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

Data Acquisition & Processing Report

Type of Survey:	Basic Hydrographic Survey
Project Number:	OPR-X388-KR-19
Time Frame:	June - January 2020

LOCALITY

State(s):	Michigan
General Locality:	Lake Huron; Lake Michigan

2019

CHIEF OF PARTY
David Neff, C.H.

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Date:

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Data Acquisition and Processing Report

eTrac Inc.
Chief of Party: David Neff, C.H.
Year: 2019
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A. System Equipment and Software

A.1 Survey Vessels

A.1.1 R/V Benthos

Vessel Name	R/V Benthos	
Hull Number	338139713	
Description	Subcontractor Geodynamics LLC provided the R/V Benthos for hydrographic survey operations on OPR-X388-KR-19. The R/V Benthos is a 34 foot Catamaran built by Armstrong Marine with the following specifications:	
Dimensions	*LOA*	34 ft.
	Beam	10.5 ft.
	Max Draft	2 ft.
Most Recent Full Static Survey	*Date*	2017-08-11
	Performed By	Lanier Surveying Company
Most Recent Full Offset Verification	*Date*	2019-05-31
	Method	A series of previously established punch marks were surveyed using a Trimble 5000 precision robotic total station. Precise measurements with a hand held metal tape to confirm and adjust the previously measured offsets during the mobilization of OPR-X388-KR-19. The static survey data and measured data were used to establish a fixed vessel frame, vessel reference point, sensor mounting locations, and draft reference measurement points.

Figure 1: R/V Benthos

A.1.2 R/V 505

Vessel Name	R/V 505	
Hull Number	338223466	
Description	eTrac Inc. provided the R/V 505 for hydrographic survey operations on OPR-X388-KR-19. The R/V 505 is a 33 foot Catamaran built by Armstrong Marine. The R/V 505 has the following specifications:	
Dimensions	*LOA*	33 ft.
	Beam	9.5 ft.
	Max Draft	2 ft.
Most Recent Full Static Survey	*Date*	2017-08-27
	Performed By	eTrac Inc.
Most Recent Full Offset Verification	*Date*	2019-05-15
	Method	A series of previously established punch marks were surveyed using a Trimble 5000 precision robotic total station. Precise measurements with a hand held metal tape to confirm and adjust the previously measured offsets during the mobilization of OPR-X388-KR-19. The static survey data and measured data were used to establish a fixed vessel frame, vessel reference point, sensor mounting locations, and draft reference measurement points.

Figure 2: R/V 505

A.1.3 R/V Endeavor

Vessel Name	R/V Endeavor	
Hull Number	338342779	
Description	eTrac Inc. provided the R/V Endeavor for hydrographic survey operations on OPR-X388-KR-19. The R/V Endeavor is a 44 foot Catamaran built by Armstrong Marine. The R/V Endeavor has the following specifications:	
Dimensions	*LOA*	44
	Beam	14
	Max Draft	2.5

Most Recent Full Static Survey	*Date*	2019-06-14
	Performed By	Using a metal tape and a long carpenters level, 2 hydrographers from eTrac Inc. measured vessel equipment offsets for all components of the hydrographic system mobilized on Endeavor. As IMU and Sonars were collocated on the same pole, lever-arms were minimal. The primary positioning antenna was located on the STBD side of the vessel to minimize the IMU to Primary lever-arm. All measurements were performed a minimum of 3 times to reduce uncertainty.

Figure 3: R/V Endeavor

A.1.4 R/V WAMV 1

<table>
<tr><td>Vessel Name</td><td colspan="2">R/V WAMV 1</td></tr>
<tr><td>Hull Number</td><td colspan="2">WAMV-1</td></tr>
<tr><td>Description</td><td colspan="2">The Wave Adaptive Modular Vessel, or WAM-V is an innovative class of watercraft using unique suspension technology to radically improve seagoing capabilities.</td></tr>
<tr><td rowspan="3">Dimensions</td><td>LOA</td><td>16</td></tr>
<tr><td>Beam</td><td>8</td></tr>
<tr><td>Max Draft</td><td>0.5</td></tr>
<tr><td rowspan="2">Most Recent Full Static Survey</td><td>Date</td><td>2019-07-24</td></tr>
<tr><td>Performed By</td><td>Using a metal tape James Coleman from Sandpoint hydrographic measured vessel equipment offsets for all components of the hydrographic system mobilized on WAM-V-1. As IMU and Sonar were collocated on the same pole, lever-arms were minimal. All measurements were performed a minimum of 3 times to reduce uncertainty.</td></tr>
</table>

Figure 4: WAMV-1

A.1.5 R/V WAMV 2

Vessel Name	R/V WAMV 2
Hull Number	WAMV-2
Description	The Wave Adaptive Modular Vessel, or WAM-V is an innovative class of watercraft using unique suspension technology to radically improve seagoing capabilities.
Dimensions	*LOA*: 16
	Beam: 8
	Max Draft: 0.5

Most Recent Full Static Survey	*Date*	2019-07-24
	Performed By	Using a metal tape James Coleman from Sandpoint hydrographic measured vessel equipment offsets for all components of the hydrographic system mobilized on WAM-V-2. As IMU and Sonar were collocated on the same pole, lever-arms were minimal. All measurements were performed a minimum of 3 times to reduce uncertainty.

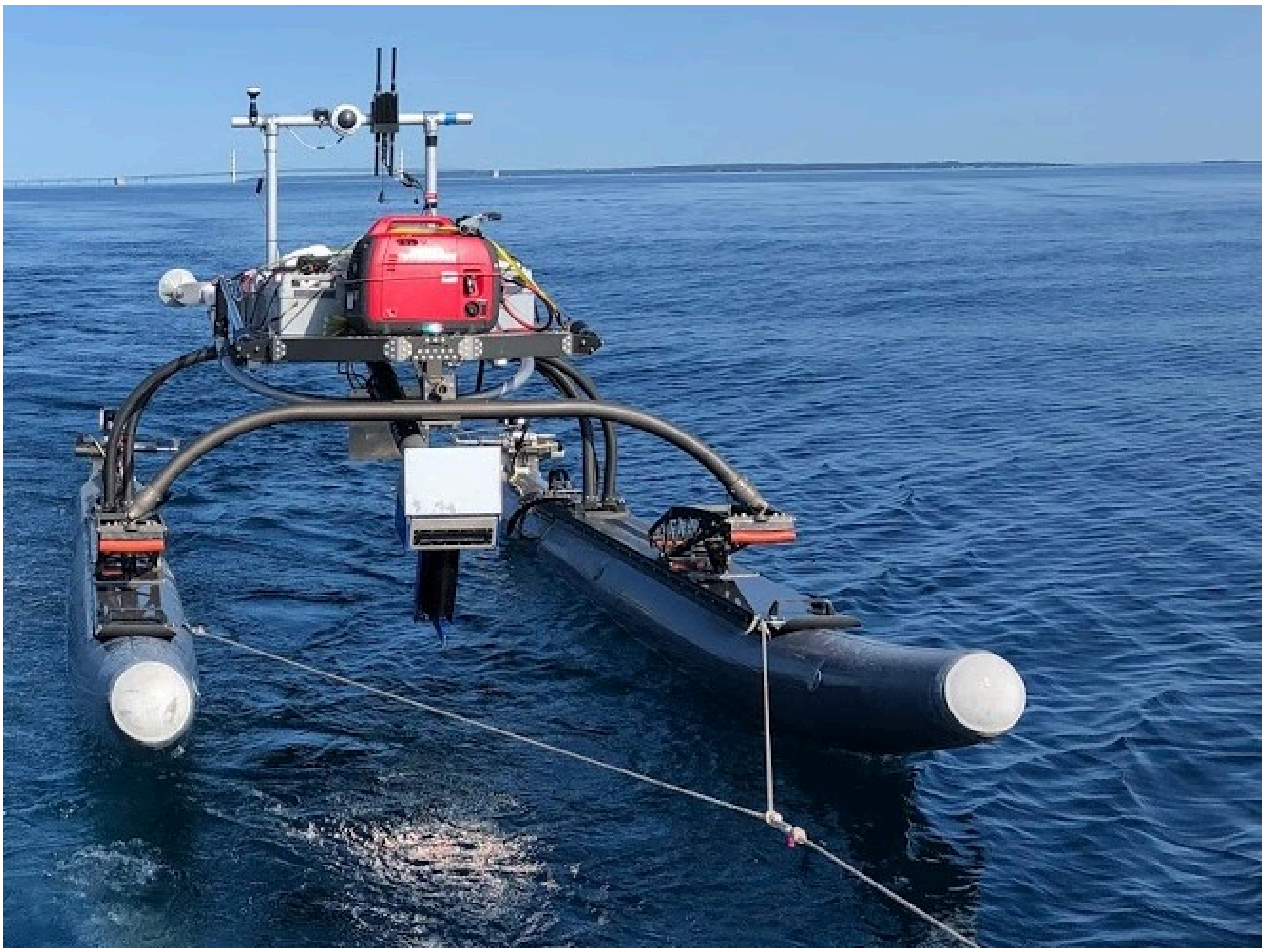

Figure 5: WAMV-2

A.2 Echo Sounding Equipment

A.2.1 Multibeam Echosounders

A.2.1.1 Kongsberg 2040C

The R/V Benthos was equipped with a dual-head Kongsberg 2040C Multibeam Echosounder System (MBES). The dual head 2040C utilizes 800 discretely formed beams of a selectable sector up to 200°. At 300kHz the 2040C focuses an across-track and along-track beamwidth of 1° and 1° respectively. The 2040C operates at a maximum ping rate of 50Hz and is designed to comply with IHO standards for depth measurement to a maximum range of 450 meters.

<table>
<tr><td>Manufacturer</td><td colspan="2">Kongsberg</td></tr>
<tr><td>Model</td><td colspan="2">2040C</td></tr>
<tr><td>Inventory</td><td>R/V Benthos</td><td>
<table>
<tr><td>Component</td><td>Deck Unit</td><td>Port Sonar Head</td><td>Stbd Sonar Head</td></tr>
<tr><td>Model Number</td><td>2040C</td><td>2040C</td><td>2040C</td></tr>
<tr><td>Serial Number</td><td>20159</td><td>1300</td><td>1284</td></tr>
<tr><td>Frequency</td><td>N/A</td><td>300</td><td>300</td></tr>
<tr><td>Calibration</td><td>2019-06-01</td><td>2019-06-01</td><td>2019-06-01</td></tr>
<tr><td>Accuracy Check</td><td>2019-06-01</td><td>2019-06-01</td><td>2019-06-01</td></tr>
</table>
</td></tr>
</table>

Figure 6: Kongsberg 2040C Dualhead MBES

A.2.1.2 R2Sonic Dual Head 2022

R/V 505 was equipped with a dual head R2Sonic 2022 Multibeam Echosounder System (MBES) and the WAMV-1 and WAMV-2 were equipped with a single head R2Sonic 2022 Multibeam Echosounder System (MBES). The dual head 2022 utilizes 512 discretely formed beams and the single head 2022 utilizes 256 discretely formed beams over a selectable sector up to 160° per sonar. At 400kHz the 2022 focuses an across-track and along-track beamwidth of 1° and 1° respectively. The 2022 operates at a maximum ping rate of 60Hz and is designed to comply with IHO standards for depth measurement to a maximum range of 400 meters.

Manufacturer	R2Sonic
Model	Dual Head 2022

Inventory

R/V 505

Component	Port Deck Unit I2NS	Port Receiver	Port Projector	Stbd Deck Unit	Stbd Receiver	Stbd Projector
Model Number	2022	2022	2022	2022	2022	2022
Serial Number	104128	100540	800083	103757	100845	806733
Frequency	N/A	300	300	N/A	400	400
Calibration	2019-06-01	2019-06-01	2019-06-01	2019-06-01	2019-06-01	2019-06-01
Accuracy Check	2019-06-01	2019-06-01	2019-06-01	2019-06-01	2019-06-01	2019-06-01

WAMV-1

Component	Deck Unit	Receiver	Projector
Model Number	2022	2022	2022
Serial Number	104253	101414	801266
Frequency	N/A	350	350
Calibration	2019-08-28	2019-08-28	2019-08-28
Accuracy Check	2019-08-28	2019-08-28	2019-08-28

WAMV-2

Component	Deck Unit	Receiver	Projector
Model Number	2022	2022	2022
Serial Number	104255	101519	800829
Frequency	N/A	400	400
Calibration	2019-08-28	2019-08-28	2019-08-28
Accuracy Check	2019-08-28	2019-08-28	2019-08-28

Figure 7: R2 Sonic 2022 Dualhead MBES

A.2.1.3 R2Sonic Dual Head 2024

R/V Endeavor was equipped with a dual head R2Sonic 2024 Multibeam Echosounder System (MBES). The dual head 2024 utilizes 512 discretely formed beams over a selectable sector up to 160° per sonar. At 400kHz the 2024 focuses an across-track and along-track beamwidth of 0.5° and 1° respectively. The 2024 operates at a maximum ping rate of 60Hz and is designed to comply with IHO standards for depth measurement to a maximum range of 400 meters.

Manufacturer	R2Sonic
Model	Dual Head 2024
Inventory	*338342779*

Component	Port Deck Unit	Port Receiver	Port Projector	Stbd Deck Unit	Stbd Receiver	Stbd Projector
Model Number	2024	2024	2024	2024	2024	2024
Serial Number	104267	101004	800013	104261	101794	806829
Frequency	N/A	300	300	N/A	400	400
Calibration	2019-06-18	2019-06-18	2019-06-18	2019-06-18	2019-06-18	2019-06-18
Accuracy Check	2019-06-18	2019-06-18	2019-06-18	2019-06-18	2019-06-18	2019-06-18

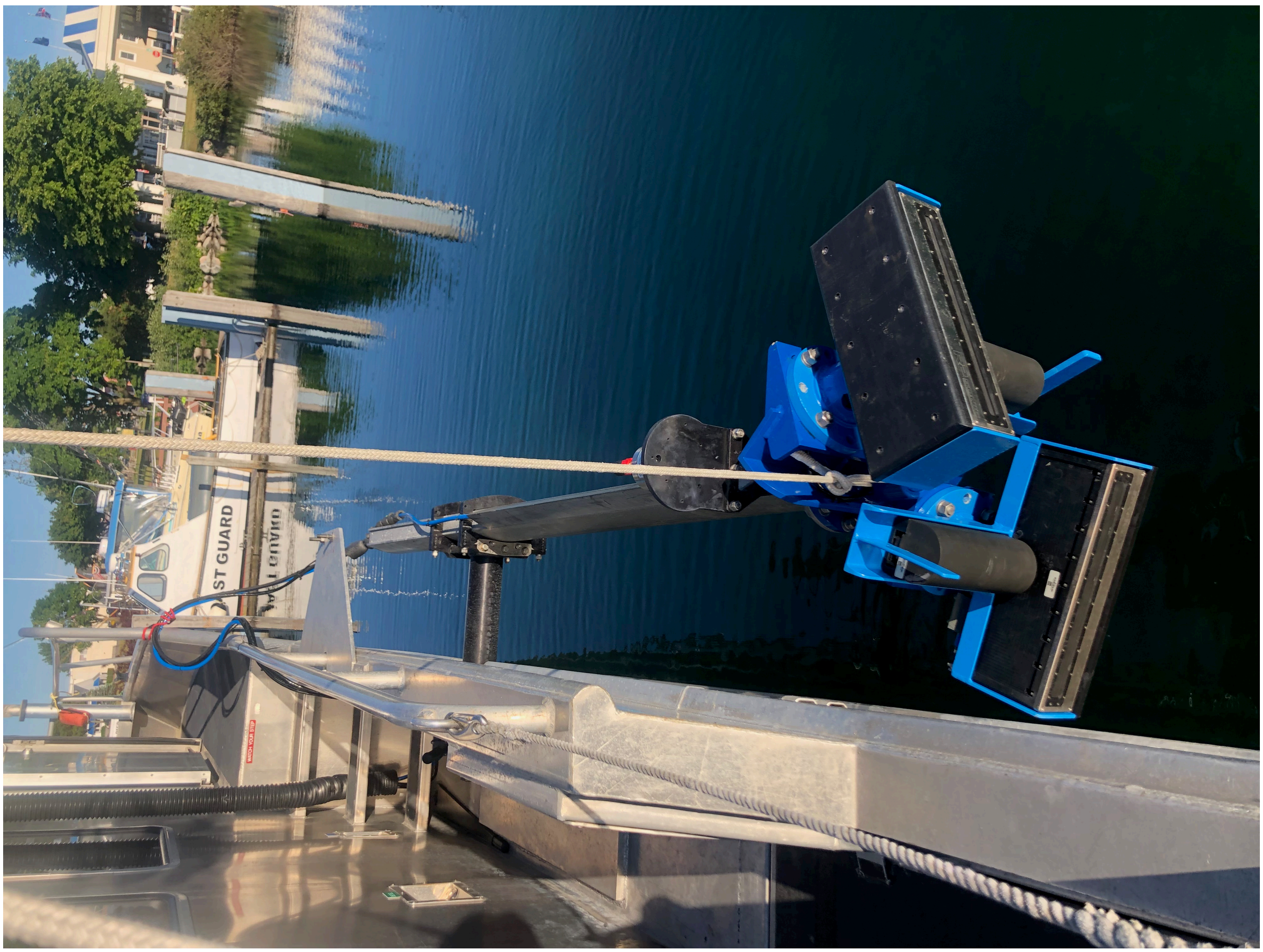

Figure 8: R2 Sonic 2024 Dualhead MBES

A.2.2 Single Beam Echosounders

No single beam echosounders were utilized for data acquisition.

A.2.3 Side Scan Sonars

No side scan sonars were utilized for data acquisition.

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 POSMV

R/V Benthos and R/V Endeavor were mobilized with an Applanix POSMV 320 V5 Global Positioning and Inertial Reference System. The POSMV was used to acquire position, attitude, and heading throughout the entire survey. The POSMV is comprised of a rack mount processor, dual GPS antenna baseline, and an inertial motion unit. Position, attitude, and heading data were broadcast to QPS QINSy acquisition software over Ethernet/UDP at 50Hz for R/V Endeavor. For the R/V Benthos, position, heading and attitude were transmitted to Kongsberg SIS over RS232 serial connections, broadcasting position and heading at 10Hz and attitude at 100Hz.

The POSMV provided precise timing of sonar instrumentation and acquisition software/hardware through a number of outputs. Timing of the multibeam data was handled at the R2Sonic topside unit or Kongsberg topside processing unit (PU). A PPS (Pulse Per Second) via BNC cable connection, as well as a NMEA ZDA message via RS232 serial connection at 1Hz, were sent from the POSMV to the R2Sonic topside unit and Kongsberg PU. The NMEA ZDA 1Hz message was additionally sent to QPS QINSy acquisition software.

<table>
<tr><td>Manufacturer</td><td colspan="4">Applanix</td></tr>
<tr><td>Model</td><td colspan="4">POSMV</td></tr>
<tr><td rowspan="8">Inventory</td><td rowspan="4">R/V Benthos</td><td>Component</td><td>Deck Unit</td><td>IMU</td></tr>
<tr><td>Model Number</td><td>POSMV 320 V5</td><td>IMU 65</td></tr>
<tr><td>Serial Number</td><td>6619</td><td>3250</td></tr>
<tr><td>Calibration</td><td>2019-05-30</td><td>2019-05-30</td></tr>
<tr><td rowspan="4">R/V Endeavor</td><td>Component</td><td>Deck Unit</td><td>IMU</td></tr>
<tr><td>Model Number</td><td>POSMV 320 V5</td><td>IMU 65</td></tr>
<tr><td>Serial Number</td><td>7163</td><td>1098</td></tr>
<tr><td>Calibration</td><td>2019-06-16</td><td>2019-06-16</td></tr>
</table>

A.5.1.2 R2Sonic I2NS

R/V 505 and WAM V-1 and WAM V-2 were mobilized with a R2Sonic I2NS. The R2Sonic I2NS is a combined Applianix POSMV 220 and R2Sonic topside unit. The POSMV portion of the I2NS was used to acquire position, attitude, and heading throughout the entire survey. The POSMV 220 integrates a dual GPS antenna baseline and an inertial motion unit. Position, attitude, and heading data were broadcast to QPS QINSy acquisition software over Ethernet/UDP at 50Hz for R/V 505 and WAM V -1 and WAM V-2.

<table>
<tr><td>Manufacturer</td><td colspan="4">R2Sonic</td></tr>
<tr><td>Model</td><td colspan="4">I2NS</td></tr>
<tr><td rowspan="12">Inventory</td><td rowspan="4">R/V 505</td><td>Component</td><td>Deck Unit</td><td>IMU</td></tr>
<tr><td>Model Number</td><td>I2NS</td><td>IMU</td></tr>
<tr><td>Serial Number</td><td>104128</td><td>501059</td></tr>
<tr><td>Calibration</td><td>2019-05-31</td><td>2019-05-31</td></tr>
<tr><td rowspan="4">WAM V - 1</td><td>Component</td><td>Deck Unit</td><td>IMU</td></tr>
<tr><td>Model Number</td><td>I2NS</td><td>IMU</td></tr>
<tr><td>Serial Number</td><td>104253</td><td>501176</td></tr>
<tr><td>Calibration</td><td>2019-07-25</td><td>2019-07-25</td></tr>
<tr><td rowspan="4">WAM V - 2</td><td>Component</td><td>Deck Unit</td><td>IMU</td></tr>
<tr><td>Model Number</td><td>I2NS</td><td>IMU</td></tr>
<tr><td>Serial Number</td><td>104255</td><td>501060</td></tr>
<tr><td>Calibration</td><td>2019-07-25</td><td>2019-07-25</td></tr>
</table>

A.5.2 DGPS

DGPS equipment was not utilized for data acquisition.

A.5.3 GPS

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

A.5.5.1 Fugro Marinestar Global Correction System

R/V Benthos, R/V Endeavor and R/V 505 received GNSS satellite corrections over the POSMV G2+ carrier signal from the Marinestar Global Correction System maintained by Fugro.

The Marinestar system is a global realtime GNSS broadcast system that delivers corrections from a network of base stations around the world via geo-stationary satellites.

<table>
<tr><td>Manufacturer</td><td colspan="3">Fugro</td></tr>
<tr><td>Model</td><td colspan="3">Marinestar Global Correction System</td></tr>
<tr><td rowspan="12">Inventory</td><td rowspan="4">R/V Benthos</td><td>Component</td><td>Marinestar Global Correction System</td></tr>
<tr><td>Model Number</td><td>N/A</td></tr>
<tr><td>Serial Number</td><td>N/A</td></tr>
<tr><td>Calibration</td><td>N/A</td></tr>
<tr><td rowspan="4">R/V 505</td><td>Component</td><td>Marinestar Global Correction System</td></tr>
<tr><td>Model Number</td><td>N/A</td></tr>
<tr><td>Serial Number</td><td>N/A</td></tr>
<tr><td>Calibration</td><td>N/A</td></tr>
<tr><td rowspan="4">R/V Endeavor</td><td>Component</td><td>Marinestar Global Correction System</td></tr>
<tr><td>Model Number</td><td>N/A</td></tr>
<tr><td>Serial Number</td><td>N/A</td></tr>
<tr><td>Calibration</td><td>N/A</td></tr>
</table>

A.6 Sound Speed Equipment

A.6.1 Moving Vessel Profilers

No moving vessel profilers were utilized for data acquisition.

A.6.2 CTD Profilers

No CTD profilers were utilized for data acquisition.

A.6.3 Sound Speed Sensors

A.6.3.1 AML Micro X

The R2Sonic 2022, R2Sonic 2024 and Kongsberg 2040C utilize an AML Micro•X located at the sonar head for surface sound speed measurement. The AML Micro•X is a time of flight SV sensor and is powered through the R2Sonic topside or powered directly from a 12 volt power source via RS232 serial cable connection. Sound speed measurements (measured in meters per second) are output through the same serial connection at 1Hz.

<table>
<tr><td>Manufacturer</td><td colspan="4">AML</td></tr>
<tr><td>Model</td><td colspan="4">Micro X</td></tr>
<tr><td rowspan="20">Inventory</td><td rowspan="4">R/V Benthos</td><td>Component</td><td>Surface Sound Speed</td><td>SV Sensor</td></tr>
<tr><td>Model Number</td><td>MicroX</td><td>SV Xchange</td></tr>
<tr><td>Serial Number</td><td>7762</td><td>201009</td></tr>
<tr><td>Calibration</td><td>N/A</td><td>2019-05-07</td></tr>
<tr><td rowspan="4">R/V 505</td><td>Component</td><td>Surface Sound Speed</td><td>SV Sensor</td></tr>
<tr><td>Model Number</td><td>MicroX</td><td>SV Xchange</td></tr>
<tr><td>Serial Number</td><td>10858</td><td>204291</td></tr>
<tr><td>Calibration</td><td>N/A</td><td>2019-05-01</td></tr>
<tr><td rowspan="4">R/V Endeavor</td><td>Component</td><td>Surface Sound Speed</td><td>SV Sensor</td></tr>
<tr><td>Model Number</td><td>Micro X</td><td>SV Xchange</td></tr>
<tr><td>Serial Number</td><td>10851</td><td>204358</td></tr>
<tr><td>Calibration</td><td>N/A</td><td>2019-05-02</td></tr>
<tr><td rowspan="4">WAMV-1</td><td>Component</td><td>Surface Sound Speed</td><td>SV Sensor</td></tr>
<tr><td>Model Number</td><td>Micro X</td><td>SV Xchange</td></tr>
<tr><td>Serial Number</td><td>10625</td><td>204683</td></tr>
<tr><td>Calibration</td><td>N/A</td><td>2019-05-02</td></tr>
<tr><td rowspan="4">WAMV-2</td><td>Component</td><td>Surface Sound Spee</td><td>SV Sensor</td></tr>
<tr><td>Model Number</td><td>Micro X</td><td>SV Xchange</td></tr>
<tr><td>Serial Number</td><td>10823</td><td>205353</td></tr>
<tr><td>Calibration</td><td>N/A</td><td>2019-01-24</td></tr>
</table>

A.6.3.2 AML Base•X2

The AML Base•X2 sound speed profiler is a high accuracy time of flight sound speed sensor capable of measuring sound speed in depths up to 500 meters. The Base•X is capable of transferring data via RS-232 serial cable. AML SeaCast software is run on the acquistion computer to facilitate the data transfer and profile formatting.

<table>
<tr><td>Manufacturer</td><td>AML</td></tr>
<tr><td>Model</td><td>Base•X2</td></tr>
<tr><td>Inventory</td><td>
<table>
<tr><td>R/V Benthos</td><td>
<table>
<tr><td>Component</td><td>Sound Speed Profiler</td><td>SV Sensor</td><td>Pressure Sensor</td><td>Sound Speed Profiler (Spare)</td><td>SV Sensor (Spare)</td><td>Pressure Sensor (Spare)</td></tr>
<tr><td>Model Number</td><td>Base•X</td><td>SV.Xchange</td><td>P.Xchange</td><td>Base•X</td><td>SV.Xchange</td><td>P.Xchange</td></tr>
<tr><td>Serial Number</td><td>25101</td><td>207350</td><td>146220</td><td>25108</td><td>200938</td><td>304496</td></tr>
<tr><td>Calibration</td><td>N/A</td><td>2019-05-07</td><td>N/A</td><td>N/A</td><td>2018-08-28</td><td>N/A</td></tr>
</table>
</td></tr>
<tr><td>R/V 505</td><td>
<table>
<tr><td>Component</td><td>Sound Speed Profiler</td><td>SV Sensor</td><td>Pressure Sensor</td><td>ound Speed Profiler (Spare)</td><td>SV Sensor (Spare)</td><td>Pressure Sensor (Spare)</td></tr>
<tr><td>Model Number</td><td>Base•X2</td><td>SV.Xchange</td><td>P.Xchange</td><td>Base•X2</td><td>SV.Xchange</td><td>P.Xchange</td></tr>
<tr><td>Serial Number</td><td>25849</td><td>208015</td><td>306108</td><td>25460</td><td>206333</td><td>305185</td></tr>
<tr><td>Calibration</td><td>N/A</td><td>2019-05-09</td><td>N/A</td><td>N/A</td><td>2019-05-02</td><td>N/A</td></tr>
</table>
</td></tr>
<tr><td>R/V Endeavor</td><td>
<table>
<tr><td>Component</td><td>Sound Speed Profiler</td><td>SV Sensor</td><td>Pressure Sensor</td></tr>
<tr><td>Model Number</td><td>Base•X2</td><td>SV.Xchange</td><td>P.Xchange</td></tr>
<tr><td>Serial Number</td><td>254847</td><td>207617</td><td>306113</td></tr>
<tr><td>Calibration</td><td>N/A</td><td>2019-05-09</td><td>N/A</td></tr>
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</td></tr>
</table>
</td></tr>
</table>

A.6.4 TSG Sensors

No surface sound speed sensors were utilized for data acquisition.

A.6.5 Other Sound Speed Equipment

No surface sound speed sensors were utilized for data acquisition.

A.7 Computer Software

Manufacturer	*Software Name*	*Version*	*Use*
QPS	Qinsy	8.17	Acquisition
R2Sonic, LLC	R2Sonic	4/13/2017	Acquisition
R2Sonic, LLC	R2Sonic 2024 Firmware (SIM)	4/21/2017	Acquisition
AML Oceanographic	Seacast	4.3.1	Acquisition
Applanix	MV-POSView	8.60	Acquisition
Applanix	PosMV 320 Firmware	8.63	Acquisition
Kongsberg	Kongsberg SIS	4.3.2	Acquisition
Microsoft	Microsoft Excel	2003	Acquisition
QPS	Qimera	1.7.6	Processing
QPS	FMGeocoder Toolbox	7.7.8	Processing
Applanix	POSPac MMS	8.2.1	Processing
eTrac Inc.	Density Trac	1.0.0.17	Processing
eTrac Inc.	DiffTrac	1.0.0.6	Processing
eTrac Inc.	JunctionTrac	1.0.0.8	Processing
eTrac Inc.	TPUTrac	1.0	Processing
Blue Marble Geographics	Global Mapper	20.0	Processing
NOAA	Pydro Explorer	19.4	Processing
NOAA	QC Tools	3.0	Processing
CARIS	HIPS and SIPS	10.2.2	Processing
Google	Google Drive	1.31	Processing

A.8 Bottom Sampling Equipment

A.8.1 Bottom Samplers

A.8.1.1 WILDCO 860-A10 Shipek Sampler

The Shipek Sampler is a spring loaded sampling device designed for sampling unconsolidated sediments from soft ooze to hard packed sand.

Figure 9: 860-A10 Shipek Sampler

B. System Alignment and Accuracy

B.1 Vessel Offsets and Layback

B.1.1 Vessel Offsets

Prior to survey operations, offsets on all vessels were determined from the static vessel surveys performed at varying times and were verified using a metal hand tape. For all vessels with a dual head system, offsets from the POSMV reference point to the acoustic center of each sonar were determined, measured, and confirmed using a metal hand tape. These offsets were entered into QPS QINSy for use during data acquisition on R/V 505, R/V Endeavor, WAMV-1 and WAMV-2. On R/V Benthos, these offsets were entered into Kongsberg SIS and QPS QINSy for use during data acquisition.

A QPS Vessel Template Database file (DB) was created for each vessel. The vessel files contain sensor offsets and biases, static and dynamic draft corrections, and uncertainty values to aid in Total Propagated Uncertainty (TPU) calculations.

The Applanix POSMV on R/V Benthos was configured to output position and motion data to a tangent point between the acoustic centers of the two MBES sonar heads. The locations and angular offsets from this tangent point to each individual sonar head's acoustic center is entered into Kongsberg SIS. Therefore, this configuration yields a Qinsy Vessel DB with (-0.215,0,0) for the port and (0.215,0,0) for starboard offsets for positioning and MBES systems.

The Applanix POSMV on R/V 505, R/V Endeavor, WAMV-1 and WAMV-2 was configured to output position and motion data at the IMU. Offsets to the acoustic centers of the Port and Starboard echosounders were input in the Qinsy Vessel DB.

B.1.1.1 Vessel Offset Correctors

Vessel offset correctors were not applied.

B.1.2 Layback

N/A

Layback correctors were not applied.

B.2 Static and Dynamic Draft

B.2.1 Static Draft

As this project utilized an ERS workflow, static draft was not utilized in final sounding computations.

B.2.1.1 Static Draft Correctors

Dynamic draft correctors were not applied.

B.2.2 Dynamic Draft

As this project utilized an ERS workflow, dynamic draft was not utilized in final sounding computations.

B.2.2.1 Dynamic Draft Correctors

Dynamic draft correctors were not applied.

B.3 System Alignment

B.3.1 System Alignment Methods and Procedures

Multibeam patch tests were performed on each vessel prior to commencing data collection. A multibeam patch test is performed in order to measure the mounting/alignment biases between the MBES sensor and the inertial motion unit (IMU). In addition to mounting/alignment biases, a patch test is also performed to determine latency between MBES and position sensor data.

Latency patch tests were performed by running reciprocal survey lines at varying speeds over a local charted wreck.
Roll patch tests were performed by running reciprocal survey lines at equal speeds over a flat bottom.
Pitch patch tests were performed by running reciprocal survey lines at equal speed over a local charted wreck and prominent rock outcropping.
Yaw patch tests were performed by running parallel survey lines at equal speeds over a local charted wreck and prominent rock outcropping.

For R/V Benthos, R/V 505, R/V Endeavor, R/V WAMV1 and R/V WAMV2, each pair of specific survey lines were analyzed in Qimera Patch Test Tool. Sensor biases were determined and entered into the Installation Parameters menu in Kongsberg SIS for the R/V Benthos as well as into the QPS Vessel Template Database file for all vessels.

Patch test data were analyzed independently by multiple hydrographers for crosscheck and also to determine an accurate uncertainty value for the mounting/alignment biases.
All calibration data is included in the digital data deliverable.

B.3.1.1 System Alignment Correctors

Vessel	R/V Benthos		
Echosounder	Kongsberg 2040C		
Date	2019-06-01		
Patch Test Values		*Corrector*	*Uncertainty*
	Transducer Time Correction	0.000 seconds	0.000 seconds
	Navigation Time Correction	0.000 seconds	0.000 seconds
	Pitch	0.150 degrees	0.020 degrees
	Roll	35.030 degrees	0.020 degrees
	Yaw	-0.100 degrees	0.050 degrees
	Pitch Time Correction	0.000 seconds	0.000 seconds
	Roll Time Correction	0.000 seconds	0.000 seconds
	Yaw Time Correction	0.000 seconds	0.000 seconds
	Heave Time Correction	0.000 seconds	0.000 seconds
Date	2019-06-01		
Patch Test Values (Transducer 2)		*Corrector*	*Uncertainty*
	Transducer Time Correction	0.000 seconds	0.000 seconds
	Navigation Time Correction	0.000 seconds	0.000 seconds
	Pitch	0.330 degrees	0.020 degrees
	Roll	-35.030 degrees	0.020 degrees
	Yaw	-0.120 degrees	0.050 degrees
	Pitch Time Correction	0.000 seconds	0.000 seconds
	Roll Time Correction	0.000 seconds	0.000 seconds
	Yaw Time Correction	0.000 seconds	0.000 seconds
	Heave Time Correction	0.000 seconds	0.000 seconds

Vessel	R/V 505		
Echosounder	R2Sonic 2022		
Date	2019-06-01		
Patch Test Values		*Corrector*	*Uncertainty*
	Transducer Time Correction	0.000 seconds	0.000 seconds
	Navigation Time Correction	0.000 seconds	0.000 seconds
	Pitch	-0.600 degrees	0.020 degrees
	Roll	19.150 degrees	0.020 degrees
	Yaw	1.020 degrees	0.050 degrees
	Pitch Time Correction	0.000 seconds	0.000 seconds
	Roll Time Correction	0.000 seconds	0.000 seconds
	Yaw Time Correction	0.000 seconds	0.000 seconds
	Heave Time Correction	0.000 seconds	0.000 seconds
Date	2019-06-01		
Patch Test Values (Transducer 2)		*Corrector*	*Uncertainty*
	Transducer Time Correction	0.000 seconds	0.000 seconds
	Navigation Time Correction	0.000 seconds	0.000 seconds
	Pitch	1.850 degrees	0.020 degrees
	Roll	-19.580 degrees	0.020 degrees
	Yaw	0.030 degrees	0.050 degrees
	Pitch Time Correction	0.000 seconds	0.000 seconds
	Roll Time Correction	0.000 seconds	0.000 seconds
	Yaw Time Correction	0.000 seconds	0.000 seconds
	Heave Time Correction	0.000 seconds	0.000 seconds
Date	2019-07-12		
Patch Test Values		*Corrector*	*Uncertainty*
	Transducer Time Correction	0.000 seconds	0.000 seconds
	Navigation Time Correction	0.000 seconds	0.000 seconds
	Pitch	-0.480 degrees	0.020 degrees
	Roll	19.020 degrees	0.020 degrees
	Yaw	0.850 degrees	0.050 degrees
	Pitch Time Correction	0.000 seconds	0.000 seconds
	Roll Time Correction	0.000 seconds	0.000 seconds
	Yaw Time Correction	0.000 seconds	0.000 seconds
	Heave Time Correction	0.000 seconds	0.000 seconds
Date	2019-07-12		
Patch Test Values (Transducer 2)		*Corrector*	*Uncertainty*
	Transducer Time Correction	0.000 seconds	0.000 seconds
	Navigation Time Correction	0.000 seconds	0.000 seconds
	Pitch	2.000 degrees	0.020 degrees
	Roll	-19.690 degrees	0.020 degrees
	Yaw	-0.450 degrees	0.050 degrees

Vessel	R/V Endeavor		
Echosounder	R2Sonic 2024		
Date	2019-06-18		
Patch Test Values		*Corrector*	*Uncertainty*
	Transducer Time Correction	0.000 seconds	0.000 seconds
	Navigation Time Correction	0.000 seconds	0.000 seconds
	Pitch	-0.170 degrees	0.020 degrees
	Roll	18.630 degrees	0.020 degrees
	Yaw	3.320 degrees	0.050 degrees
	Pitch Time Correction	0.000 seconds	0.000 seconds
	Roll Time Correction	0.000 seconds	0.000 seconds
	Yaw Time Correction	0.000 seconds	0.000 seconds
	Heave Time Correction	0.000 seconds	0.000 seconds
Date	2019-06-18		
Patch Test Values (Transducer 2)		*Corrector*	*Uncertainty*
	Transducer Time Correction	0.000 seconds	0.000 seconds
	Navigation Time Correction	0.000 seconds	0.000 seconds
	Pitch	0.510 degrees	0.020 degrees
	Roll	-20.340 degrees	0.020 degrees
	Yaw	2.570 degrees	0.050 degrees
	Pitch Time Correction	0.000 seconds	0.000 seconds
	Roll Time Correction	0.000 seconds	0.000 seconds
	Yaw Time Correction	0.000 seconds	0.000 seconds
	Heave Time Correction	0.000 seconds	0.000 seconds
Date	2019-07-01		
Patch Test Values		*Corrector*	*Uncertainty*
	Transducer Time Correction	0.000 seconds	0.000 seconds
	Navigation Time Correction	0.000 seconds	0.000 seconds
	Pitch	-0.620 degrees	0.020 degrees
	Roll	18.830 degrees	0.020 degrees
	Yaw	3.410 degrees	0.050 degrees
	Pitch Time Correction	0.000 seconds	0.000 seconds
	Roll Time Correction	0.000 seconds	0.000 seconds
	Yaw Time Correction	0.000 seconds	0.000 seconds
	Heave Time Correction	0.000 seconds	0.000 seconds
Date	2019-07-01		
Patch Test Values (Transducer 2)		*Corrector*	*Uncertainty*
	Transducer Time Correction	0.000 seconds	0.000 seconds
	Navigation Time Correction	0.000 seconds	0.000 seconds
	Pitch	0.120 degrees	0.020 degrees
	Roll	-20.030 degrees	0.020 degrees

Vessel	WAMV-1
Echosounder	R2Sonic 2022
Date	2019-07-28

Patch Test Values

	Corrector	*Uncertainty*
Transducer Time Correction	0.000 seconds	0.000 seconds
Navigation Time Correction	0.000 seconds	0.000 seconds
Pitch	-1.130 degrees	0.020 degrees
Roll	-0.820 degrees	0.020 degrees
Yaw	1.530 degrees	0.050 degrees
Pitch Time Correction	0.000 seconds	0.000 seconds
Roll Time Correction	0.000 seconds	0.000 seconds
Yaw Time Correction	0.000 seconds	0.000 seconds
Heave Time Correction	0.000 seconds	0.000 seconds

Vessel	WAMV-2
Echosounder	R2Sonic 2022
Date	2019-07-28

Patch Test Values

	Corrector	*Uncertainty*
Transducer Time Correction	0.000 seconds	0.000 seconds
Navigation Time Correction	0.000 seconds	0.000 seconds
Pitch	-2.080 degrees	0.020 degrees
Roll	0.280 degrees	0.020 degrees
Yaw	-0.020 degrees	0.050 degrees
Pitch Time Correction	0.000 seconds	0.000 seconds
Roll Time Correction	0.000 seconds	0.000 seconds
Yaw Time Correction	0.000 seconds	0.000 seconds
Heave Time Correction	0.000 seconds	0.000 seconds

C. Data Acquisition and Processing

C.1 Bathymetry

C.1.1 Multibeam Echosounder

Data Acquisition Methods and Procedures

Data acquisition and processing throughout the entire project was overseen by the Chief of Party. Field acquisition was performed under the direct, on site, supervision of a Lead Hydrographer and a Senior Hydrographer, both with well over 3 years of experience conducting hydrographic survey operations.

Line plans were established prior to survey operations. Line plan orientations were based on historical sea state, wind direction, and swell direction in order to avoid a “beam to” scenario where the vessel would be running survey lines in a direction perpendicular to the direction of the swell. Throughout the entire survey, there was never a need to revise the line plan orientation.

MBES line spacing for Complete Coverage MBES and Object Detection MBES operations were based upon charted depths as well as coverage requirements set forth in the Project Instructions and the HSSD 2019.

For the R2 Sonic, incremental adjustments to the range, gain, and pulse width were made during the survey and were dependent on water depth and seabed composition (bottom type). Since the Kongsberg 2040C can be operated in a more automated fashion, most sonar settings auto-adjust to varying depths and seabed composition. The main adjustment made by the hydrographer was the adjustment of swath width based on environmental conditions and sea state.

Every effort was made to tune the sonars to provide the highest quality of both bathymetric and backscatter data, with bathymetry being the primary focus. The R2Sonic 2024 & 2022 and the Kongsberg 2040C were monitored realtime during all MBES acquisition efforts. Raw MBES information, including intensity, surface sound velocity, time synchronization, and ping rate, were displayed and monitored in the Kongsberg SIS Controller Interface or R2Sonic Sonic Controller Interface during acquisition.

Prior to survey operations, offsets on all vessels were determined from the static vessel surveys performed at varying times and were verified using a metal hand tape. For all vessels with a dual head system, offsets from the POSMV reference point to the acoustic center of each sonar were determined, measured, and confirmed using a metal hand tape. These offsets were entered into QPS QINSy for use during data acquisition on R/V 505, R/V Endeavor, R/V WAMV 1 and R/V WAMV2. On R/V Benthos, these offsets were entered into Kongsberg SIS and QPS QINSy for use during data acquisition.

The R2Sonic’s roll stabilization and precise timing were achieved through a combination of outputs from the POSMV. The 1PPS pulse from the POSMV is sent via BNC cable to the PPS input of the R2Sonic SIM. Additionally, a NMEA ZDA message at 1Hz is transferred from a POSMV serial port to the R2Sonic SIM via standard DB9 serial cable. For roll stabilization, the TSS1 binary motion string is transferred from the POSMV to the R2Sonic SIM via DB9 Serial connection at 200Hz.

The Kongsberg 2040C’s roll, pitch and yaw stabilization is achieved in the Kongsberg 2040C PU through serial connection accepting binary motion data from the POSMV at 100Hz. The 1PPS pulse from the POSMV is sent via BNC cable to the PPS input of the Kongsberg 2040C PU. Additionally, a NMEA ZDA message at 1Hz is transferred from a POSMV serial port to the Kongsberg 2040C PU via standard DB9 serial cable. For beam stabilization, the TSS1 binary motion string is transferred from the POSMV to the Kongsberg 2040C PU via DB9 serial connection at 100Hz.

In addition to performing the confidence checks on each vessel, a vessel-to-vessel comparison was performed as an added quality assurance measure. All vessels acquired sound velocity casts independently using their assigned sound velocity probe. Data were processed though the processing pipeline and comparisons were made between the independent datasets.

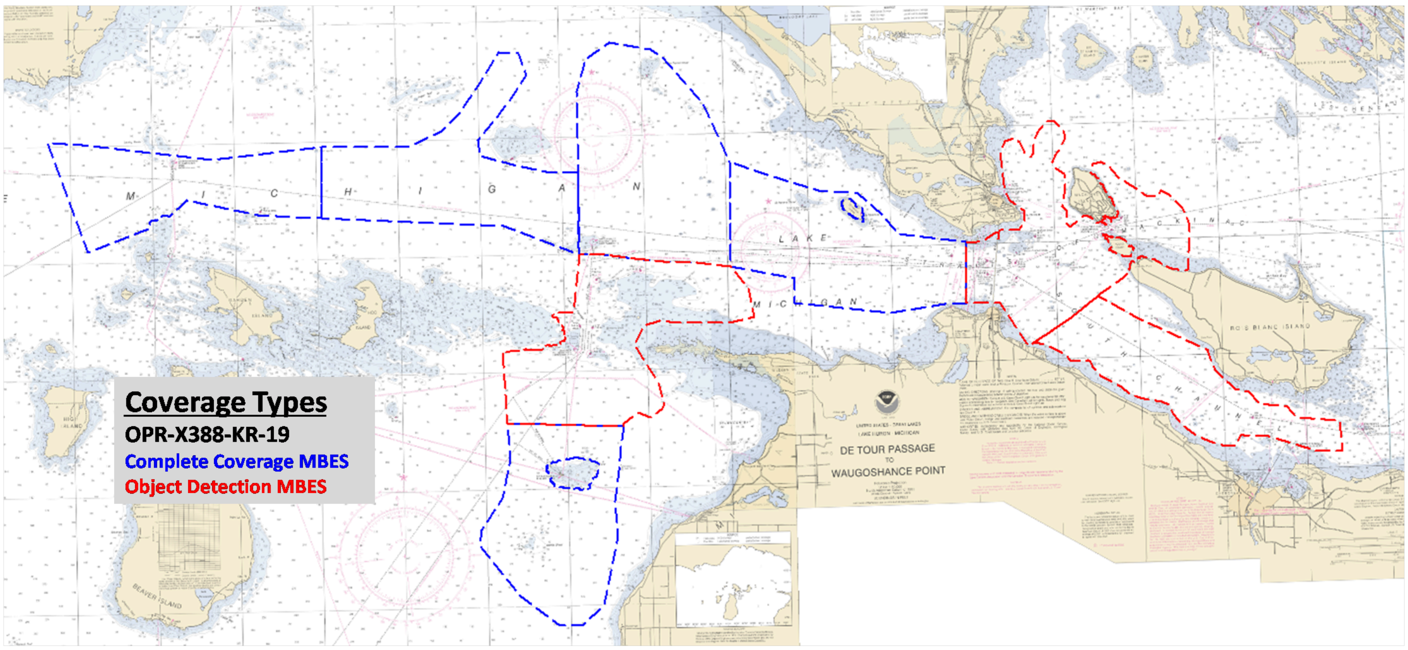

Figure 10: OPR-X388-KR-19 Survey Coverage Types

Data Processing Methods and Procedures

Qimera was exclusively utilized for MBES processing throughout the entire project. Processing steps and procedures are detailed below in the image below.

The first part (PART 1 in the image below) of the processing pipeline consists of a series of standard Qimera processing procedures, which are completed using the Qimera process tool bar and auto processing prompts. In order to ensure each process has been completed, processes are reviewed in the output window.

The second part (PART 2 in the image below) of the Qimera processing pipeline consists of detailed review and cleaning of data, as well as project specific tasks such as investigating features or preparing DTON reports for submittal.

The third part (PART 3 in the image below) of the Qimera processing pipeline is performed once data collection has been completed for an entire H-Cell sheet. CUBE surfaces are “finalized” by choosing the option to override the CUBE hypothesis with any flagged soundings. This finalized surface then represents the least depth of features and designated soundings.

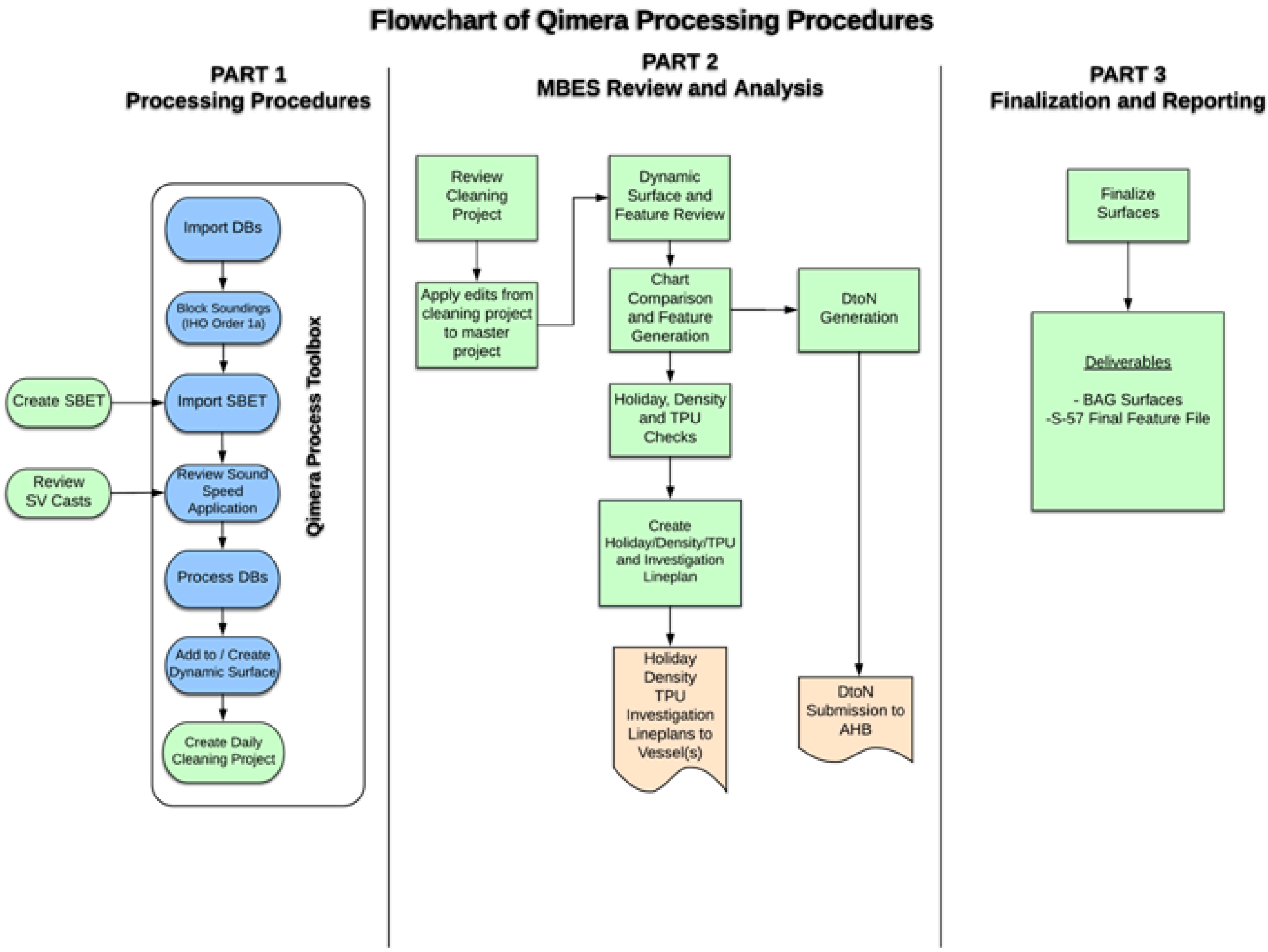

Figure 11: Qimera Processing Procedures

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

All CUBE surfaces were created in Qimera. Sheet wide parent surfaces were created in each resolution that were relevant to surveyed depths.

C.1.4.2 Depth Derivation

Once data cleaning and a detailed review has been completed, finalized surfaces are created by using the "clip" tool in Qimera. This tool uses a parent surface to create a final surface with a depth threshold. The resolution and depth ranges for each finalized surface follows the specifications in the HSSD 2019. The parent and finalized CUBE surfaces are exported as BAG files for deliverables.

C.1.4.3 Surface Computation Algorithm

The NOAA parameters per surface resolution were imported into Qimera. These parameters were used for all surface generations throughout the duration of processing efforts.

C.2 Imagery

C.2.1 Multibeam Backscatter Data

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

Snippets were collected simultaneously with MBES data collection to meet Complete Coverage and Object Detection requirements as specified in the HSSD.

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

QPS FMGeocoder Toolbox (FMGT) is a program designed to process, view, and analyze backscatter data. FMGT was utilized in the processing workflow as the exclusive snippets/backscatter processing software to confirm that snippets were collected during all MBES data collection to meet Complete Coverage and Object Detection requirements as specified in the HSSD. Snippets data from Qinsy Paired (DB/QPD) files and Kongsberg ALL files were brought into FMGT and processed into backscatter mosaics daily to confirm backscatter complete coverage. Below is an example image of the raw backscatter from H13256.

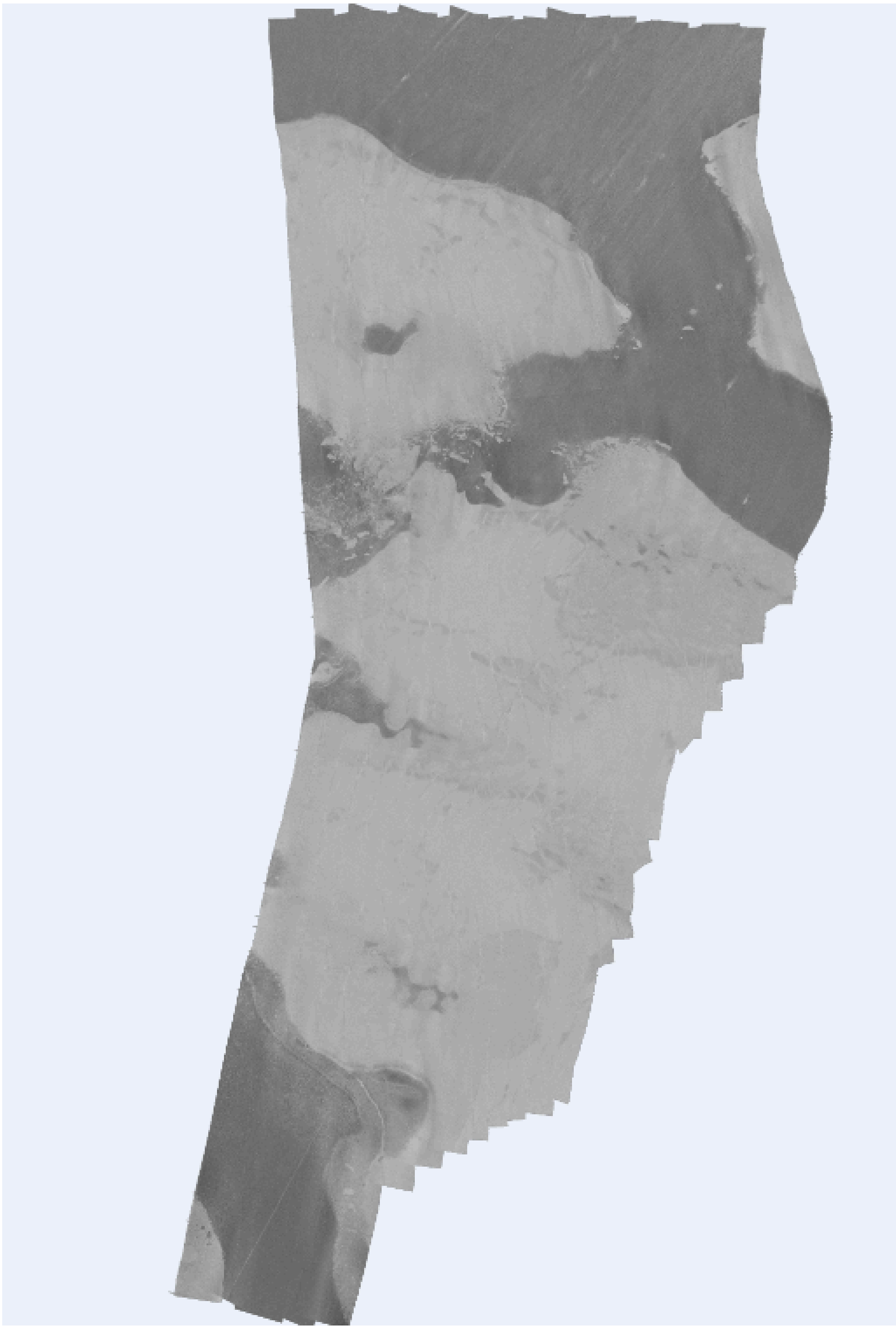

Figure 12: Raw Backscatter from R/V Benthos on DN280 in H13256

C.2.2 Side Scan Sonar

Side scan sonar imagery was not acquired.

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

DGPS data was not acquired.

C.3.1.3 Other Horizontal Control Equipment

Data Acquisition Methods and Procedures

During acquisition, R/V Benthos, R/V 505, and R/V Endeavor received GNSS satellite corrections over the POS MV G2+ carrier signal from the Marinestar Global Correction System maintained by Fugro. Marinestar is a global real-time GNSS broadcast system that delivers corrections from a network of base stations around the world via geo-stationary satellites. Corrections were monitored during data acquisition to ensure no dropouts occurred throughout the survey.

Data Processing Methods and Procedures

During calibration procedures and throughout the project, POSMV data were logged and post-processed in POSPac MMS to output a SBET. The SBET was applied in QPS Qimera in order to reduce the THU of the data and achieve a higher accuracy.

C.3.2 Vertical Control

C.3.2.1 Water Level Data

Data Acquisition Methods and Procedures

In accordance with the Project Instructions, OPR-X388-KR-19 was an Ellipsoidally Referenced (ERS) survey. Data were vertically referenced to the ITRF-08 ellipsoid using Marinestar G2+ Space Based corrections. Using VDatum, a vertical separation model was created to transform the ellipsoidally referenced data from ITRF-08 to Low Water Datum (LWD). This separation model was applied in QPS Qinsy on the vessels in realtime to achieve LWD in the field. Achieving LWD in the field was extremely efficient for field operations, as the NALL was easily identified in real-time.

Data Processing Methods and Procedures

The separation model automatically carried over into QPS Qimera through the DB files during processing. The separation model generated from VDatum is noted to have an uncertainty of 7.6 cm throughout the project area.

C.3.2.2 Optical Level Data

Optical level data was not acquired.

C.4 Vessel Positioning

Data Acquisition Methods and Procedures

During acquisition, trajectory data was logged by the Applanix POSMV. R/V Benthos, R/V 505 and R/V Endeavor received GNSS satellite corrections over the POS MV G2+ carrier signal from the Marinestar Global Correction System maintained by Fugro. Marinestar is a global real-time GNSS broadcast system that delivers corrections from a network of base stations around the world via geo-stationary satellites. WAMV1 and WAMV2 recieved corrections through the internal DGNSS capabilities onboard the R2Sonic I2NS. Corrections were monitored during data acquisition to ensure no dropouts occurred throughout the survey.

Data Processing Methods and Procedures

Applanix PosPac MMS was utilized for all survey data to post-process realtime positioning data utilizing Trimble's PP-RTX implementation of Trimble CenterPoint RTX. The Trimble CenterPoint RTX correction service is delivered via internet connection and integrated into Applanix PosPac MMS 8, to aid in post processed trajectories. A Smoothed Best Estimate of Trajectory (SBET) is provided by PosPac MMS and applied to survey data in Qimera 1.7.6.

C.5 Sound Speed

C.5.1 Sound Speed Profiles

Data Acquisition Methods and Procedures

All sound speed sensors used on the project were calibrated within 1 year of survey commencement per the HSSD 2019. Manufacturer certified calibration sheets can be referenced in Appendices of this document.

All sound speed measurements were collected in accordance with specifications set forth in the HSSD 2019.

Sound speed profiles were collected using AML Base•X2 profiling units. On R/V Benthos, R/V 505 and R/V Endeavor, SV profilers were lowered on a data cable by hand. SV profiles were taken immediately prior to daily survey operations, as well as approximately every 2 hours during survey operations. In addition to planning SV casts around a 2 hour time interval, positional variance was considered when suspending survey operations to perform an SV cast.

During a cast on R/V 505 and R/V Endeavor, realtime SV profiler data was collected and displayed during the downcast of the probe. The SV profiler communicated with the acquisition computer via serial data communication. The profiler data is then saved as a CSV on the MBES acquisition computer. Then, the CSV was imported to QPS QINSy acquisition software for use online and is stored in each .DB file. Once imported into the QPS QINSy software, the cast data was exported into the .SVP format for use in office processing at a later data if needed. Application of .SVP files to R/V Taku data was typically not required in post processing because the applied SVP is stored in the .DB file.

During a cast on R/V Benthos, realtime SV profiler data was collected and displayed during the downcast of the probe. The SV profiler communicated with the acquisition computer via serial data communication. The profiler data is then saved as an ASVP and a CSV on the MBES acquisition computer. Then, the ASVP was imported in Kongsberg SIS acquisition software as well as QPS QINSy acquisition for use online and is stored in each .DB file. Once imported into the QPS QINSy software, the cast data was exported into the .SVP format for use in office processing at a later data if needed. In addition to the SV vs. depth information, the .SVP exported format included date, time, and position (lat/long) of each cast. Application of .SVP files to R/V Benthos and R/V Marcelle data was not typically required in post processing because the applied SVP is stored in the .DB file.

WAMV-1 and WAMV-2 used SV profiler data from R/V Endeavor, since WAMV-1 and WAMV-2 were closely following R/V Endeavor during their data acquisition.

Data Processing Methods and Procedures

Sound speed profiles collected in the field were applied to the MBES data. On each vessel, raw Qinsy .DB files store sound speed profile data real-time for each separate line of data. In Qimera, sound speed data is imported simultaneously with each respective raw DB file. During acquisition, hydrographers would choose which sound speed profile to apply to the bathymetry currently being collected. This decision was based on a number of factors, including age of sound speed data, deviation from current surface sound speed measurements, and changes in oceanographic characteristics. If sound speed data existed within the past 4 hours in a particular area that the ship was working in, that sound speed cast would be applied to the realtime data. Essentially, this realtime method of managing sound velocity casts produces the same result as using "Nearest in Distance within Time" as the sound speed strategy in Qimera, eliminating the need for extra sound speed processing in the office. However, in certain cases, the sound speed strategy in Qimera could be changed from "Real-Time Scheduling" to "Nearest in Distance within Time" should the processor need to engage in post collection sound speed processing.

Surface sound speed was collected at the R2Sonic or Kongsberg transducer face, and sent via serial connection directly to the R2Sonic topside unit or to the Kongsberg topside workstation in order to facilitate beam steering.

C.5.2 Surface Sound Speed

Data Acquisition Methods and Procedures

The R2sonic 2022 & 2024 and Kongsberg 2040C utilize an AML Micro•X located at the sonar head for surface sound speed measurement. The AML Micro•X is a time of flight SV sensor and is powered through the R2Sonic topside or powered directly from a 12 volt power source via RS232 serial cable connection. Sound speed measurements (measured in meters per second) are output through the same serial connection at 1Hz.

Surface sound speed measured by the AML Micro•X, located at the sonar head, was compared in realtime against the corresponding SV from the most current cast entered into QINSy. An alarm was set to notify the operator if the difference between the two SV readings exceeded 2m/s. If the difference was ever in consistent excess of 2m/s and persisted longer than a designated time threshold, survey operations were suspended and a new sound velocity cast was performed.

Surface sound speed was measured at 1Hz during all MBES operations using the AML Micro•X. The AML Micro•X is installed using the AML or R2Sonic provided mounting bracket and installed just above the face of the MBES receiver. On R/V Benthos, surface sound speed was transmitted at 1Hz to the Kongsberg topside workstation, where it was utilized for realtime beam forming in the Kongsberg SIS acquisition software and recorded into the raw ALL file as well as into the raw .DB. On R/V 505, R/V Endeavor, WAMV-1 and WAMV-2, surface sound speed was transmitted at 1Hz to the R2Sonic topside SIM box and subsequently transmitted with the MBES data to QPS QINSy, where it was permanently logged in the raw .DB files. As mentioned above, surface sound speed was additionally utilized during online operations as a QC comparison to sound speed profile data.

Data Processing Methods and Procedures

Surface sound speed was not post-processed and all values remain as realtime.

C.6 Uncertainty

C.6.1 Total Propagated Uncertainty Computation Methods

Values were determined from manufacturer's specified/suggested values and/or calibration methodology/ accuracy. CUBE surfaces were created in Qimera using the NOAA CUBE parameters based on surface resolution which determines uncertainty of each grid node. Uncertainty was cheked in NOAA QC Tools. Further dicussion of uncertainty assesment is located in section D.1.4.

C.6.2 Uncertainty Components

C.6.2.1 A Priori Uncertainty

Vessel		R/V Benthos	R/V 505	R/V Endeavor	WAMV-1	WAMV-2
Motion Sensor	*Gyro*	0.02 degrees	0.02 degrees	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	5.00% 0.05 meters	5.00% 0.05 meters
	Roll	0.01 degrees	0.01 degrees	0.01 degrees	0.01 degrees	0.01 degrees
	Pitch	0.01 degrees	0.01 degrees	0.01 degrees	0.01 degrees	0.01 degrees
Navigation Sensor		0.10 meters	0.10 meters	0.10 meters	0.10 meters	0.10 meters

C.6.2.2 Real-Time Uncertainty

Real-time uncertainty was not applied.

C.7 Shoreline and Feature Data

Shoreline and feature data was not acquired.

C.8 Bottom Sample Data

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

Bottom Sample locations were assigned in the CSF. The Shipek Sampler was lowered to the sea floor from R/V Endeavor to collect bottom samples for OPR-X388-KR-19. Below is an image of the Shipek Sampler as well as an image of its use during bottom sample collection for H13256.

Figure 13: 860-A10 Shipek Sampler in use for bottom sample collection in H13256

Data Processing Methods and Procedures

All assigned bottom samples were collected and results can be found in the Final Feature File of each H-cell sheet. Bottoms samples were categorized using qualitative descriptives following specifications in the HSSD 2019.

D. Data Quality Management

D.1 Bathymetric Data Integrity and Quality Management

D.1.1 Directed Editing

Within Qimera, the standard deviation layer is used to detect vertical discrepancies or spurious noise.

D.1.2 Designated Sounding Selection

Within 3D editor of Qimera, soundings and the CUBE surface were visible to analyze if the CUBE surface was incorporating natural or man-made features adequately. The determination on if a sounding should become a designated sounding follows the specifications set fourth in the HSSD 2019.

D.1.3 Holiday Identification

The CUBE surface is exported as a BAG file and loaded into QC Tools within NOAA's HydrOffice. Within QC Tools, the BAG is processed through the "detect holidays" tool. QC Tools produces a shapefile of the detected holidays, which then can be loaded into Qimera for analysis. All holidays are added to a survey line plan to be collected by the vessels.

D.1.4 Uncertainty Assessment

The CUBE surface is exported as a BAG file and loaded in QC Tools within NOAA's HydrOffice. Within QC Tools, the BAG is processed through the "Grid QA" tool. QC Tools produces a graph of the uncertainty statistics, which then states whether the data is within uncertainty specifications.

D.1.5 Surface Difference Review

D.1.5.1 Crossline to Mainscheme

A beam-to-beam statistical analysis was performed using the Cross Check tool in Qimera. A 1 meter Combined Uncertainty and Bathymetric Estimator (CUBE) weighted dynamic surface of each sheet was created incorporating only the mainscheme lines and excluded crosslines. The Cross Check tool was used to perform the beam-by-beam comparison of the crossline data to the mainscheme surface. Comparisons showed excellent agreement, well above 95% of the allowable TVU. Note: These surfaces were created for QC only and are not submitted as a surface deliverable. The beam-to-beam crossline comparison report generated through the Qimera Cross Check tool is included in Separates II in each H-cell's Decriptive Report.

D.1.5.2 Junctions

Depth differences between junctioning surveys were evaluated using the JunctionTrac program, developed in-house by eTrac Inc. For every junction, each CUBE weighted dynamic surface's nodes were exported to an ASCII CSV file where the fields were (Easting, Northing, Depth) for each node. A 1 meter difference surface between the junctioning datasets was also created and exported to an ASCII CSV file where the fields were (Easting, Northing, Diff) for each node. The three ASCII CSV files were then loaded into the JunctionTrac program and junction statistics were computed. A file was also created in this process to locate any nodes from the difference surface that exceed the allowable TVU, which was imported into Qimera and any identified points from JunctionTrac were analyzed. Note: the difference surfaces were created for comparison efforts only and are not submitted as surface deliverables.

D.1.5.3 Platform to Platform

A performance test between the vessels and the systems on each vessel was preformed as an additional quality assurance measure. The confidence check between all vessels can be found in Appendix V.

D.2 Imagery data Integrity and Quality Management

Imagery data integrity and quality management were not conducted for this survey.

E. Approval Sheet

As Chief of Party, field operations for this hydrographic survey were conducted under my direct supervision, with frequent personal checks of progress and adequacy. I have reviewed the attached survey data and reports.

The survey data meets or exceeds requirements as set forth in the NOS Hydrographic Surveys Specifications and Deliverables, Field Procedures Manual, Letter Instructions, and all HSD Technical Directives. These data are adequate to supersede charted data in their common areas. This survey is complete and no additional work is required with the exception of deficiencies noted in the Descriptive Report.

Approver Name	Approver Title	Date	Signature
David Neff	VP Survey	10/31/2019	David Neff Digitally signed by David Neff DN: C=US, E=david@etracinc.com, O=eTrac Inc., CN=David Neff Date: 2019.10.31 09:51:57-07'00'

List of Appendices:

Mandatory Report	*File*
Vessel Wiring Diagram	Appendix I - Vessel Wiring Diagrams.pdf
Sound Speed Sensor Calibration	Appendix II - Sound Speed Sensor Calibration Reports.pdf
Vessel Offset	Appendix III - Vessel Offset Reports.pdf
Position and Attitude Sensor Calibration	Appendix IV - Positioning and Attitude Sensor Calibration Reports.pdf
Echosounder Confidence Check	Appendix V - Echosounder Confidence Reports.pdf
Echosounder Acceptance Trial Results	N/A