler impacts the bottom. Once the line goes slack, the operator tugs on the line to lift the sampler ensuring that the jaws have closed around a sample. The bottom sampler is then hauled to the surface and the sample is inspected and compared to sediment color and size cards. If no sample was obtained, the process is completed twice more in accordance with the 2020 FPM.

Figure 22: Mud Snapper bottom sampler in open position

Figure 23: Mud Snapper bottom sampler in closed position

B. System Alignment and Accuracy

B.1 Vessel Offsets and Layback

B.1.1 Vessel Offsets

Vessel offsets describe the location of all hydrographic sensors in relation to a defined reference point. These values are needed to compensate sensor measurements acting over lever arms under vessel rigid body motion, and ultimately produce the final geographic position for every sounding collected.

All offsets for S222 are derived from full surveys performed by Kongsberg USA-contracted personnel and have been verified by Hydrographic Systems and Technology Branch (HSTB) personnel. Offset values are established using physical marks within a vessel reference frame, that is in turn used to realize the relative relation between the IMU and MBES reference frames. Offsets for the Kongsberg transducer reference points are entered into the S222 SIS installation parameters (Locations: TX & RX) and the S222 CARIS HIPS Hydrographic Vessel File (HVF: SVP1 & 2). The offsets between the primary GNSS antenna and the IMU are entered into the POS MV configuration (POSView: Ref. to Primary GNSS Lever Arm), to establish both the attitude and navigation in the IMU reference frame. The HVF Nav sensor offsets are hence (0,0,0); however, the HVF TPU values include the total relative (non-zero) offset values between the primary GNSS antenna and the MBES. This is required in order to accurately model navigation error at the IMU reference point as calculated using the HVF. All other offsets are applied to data during the SVP or Merge processing steps in CARIS HIPS.

All offsets for HSL 2903 and HSL 2904 are derived from full vessel surveys performed by NGS personnel. Offset values to relate the IMU and Kongsberg (transducer) reference frames are established via measurements in a vessel reference frame of convenience. Offset values for the Kongsberg MBES systems are entered into POS MV to establish the EM2040 TX transducer face as the reference point (POSView: Ref. to IMU Lever Arm) for each HSL. Additonally, each HSL primary GNSS antenna offset is applied within the POS MV as well (POSView: Ref. to Primary GNSS Lever Arm), to establish both the attitude and navigation data in the Kongsberg reference frame. The relative-location and angular-offset components of the TX and RX transducers as well as static draft information for all Kongsberg systems are entered into SIS Sensor Setup (TX/RX Locations & Angular Offsets and Waterline) and the CARIS HVF (SVP 1/2 and Waterline Height) for proper application from acquisition through the SVP or Merge processing steps in CARIS HIPS and SIPS.

All offsets are tracked and updated as needed. For the HSL data, patch test angular corrections are achieved during acquisition via the POS MV configuration (IMU w.r.t. Reference Mounting Angles). For S222, patch test corrections are handled via SIS Sensor Setup (Angular Offsets: Attitude 1 Roll, Pitch, Heading)—with separate configurations maintained for Kongsberg 2040 and 710 operations. Any changes required on top of the POS MV-or SIS-applied patch values are achieved via the CARIS HIPS HVF (Transducer 1: Pitch, Roll, Yaw).

Offsets in side scan sonar operations are achieved in CARIS HIPS and SIPS, Compute Towfish Navigation step (HVF: Tow Point and Waterline Height).

All offsets, correctors, and values used in TPU calculation that are stored in the HVF file can be found in the Appendices to this report. HVF Reports are output from the CARIS HVF Editor in a plain text document and include all of the requested values for the DAPR necessary to reproduce an HVF.

For a detailed look at the applied lever arms and mounting angles are located in the appendices.

B.1.1.1 Vessel Offset Correctors

Vessel	2903
Echosounder	Kongsberg Simrad EM2040 300kHz 0.5x1_Normal Mode
Date	2022-04-18

Offsets

		Measurement	*Uncertainty*
MRU to Transducer	*x*	0.208 meters	0.020 meters
	y	0.153 meters	0.020 meters
	z	0.492 meters	0.020 meters
	x2	-0.108 meters	N/A
	y2	0.046 meters	N/A
	z2	0.477 meters	N/A
Nav to Transducer	*x*	0.939 meters	0.020 meters
	y	0.946 meters	0.020 meters
	z	4.187 meters	0.020 meters
	x2	0.623 meters	N/A
	y2	0.839 meters	N/A
	z2	4.172 meters	N/A
Transducer Roll	*Roll*	0.542 degrees	
	Roll2	0.000 degrees	

Vessel	2904			
Echosounder	Kongsberg Simrad EM2040 300kHz 0.5x1_Normal Mode			
Date	2022-03-28			
Offsets			*Measurement*	*Uncertainty*
	MRU to Transducer	*x*	0.187 meters	0.020 meters
		y	0.170 meters	0.020 meters
		z	0.511 meters	0.020 meters
		x2	-0.115 meters	N/A
		y2	0.061 meters	N/A
		z2	0.497 meters	N/A
	Nav to Transducer	*x*	0.918 meters	0.020 meters
		y	0.922 meters	0.020 meters
		z	4.233 meters	0.020 meters
		x2	0.616 meters	N/A
		y2	0.813 meters	N/A
		z2	4.219 meters	N/A
	Transducer Roll	*Roll*	0.170 degrees	
		Roll2	0.000 degrees	

Vessel	S222			
Echosounder	Kongsberg Simrad EM2040 300kHz 0.5x1_Normal Mode			
Date	2022-06-10			
Offsets	*MRU to Transducer*		*Measurement*	*Uncertainty*
		x	2.115 meters	0.020 meters
		y	-2.963 meters	0.020 meters
		z	4.980 meters	0.020 meters
		x2	2.387 meters	N/A
		y2	-2.858 meters	N/A
		z2	4.966 meters	N/A
	Nav to Transducer	*x*	0.754 meters	0.020 meters
		y	6.929 meters	0.020 meters
		z	27.481 meters	0.020 meters
		x2	1.026 meters	N/A
		y2	7.034 meters	N/A
		z2	27.467 meters	N/A
	Transducer Roll	*Roll*	0.327 degrees	
		Roll2	0.419 degrees	

B.1.2 Layback

Towfish positioning is provided to CARIS HIPS using cable-out values registered by the Totco cable counter and recorded in the SonarPro SDF files. SonarPro uses Payout and Towfish Depth to compute towfish positions. The towfish position is calculated from the position of the tow point using the cable-out value received by SonarPro for Klien systems from the cable payout meter, the towfish pressure depth (sent via a serial interface from the Klein 5000 TPU to the SonarPro software), and the Course Made Good (CMG) of the vessel. This method assumes that the cable is in a straight line. Therefore, no catenary algorithm is applied at the time of acquisition, but in processing, CARIS SIPS applies a 0.9 coefficient to account for the catenary.

Layback error is calculated by running a side scan certification test. This test consists of running parallel to a known feature at varying ranges from nadir to ensonify the target in the near-field (approximately 15% of range scale in use), mid-field (approximately 50 % of range scale in use), and far-field (approximately 85% of the range scale in use). The test requires that each side of the sonar ensonify the feature at each of these areas in the swath. Then the test is repeated in a direction that is orthogonal to the original set of lines such that the feature is ensonified a total of 12 times. A successful test will detect the feature in at least 10 of the 12 passes as outlined in the 2022 HSSD and 2020 FPM. For hull-mounted systems, the selected contact positions must be within 5m; for towed systems, the contact positions must be within 10m. Layback error is the amount of correction that must be applied to minimize the distance between contact positions.

B.1.2.1 Layback Correctors

<table>
<tr><td>Vessel</td><td colspan="3">2903</td></tr>
<tr><td>Echosounder</td><td colspan="3">Edgetech 4200</td></tr>
<tr><td>Frequency</td><td colspan="3">600 kHz</td></tr>
<tr><td>Date</td><td colspan="3">2022-01-01</td></tr>
<tr><td rowspan="4">Layback</td><td rowspan="3">Towpoint</td><td>x</td><td>0.344 meters</td></tr>
<tr><td>y</td><td>0.955 meters</td></tr>
<tr><td>z</td><td>-0.216 meters</td></tr>
<tr><td>Layback Error</td><td colspan="2">0.000 meters</td></tr>
</table>

<table>
<tr><td>Vessel</td><td colspan="3">S222</td></tr>
<tr><td>Echosounder</td><td colspan="3">Klein 5000V2</td></tr>
<tr><td>Frequency</td><td colspan="3">455 kHz</td></tr>
<tr><td>Date</td><td colspan="3">2022-01-01</td></tr>
<tr><td rowspan="4">Layback</td><td rowspan="3">Towpoint</td><td>x</td><td>6.370 meters</td></tr>
<tr><td>y</td><td>-42.550 meters</td></tr>
<tr><td>z</td><td>-4.800 meters</td></tr>
<tr><td>Layback Error</td><td colspan="2">-2.000 meters</td></tr>
</table>

B.2 Static and Dynamic Draft

B.2.1 Static Draft

Static draft is measured on the S222 using a Sutron Bubbler system. The orifice was surveyed into the IMU reference frame and a waterline height was calculated. A common waterline for the ship when fully loaded with fuel and ballasted normally is approximately 35cm below the reference point of the ship, but the waterline may change by as much as +/- 30cm over the course of a field season.

The static draft is not applied as a simple vertical offset to soundings for ERS Surveys; instead, it factors into the determination of the sound speed profile value to use at the start of beam ray tracing in sound velocity correction.

The waterline for HSL platforms is measured using physical measurements from the waterline of the vessel to physical known benchmarks. Measuring the waterline occurs annually during HSRR, and if there are any major changes in weight or loading onboard the launches.

All offsets, correctors, and values used in TPU calculation that are stored in the HVF file can be found in the appendixes submitted with this report, under HVF Reports. These HVF Reports are output from the CARIS HVF Editor in a plain text document readable anywhere, and include all of the requested values for the DAPR necessary to reproduce an HVF.

B.2.1.1 Static Draft Correctors

Vessel	*Date*	*Loading*	*Static Draft*	
			Measurement	*Uncertainty*
2903_2022_EM2040	2022-05-16	0.030 meters	-0.662 meters	0.030 meters
2904_2022_EM2040	2022-03-21	0.030 meters	-0.683 meters	0.030 meters
S222_2022_EM2040	2022-03-02	0.100 meters	0.451 meters	0.030 meters

B.2.2 Dynamic Draft

Dynamic draft for all platforms was measured using the Post Processed Kinematic GPS method outlined in section 1.4.2.1.2.1 of NOAA's FPM. To reduce the effect of any potential current, reciprocal lines were run at each RPM step in order to get an average speed over ground for each RPM. This average speed was used to estimate the vessel’s speed through the water. Dynamic draft and vessel offsets corrector values are stored in the HIPS Vessel Files (HVF).

In ERS hydrography the dynamic draft correction is not applied as a simple vertical offset to the soundings; instead, it factors into the determination of the sound speed profile value to use at the start of beam ray tracing in sound velocity correction.

All offsets, correctors, and values used in TPU calculation that are stored in the HVF file can be found in the included Appendix Folder, HVF Reports. These HVF Reports are output from the Caris HVF Editor in a plain text document readable anywhere, and include all of the requested values for the DAPR necessary to reproduce an HVF.

B.2.2.1 Dynamic Draft Correctors

Vessel	2904_2022_EM2040		2903_2022_EM2040		S222_2022_EM2040	
Date	2022-01-01		2022-03-01		2021-01-01	
Dynamic Draft	*Speed (m/s)*	*Draft (m)*	*Speed (m/s)*	*Draft (m)*	*Speed (m/s)*	*Draft (m)*
	0.00	0.00	0.00	0.00	0.00	0.00
	0.50	0.02	0.50	0.00	0.50	0.00
	1.00	0.03	1.00	0.02	1.00	0.04
	1.50	0.04	1.50	0.04	1.50	0.06
	2.00	0.06	2.00	0.06	2.00	0.05
	2.50	0.06	2.50	0.07	2.50	0.04
	3.00	0.06	3.00	0.08	3.00	0.03
	3.50	0.05	3.50	0.08	3.50	0.03
	4.00	0.04	4.00	0.08	4.00	0.05
	4.50	0.02	4.50	0.04	4.50	0.11
	5.00	-0.02	5.00	0.00	5.00	0.22
	5.50	-0.06	5.50	-0.06	5.50	0.29
	6.00	-0.12	6.00	-0.14	6.00	0.38
	6.50	-0.18	6.50	-0.24		
Uncertainty	*Vessel Speed (m/s)*	*Delta Draft (m)*	*Vessel Speed (m/s)*	*Delta Draft (m)*	*Vessel Speed (m/s)*	*Delta Draft (m)*
	0.50	0.04	0.50	0.07	0.50	0.17

B.3 System Alignment

B.3.1 System Alignment Methods and Procedures

THOMAS JEFFERSON conducted MBES calibration tests during annual HSRR activities for each individual multibeam system on the ship and her launches in the vicinity of Norfolk, VA in March 2022 and Cleveland, OH in May 2022.

The procedure used follows that outlined in 2020 FPM. Timing bias was determined using the method of running the same line at different speeds. Pitch and yaw bias was determined using a target on the seafloor. Finally, roll bias was determined using the standard flat bottom method. Offset values for all platforms were derived using CARIS patch testing tools during annual HSRR activities. Alignment between components are measured using patch test methods that result in differences between the IMU and the sonar transceiver face along the x-, y-, and z-axes (pitch, roll, and yaw). Timing bias is assumed to be zero. True heave, water levels, the most recent dynamic draft, and sound velocity profiles were applied and the data georeferenced before cleaning via Swath Editor. Biases were determined by survey personnel, and checked against CARIS HIPS Calibration tool and Qimera's Patch Test Tool.

Patch test angular biases are applied during acquisition via SIS Sensor Setup for S222, and via POS MV configuration for HSL 2903 and HSL 2904. The following tables do not reflect the entire configuration settings contained within SIS, POS MV, and the HVF. All calibration reports can be found in the Appendix Folder.

B.3.1.1 System Alignment Correctors

Vessel	2903		
Echosounder	Kongsberg Simrad EM2040 300kHz 0.5x1_Normal Mode		
Date	2022-03-24		
Patch Test Values		*Corrector*	*Uncertainty*
	Transducer Time Correction	0.000 seconds	0.001 seconds
	Navigation Time Correction	0.000 seconds	0.001 seconds
	Pitch	0.000 degrees	0.040 degrees
	Roll	0.000 degrees	0.040 degrees
	Yaw	0.000 degrees	0.080 degrees
	Pitch Time Correction	0.000 seconds	0.001 seconds
	Roll Time Correction	0.000 seconds	0.001 seconds
	Yaw Time Correction	0.000 seconds	0.001 seconds
	Heave Time Correction	0.000 seconds	0.001 seconds
Date	2022-03-24		
Patch Test Values (Transducer 2)		*Corrector*	*Uncertainty*
	Transducer Time Correction	0.000 seconds	0.001 seconds
	Navigation Time Correction	0.000 seconds	0.001 seconds
	Pitch	0.000 degrees	0.040 degrees
	Roll	0.000 degrees	0.040 degrees
	Yaw	0.000 degrees	0.080 degrees
	Pitch Time Correction	0.000 seconds	0.001 seconds
	Roll Time Correction	0.000 seconds	0.001 seconds
	Yaw Time Correction	0.000 seconds	0.001 seconds
	Heave Time Correction	0.000 seconds	0.001 seconds

Vessel	2904
Echosounder	Kongsberg Simrad EM2040 300kHz 0.5x1_Normal Mode
Date	2022-03-24

Patch Test Values

	Corrector	*Uncertainty*
Transducer Time Correction	0.000 seconds	0.001 seconds
Navigation Time Correction	0.000 seconds	0.001 seconds
Pitch	0.000 degrees	0.110 degrees
Roll	0.000 degrees	0.110 degrees
Yaw	0.000 degrees	0.300 degrees
Pitch Time Correction	0.000 seconds	0.001 seconds
Roll Time Correction	0.000 seconds	0.001 seconds
Yaw Time Correction	0.000 seconds	0.001 seconds
Heave Time Correction	0.000 seconds	0.001 seconds

Date	2022-03-24

Patch Test Values (Transducer 2)

	Corrector	*Uncertainty*
Transducer Time Correction	0.000 seconds	0.001 seconds
Navigation Time Correction	0.000 seconds	0.001 seconds
Pitch	0.000 degrees	0.110 degrees
Roll	0.000 degrees	0.110 degrees
Yaw	0.000 degrees	0.300 degrees
Pitch Time Correction	0.000 seconds	0.001 seconds
Roll Time Correction	0.000 seconds	0.001 seconds
Yaw Time Correction	0.000 seconds	0.001 seconds
Heave Time Correction	0.000 seconds	0.001 seconds

Vessel	S222
Echosounder	Kongsberg EM2040 300kHz 0.5x1_Normal Mode
Date	2021-01-01

Patch Test Values

	Corrector	*Uncertainty*
Transducer Time Correction	0.000 seconds	0.001 seconds
Navigation Time Correction	0.000 seconds	0.001 seconds
Pitch	-0.266 degrees	0.070 degrees
Roll	0.327 degrees	0.070 degrees
Yaw	179.504 degrees	0.070 degrees
Pitch Time Correction	0.000 seconds	0.001 seconds
Roll Time Correction	0.000 seconds	0.001 seconds
Yaw Time Correction	0.000 seconds	0.001 seconds
Heave Time Correction	0.000 seconds	0.001 seconds

<table>
<tr><td>Date</td><td>2021-01-01</td></tr>
<tr><td>Patch Test Values (Transducer 2)</td><td>
<table>
<tr><td></td><td>Corrector</td><td>Uncertainty</td></tr>
<tr><td>Transducer Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
<tr><td>Navigation Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
<tr><td>Pitch</td><td>-0.277 degrees</td><td>0.070 degrees</td></tr>
<tr><td>Roll</td><td>0.419 degrees</td><td>0.070 degrees</td></tr>
<tr><td>Yaw</td><td>179.498 degrees</td><td>0.070 degrees</td></tr>
<tr><td>Pitch Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
<tr><td>Roll Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
<tr><td>Yaw Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
<tr><td>Heave Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
</table>
</td></tr>
</table>

C. Data Acquisition and Processing

C.1 Bathymetry

C.1.1 Multibeam Echosounder

Data Acquisition Methods and Procedures

All multibeam data on is logged using Kongsberg Seafloor Information System (SIS) in the .all file format. Data are displayed using 2-D and 3-D data display windows in the real-time screen display. Mainscheme data are acquired using either planned lines, or adaptive line steering approach whereby the coxswain views a real-time coverage map in Hysweep and accordingly adjusts line steering to ensure assigned coverage requirements are met. Additionally, vessel speed is adjusted as necessary in accordance with the HSSD and Project Instructions to ensure the required along-track coverage for either complete coverage or object detection.

During acquisition aboard S222, HSL 2903, and HSL 2904 the hydrographer:

- Monitors the SIS interface for errors and data quality. SIS settings are not typically changed from auto, but in some cases the range scale, gain, and pulse width parameters are adjusted. Adjustable filtering and cleaning is not utilized.

- Monitors the SIS interface for indication of sound speed changes requiring a cast, and conducts casts as necessary

- Monitors the Hysweep interface in HYPACK

- Monitors the vessel speed and requests the bridge to adjust as necessary to ensure density and coverage specifications are met

Data Processing Methods and Procedures

Following acquisition, multibeam sonar data were processed either using CARIS HIPS and SIP manually or by using the automated Pydro Explorer application, Charlene, to perform the same steps. The standard data processing steps are as follows for Applanix RTX with Kongsberg EM2040:

1) Create SBET and RMS files in POSPac MMS from logged .000
2) Convert raw Kongsberg (.all) data to CARIS HDCS format
3) Load Delayed Heave
4) Import ancillary data: SBET and RMS
5) Apply sound speed velocity correctors
6) Compute GPS tide to transform data from the ellipsiod to the tidal datum using a VDatum separation model
7) Georeference data to apply position, attitude, and dynamic draft correctors to bathymetry and computer the corrected depth of each sounding
8) Compute Total Propagated Uncertainty (TPU)
9) Create a Combined Uncertainty and Bathymetry Estimator (CUBE) surface encompassing the survey area. The following settings are used when creating a CUBE surface:
Surface type- CUBE
IHO S-44 Order- Order 1a
Include status- check accepted, examined, and outstanding
Disambiguation method- density & locale (this method contains the greatest number of soundings and is also consistent with neighboring nodes)
advanced configuration- dependent upon the surface resolution (object detection v. complete coverage)
10) Conduct data quality controls and analysis
11) If necessary, create a holiday line plan

THOMAS JEFFERSON utilizes Charlene as part of the daily processing pipeline, an automated night processing and data transfer tool developed by NOAA's Office of Coast Survey in early 2017. Night processing includes all of those tasks in between raw data collection and a final daily product. Charlene allows the user to:

1. Perform verification of raw data
2. Build deliverable directory structure
3. Transfer and verify raw data
4. Process MBES and SSS data with CARIS Batch Processor
5. Generate SBETs with POSPac Batch
6. Use NOAA tools like AutoQC, QCTools and TCARI

C.1.2 Single Beam Echosounder

Single beam echosounder bathymetry was not acquired.

C.1.3 Phase Measuring Bathymetric Sonar

Phase measuring bathymetric sonar bathymetry was not acquired.

C.1.4 Gridding and Surface Generation

C.1.4.1 Surface Generation Overview

After initial processing, the bathymetric data is gridded into BASE surfaces using the Combined Uncertainty and Bathymetry Estimator (CUBE) algorithm. This type of surface calculates a horizontal and vertical uncertainty for each sounding, derived from the combined uncertainty from each of the sensors that contributes data to the sounding (e.g water levels, tide zoning, attitude sensor error, navigation sensor horizontal position error, and sound velocity profile error). Individual soundings are then propagated to grid nodes, which takes on a depth value as well as an uncertainty value based on all the soundings that contribute to the node. The influence of a sounding on a grid node is limited to 0.707 times the grid resolution.

C.1.4.2 Depth Derivation

Chart-datum depths are derived using ellipsoidally referenced ortho-tidal models provided to the field unit, using a VDatum separation model approach to transform from the acquisition datum (GNSS ellipsoid height) to chart datum (navigable water level). Anomalous data (fliers) may corrupt gridded depth estimates and draw gridded depth nodes away from reliable soundings. Flier Finder within Pydro Explorer's QC Tools is used to help identify such anomalous soundings for the hydrographer to clean, or reject, from the submitted sounding dataset.

Filters are used on a case-by-case basis as determined by the hydrographer. Refer to the Descriptive Report for more information. Gridding parameters and surface computation algorithms comply with the HSSD and are described above.

C.1.4.3 Surface Computation Algorithm

MBES data is gridded using the CUBE algorithm. Resolution is dictated by the Project Instructions, as well as the 2022 HSSD. The disambiguation method used is always Density and Local. The settings used for Capture Distance Scale, Horizontal Error Scale, and Capture Distance Minimum are those listed in the 2020 FPM. After creation, Uncertainty and CUBE surfaces go through a quality control process. During this process, the Depth, Uncertainty, Standard Deviation, and Density child layers are examined for compliance with NOAA specifications. After the surfaces pass quality control, they are finalized. Uncertainty values for finalized surface come from the greater of either Uncertainty, or Standard Deviation.

The advanced options configuration is manipulated to create VR surfaces. Estimation methods parameters for Density- Based CARIS VR Surfaces have the estimation method: "Ranges", with the range/resolution file set to NOAA_DepthRanges_ObjectDetection_2022.txt or NOAA_DepthRanges_CompleteCoverage_2022.txt, in addition to maximum and minimum grid size. The NOAA Office of Coast Survey (OCS) has created and provided a customized CUBE parameters file (CubeParams_NOAA_2022.xml) with new CUBE parameters that are required for each grid resolution. When creating CUBE surfaces, the user is provided an option to select parameter configuration based on the surface resolution required for the survey, which optimizes the performance of the CUBE algorithm. The population parameters for CARIS VR surfaces is CUBE, with the IHO Order selected and set to "S44 Order 1a", and the CUBE Configuration is "NOAA_VR" for a given surface.

C.2 Imagery

C.2.1 Multibeam Backscatter Data

Data Acquisition Methods and Procedures

The acoustic backscatter receiver of the Kongsberg MBES is calibrated in the factory, and has a typical accuracy of ±1 dB. However, this value may be offset from zero to serve as a correction factor, for example if there is a change with the age of the system, or if data from two different systems are merged and there is a systematic offset between the two systems. These offset values are kept at zero unless otherwise documented.

MBES backscatter data are logged via SIS and are included in the MBES files (.all format) by default.

The absorption coefficient depends upon depth, water temperature, salinity and frequency. A correct value is important with respect to the validity of the bottom backscatter data measured by the system.

The normal incidence sector defines the angle from nadir at which the bottom backscatter can be assumed not to be affected by the strong increase at normal incidence. For seabed imaging, it is important to adjust this angle so that a minimum of angle dependent amplitude variation is seen across the swath. The value for this parameter is kept at 15 degrees unless otherwise documented.

Data Processing Methods and Procedures

All acquired backscatter data are processed into a mosaic and delivered to AHB. All processing of backscatter is done using the FM Geocoder Toolbox (FMGT) 7.10.0 module of the QPS Fledermaus software package in accordance with OCS standard data processing methods.

The following is the general workflow for creating backscatter imagery:

-A new project is created for each sheet and each vessel and each sonar frequency. Metadata within the .all files ensures that sonar-specific characteristics are captured during mosaic processing.

-Vessel parameters are set, and allow the hydrographer to set configuration for each frequency and pulse length in order to calibrate slight differences in decibel levels. This produces a smoother, less patchwork appearance of backscatter mosaics between each frequency and pulse length. Parameter values may be determined by running a calibration line in the same direction with each possible combination of vessel, frequency, and pulse length.

-Lines are imported into FMGT. One mosaic is created per boat and frequency (300kHz), meaning two mosaics are created.

-Create a mosaic. Crosslines are not needed in the mosaic and are deselected. Mosaic gridding resolution is set to 1m. The product is exported as a floating point GeoTIFF grid with a value for no data set to -9999.

C.2.2 Side Scan Sonar

Data Acquisition Methods and Procedures

Side scan sonar data collected with the Klein 5000 SSS are logged using Klein SonarPro, in the .SDF format. Data collected with the Edgetech 4200 SSS are logged in Edgetech Discover in .XTF format.

During acquisition the hydrographer:

- Monitors range, towfish height, heading, pitch, roll, latitude, longitude, speed, pressure, and temperature;

- Adjusts towfish height for operations aboard S222

Data Processing Methods and Procedures

Following acquisition, SSS data were processed either using CARIS HIPS and SIP manually or by using the automated Pydro Explorer application, Charlene, to perform the same steps. The standard data processing steps are as follows for Klein 5000 or Edgetech 4200 SSS:

1) Convert raw SSS (.SDF or .XTF) data using CARIS SIPS;
2) Scan Navigation and Attitude data, flagging erroneous data as rejected;
3) Re-compute towfish navigation. Towfish navigation is developed from data collected, using ship's navigation (POS .000 file), towfish altitude, and layback. Layback is calculated from the towpoint that is recorded in the CARIS HVF; towfish gyro is used for direction This is when tow point offsets and horizontal layback is applied to the data;
4) Create Beam Pattern- build .BBP file through averaging the intensities and angles from across the data set. These averages are then applied to "Create Mosaic" to produce more consistent images;
5) Create SIPS mosaics utilizing the beam pattern, transmit and receiver gain, and the time varied gain (TVG) corrections.
6) A primary reviewer scans each line for significant contacts;

7) A secondary reviewer makes an independent check-scan of all lines, verifying contacts and checking for missed contacts;
8) If the Project Instructions call for 200% Side Scan coverage, the scanners check correlation of contacts between 100% and 200% coverage;
9) Correlation is also used to reveal systematic errors, particularly if a contact shows up on lines collected in opposite or orthogonal directions;
10) Create individual mosaics for 100% and 200% coverage. Examine for coverage;
11) If necessary, create a holiday line plan.

THOMAS JEFFERSON utilizes Charlene as part of the daily processing pipeline, an automated night processing and data transfer tool developed by NOAA's Office of Coast Survey in early 2017. Night processing includes all of those tasks in between raw data collection and a final daily product. Charlene allows the user to:

1. Perform verification of raw data
2. Build deliverable directory structure
3. Transfer and verify raw data
4. Process MBES and SSS data with CARIS Batch Processor
5. Use NOAA tools like AutoQC, QCTools and TCARI

C.2.3 Phase Measuring Bathymetric Sonar

Phase measuring bathymetric sonar imagery was not acquired.

C.3 Horizontal and Vertical Control

C.3.1 Horizontal Control

C.3.1.1 GNSS Base Station Data

GNSS base station data was not acquired.

C.3.1.2 DGPS Data

<u>Data Acquisition Methods and Procedures</u>

The POS MV systems include the option to receive correctors from the Wide Area Augmentation System (WAAS) to aid navigation. The WAAS is a Satellite Based Augmentation System (SBAS) for North America, developed by the Federal Aviation Administration and the Department of Transportation as an aid to air navigation. Usable by any WAAS-enabled GPS receiver, WAAS corrects for GPS signal errors caused by ionospheric disturbances, timing and satellite orbit errors, and it provides vital integrity information regarding the health of each GPS satellite. WAAS consists of multiple widely-spaced Wide Area Reference Stations (WRS) sites that monitor GPS satellite data. The WRS locations are precisely surveyed so that any errors in the received GPS signals can be detected. Two master stations, located on either coast, collect data from the reference stations via a terrestrial communications network and create a GPS correction message. This correction accounts for GPS satellite orbit and clock drift plus signal delays caused by the atmosphere and ionosphere. The corrected differential message is then broadcast through geostationary satellites with a fixed position over the equator. The information is compatible with the basic GPS signal structure, which means any WAAS-enabled GPS receiver can read the signal. The WAAS specification requires it to provide a position accuracy of 7.6 meters (25 ft) or better (for both horizontal and vertical measurements), at least 95% of the time. Actual performance measurements of the system at specific locations have shown it typically provides better than 1.0 meter horizontally and 1.5 meters vertically throughout most of the contiguous United States.

Data Processing Methods and Procedures

DGPS Processing Methods and Procedures: DGPS data are utilized within the POS MV system in real time, and included within the .000 file. Typically, the DGPS data are superseded by the more accurate, post-processed SBET files created from POSPac, or superseded by the use of Precise Point Positioning when available.

C.3.2 Vertical Control

C.3.2.1 Water Level Data

Data Acquisition Methods and Procedures

Raw GNSS-INS observables data are logged through POSView for S222, HSL 2903, and HSL 2904.

Data Processing Methods and Procedures

THOMAS JEFFERSON reduces all data to chart datum via Ellipsoidally Referenced Survey (ERS) workflows for all surveys.

GPS Tides:
The ‘Compute GPS Tides’ process in Caris HIPS is the primary means by which bathymetric data is reduced to chart datum. The Compute GPS Tides step references all MBES data to an ellipsoid and then applies a separation model to the ellipsoidally referenced data to achieve reduction to chart datum. The separation model is an XYZ surface that represents the difference between the ellipsoid and chart datum for the a given geographic area. The XYZ separation model used for typical NOAA workflows is delivered as a Caris CSAR file and represents the difference between the WGS84 ellipsoid and chartd datum at a given location. All separation models for waters in which THOMAS JEFFERSON operates are derived from the NGS Vertical Datum (VDatum) program. Separation models are usually generated, approved and disseminated by HSD Ops.

GNSS positioning methods employed to meet ERS specifications include the methods described below:

Raw GNSS-INS observables data are logged through POSView can be post-processed in POSPac MMS to provide a trajectory solution that can be applied to MBES data in CARIS HIPS and SIPS. Post-Processed Trimble CenterPoint real-time extended is the standard practice for S222, HSL 2903, and HSL 2904.

Inertially aided Fusion Post-Processed real-time extended:

During post-processing, horizontal positioning can be shifted to an Inertially aided Fusion Post-Processed real-time extended (Trimble PP-RTX) solution. The solution is created by combining GNSS satellite ephemeris and clock data with position information downloaded from a network of Continually Operating Reference Stations (CORS). The resulting position data is corrected for the effects of atmospheric interference on the GPS signal. The corrected GPS position is then combined with the vessel's inertial data using the POSPac MMS program to create a Smoothed Best Estimate of Trajectory (SBET). The resulting position can be used to apply higher quality navigation information to the processed data.

C.3.2.2 Optical Level Data

Optical level data was not acquired.

C.4 Vessel Positioning

Data Acquisition Methods and Procedures

THOMAS JEFFERSON survey systems utilizes Post Processed Kinematic (PPK) methods for the horizontal positioning of bathymetric data. The exact method selected is based upon the availability, or lack thereof, of Continually Operating Reference Stations (CORS) near the project area. The three methods available in order of preference are 1) Smart Base, 2) Single Base, and finally 3) Precise Point Positioning (PPP).

Smart Base:
Smart Base is the preferred method when a minimum of four (six recommended) CORS stations are available for selection near the project area. In situations with a maximum baseline of 70 km, an optimal horizontal accuracy of 3-10 cm should be achieved. Applanix POSPac software is used to produce a smoothed Best Estimate of Trajectory (SBET) file. The SBET file consists of GPS position and attitude data corrected and integrated with inertial measurements and reference station correctors, exported into WGS84. The SBET is created using the Applanix proprietary “SmartBase” algorithm, which generates a Virtual Reference Station (VRS) on site from a network of established reference stations surrounding the project area, generally the Continually Operating Reference Station (CORS) network. Reference station data is downloaded with the POSPac MMS download tool and usually available within 24 hours. These SBET navigation and attitude files are applied to all lines in CARIS and supersede initial positioning and attitude data. For further details on the CORS network stations utilized in addition to processing methodology, refer to the HVCR of the appropriate project.

Single Base:
The Single Base solution of processing SBETs requires the input of attitude data acquired by the POS/MV in addition to simultaneously collected base station data. Vessel kinematic data is post-processed using Applanix POSPac processing software, POSGNSS processing software and Single Base processing methods. These SBET navigation and attitude files are applied to all lines in CARIS and supersede initial positioning and attitude data. Further details on the CORS station(s) and/or THOMAS JEFFERSON-installed GPS base station(s) utilized in addition to processing methodology would be included in the HVCR of the appropriate project.

Precise Point Positioning:
Precise Point Positioning (PPP) is used as a last resort when Smart Base or Single Base is not available. This occurs when THOMAS JEFFERSON conducts survey operations far enough offshore that it is physically impossible to install a shore base station within the recommended 20km radius. Precise Point Positioning may also be used to cover data gaps and/or outages in data from a CORS station or a THOMAS JEFFERSON-installed base station. When PPP is chosen, an optimal horizontal accuracy of 10-50 cm should be achieved.

Data Processing Methods and Procedures

POSPac creates SBET (smoothed best estimate trajectory) files by post-processing the POSPac .000, GNSS and base station data. SBETs are ingested by CARIS, along with the original POSPac .000 file, to provide high accuracy positioning data to collected bathymetry. The favored method of processing raw POS MV data requires input from nearby semipermanent shore stations. POSPac has two options for handling shore stations, Single Baseline and SmartBase processing. SmartBase processing is the preferred method, when an eligible network of installed base stations are available. For the SmartBase method, an optimal network consists of six to eight reference stations evenly distributed around the surveyed area and separated by 50 to 70 km. A minimum of four stations are required for Applanix SmartBase processing. For the single base station method, the primary-reference baseline separation must be less than 20 km at the start and end of the mission and can occasionally grow to 100 km during the mission. This information is utilized by Charlene for SBET and RMS processing.

• Smart Base Processing
1) Open Applanix POSPacTM Mobile Mapping Suite and set up the project
2) Load the Applanix .000 file (recorded on the launch)
3) Select the "Find Base Stations" option which will generate a list of nearby CORS stations and then click on the "Smart Select" button.
4) POSPac will need the Internet to access and download the base station data it finds as the best option to import. It will need a minimum of 4 stations as well as adequate ephemeris data to continue. This process is done automatically.
5) Once the base stations and ephemeris data have been downloaded, the Raw Data Check-In window will appear automatically, click OK. Once you click OK, POSPac will create a triangulated network of all the base stations it has chosen for processing.
6) Next run the SmartBase Quality Check. POSPac will run the quality check to see if the data downloaded is good enough for processing and generate a Results Summary. If the data is inferior, it will recommend to Re-run the SmartBase Quality Check processor or that there is not enough adequate data to continue.

7) In remote areas there may not be an optimal amount of data available. Occasionally you have to override the system and see if the SBET generated is up to spec. This is done by running the Applanix SmartBase processor.
8) Once the Applanix SmartBase processor has finished, the outline of the triangulated network will be highlighted in yellow. This means that you are ready for processing and that the appropriate base stations have been designated and set.
• Batch Processing -- Batch processing allows processing of multiple POS/MV .000 files from multiple vessels on a once per day per survey sheet basis.
• POSPac SBET Quality Control -- Once the POSPac project has completed processing successfully, quality control of the SBETs (Smoothed Best Estimated Trajectories) is performed.
• Exporting Custom SBET -- Once the QC is complete and the processing log updated, the next step is to export a custom SBET in NAD83.

• Single Base Station Processing
1) Open Applanix POSPacTM Mobile Mapping Suite and set up the project
2) Load the Applanix .000 file (recorded on the launch)
3) Load the satellite data logged by the base station (the .YYo file that corresponds to the day number being processed).
4) Once the coordinate manager window opens, the true ITRF coordinates from the OPUS report is input. The same ITRF coordinates are used throughout the project and are checked against "new" OPUS solutions to maintain consistency.
5) Both the SBET (in ITRF format) and smrmsg error data files are created.

For both a Single Base or Smart Base solution, SBETs are applied in CARIS by loading both the SBET files and error data files in smrmsg format. For every SBET file generated during single base station processing there is an associated smrmsg file.
1) Process --> Load Attitude/Navigation data... Load the WGS84 SBET files. Import data for Navigation, Gyro, Pitch, Roll, and GPS Height are all selected for survey launches. Only Navigation and GPS Height are selected for the ship.
2) Process --> Load Error data... Load the smrmsg error data file. Import data for Position RMS, Roll RMS, Pitch RMS, and Gyro RMS are selected for survey launches. Vertical RMS is not selected since HIPS will default to using the trueheave RMS values. Only Position RMS is selected for the ship.

In the event that no base station falls within the 20km limit as is often the case with offshore sheets, and a Precise Point Positioning (PPP) solution utilizing precise ephemeris data is used, SBET and RMS are loaded as followed.
1) Process --> Load Attitude/Navigation data... Load the custom SBET files (WGS84). Import data for Navigation and GPS Height are selected for survey launches and the ship.
2) Process --> Load Error data... Load the smrmsg error data file. Import data for just the Position RMS, is selected for survey launches and the ship. Vertical RMS is not selected since HIPS will default to using the trueheave RMS values for the launches.

C.5 Sound Speed

C.5.1 Sound Speed Profiles

Data Acquisition Methods and Procedures

S222 uses an AML MVP-X Probe installed inside an MVP free-fall fish to acquire sound speed profiles. Profiles aboard the ship are generally acquired at 30 - 90 minute intervals. Cast frequency is increased when the comparisons show significant variability. Sampling intervals are adjusted to ensure spatial variability or if there is suspicion of sudden changes in the water-column.

The Moving Vessel Profiler (MVP) is an automated winch system that deploys a towfish containing a sound speed sensor. The fish is towed behind S222 in a ready position that is marked by messengers attached to the tow cable. The towfish is typically deployed at a ready depth that is approximately the same depth of the ship MBES transducers. Deployment depth is a function of water depth. The towfish descends at the rate of freefall when deployed. Towfish freefall is automatically stopped once a specified depth limit is met and the drag forces on the fish cause it to rise toward the surface due to the ship's forward motion. The cable slack is then pulled in by the winch to the ready towing position.

HSL 2903 and HSL 2904 both use Sea-Bird SBE 19plus CTDs to collect sound speed profiles. Casts are generally taken at 2-4 hour intervals. Casts are also conducted when changing survey areas or when a change of weather, tide, or current warrant. The launch crew also monitors the real time display of the Reson SVP-70 sound velocity probe for significant changes in the surface sound velocity.

When conducting manual CTD casts with the SBE 19plus, the instrument is lowered into the water and submerged just below the water's surface for about 2 minutes to allow air to escape the salinity cell. The instrument is lowered at the rate of free fall. The instrument is lowered slowly (in some cases, much less than 1 meter/second) through the first 5-10 meters of water in order to accurately sample the sound speed for areas with lenses of fresh water or other complex sound speed variation near the surface.

Data Processing Methods and Procedures

Downloading and processing of sound speed data is performed using Sound Speed Manager, part of the HSTB-supplied Pydro 19 program suite. Sound speed values are calculated using the UNESCO equation (Fofonoff and Millard, 1983). Processed profiles are sent to SIS for realtime beam control. In addition, both raw and processed CTD files are archived and submitted to the hydrographic branch as part of the sheet submission package.

All sound velocity profiles for CARIS are concatenated into a vessel-wide or sheet-wide files in order of ascending time and date. These concatenated file(s) are applied to all HDCS data acquired with "Nearest in distance within time (4 Hours)" selected under the "Profile selection Method".

Processed sound speed data data is applied to the MBES data in Caris HIPS.

C.5.2 Surface Sound Speed

Data Acquisition Methods and Procedures

S222 uses a Valeport probe to find the speed of sound at the approximate depth of the Kongsberg transducers.

HSL 2903 and HSL 2904 use Reson SV-70 probes to acquire sound speed at their respective transducer faces.

Sound speed values are applied in real-time to all MBES systems to provide refraction corrections to flat-faced transducers.

The accuracy of each surface sound speed device is checked against the closest CTD data point after every CTD cast.

Data Processing Methods and Procedures

Surface sound speed data are logged directly into Kongsberg raw .all data files. Surface sound speed data is not typically processed after the time of acquisition.

C.6 Uncertainty

C.6.1 Total Propagated Uncertainty Computation Methods

Total Propagated Uncertainty (TPU) is calculated in CARIS HIPS using the 'Compute TPU tool'.

The uncertainty values for each input into the TPU model can come from one of three sources: Real-time, Static, or Vessel. Real-time values are provided from the sensor or processing package (e.g. POSPac RMS values). Static values are those entered manually into the Compute TPU dialog (e.g. tidal zoning uncertainty and sound speed measurement uncertainties). Static values are documented in each Descriptive Report. Vessel values are taken from the HVF if no realtime or static values are available.

Uncertainty values entered into the HVF for the multibeam and positioning systems are derived from manufacturer specifications sheets for each sensor and from values set forth in section 4.2.3.8 and Appendix 1 - CARIS HVF Uncertainty Values of the 2020 FPM.

Sound speed static values are derived from the guidance in the FPM, manufacturer specifications and annual calibration results.

Tide correction uncertainty values for the ERS work flow are static values specified in the Project Instructions. The field unit checks the uncertainty value provided in the project instructions with the associated VDatum text file (XXXXX_sheets_exysep.txt.log) under the VDatum Vertical Area-Weighted SEP Uncertainty.

Ellipsoid height uncertainty values for ellipsoid measurements derived from 5P or Trimble PP-RTX work flows are applied as real-time values from RMS files. Kongsberg systems provide uncertainty statistics that are recorded in raw MBES files.

All offsets, correctors, and values used in TPU calculation that are stored in the HVF file can be found in the included Appendix Folder, HVF Reports. These HVF Reports are output from the CARIS HVF Editor in a plain text document readable anywhere, and include all of the requested values for the DAPR necessary to reproduce an HVF.

C.6.2 Uncertainty Components

C.6.2.1 A Priori Uncertainty

Vessel		2903_2022_EM2040	2904_2022_EM2040	S222_2022_EM2040
Motion Sensor	*Gyro*	0.02 degrees	0.02 degrees	0.02 degrees
	Heave	5.00% 0.05 meters	5.00% 0.05 meters	5.00% 0.05 meters
	Roll	0.02 degrees	0.02 degrees	0.02 degrees
	Pitch	0.02 degrees	0.02 degrees	0.02 degrees
Navigation Sensor		0.50 meters	0.50 meters	0.05 meters

C.6.2.2 Real-Time Uncertainty

Vessel	*Description*
S222	Some real-time uncertainty values are incorporated into the depth estimates of THOMAS JEFFERSON surveys by way of post-processing. Real-time uncertainties from the Kongsberg EM2040 are recorded and applied in post-processing. Applanix TrueHeave files are recorded on all survey vessels, which include an estimate of the heave uncertainty, and are applied during post-processing. Finally, the post-processed uncertainties associated with vessel roll, pitch, gyro and navigation are applied in CARIS HIPS via an SBET RMS file generated in POSPac.
2903	Some real-time uncertainty values are incorporated into the depth estimates of THOMAS JEFFERSON surveys by way of post-processing. Real-time uncertainties from the Kongsberg EM2040 are recorded and applied in post-processing. Applanix TrueHeave files are recorded on all survey vessels, which include an estimate of the heave uncertainty, and are applied during post-processing. Finally, the post-processed uncertainties associated with vessel roll, pitch, gyro and navigation are applied in CARIS HIPS via an SBET RMS file generated in POSPac.
2904	Some real-time uncertainty values are incorporated into the depth estimates of THOMAS JEFFERSON surveys by way of post-processing. Real-time uncertainties from the Kongsberg EM2040 are recorded and applied in post-processing. Applanix TrueHeave files are recorded on all survey vessels, which include an estimate of the heave uncertainty, and are applied during post-processing. Finally, the post-processed uncertainties associated with vessel roll, pitch, gyro and navigation are applied in CARIS HIPS via an SBET RMS file generated in POSPac.

C.7 Shoreline and Feature Data

Data Acquisition Methods and Procedures

The definition of the NALL is subject to modification by the Project Instructions, Chief of Party, and the team as a whole. Some likely additional reasons for modifying the position of the NALL included:
- Sea conditions such as kelp or breakers in which it is unsafe to approach the shore to the specified distance or depth.
- Regular use of waters inshore of this limit by vessels navigating with NOAA nautical chart products.

The following workflow is used to develop and verify features:
- Potentially significant features are initially identified and inspected in CARIS HIPS and SIPs(both MBES and SSS contacts).
- A development area polygon or point feature is exported from HIPS; a line plan is created using HIPS, Hypack, or ArcMap if needed.
- Object Detection level MBES data is collected over all MBES and/or SSS contacts, and all possible shoal areas.

Quality of data is controlled through:
- Real time monitoring during acquisition to ensure that all features are covered by near nadir beams.
- Inspection of the CUBE surface's Density, Standard Deviation, and Uncertainty layers.
- All developments are examined for significance. Objects found to be significant are flagged with a designated sounding, and become part of the Final Feature File.

Features are addressed in the following manner for offshore the NALL:
-The height/depth of a feature found within 2mm at survey scale of the composite source position
-A feature outside 2mm at survey scale of the composite source position has its field position revised in addition to a height/depth determination
-Features with any linear dimension greater than 1mm at survey scale are treated as an area and delineated
-New features not identified in the Composite Source file
-Maritime boundary points and other features specifically identified for investigation

Navigationally Significant features are defined as the following:
-All features within the limits of safe navigation (i.e. offshore the NALL)
-Significantly (a ground unit distance equivalent to 0.8mm at the scale of the largest scale chart of the area) deflect this limit. Common examples include foul areas and ledges
-Man-made permanent features connected to the natural shoreline (such as piers and other mooring facilities) larger than the resolution specified for the survey. Seasonal features will be evaluated as they arise
-Man-made permanent features disconnected from the shoreline, such as stakes, pilings, and platforms

Data Processing Methods and Procedures

THOMAS JEFFERSON will not venture inshore of the NALL for investigation of assigned items if there is a question of safety or potential equipment damage. If the feature in question is exposed, time and height attributes are assigned while it is visible. If the features is not evident while investigating the NALL during shoreline verification, a remark of "inshore of NALL not investigated" is made with a recommendation of "Retain as charted." Feature attribution is completed for all 'Assigned' and any newly discovered items. Unassigned features are left untouched. Submerged features, such as wrecks and submerged piles designated in CARIS HIPS and SIPS are also brought into .000 for attribution.

Feature verification begins during initial data processing and throughout data collection. Both SSS and MBES data are processed following the conclusion of daily acquisition operations or at regular intervals (typically daily) for continuous ship operations. Significant contacts are identified and noted during initial processing. All significant contacts are then developed using a MBES. When conducting Multibeam surveys, or when reviewing MBES developments over side scan sonar contacts, the least depths over navigationally significant features are flagged as 'designated soundings', then imported into CARIS BASE Editor or HIPS and SIPS. Each significant contact is given an S-57 attribution, and the hydrographer recommends charting action. The final deliverable is a Final Feature File (FFF) in .000 format.

NOAA specific S-57 attribution includes "descp" with a drop-down menu which is edited to reflect the hydrographer recommendations as follows:

• descrp - new -- A new feature is identified during survey operations. The hydrographer recommends adding the feature to the chart. Also, in cases in which the geographic position of an existing point feature is modified; the newly proposed feature is characterized as "new", while the original feature is flagged as "delete".

• descrp - update -- The feature was found to be portrayed incorrectly on the chart. Update is also used in the case where the feature was found to be attributed incorrectly or insufficiently and is modified to reflect the additional or corrected attribution. Also, for cases in which the geographic extents/position of an existing line feature are modified; the newly proposed feature is characterized as "update"

• descrp - delete -- The feature is disproved using approved search methods and guidelines. The hydrographer recommends removing it from the chart. Also, for cases in which the geographic position of an existing point object is modified; the newly proposed feature is characterized as "new", while the original feature was flagged as "delete".

• descrp - retain -- The feature is found during survey operations to be positioned correctly and no additional attribution was required. The hydrographer recommends retaining the feature as charted.

• descrp – not addressed -- The feature is not investigated during shoreline acquisition, typically because it is either inshore of the NALL or unsafe to approach. The hydrographer recommends retaining the feature as charted.

Features described as "new" and "update" are updated with the SORIND/SORDAT attribution of the current survey. Features described as "delete", "Retain" and "not addressed" have their SORIND/SORDAT attribution remain unchanged.

C.8 Bottom Sample Data

Data Acquisition Methods and Procedures

HSD Operations typically provides the field unit with a number of recommended bottom sample sites. Proposed sample sites are encoded as S-57 SPRINGS and are provided in files distributed with the Project Instructions for the survey.

Bottom sample acquisition typically occurs after the majority of main-scheme MBES acquisition has completed. Bathymetric surfaces, backscatter surfaces and SSS intensity mosaics are examined to confirm the validity of the proposed sample sites. Sample sites may be moved or eliminated depending on field conditions. Samples are collected by launch or ship using one of the bottom samplers described in the equipment section of this report.

Imagery of the bottom type is collected in accordance with 2022 HSSD requirements. Physical sample bottom material is discarded after field analysis is complete.

Data Processing Methods and Procedures

Samples are analyzed for sediment type and classified with S57 attribution.

The NATSUR S-57 attribute for a sample site is characterized as “unknown” in the event that no sample is obtained after three collection attempts.

S-57 attribution is conducted in CARIS HIPS or BASE Editor.

Imagery is included as a feature file media attachment.

All bottom samples are processed, attributed, and named in accordance with 2022 HSSD.

Figure 24: An example of a bottom sample collected from the Lake Erie.

D. Data Quality Management

D.1 Bathymetric Data Integrity and Quality Management

D.1.1 Directed Editing

All statistics layers generated by the CARIS CUBE implementation are used (including uncertainty, hypothesis count, hypothesis strength, and standard deviation) to direct data cleaning. The Flier Finder function in Pydro QC Tools is used to direct cleaning of potential 'fliers' in the bathymetric surface data.

D.1.2 Designated Sounding Selection

On occasion, the resolution of the CUBE surface may not be sufficient to capture the high point of a feature. In less than 20m of water, any feature where the most probable accurate sounding is shoaler than the CUBE surface by greater than one half the allowable error under IHO S-44 Order 1 is considered inadequately captured by the CUBE surface. In greater than 20m of water, this allowable error is expanded to the full Order 1 error allowance at that depth. By the criteria above, if a sounding is eligible for designation it is not necessarily implied that a sounding must be designated. In general, sounding designation solely to adjust the surface is frowned upon and rarely used. Rather, sounding designation is used only when those soundings are of critical importance. The hydrographer uses discretion when designating soundings on features.

D.1.3 Holiday Identification

Holidays are addressed in the field throughout survey collection, and then reviewed prior to data acquisition of the survey area. They are identified primarily through the use of QC Tools "Holiday Finder, " or Pydro Explorer's Survey Outline tool for surveys that are mixed MBES and SSS coverage. Determining holidays is completed using an appropriate resolution single surface, or utilizing the variable resolution surface. All surfaces are also visually inspected.

D.1.4 Uncertainty Assessment

QC Tools included as part of Pydro Explorer contains the tool “Grid QA” largely automates the computation of grid statistics to ensure compliance to uncertainty and density requirements. The Depth, Uncertainty, Density (if available), and a computed Total Vertical Uncertainty (TVU) QC layer (optional) are used to compute particular statistics shown as a series of plots. The TVU QC is either given to the program in the grid input, or calculated on-the-fly. It is determined by a ratio of uncertainty to allowable error per NOAA and IHO specification. Grid QA outputs the following plots:

- The Depth layer plotted as a distribution (entitled “Depth Distribution”), the Density layer is plotted as a distribution (entitled “Object Detection Coverage”).
- The Density layer plotted as a distribution (entitled “Object Detection Coverage”).
- Density plotted against the corresponding Depth of the node (entitled “Node Depth vs. Sounding Density”).
- TVU QC plotted as a distribution (entitled “Uncertainty Standards”).
- TVU QC plotted against the corresponding Depth of the node (entitled “Node Depth vs. TVU QC”).
- Only for Variable Resolution grids, a histogram with the percentage of nodes at the prescribed resolution is created. This histogram can be used to evaluate whether “95% of all surface nodes have a resolution equal to or smaller than the coarsest allowable resolution for the node depth” as required by 2022 HSSD.

These plots once generated are analyzed for compliance with the applicable specifications and may be included in a sheet’s Descriptive Report as proof of compliance.

D.1.5 Surface Difference Review

D.1.5.1 Crossline to Mainscheme

Pydro Explorer includes the tool “Compare Grids” which now largely automates the comparison of co-located bathymetry data sets. This tool analyzes the difference between two gridded Depth/Elevation layers in CSAR/BAG format. The CSARs and/or BAGs input may be any combination of variable resolution or raster grids. Output consists of two CSAR grids and three plot files containing summary statistics. One of the CSAR output files contains the simple depth differences in a Diff layer. The other CSAR grid contains the layer fracAllowError, the fraction of the IHO-allowable error. As a quality control (QC) measure, cross-lines with a linear nautical total of at least 4% of mainscheme multibeam lines were run on each survey. Then a CUBE surface was created using strictly the main scheme lines, while a second surface was created using only the crosslines. The differences between these two surfaces are then analyzed using the “Compare Grids” tool. Summary statistics generated using “Compare Grids” are incorporated within the Descriptive Report for each survey.

D.1.5.2 Junctions

The Pydro Explorer tool “Compare Grids” described in D.1.5.1 is utilized for junction comparison analysis in the similar manner to crossline to mainscheme analysis.

D.1.5.3 Platform to Platform

Agreement and continuity of data collected between platforms is visually investigated by the survey manager to ensure consistency and highlight any potential biases in the data. To aid in the determination of potential biases, the depth child layer of the surfaces is inspected with an increased vertical exaggeration, generally between five and ten times greater.

D.2 Imagery data Integrity and Quality Management

D.2.1 Coverage Assessment

Coverage is assessed in accordance with 2022 HSSD.

Automated and visual methods are used to inspect surface coverage: ArcGIS tools are used to automatically identify coverage deficiencies; surfaces are inspected against brightly colored backgrounds for visible gaps in coverage.

CUBE statistical surfaces that show gridded node density are used to visually assess surfaces for compliance with bathymetric surface node density requirements.

Pydro QC Tools is used to statistically inspect CUBE surfaces for compliance with bathymetric surface node density requirements.

D.2.2 Contact Selection Methodology

Contacts are selected in accordance with 2022 HSSD.

Visual inspection of all SSS data is conducted in CARIS HIPS by multiple scanners (initially processor, check scanner and/or sheet manager).

E. Approval Sheet

As Chief of Party, I have ensured that standard field surveying and processing procedures were adhered to during these projects in accordance with the Hydrographic Surveys Specifications and Deliverables (2022 ed) and the Field Procedures Manual for Hydrographic Surveying (2020 ed).

I acknowledge that all of the information contained in this report is complete and accurate to the best of my knowledge.

Approver Name	Approver Title	Date	Signature
Matthew J. Jaskoski, CDR/NOAA	Commanding Officer	08/20/2022	JASKOSKI.MATTHEW.JACOB.1275636262 2022.08.20 13:00:42 -04'00'
Sydney M. Catoire, LT/NOAA	Field Operations Officer	08/20/2022	CATOIRE.SYDNEY.MARIE.1120060623 Digitally signed by CATOIRE.SYDNEY.MARIE.1120060623 Date: 2022.08.20 11:11:45 -04'00'
Erin K. Cziraki	Chief Hydrographic Survey Technician	08/20/2022	CZIRAKI.ERIN.KAYE.1550015338 Digitally signed by CZIRAKI.ERIN.KAYE.1550015338 Date: 2022.08.20 12:39:54 -04'00'

List of Appendices:

Mandatory Report	***File***
Vessel Wiring Diagram	2904_WiringDiagram_March2022.pdf 2903_WiringDiagram_March2022.pdf S222_2019_wiring_diagram.pdf
Sound Speed Sensor Calibration	SBE 19plus C4472 01Dec21.pdf SBE 19plus C4487 01Dec21.pdf SBE 19plus C4630 01Dec21.pdf SBE 19plus P4472 01Dec21.pdf SBE 19plus P4487 01Dec21.pdf SBE 19plus P4630 01Dec21.pdf SBE 19plus T4472 01Dec21.pdf SBE 19plus T4487 01Dec21.pdf SBE 19plus T4630 01Dec21.pdf SBE 19plus V2 C6667 03Dec21.pdf SBE 19plus V2 P6667 03Dec21.pdf SBE 19plus V2 T6667 03Dec21.pdf
Vessel Offset	2903_2022_EM2040_104142.pdf 2904_2022_EM2040_151624.pdf S222_2022_EM2040_101313.pdf
Position and Attitude Sensor Calibration	2903_POS_MV_Cal_Report_2022.pdf 2904_POS_MV_Cal_Report_2022.pdf
Echosounder Confidence Check	N/A
Echosounder Acceptance Trial Results	TJ_2903_2020.pdf TJ_2904_2020.pdf TJ_EM2040_and_EM710_Acceptance_2016.pdf