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-R340-KR-21
Time Frame:	July - September 2021

LOCALITY

State(s):	Alaska
General Locality:	Bristol Bay

2021

CHIEF OF PARTY
Andrew Orthmann

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Data Acquisition and Processing Report

Terrasond
Chief of Party: Andrew Orthmann
Year: 2021
Version: 1
Publish Date: 2022-01-07

A. System Equipment and Software

A.1 Survey Vessels

A.1.1 Sealegs

Vessel Name	Sealegs
Hull Number	SeaLegs RHIB
Description	The SeaLegs is a 7.1 meter long RHIB boat equipped with USM sonar mount bracket designed for shallow water work. The vessel is owned and operated by SVA and designed to be able to be deployed and recovered via crane from the back deck of the Qualifier 105. Vessel is equipped with a Yamaha 150 outboard motor, as well as a hydraulic motor that runs the wheels when used for beach landing operations. Since no beach operations were performed from this skiff, " legs" were removed prior to survey. This made lifts more manageable with a lighter load. On this project, the Sealegs surveyed as the secondary survey platform, operating only in daylight and when tides were favorable for nearshore or shallow water work. Vessel was crewed by one TerraSond survey personnel and one SVA captain. The vessel was used to collect MBES data, including sound speed profiles, bottom samples, and conduct initial reconnaissance survey date within Egegik Bay and channel.
Dimensions	*LOA*: 5.5 meters *Beam*: 2.5 meters *Max Draft*: 0.5 meters
Most Recent Full Static Survey	*Date*: 2021-06-20 *Performed By*: Terrasond

Most Recent Full Offset Verification	*Date*	2021-06-20
	Method	Taped applicable offsets
Most Recent Partial Offset Verification	*Date*	2021-07-27
	Method	Taped applicable offsets

Figure 1: SeaLegs, with sonar pole recovered, outside Egegik Bay, Alaska, 2021

A.1.2 Qualifier 105 (Q105)

Vessel Name	Qualifier 105 (Q105)
Hull Number	338192000 (MMSI)
Description	The Q105 is a 105' aluminum-hulled vessel that is owned and operated by Support Vessels of Alaska (SVA). It is home-ported in Homer, Alaska and has been chartered by TerraSond every year since 2013 to complete NOAA task orders as well as other projects along the Alaska coast. The Q105 carries a USCG COI (200-mile offshore). It is powered by three Detroit D-60 diesel engines and has a 4,000 nautical mile endurance. Features include a maximum 6-ton deck crane, A-frame, davit, survey skiff, and hydraulic over-the-side MBES arm. On this project, the Q105 surveyed as the primary survey platform, housing all staff and operating on a 24/7 schedule. It was used to collect MBES data including sound speed profiles, deploy offshore tide gauges, collect bottom samples, and deploy the Sealegs vessel. Preliminary (field) data processing was also completed aboard the vessel.
Dimensions	*LOA*: 32 meters *Beam*: 9.1 meters *Max Draft*: 1.8 meteras
Most Recent Full Static Survey	*Date*: 2019-03-23 *Performed By*: TerraSond
Most Recent Full Offset Verification	*Date*: 2021-06-20 *Method*: Taped applicable offsets

Figure 2: The Qualifier 105 (Q105) outside of Sand Point, Alaska, 2017

A.2 Echo Sounding Equipment

A.2.1 Multibeam Echosounders

A.2.1.1 Teledyne Reson Seabat T50-R

The Seabat T-50 R system, consisting of a transmit (TX) array, receive (Rx) array, and a topside rack mount processor, was used on the Q-105. On this vessel wet-end components were mounted on a hydraulic arm on the vessel's port side, approximately midship. Specifications of the T50-R MBES are as follows:

Sonar Operating Frequency: 200 or 400 kHz (400 used on the majority of this project)
Along-track Beamwidth: 1 degree at 400 kHz
Across-track Receiver Beamwidth: 0.5 degrees at 400 kHz
Max Ping Rate: 50 pings/s (normally 10 pings/s used on this project)
Pulse Length: 30 to 300 microseconds (30 used on Q105)
Number of Beams: 512 max at 400 kHz
Max Swath Angle: 165 degrees
Depth Range: 0.5 to 300 meters at 400kHz
Depth Resolution: 0.006 meters

Manufacturer	Teledyne Reson				
Model	Seabat T50-R				
Inventory	*Q105*	*Component*	TX Array	RX Array	Topside
		Model Number	TC 2181	EM 7218	T50 RSP
		Serial Number	0818042	1518006	na
		Frequency	400kHz	400kHz	N/A
		Calibration	N/A	N/A	N/A
		Accuracy Check	2021-06-19	2021-06-19	2021-06-19

Figure 3: Teledyne Reson SeaBat T50-R transducer mounted on Q105's hydraulic arm in up position.

A.2.1.2 Teledyne Reson Seabat T20-P

The Seabat T-20 P system, consisting of a transmit (TX) array, receive (Rx) array, and a portable sonar processor, was used on the SeaLegs. On this vessel wet-end components were mounted on a manually rotating arm on the vessel's starboard side, slightly aft of midship. Specifications of the T20-P MBES are as follows:

Sonar Operating Frequency: 200-400 kHz (400 used on the majority this project)
Along-track Beamwidth: 1 degree at 400 kHz
Across-track Receiver Beamwidth: 1.0 degrees at 400 kHz
Max Ping Rate: 50 pings/s (normally 10 pings/s used on this project)
Pulse Length: 10 to 300 microseconds (30 used on Sealegs)
Number of Beams: 512 max at 400 kHz
Max Swath Angle: 165 degrees
Depth Range: 0.5 to 300 meters at 400kHz
Depth Resolution: 0.006 meters

Manufacturer	Teledyne Reson				
Model	Seabat T20-P				
Inventory	*Sealegs*	*Component*	TX Array	RX Array	Topside
		Model Number	TC2181	EM7219	T-20-PSP
		Serial Number	251055	2013004	95774415093
		Frequency	400kHz	400kHz	N/A
		Calibration	N/A	N/A	N/A
		Accuracy Check	2021-06-19	2021-06-19	2021-06-19

Figure 4: Teledyne Reson Seabat T20-P mounted on SeaLeg's Universal Sonar Mount (USM).

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

A.4.3.1 Offshore Egegik Bay ERTDM Validation Station (GNSS Tide Buoy)

One GNSS Tide Buoy collected data for one 30 day interval to the southwest of the Egegik Bay entrance.

Manufacturer	Offshore Egegik Bay ERTDM Validation Station (GNSS Tide Buoy)				
Model					
Inventory	*Component*	Receiver	Antenna	Datalogger	Modem
	Model Number	AsteRx-SB	PolaNt-x	CR-300	Iridium
	Serial Number	510117	15504	11125	J1B9NW
	Calibration	N/A	N/A	N/A	N/A

A.4.3.2 Dago Creek Mouth (9464512)

Installation of this tide station included establishment of 4 new deep rod bench marks. Equipment installed included two bubbler gauges, one MWWL, one non-vented pressure gauge, and one conductivity and temperature sensor. Level ties were established between all new bench marks, the bubbler orifices, and the non-vented pressure sensor. During install, 2 of the benchmarks were simultaneously observed with GPS for over six hours. Three hours of water level staff observations were also performed.

<table>
<tr><td>Manufacturer</td><td colspan="5">Dago Creek Mouth (9464512)</td></tr>
<tr><td>Model</td><td colspan="5"></td></tr>
<tr><td rowspan="12">Inventory</td><td>Component</td><td>Data Logger aand Pressure Sensor</td><td colspan="2">GOES Antenna</td><td>Solar Panel</td></tr>
<tr><td>Model Number</td><td>H-350 XL</td><td colspan="2">EON2</td><td>LS-30FX2 30W</td></tr>
<tr><td>Serial Number</td><td>2994</td><td colspan="2">124260</td><td>20210302030054</td></tr>
<tr><td>Calibration</td><td>N/A</td><td colspan="2">N/A</td><td>N/A</td></tr>
<tr><td>Component</td><td>Data Logger aand Pressure Sensor</td><td colspan="2">GOES Antenna</td><td>Solar Panel</td></tr>
<tr><td>Model Number</td><td>H-350 XL</td><td colspan="2">EON2</td><td>LS-30-FX2 30W</td></tr>
<tr><td>Serial Number</td><td>1050</td><td colspan="2">125550</td><td>20210302030051</td></tr>
<tr><td>Calibration</td><td>N/A</td><td colspan="2">N/A</td><td>N/A</td></tr>
<tr><td>Component</td><td colspan="2">Non-vented Pressure Sensor</td><td colspan="2">CTD</td></tr>
<tr><td>Model Number</td><td colspan="2">RBR Solo D</td><td colspan="2">37SMP</td></tr>
<tr><td>Serial Number</td><td colspan="2">201780</td><td colspan="2">11495</td></tr>
<tr><td>Calibration</td><td colspan="2">N/A</td><td colspan="2">N/A</td></tr>
</table>

A.4.3.3 Egegik Tide Station (9464874)

Installation of this tide station included establishment of 4 new deep rod bench marks. Equipment installed included one bubbler, one MWWL, one non-vented pressure gauge, one GNSS-R station, and one conductivity and temperature sensor. Level ties were established between all new bench marks, the bubbler orifice, the non-vented pressure sensor, and the MWWL sensor. During install, 2 of the benchmarks were simultaneously observed with GPS for over six hours. four and a half hours of water level staff observations were also performed.

Manufacturer	Egegik Tide Station (9464874)
Model	
Inventory	

Component	Data Logger	Radar	Barometer
Model Number	IRIDIUMLINK	NILE 502	Accubar
Serial Number	1403514	19C105066	9100028
Calibration	N/A	N/A	N/A

Component	Data Logger & Pressure Sensor	Bubbler	GOES Radio	GOES Antenna	Solar Panel
Model Number	H-350 XL	H-355	H-222DASE	EON2	LS-30FX2 30W
Serial Number	3090	1791	1085	125549	20210302030086
Calibration	N/A	N/A	N/A	N/A	N/A

Component	Non-vented Pressure Sensor	CTD	GNSS-R Receiver	GNSS-R Solar Panel
Model Number	RBR Solo D	375MP	Septentrio PolaRx5	AMeresco Solar 40J, 40W
Serial Number	201622	11494	3047773	D31306201066941
Calibration	N/A	N/A	N/A	N/A

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 Wavemaster II

This system is branded by Teledyne Reson with a T-series IMU-20 but is a repackaged Applanix POSMV Wavemaster integrated with the Reson T-50 system.

The primary components are two GNSS antennas, a IP68-rated (submersible) inertial measurement unit (IMU), and a topside processor. The IMU was co-located with the MBES sonars as closely as possible and the GNSS antennas were mounted in locations that gave a clear view of the sky. The INS system is built into the same rack-mount sonar processor topside as the multibeam, which simplifies and streamlines connections and communications between the systems.

On the Q105, the system utilized POS software version 10.2 (firmware version 10.21 and POSView version 10.2).

Calibrations consisted of an initial GAMS (GPS-azimuth measurement subsystem) calibration and alignment with the MBES frame of reference via standard patch test methodology.

Manufacturer	Applanix
Model	POSMV Wavemaster II
Inventory	*Q105*

Component	IMU	GNSS Antenna 1	GNSS Antenna 2	Rack Mount Topside
Model Number	T-Series IMU-20	AT1675-540TS	AT1675-540TS	T50 RSP INS
Serial Number	1010790	13007	13009	na
Calibration	N/A	N/A	N/A	N/A

A.5.1.2 Applanix POS MV Wavemaster II

The primary components are two GNSS antennas, a IP68-rated (submersible) inertial measurement unit (IMU), and a topside small form factor processor. On the Sealegs, the POSMV IMU was co-located with the MBES sonar as closely as possible and the GNSS antennas were mounted in locations that gave a clear view of the sky.

On the Sealegs, the POSMV utilized POS software version 9.0 (firmware version 9.03 and POSView version 9.02)

Calibrations consisted of an initial GAMS (GPS-azimuth measurement subsystem) calibration and alignment with the MBES frame of reference via standard patch test methodology.

Manufacturer	Applanix
Model	POS MV Wavemaster II
Inventory	*Sealegs*

Component	IMU	GNSS Antenna 1	SS Antenna 2	Small Form Factor PCS
Model Number	Type 45	AT1675-540TS	AT1675-540TS	N/A
Serial Number	3171	9861	9857	7793
Calibration	N/A	N/A	N/A	N/A

A.5.2 DGPS

A.5.2.1 Hemisphere AtlasLink Smart Antenna

Each survey vessel was outfit with a Hemisphere AtlasLink receiver to provide real-time, RTK-level GNSS corrections to the vessel POSMV to assist with navigation.

The receivers utilized the SBAS, subscription-based Atlas H10 offshore service.

However, all real-time corrections were replaced in CARIS HIPS for final deliverables through application of post-processed kinematic (PPK) SBET data generated in Applanix POSPac MMS software, as described elsewhere in this report.

Manufacturer	Hemisphere		
Model	AtlasLink Smart Antenna		
Inventory	*Q105*	*Component*	AtlasLink
		Model Number	Smart Antenna
		Serial Number	ESN 18925611
		Calibration	N/A
	Sealegs	*Component*	AtlasLink
		Model Number	Smart Antenna
		Serial Number	ESN 18925594
		Calibration	N/A

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 Teledyne Oceanscience RapidCast

A Teledyne Oceanscience RapidCast system was used on the Q105 to deploy a sound speed profiler while underway during survey operations.

The system utilized RapidCast Interface Software V1.5.1 for configuring and controlling the system.

The Sealegs was not equipped with a moving vessel profiler.

Manufacturer	Teledyne Oceanscience		
Model	RapidCast		
Inventory	*Q105*	*Component*	Sound Speed Deployment Winch
		Model Number	RapidCast
		Serial Number	147
		Calibration	N/A

A.6.2 CTD Profilers

No CTD profilers were utilized for data acquisition.

A.6.3 Sound Speed Sensors

A.6.3.1 Valeport SWiFT SVP

A Valeport SWiFT SVP was used on the Q105 as the primary sound speed sensor.

The SWiFT is designed to be used with the RapidCast deployment system and features a 32 Hz measurement rate, but is lighter and smaller than the RapidPro, making it ideal for shallow water casts.

A SWiFT was also used on the Sealegs, but only as a backup, comparison, and for initial corrections because it did not have a recent calibration. Final corrections for Sealegs data used an AML Minos-X profiler which was deployed simultaneously.

Manufacturer	Valeport		
Model	SWiFT SVP		
Inventory	*Q105*	*Component*	Sound Speed Profiler
		Model Number	SWiFT SVP
		Serial Number	68631
		Calibration	2020-09-24
	Sealegs	*Component*	Sound Speed Profiler
		Model Number	SWiFT SVP
		Serial Number	63780
		Calibration	N/A

A.6.3.2 AML Oceanographic Minos-X (SV- and P-Xchange sensors)

This sound velocity system was used perform sound speed casts on the Sealegs. The Minos-X utilized SV- and P-Xchange sensors with a recent calibration. The Minos-X was manually lowered to the seafloor approximately every two hours and when changing areas, and downloaded at the end of each day.

As described previously, a Valeport SWiFT was deployed simultaneously with the Minos-X but was not used for final corrections to Sealegs data.

Manufacturer	AML Oceanographic				
Model	Minos-X (SV- and P-Xchange sensors)				
Inventory	*Sealegs*	*Component*	Minos X (Housing)	Sound Speed Sensor	Pressure (Depth) Sensor
		Model Number	Minos-X	SV-Xchange	P-Xchange
		Serial Number	30452	206714	304614
		Calibration	N/A	2021-06-03	2021-06-03

A.6.4 TSG Sensors

A.6.4.1 AML Oceanographic Micro-X with SV-Xchange Surface Speed Sensor

Both vessels utilized AML Oceanographic sound speed sensors to measure sound speed at the multibeam sonar heads (surface sound speed sensors). This data stream was interfaced directly with the Reson MBES system to provide sound speed for beam-forming purposes.

Each sensor consisted of an AML Micro-X housing with a SV-Xchange sensor tip.

As a QC check, during each sound speed profile cast the value reported by the surface speed sensor aboard the Q105 was noted in the acquisition log for comparison with the sound speed profile's value at the same depth. These compared well, with the mean difference of 0.271 m/s with a standard deviation of 0.301 m/s.

The check also occurred on the Sealegs, with the sensors agreeing to within 1.121 m/s on average, with a standard deviation of 1.735 m/s.

Results are available with each project DR.

<table>
<tr><td>Manufacturer</td><td colspan="4">AML Oceanographic</td></tr>
<tr><td>Model</td><td colspan="4">Micro-X with SV-Xchange Surface Speed Sensor</td></tr>
<tr><td rowspan="8">Inventory</td><td rowspan="4">Q105</td><td>Component</td><td>Surface Sound Speed Sensor-Housing</td><td>Surface Sound Speed Sensor-Sensor</td></tr>
<tr><td>Model Number</td><td>Micro-X</td><td>SV-XChange</td></tr>
<tr><td>Serial Number</td><td>11998</td><td>209582</td></tr>
<tr><td>Calibration</td><td>N/A</td><td>N/A</td></tr>
<tr><td rowspan="4">Sealegs</td><td>Component</td><td>Surface Sound Speed Sensor-Housing</td><td>Surface Sound Speed Sensor-Sensor</td></tr>
<tr><td>Model Number</td><td>Micro-X</td><td>SV-Xchange</td></tr>
<tr><td>Serial Number</td><td>12459</td><td>208079</td></tr>
<tr><td>Calibration</td><td>N/A</td><td>N/A</td></tr>
</table>

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*
QPS	Qinsy	9.3.1.313	Acquisition and Navigation
Teledyne Reson	7k Sonar UI	5.0.0.17	Sonar Interface and Tuning
Teledyne Oceanscience	RapidCAST Interface	1.5.1	Acquisition of SV Profiles
Valeport	Connect	1.0.7.10	Download of SV Profiles
Applanix	POSView	10.00 (SeaLegs) 10.2 (Q105)	POSMV Interface & Logging
NOAA/UNH/CCOM	Sound Speed Manager	2019.2.6	Processing SVPs
Applanix	POSPac MMS	8.5	PPK Processing - Field
Applanix	POSPac MMS	8.7	PPK Processing - Office
Teledyne CARIS	HIPS & SIPS	11.3.13	Bathymetry Processing - Field
Teledyne CARIS	HIPS & SIPS	11.3.19	Bathymetry Processing - Office
NOAA	Pydro	19.4	QC Tools and Surface Comparisons
QPS	Fledermaus FMGT	7.9.3	Backscatter Checks

A.8 Bottom Sampling Equipment

A.8.1 Bottom Samplers

A.8.1.1 Wildco Standard Ponar

A Wildco Standard Ponar, a Van Veen style grab sampler, was used to acquire all bottom samples.

B. System Alignment and Accuracy

B.1 Vessel Offsets and Layback

B.1.1 Vessel Offsets

For this project, the top-center of the IMUs served as the Central Reference Point (CRP) on each vessel.

The IMU was co-located as closely as possible with the sonar heads. On the Q105 this resulted in the IMU being mounted directly on the standard integrated MBES bracket, and on the Sealegs the IMU was mounted on a standard T-20 MBES bracket with an adapter plate to match the IMU's bolt pattern.

The co-location of the CRP and MBES sonars greatly reduced the complexity of the vessel surveys, which were completed with measuring tape methods on June 19, 2021 on both vessels.

Offset from the CRP down to the MBES was measured directly by tape to a physical point on the sonar, from where the manufacturer-provided acoustic center offsets provided in the system user manuals were applied.

Offset from the CRP up to the static draft (measure-down) point-or point from where draft measurements would be made--was also measured directly by tape. On the Q105, this point was on the rail directly above the MBES head. Similarly, on the Sealegs, this point was on the over-the-side mount directly above the MBES head.

Offset from the CRP up to the POSMV antennas were also directly measured by tape on the SeaLegs. On the Q105, which had a large IMU lever arm, a value derived by laser scanner in March 2019 was used initially but refined following mobilization using calibrated installation lever arms derived from Applanix POSPac software.

Note that per CARIS Technical Bulletin "HIPS and SIPS Technical Note Sound Velocity Correction for Teledyne Reson 7k Data", the HVF files for the T-50 MBES system on the Q105 and the T-20 on the Sealegs were configured as dual- head with separate Rx and Tx array offsets even though they were physically single-head systems. The offsets for the separate Rx and Tx acoustic centers were derived from the user manuals for the systems.

Refer to Appendix III for vessel offset survey results.

B.1.1.1 Vessel Offset Correctors

Vessel	Sealegs			
Echosounder	Teledyne Reson T20-P			
Date	2021-06-19			
Offsets			*Measurement*	*Uncertainty*
	MRU to Transducer	*x*	0.000 meters	0.010 meters
		y	0.115 meters	0.010 meters
		z	0.185 meters	0.010 meters
		x2	0.000 meters	0.010 meters
		y2	0.306 meters	0.010 meters
		z2	0.232 meters	0.010 meters
	Nav to Transducer	*x*	0.000 meters	0.010 meters
		y	0.115 meters	0.010 meters
		z	0.185 meters	0.010 meters
		x2	0.000 meters	0.010 meters
		y2	0.306 meters	0.010 meters
		z2	0.232 meters	0.010 meters
	Transducer Roll	*Roll*	0.000 degrees	

<table>
<tr><td>Vessel</td><td colspan="4">Qualifier 105</td></tr>
<tr><td>Echosounder</td><td colspan="4">Teledyne Reson T50-R</td></tr>
<tr><td>Date</td><td colspan="4">2021-06-19</td></tr>
<tr><td rowspan="14">Offsets</td><td rowspan="7">MRU to Transducer</td><td></td><td>Measurement</td><td>Uncertainty</td></tr>
<tr><td>x</td><td>0.000 meters</td><td>0.010 meters</td></tr>
<tr><td>y</td><td>0.091 meters</td><td>0.010 meters</td></tr>
<tr><td>z</td><td>0.167 meters</td><td>0.010 meters</td></tr>
<tr><td>x2</td><td>0.000 meters</td><td>0.010 meters</td></tr>
<tr><td>y2</td><td>0.279 meters</td><td>0.010 meters</td></tr>
<tr><td>z2</td><td>0.214 meters</td><td>0.010 meters</td></tr>
<tr><td rowspan="6">Nav to Transducer</td><td>x</td><td>0.000 meters</td><td>0.010 meters</td></tr>
<tr><td>y</td><td>0.091 meters</td><td>0.010 meters</td></tr>
<tr><td>z</td><td>0.167 meters</td><td>0.010 meters</td></tr>
<tr><td>x2</td><td>0.000 meters</td><td>0.010 meters</td></tr>
<tr><td>y2</td><td>0.279 meters</td><td>0.010 meters</td></tr>
<tr><td>z2</td><td>0.214 meters</td><td>0.010 meters</td></tr>
<tr><td>Transducer Roll</td><td>Roll</td><td>0.000 degrees</td><td></td></tr>
</table>

B.1.2 Layback

Layback calculations are not applicable to this project.

Layback correctors were not applied.

B.2 Static and Dynamic Draft

B.2.1 Static Draft

Vessel static draft (waterline) measurements were taken to correct for the depth of the vessel's sonars below the water level. Draft was measured when sea conditions were calm enough to obtain a high confidence value. Measurements were also taken whenever the potential to significantly change the draft was experienced, such as after fueling or adjustments in ballast.

On the Q105, a static draft ("measure-down") was recorded in the following manner: With the vessel at rest, a calibrated (corrected/checked by tape) plastic pole was used to measure the distance from a designated measure-down (MD) point to the water. The MD point was located on the vessel rail/gunwale directly above the CRP on the vessel's port side, midship.

On the Sealegs, the static draft was recorded in the following manner: With the vessel at rest and the multibeam mount deployed in the water, a measuring tape was ran from the top of the multibeam pole to the water. The top of the multibeam pole was the designated measure-down (MD) point for this vessel. The multibeam pole and MD point were located on the starboard side of the vessel, aft of midship, and attached to the sonar mount structure.

For each vessel, the CRP to waterline correction value was computed by subtracting the above measurement from the known offset between the CRP and MD point. The resulting value was entered as a waterline offset in the CARIS HVF file. This value was always negative in this configuration since the CRP on both vessels was under the water level.

B.2.1.1 Static Draft Correctors

Vessel	*Date*	*Loading*	*Static Draft*	
			Measurement	*Uncertainty*
Q105	2021-07-28	0.020 meters	-1.872 meters	0.020 meters
Q105	2021-07-31	0.020 meters	-1.872 meters	0.020 meters
Q105	2021-08-30	0.020 meters	-1.792 meters	0.020 meters
Q105	2021-08-31	0.020 meters	-1.812 meters	0.020 meters
Q105	2021-09-03	0.020 meters	-1.812 meters	0.020 meters
Q105	2021-09-08	0.020 meters	-1.842 meters	0.020 meters
Q105	2021-09-18	0.020 meters	-1.832 meters	0.020 meters
Sealegs	2021-08-03	0.020 meters	-0.314 meters	0.020 meters
Sealegs	2021-09-03	0.020 meters	-0.340 meters	0.020 meters

B.2.2 Dynamic Draft

Dynamic Draft was measured using Squat-Settlement test methodology. However, the results were not directly applied to the data since as an ERS survey the effects of dynamic draft are already accounted for in the vertical positioning of the vessel CRP.

Corrections for dynamic draft were determined for each vessel by means of a squat settlement test. PPK GPS methods were used to produce and extract the GPS altitudes from the test. Corrections were determined for a range that covered normal vessel speeds experienced while surveying.

The tests were competed on JD260 for the Qualifier and on JD255 for the SeaLegs. During the squat settlement test, the vessel logged raw POSMV attitude and positioning data to a POS file. A survey line was run in each direction at incrementing engine RPM/ speed. Between each line set, as well as at the start and end of the test, a “static” was collected whereby the vessel would sit with engines in idle and log for a minimum of 3 minutes. The survey crew would note the time and speed of each event.

The tests were performed but not processed. As an ERS survey, all sounding data is already corrected for the effect of dynamic draft.

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

Patch tests were conducted on both vessels to establish latency, pitch, roll, and yaw alignment values between the POSMV and the MBES systems.

Patch tests were completed on the Q105 on JD221, and back dated to JD209 in the HVF to replace initial values from the mobilization. The values were reconfirmed on a patch test near the end of the project on JD247, indicating no changes occurred during the project.

On the Sealegs, a patch test was completed on JD255, and back dated to JD215 in the HVF to replace initial values from the mobilization. The JD255 values reconfirmed the initial mobilization values, indicating no changes occurred during the project.

Industry-standard patch test procedures--summarized below--were used to determine latency, pitch, roll, and yaw correctors for the single head T-50 on the Q105 and the T-20 on the SeaLegs.

To determine latency, a survey line was run twice – in the same direction – at low and high speeds over the feature. The data was examined in CARIS HIPS Calibration mode. Any horizontal offset of the features indicated latency between the positioning and sounding systems. A correction (in seconds) that improved the match-up was determined and entered into the HVF.

Note that the timing correction (if any) was entered into the HVF for the Transducer1 sensor instead of the navigation sensor, which resulted in the correction being applied to all positioning and attitude data (not just navigation). This was desirable because latency, determined with the POSMV, is system-wide and affects all output data. The sign of the value found also needed to be reversed since the correction was being added to the Transducer1 sonar times, instead of the navigation sensor. For this project, latency was indiscernible in the patch test data for both vessels and no correction was necessary.

To determine pitch offset, a third line was run back over the feature at low speed in the same direction as the first line. The first and third lines were examined for feature alignment. Any remaining horizontal offsets of bottom features in this line set, following latency correction, indicated the pitch offset between the attitude and sounding systems. The value that best compensated for the pitch misalignment was entered into the HVF.

Yaw offset was then determined following the corrections for latency and pitch. Survey lines run in opposite directions with outer beams overlapping the feature were examined. Any remaining horizontal offset of corresponding beams indicated a yaw offset between the sounder and motion sensor reference frames. A value that improved match-up was determined and entered into the HVF.

Roll offset was then determined. The same survey line run twice over flat bottom topography, in opposite directions, was examined. Any vertical offset of outer beams indicated a roll offset between the sounder and motion sensor reference frames. A value that brought the data into alignment was determined and entered into the HVF.

Patch test data received standard corrections and processing prior to examination in CARIS HIPS prior to determining the calibration values.

B.3.1.1 System Alignment Correctors

<table>
<tr><td>Vessel</td><td colspan="3">Q105</td></tr>
<tr><td>Echosounder</td><td colspan="3">Teledyne Reson T-50 R</td></tr>
<tr><td>Date</td><td colspan="3">2021-08-09</td></tr>
<tr><td rowspan="10">Patch Test Values</td><td></td><td>Corrector</td><td>Uncertainty</td></tr>
<tr><td>Transducer Time Correction</td><td>0.000 seconds</td><td>0.010 seconds</td></tr>
<tr><td>Navigation Time Correction</td><td>0.000 seconds</td><td>0.010 seconds</td></tr>
<tr><td>Pitch</td><td>0.400 degrees</td><td>0.010 degrees</td></tr>
<tr><td>Roll</td><td>0.020 degrees</td><td>0.010 degrees</td></tr>
<tr><td>Yaw</td><td>0.100 degrees</td><td>0.010 degrees</td></tr>
<tr><td>Pitch Time Correction</td><td>0.000 seconds</td><td>0.010 seconds</td></tr>
<tr><td>Roll Time Correction</td><td>0.000 seconds</td><td>0.010 seconds</td></tr>
<tr><td>Yaw Time Correction</td><td>0.000 seconds</td><td>0.010 seconds</td></tr>
<tr><td>Heave Time Correction</td><td>0.000 seconds</td><td>0.010 seconds</td></tr>
</table>

Vessel	Sealegs
Echosounder	Teledyne Reson T-20 P
Date	2021-09-12
Patch Test Values	

	Corrector	*Uncertainty*
Transducer Time Correction	0.000 seconds	0.010 seconds
Navigation Time Correction	0.000 seconds	0.010 seconds
Pitch	-0.300 degrees	0.010 degrees
Roll	0.100 degrees	0.010 degrees
Yaw	0.000 degrees	0.010 degrees
Pitch Time Correction	0.000 seconds	0.010 seconds
Roll Time Correction	0.000 seconds	0.010 seconds
Yaw Time Correction	0.000 seconds	0.010 seconds
Heave Time Correction	0.000 seconds	0.010 seconds

C. Data Acquisition and Processing

C.1 Bathymetry

C.1.1 Multibeam Echosounder

Data Acquisition Methods and Procedures

General Acquisition Systems Configuration

Q105 and Sealegs acquisition systems were configured nearly identically.

Both vessels utilized Intel-based Windows 10 PCs for acquiring data. QPS QINSy data acquisition software was used to log all bathymetric data and to provide general navigation for survey line tracking. QPS QINSy was configured with inputs that included positioning and attitude data from the POSMV via network, bathymetric and backscatter data from the Reson SeaBat MBES via network, and 1-PPS timing over coax cable with 1 Hz ZDA timing string via serial cable from the POSMV. Since both the POSMV and Reson systems share the same topside on the Q105, there is only one network connection between the Windows PC and integrated rack mount topside.

Teledyne Reson Sonar UI software was used to monitor, configure, and tune the MBES systems. Inputs into the software included surface sound speed via serial cable and a 1-PPS timing over coax cable with 1 Hz ZDA timing string via serial cable from the POSMV. For the Q105, connections between the POSMV and Reson systems are integrated internally in one rack mount topside.

QPS QINSy Navigation and MBES Collection

The software features many quality assurance tools, which were taken advantage of during this survey. Using the raw echosounder depth data, the acquisition software generated a real-time digital terrain model (DTM) during data logging that was tide and draft corrected. The DTM was displayed as a layer in a plan-view layer. The vessel position was plotted on top of the DTM, along with other common data types including shape files containing survey lines and boundaries, nautical charts, waypoints, and shoreline features as necessary. Note that the DTM was only used as a field quality assurance tool and was not used during subsequent data processing. Tide and offset corrections applied to the DTM and other real-time displays had no effect on the raw data logged and later imported into CARIS HIPS. Final tide and offset corrections were applied in CARIS HIPS.

In addition to the DTM and standard navigation information, QINSy was configured with various tabular and graphical displays that allowed the survey crew to monitor data quality in real-time. Alarms were setup to alert the survey crew immediately to certain quality-critical situations. These included alarms for loss of time sync and critical data streams from the POSMV and Reson sonars.

Data Coverage and Density

Effort was made to ensure coverage and density requirements described in the HSSD were met.

Work was done to “Set Line Spacing” (“Option A: Multibeam Sonar Set Line Spacing without Concurrent Side Scan Sonar Coverage”), or Complete Coverage standards, as described in the HSSD depending on the survey sheet. MBES backscatter was also acquired during all MBES data acquisition. Per the project Work Instructions, line spacing was assigned at 100, 240, or 400 meters in Set Spacing sheets.

A line plan, with lines at the required spacing by area, was developed prior to commencement of operations. Line plans with multiple orientations were made to provide options, with the orientation most suitable to weather conditions or bottom topography was utilized during operations. Line plans were periodically modified on the fly as necessary, usually by the addition of splits to develop shoals and investigation areas, or addition of diagonal crosslines. Set Line Spacing areas had mainscheme lines oriented perpendicular to the depth contours of the area.

Coverage was monitored relative to the line plans as well as the assigned survey area boundaries in realtime in the QPS QINSy acquisition software. When running lines, each vessel navigated the line as closely as possible while surveying, with the Q105 generally able to maintain average off-track errors of 5 m or less, and the Sealegs 3 m or less. Care was taken during run-ins and run-outs to collect data at least to the survey boundaries.

Data density requirements were met through close attention to vessel speed, ping rates, and use of best possible across-track beam density. Ping rate was capped at a relatively high rate (10 pings / second) while vessel speeds were moderated (less than 9 knots, but usually 6.5 to 7.5 knots, and much less in shallow water) to control pings-per-meter on the seafloor. Across-track density for MBES was maximized by utilizing the “best coverage” beam mode on the T50 and T20 sonars, generating up to 512 beams spaced equidistant across the swath for every ping, which was the maximum capability of the MBES systems. This combination of ping rate and beam mode allowed the systems to generate up to 5,120 soundings per second. At the speeds used on this project exceed density specifications for the required grid resolutions were greatly exceeded for the majority of grid cells.

Coverage and density were confirmed by processing in CARIS HIPS. Following application of preliminary correctors, filters, and manual cleaning, CUBE BASE surfaces, at the required resolutions, were generated and examined for coverage and density. When identified, holidays or other gaps were re-run unless deemed unsafe due to water depth or other conditions.

Data Processing Methods and Procedures

Initial data processing was carried out in the field aboard the Q105. Final data processing and reporting was completed in the office following the completion of field operations.

Following transfer from the acquisition, raw bathymetric data was converted, cleaned, and preliminary tide and GPS corrections were applied in accordance with standard TerraSond processing procedures-customized as necessary--for this survey. This was accomplished in near real-time, immediately after each line was acquired, providing relatively rapid coverage and quality determination.

Following the completion of field operations, final data processing was completed at TerraSond’s Palmer, Alaska office. This included a comprehensive review of all collected data for completeness and accuracy of corrections, application of final tides (if applicable) and TPU, final cleaning and surface review, compilation of reports, S-57 deliverables, and generation of final products.

Checks and data corrections applied by data processors for MBES data were recorded to a log sheet in Microsoft Excel. Logsheets were then output to PDF format and are available with each project DR.

Conversion into CARIS HIPS and the HIPS Vessel File

CARIS HIPS was the primary software used for bathymetric processing for this project. The XTF (extended Triton Format) files written by QINSy were imported into CARIS HIPS using the “Triton XTF” conversion wizard. Import options selected during conversion included importing coordinates as geographic, automatic time stamping, use of the ship ping header for navigation, and gyro data from attitude packets. No soundings were rejected during conversion.

During conversion, raw data was converted under the appropriate HVF (HIPS Vessel File) corresponding to the vessel that acquired the bathymetric data. The HVF contains time-based, vessel-specific static vessel offsets, configurations, and error estimates that are utilized by CARIS HIPS during various processes including SVP, TPU computation, and Merge.

During conversion, ITRF2008 was selected as the geographic datum to match the output reference system of the AtlasLink RTK positioning source. Note that all real-time positions are ITRF2008, but final positions are all NAD83(2011) due to the application of NAD83(2011) SBETs to all survey lines.

CARIS HIPS created a directory structure organized by project (area) and line. Sensors were parsed from the input raw data files, allowing them to be reviewed and edited separately from each other.

HIPS Vessel Files (HVF) - Dual Head Configuration

The CARIS HVFs (HIPS Vessel Files) for this project were setup in a dual-head configuration to ensure proper application of offsets and sound speed correction. This was done per CARIS' technical bulletin "HIPS and SIPS Technical Note for Sound Velocity Correction for Teledyne Reson 7k Data" even though both T20 and T50 systems were a single head. Per the bulletin, this was necessary because QINSy was configured to log "new" style (Reson 7027) bathymetric records, and XTFs were set to contain "raw" Reson records instead of "QPS" records.

Note that in this configuration vessel offsets appear only under the SVP1 and SVP2 sensors in the HVF, not under the Transducer 1 and Transducer 2 sensors as they might for other sonar configurations. Angular corrections derived from the patch tests are still included under Transducer 1 (but not the non-existent Transducer 2).

Waterline

To correct for the depth of the transducer, the HVF for each vessel was updated with a new waterline value prior to processing. The static draft, or computed distance from the vessel CRP to the water level with the vessel at rest (computed as described previously in this report), was entered as a waterline correction in the CARIS HVF. Values were occasionally pre-dated in the HVF when necessary.

Static draft measurements were logged in an Excel logsheet, which was exported to PDF and is available with each DR.

Import Auxiliary Data

On this project, positioning and attitude data was processed using post-processed kinematic (PPK) methodology. The PPK process (described later in this report) produced smoothed best estimate of trajectory (SBET) files, which contain a significantly improved navigation and attitude solution over the real-time.

SBETs were loaded into lines using CARIS HIPS "Import Auxiliary Data" utility. During the loading process, the option to import "Applanix SBET" was selected. Navigation and GPS Height records were imported. Data rate was set to '0' to use the data at the default rate within the SBET, which on this project was produced at 50 Hz. Attitude data, also available in the SBET, was NOT loaded. Gaps were allowed in order to show as holidays for rerun.

Through this process, each line's original, real-time navigation and GPS Height records were superseded in CARIS HIPS by the records in the SBET files.

Additionally, "Import Auxiliary Data" was used to load Delayed Heave from POSMV (POS) files to all lines. Only Delayed Heave and Delayed Heave RMS error was loaded from POS files. Note that on occasion, usually due to a crash of the PC running POSView, a POS file would not be able to be applied to a line segment. In these cases real-time heave was used in all HIPS processes. These cases are itemized where the occurred in the appropriate DRs.

Dynamic Draft Corrections

Dynamic draft corrections were determined for this project using squat-settlement tests, but were not applied to the data.

As an Ellipsoid Referenced Survey (ERS) project, vertical changes in vessel displacement were captured in the GPS data for the vessels and are therefore corrected for without the need to apply separate Dynamic Draft Corrections. The HVF files therefore do not contain Dynamic Draft Correction tables.

Multibeam Swath Filtering

Prior to manual review and cleaning, all multibeam data was filtered using CARIS HIPS “HIPS Data Filters > Apply > Bathymetry” function.

All soundings were filtered based on Reson MBES quality flags and angle from nadir. Soundings flagged as 0, 1, and 2 were “rejected” automatically in filtering, which left only high quality (3, being both co-linear and bright) soundings. Beams greater than 65 degrees from nadir were also rejected, except in Complete Coverage areas where a beam angle filter was generally not used. This removed a large amount of water column noise and reduced the amount of manual editing necessary.

During final review, some lines exhibiting SVP error received additional beam filtering, to 50 degrees from nadir.

Georeference

The “Georeference” process was run on all lines in CARIS HIPS.

During this process, the following corrections were made.

1. Sound Velocity Correction was enabled. The appropriate SVP file for the vessel and area was selected. The option to use nearest in distance in time 3 hours was used for final corrections.

2. TPU computation was enabled. Measured tide error was set to 0.150 m per the Work Instructions. Measured sound velocity error was set to a value that was determined by area and vessel. Surface sound velocity error was set to 0.025 per AML specifications for the surface sound speed sensors. All error sources were set to "Vessel" to use the estimated errors in the HVF, except for "Tide" which was set to use "Static" error.

3. GPS Vertical Adjustment (GPS Tide) was enabled. The NOAA-provided CSAR separation surface was selected as the model file, using the band name "NAD83_MLLW". The coordinate reference system was set to NAD83(2011) to match the SBET processing system. Dynamic Heave source was set to "Delayed Heave", except in rare cases (itemized in the DRs) where Delayed Heave was not available and Real-Time heave was selected instead. The waterline source was set to "Vessel".

Multibeam Swath Editing

Initial cleaning of multibeam data was done in the field using CARIS HIPS Swath Editor.

Following application of filters and other correctors, soundings were examined for spikes, fliers, or other abnormalities, and obviously erroneous soundings (fliers) were rejected.

Cleaning status was tracked in the processing section of an Excel logsheet, included with each DR.

GPS Height Busts

Although the majority of overlapping multibeam data showed good vertical agreement (to 0.10 m or better), vertical separation or busts of 0.20 m or greater are observed occasionally in the dataset. When these were found to approach or exceed HSSD specifications (generally 0.5 m) they were addressed by repairing in processing.

Three methods were used to address these:

1) If possible, bad altitudes apparent in the GPS Height record in CARIS attitude editor were rejected "with interpolation". This was only possible where bad GPS Height records were fully bracketed by good GPS Height records, i.e. not possible if at the start or end of a line.

2) If it was not possible to fix through GPS Height interpolation, alternate SBETs were loaded and the results observed. Final processing used PPRTX SBETs (see POSPac discussion), though in rare cases ASB SBETs provided better results on problem lines.

Any line files requiring alternate SBETs or application of GDP heights are itemized in the appropriate DR.

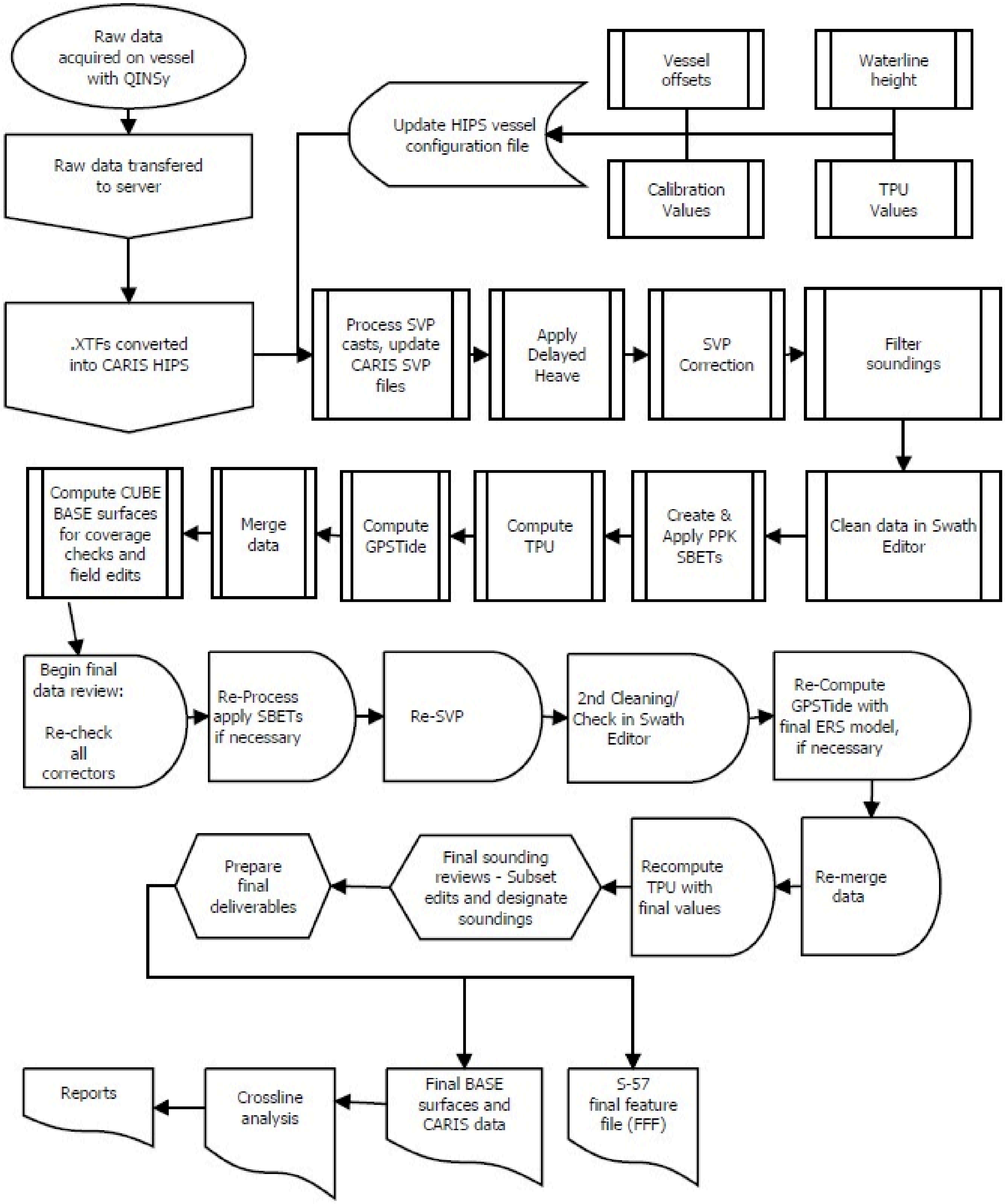

Figure 5: Processing flow diagram. Note this diagram is based on HIPS 10. SVP, TPU, Merge, and GPS Tide functions are still completed in HIPS 11 but are grouped under the single "Georeference" Option.

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

The final depth information for this survey is submitted as a collection of surfaces gridded from the sounding data. Surfaces were generated in CARIS HIPS 11.3.19 in CSAR format, and represent the seafloor at the time of survey with depths relative to chart datum (MLLW).

Resolutions of the CSAR surfaces were created in accordance with the 2020 HSSD based on coverage type and depth. Coverage types required on this survey were “Set Line Spacing” (Option A, Section 5.2.2.4 in the 2020 HSSD) and "Complete Coverage" (Option A, Section 5.2.2.3 in the 2020 HSSD).

As all depths were less than 80 m, only 4 m resolution surfaces were created for final deliverables in Set Line Spacing areas. Within Complete Coverage areas (and feature investigations within Set Line Spacing area), 1 m resolution surfaces were created for final deliverables.

C.1.4.2 Depth Derivation

Surface filters, sounding suppression parameters, and data decimation parameters were not used to derive depths. Beam and quality filters were run on the data and are discussed previously.

C.1.4.3 Surface Computation Algorithm

CUBE (Combined Uncertainty and Bathymetric Estimator) was used as the gridding algorithm for all surfaces. Per NOAA/CCOM definition, CUBE is "an error-model based, direct DTM generator that estimates the depth plus a confidence interval directly on each node point of a bathymetric grid."

NOAA standard CUBE parameters for 1 m and 4 m resolution surfaces were utilized. This included a 0.71 m and 2.83 m limit on the capture distance of soundings contributing to each grid node, which corresponds to the resolution (1 and 4 meters, respectively) divided by the square root of 2.

During surface computation, “Density and Locale” was chosen as the “disambiguity” method. “Order 1a” was selected as the IHO S-44 Order type.

Each surface was “finalized” in CARIS HIPS prior to submittal. During this process, final uncertainty was determined using the “Greater of the Two” (Uncertainty or Std. Dev. at 95% C.I.) option. Maximum and minimum depth cutoffs were entered based on the HSSD requirements for the resolution (0 to 80 m for both

1 m and 4 m resolution surfaces on this project). The option to apply designated soundings was selected, which forced the final surfaces to honor these soundings (where applicable).

C.2 Imagery

C.2.1 Multibeam Backscatter Data

Data Acquisition Methods and Procedures

MBES backscatter was collected continuously during MBES operations.

DB and QPD ("DTM result") files, which are compatible with QPS Fledermaus Geocoder Toolbox (FMGT), are provided with the survey deliverables to allow backscatter processing. Basic beam quality filters (reject flags 0, 1 and 2) were applied to the QPD files in QINSy in real-time.

Note that XTF files on this project do not contain backscatter records; these were intentionally configured to contain bathymetric sounding data-only in order to reduce file sizes from redundant recording of backscatter data to both DB and XTF files.

Data Processing Methods and Procedures

During field operations, the presence and quality of backscatter records in the raw MBES files was confirmed by periodic random checks through processing in FMGT.

Backscatter processing and mosaic generation was not a requirement of this survey.

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

Data Acquisition Methods and Procedures

The POSMV positioning systems on both vessels were configured to receive Atlas H-10 correctors using Hemisphere SmartLink antennas. Atlas H-10 correctors allowed the POSMVs to operate in RTK mode, assisting with real-time vessel positioning -- especially corrected depth determination.

As a backup, the POSMVs would operate using their integrated WAAS receivers if Atlas H-10 was not available.

Most lines therefore used Atlas H-10 for real-time corrections, but were occasionally (in whole or part) WAAS. All realtime corrections were ITRF.

However, in all cases, H-10 and WAAS corrections were replaced with post-processed positions in NAD83(2011) from post-processed SBET files.

Data Processing Methods and Procedures

All positions were post-processed in Applanix POSPac software, which is described in more detail in the Vessel Positioning section of this report.

C.3.2 Vertical Control

C.3.2.1 Water Level Data

Data Acquisition Methods and Procedures

Two tertiary (subordinate) tide stations were installed for this project, as well as one ERTDM validation site. These stations were installed near the communities of Egegik and Pilot Point, while the ERTDM validation site was installed offshore as a GNSS buoy.

A combination of bubblers, non-vented pressure sensors, GNSS Tide Buoys, radar gauges, and GNSS-R systems were used to measure water levels at the different sites. Vented and nonvented sensors were attached to rebar and driven into seafloor or riverbed. The GNSS Tide buoy was moored in place using a danforth anchor. The water levels for each station were tied to a global reference frame via differential levels and GNSS observations. The equipment was calibrated by the manufacturer prior to deployment. Pre and post-deployment tests were also performed on the equipment to monitor for sensor drift.

However, no project tide data was used to correct project echo soundings. The ERTDM provided by NOAA for this purpose was used instead.

Refer to the HVCR and its accompanying appendices for additional detail.

Data Processing Methods and Procedures

Final tides were completed using ERS (Ellipsoid-Referenced Survey) techniques. NAD83(2011) ellipsoid based altitudes, loaded from PPK SBET files, were reduced to MLLW in CARIS HIPS using the Georeference (Compute GPSTide) routine in conjunction with the NAD83 to MLLW separation model provided by NOAA for this purpose.

Data from the pressure sensors were converted from PSI to meters by correcting for water density and gravity. The non-vented pressure sensors were also corrected for barometric pressure. Water levels from the GNSS Tide Buoy were resolved using baseline processing. The stability of each water level sensor was assessed by either differential levels or differences between simultaneous water level readings. Tidal datums for each location were computed using a control station and at least one calendar month of data.

A total water level error estimate was assigned to each water level record using the methodology outlined in the "COOPS Policy for Management and Dissemination of External Source Water Level Data Revised December 2015".

PPK and ComputeGPS tide procedures are described elsewhere in this report. Refer to the project HVCR for additional information on tide correction methodology as well as comparison results.

C.3.2.2 Optical Level Data

Optical level data was not acquired.

C.4 Vessel Positioning

Data Acquisition Methods and Procedures

Positioning and Attitude Data

Positioning and attitude data was computed during acquisition with Applanix POSMV systems. This data included horizontal position, vertical position, and attitude data consisting of heave, pitch, roll, and heading (gyro).

The POSMV systems were configured to output positioning and attitude data in real-time to the QPS QINSy acquisition software at a rate of 50 Hz. The real-time positions were written to DB and XTF file by QINSy for later import into CARIS HIPS during processing.

Raw POSMV data was also logged at a rate of 50 Hz to POS (.000) file continuously during data acquisition operations, with a new file created approximately every 12 hours. All data packets necessary for Delayed Heave and Applanix POSPac post-processing were included in the records. Care was taken to ensure the POS files were logged for at least two minutes before and after applicable survey lines to allow for the application of Delayed Heave as well as post-processed solutions from Applanix POSPac.

Note real-time positioning data (horizontal and vertical) was superseded with application of post-processed positioning, as described below.

Data Processing Methods and Procedures

Apply Delayed Heave

In processing, CARIS HIPS' "Import Auxiliary Data" utility was utilized to load lines with the "Delayed Heave" record. Delayed Heave was imported at the default data rate (25 Hz) from POS (.000) files logged during acquisition. Along with the Delayed Heave data, Delayed Heave RMS error records were also imported during this process.

Delayed Heave records were then utilized by CARIS HIPS over real-time heave for final heave correction. In rare cases (noted in the applicable DRs) some lines did not receive application of Delayed Heave because of POS file issues, typically caused by occasional software crashes that prematurely ended the POS file logging prior to reaching the 2-minute logging requirement after survey lines. In these cases the lines utilized realtime heave instead.

In CARIS HIPS, options to apply Delayed Heave were utilized during Georeferencing. The option to apply Delayed Heave was also used on the vast majority of survey lines during the Compute GPSTide process, with exceptions noted in the applicable DRs.

Post-Processed Kinematic (PPK) Navigation and Attitude

Final position and attitude data for this project were post-processed.

The project was not located within a region of USCG DGPS coverage. As described elsewhere in this report, Atlas H10 corrections (GNSS) corrections were the primary source for real-time positioning but were replaced in final processing with PPK positions.

PPK processing for this project utilized Applanix POSPac MMS software. POSPac produced SBET format .OUT files, which were loaded into all lines during processing. This superseded real-time navigation (position and GPS height). Note that SBET files also contain post-processed roll, pitch, and gyro (heading) records but these were not applied in processing.

To process POS files to produce an SBET, a POSPac MMS project was first established based on a predefined template with project-specific settings. Project-specific settings consisted of custom SBET output using a decimated data rate of 50 Hz (from the default 200 Hz) and output datum of NAD83 (2011). One project was set up for each POS file, and the POS file was imported into the project. The correct antenna type (AT1675-540TS) was selected.

Trimble PP-RTX methodology was used for initial (field) POSPac processing. PP-RTX is a subscription-based service available within POSPac, that utilizes nearby publicly available GNSS base stations to post-process data. Advertised accuracies are 0.1 m RMS Horizontal and 0.2 m RMS vertical. Advantages of PP-RTX are primarily that no base stations are needed and processing can be completed quickly, usually within 1 hour of completion of file logging.

Following completion of operations and availability of precise ephemeris and nearby CORS station data, some POSMV data was reprocessed in POSPac using Applanix Smart Base (ASB) methodology. This was possible because the survey area was encompassed in a network of regional CORS sites. ASB was used to troubleshoot lines that exhibited vertical busts when using PP-RTX, and in most cases improved their vertical agreement. Individual lines that utilized ASB instead of PP-RTX are itemized in the appropriate DRs.

The PP-RTX and ASB methods were compared to each other during Vessel Position Confidence checks. Results were good, with agreement always within horizontal and vertical specifications, but usually to 0.20 m or better. Refer to Data Quality Management section of this report.

Following PP-RTK (or ASB in final processing) generation, the POSPac Inertial processor function was run.

After completion of the inertial processor, QC plots of RMS error and vessel altitude were examined for spikes and other anomalies. The real-time position was compared visually to the post-processed position in the POSPac MMS plan view window as a check for gross positioning error.

Finally, Smooth Best Estimate of Trajectory (SBET) files were exported from POSPac. The option to produce “Custom Smoothed BET” was used to produce an SBET in the NAD83 (2011) reference frame at 50Hz. This made it so that all final positions were NAD83 (2011) per the 2020 HSSD.

Load Navigation Data (SBETs)

SBETs were loaded into lines using CARIS HIPS “Import Auxiliary Data” utility. During the loading process, the option to import “Applanix SBET” was selected, and the option to import only "Navigation" and "GPS Height" were selected. Data rate was set to ‘0’ to use the data at the default rate within the SBETs, which on this project were produced at 50 Hz. The option to allow partial coverage of SBETs to lines was also used, which resulted in coverage gaps from missing SBET data (if applicable) during coverage review and subsequent rerun of the affected lines or sections of lines while still in the field.

Through this process, each line’s original, real-time horizontal and vertical positions were superseded in CARIS HIPS by the records in the SBET files.

Compute GPSTide (in Georeference)

Following loading of PPK altitude data from the SBET files, CARIS HIPS' "Compute GPSTide" function was run on all lines. This created a GPSTide record within each survey line. Options to apply dynamic heave, vessel waterline, and the NOAA-provided ellipsoid separation model were used so that the GPSTide record reflects the elevation of the vessel waterline above MLLW.

Note that "Delayed Heave" was used as the heave source since the vast majority of lines were loaded with this record. Rare lines without Delayed Heave used real-time heave during this computation instead. These cases are noted in the applicable DR(s).

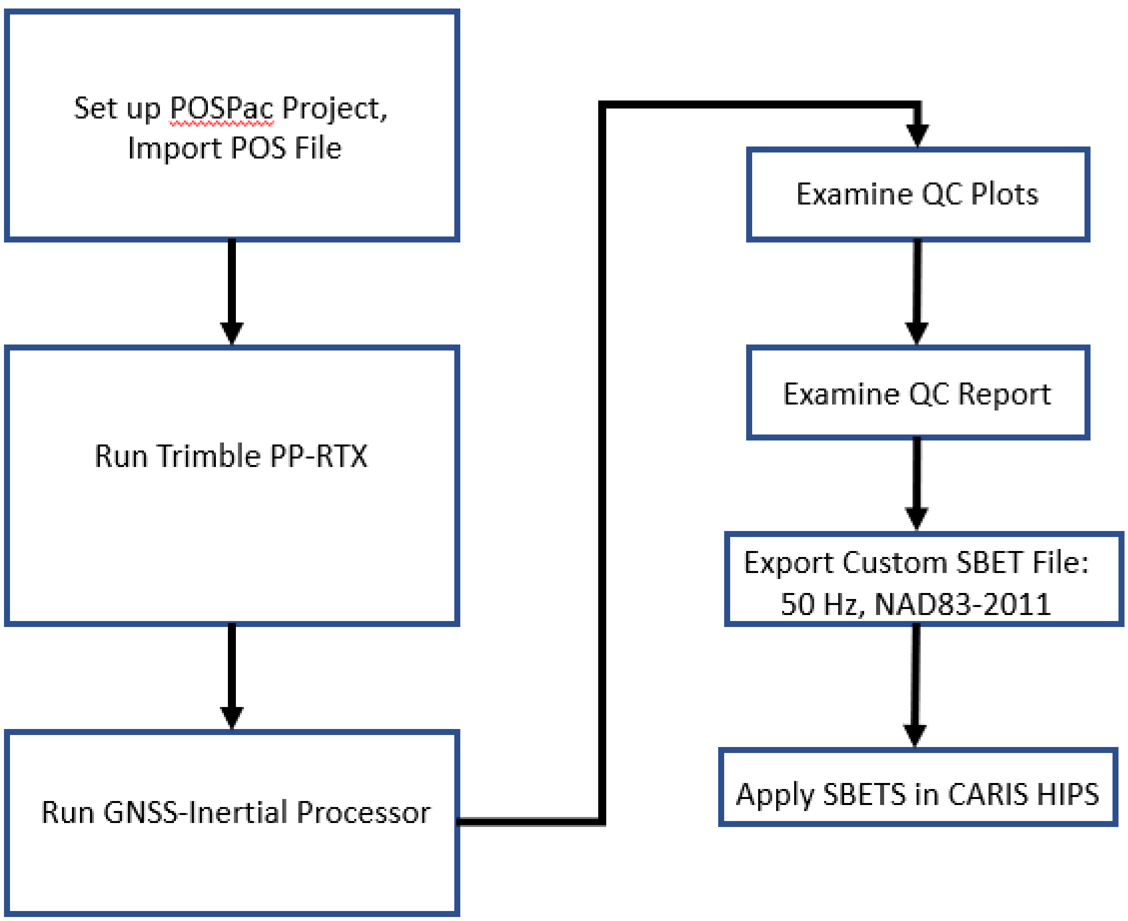

Figure 6: Generalized POSPac processing workflow.

C.5 Sound Speed

C.5.1 Sound Speed Profiles

Data Acquisition Methods and Procedures

Sound speed profiles (casts) were taken from the Q105 using an Oceanscience RapidCAST system, which utilized a Valeport SWiFT sensor. During the cast, sensor depth is estimated by the RapidCAST software based on the manufacturer's algorithm utilizing line tension measured at the winch, free-fall time, and other factors. Survey personnel set a desired target depth and the system would typically achieve the target depth with a margin of error of +/- 5% to 10%. Due to the margin of error on the system's estimates of the probe depth, conservative target depths were entered into the system to avoid striking bottom. This resulted in profiles that were at least 80% of the water depth, but not extending completely to the seafloor. However, effort was made to ensure at least one cast per 24 hours (or more) extended to 95% of the water depth.

Sound speed profiles in their raw format were logged as ".vp2" (Valeport Connect) format. In addition to depth and sound speed, VP2 files contained various metadata including UTC timestamp and geographic position generated from the Valeport sensor's GPS. These files were transferred via Bluetooth connection from the SWiFT to a PC running Valeport Connect software after each cast.

Sound speed casts were completed approximately every 2 hours. The sound speed sensor on the sonar head (surface sound speed) was also monitored continuously and compared automatically in QINSy software to the prior sound speed profile. When the software indicated a 2 m/s or greater differential, another cast was performed.

Additionally, line lengths were limited (generally 20 km or less). This led to a collection of well distributed casts that minimized both the distance and time between bathymetric data and applicable sound speed profiles. When depth varied significantly along a survey line, preference was given to casting in the deeper portion of the line to obtain as much of the water column profile as possible.

On the Sealegs, casts were completed by a manually deployed AML Oceanographic Minos-X sensor outfit with SV- and P-Xchange sensors. Casts were collected normally every 2 to 3 hours, and when changing survey areas. The sensor was turned on to allow data logging and lowered slowly by hand to the seafloor and back. The profiles were downloaded by a cable connection to the Minos-X at the end of each day to AML software, from which CARIS-compatible .SVP files were exported. Note a Valeport SWiFT was also deployed simultaneously during each cast on the Sealegs, but this sensor was out of calibration and therefore only used for initial corrections, as backup, and for comparisons.

Sound speed profiles were applied in CARIS HIPS using the methodology by nearest in distance, with a time interval equal to 3 hours. Exceptions were rare and are described in the applicable DR.

Data Processing Methods and Procedures

Sound speed profiles (casts) were normally processed in HydroOffice Sound Speed Manager.

Each VP2 files logged in acquisition was imported into Sound Speed Manager (SSM). SSM presented a graph of depth versus sound speed, which was examined for spikes (fliers) and to confirm that the desired cast depth was achieved. The VP2 was edited when necessary to remove fliers, and then exported to CARIS ".SVP" format and amended to the master CARIS SVP files by survey area prior to sound speed correction. The profile data was also exported to the acquisition software (QPS QINSy) in order to allow QINSy to alert the acquisition crew if sound speed had changed by greater than 2 m/s between casts.

Note that AML Minos-X casts logged on the Sealegs vessel were not processed in HydroOffice. These were instead exported directly from AML software to CARIS .SVP format and amended to the master CARIS .SVP file for each sheet.

In CARIS HIPS, each line was corrected for sound speed using CARIS HIPS “Sound Velocity Correct using CARIS Algorithm” utility. The CARIS-format .SVP file corresponding to the survey area was selected. To prevent the use of sound speed profiles that were too old or distant relative to the bathymetric data, “Nearest in Distance Within Time” was used for the profile selection method. For the time constraint, 3 hours was used. Exceptions, if any, are noted in the applicable DR.

In addition to the profile selection method, options applied during sound velocity correction were; setting heave source to “Delayed” (to apply Delayed Heave records loaded earlier), and including the option to “Use Surface Sound Speed” (if available).

C.5.2 Surface Sound Speed

Data Acquisition Methods and Procedures

Surface sound speed data was acquired using AML Oceanographic Micro-X sensors mounted on the MBES sonar heads. These were configured to continuously feed sound speed data directly to the MBES systems for internal beam forming purposes.

The surface sound speed value updated in real-time in the Reson 7k Sonar UI interface software. The software was set to alarm upon loss of sound speed data, and during data collection, the value was checked for reasonableness regularly by the survey crew. The acquisition software, QPS QINSy, was also set to alert the acquisition crew if there was significant change (greater than 2 m/s) in the surface sound speed value relative to the previous sound speed profile.

In addition, a formal check was carried out whenever a sound speed profile was collected, which was approximately every 2 hours during data collection. During this check, the surface sound speed value shown in the Reson 7k Sonar UI was noted in the Acquisition Log and then compared to the sound speed profile value at the same depth as the sensor (approximately 2 meters on the Q105, 0.5 meters on the Sealegs).

Results of the surface sound speed checks are available with the project DRs.

Data Processing Methods and Procedures

Surface sound speed data was not processed. It was utilized in acquisition only, for internal beam forming purposes by the Reson T50 and T20 systems.

C.6 Uncertainty

C.6.1 Total Propagated Uncertainty Computation Methods

CARIS HIPS was used to compute total propagated uncertainty (TPU) for all soundings as well as uncertainty for the final grids. The CARIS HIPS TPU computation (under "Georeference" in CARIS HIPS 11) assigned a horizontal and vertical error estimate to each sounding based on the combined error of all contributing components. These error components include uncertainty associated with navigation, gyro (heading), heave, tide, latency, sensor offsets, and individual sonar model characteristics. Stored in the HVF, these error sources were obtained from manufacturer specifications, determined during the vessel survey (sensor offsets), or while running operational tests (patch test, squat settlement). Note that all values are entered at 1-sigma, per CARIS guidance, while CARIS reports TPU a 2sigma. HVF entries and their justification are shown below.

Sonar Type: Teledyne RESON SeaBat T50P And T20P (400kHz 512 beams)

Motion Gyro: 0.020 degrees CARIS TPU values for Applanix POSMV 320 (2 m baseline)

Heave: 5% of Heave Amplitude or 0.05m, whichever is greater -- CARIS TPU values for Applanix POSMV 320

Roll and Pitch: 0.02 degrees -- CARIS TPU values for Applanix 320, non-RTK

Position Nav: 0.1 m -- PPK position processing results report RMS errors that were better than 0.10 m on average

Timing (all systems) 0.010 seconds -- estimated overall synchronization error using 1-PPS

Offset X, Y, and Z: 0.01 m -- estimated measurement error from vessel survey

Vessel speed: 2 m/s Sealegs, 1 m/s Q105 -- estimated maximum average speed of water currents experienced during survey operations

Loading: 0.02 m -- mean difference between subsequent static draft measurements

Draft: 0.020 m -- estimated accuracy of the visually observed static draft measurements

Delta Draft: 0.029 m Q105, 0.026 Sealegs -- estimated uncertainty of squat settlement results.

MRU Align StdDev Gyro and Roll/Pitch -- 0.01 degrees, overall accuracy estimate of patch test results for gyro, pitch, and roll

The TPU computation also incorporated error estimates for tide which were entered at the time of TPU computation. Tidal error was entered as 0.15 based on the value provided for the ERTDM model in the project Work Instructions document.

Sound speed error (measured) differed by sheet and ranged from 0.14 to 6.5 m/s. This was computed, for each vessel, by determining the standard deviation of the difference between subsequent casts taken in each survey sheet. The actual value of the analysis or 1 m/s -- whichever was higher -- was entered into CARIS HIPS during TPU computation. The value used for each sheet is noted in the applicable DR.

Sound speed error (instrument) was entered as the manufacturer's provided value for the surface sound speed sensor on each vessel as 0.025 m/s.

Final CUBE surfaces include an "Uncertainty" layer that shows the estimated uncertainty for the depth value of each cell. Surfaces were finalized in CARIS HIPS with the "Uncertainty Source" selected as "Greater of the two values", which ensured final uncertainty values for the surfaces were the larger of either surface uncertainty or standard deviation (at 2-sigma).

C.6.2 Uncertainty Components

C.6.2.1 A Priori Uncertainty

Vessel		Q105	SeaLegs
Motion Sensor	*Gyro*	0.02 degrees	0.02 degrees
	Heave	5.00% 0.05 meters	5.00% 0.05 meters
	Roll	0.02 degrees	0.02 degrees
	Pitch	0.02 degrees	0.02 degrees
Navigation Sensor		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

Data Acquisition Methods and Procedures

Locations for bottom samples were assigned by NOAA via the S-57 format Project Reference File (PRF). Assigned locations were given a name for reference, imported, and displayed in the acquisition software.

To collect the samples, the vessel would navigate as close as possible to each assigned location. With the vessel at full stop, the survey crew on the back deck would set a spring-loaded Van Veen grab sampler and lower it quickly to the seafloor. A GPS position fix was taken when the sampler was noted to touch bottom. Back on the surface, the sampler was opened, and the contents analyzed to determine its “SBDARE” (Seabed Area) S-57 attributes including “NATSUR” (nature of surface), “NATQUA” (qualifying terms), and “COLOUR”. Time of acquisition was noted, and a photo was taken of each sample. Following analysis, the sample was discarded overboard.

If no sample was obtained, the vessel was repositioned if it had moved more than 100 m from the planned location, and another attempt made. Attempts at collecting a bottom sample would be made at least three times. If no sample was obtained after three attempts, the vessel would move on. An attempt was only considered valid if the grab sampler had returned to the surface in the closed state. For this project, samples were successfully obtained at the vast majority of assigned locations, with exceptions noted in the applicable DR, and encoded with a “NATSUR” as “Unknown” in the FFF.

During analysis, sample particle dimensions were not actually measured. Instead, careful estimations were done visually and by touch. Samples determined in the field to have particle sizes smaller than sand (silt and/or clay) were encoded with “NATSUR” as “mud” and “NATQUA” as “soft” when encoding S-57 attributes, though field comments may retain the original determination of silt or clay. Similarly, samples determined in the field to be pebbles or gravel (“NATSUR”) with field determinations for “NATQUA” as course, medium, or fine were encoded with “volcanic” for “NATQUA” to conform with allowable NATSUR/NATQUA combinations in the HydrOffice QC Tools manual.

If multiple constituents were present in the sample, only the three most prevalent were noted. Constituents were encoded in order of most predominant first.

Field results were recorded in a Bottom Sample logsheet, which is included with the project DRs.

Data Processing Methods and Procedures

Bottom samples were encoded into the Final Feature File (FFF) for each sheet in CARIS HIPS.

In CARIS, an SBDARE S-57 point object was created for each bottom sample. The object position was encoded to be the actual position of the sample as noted in the Bottom Sample Logsheet. Applicable information was entered for Nature of Surface, Nature of Surface -- Qualifying Terms, Color, Source Date, Source Indication, Description, and Recommendations. Notes from the acquisition log were kept in the Remarks field. They were also coded with the time of acquisition and the associated photo, if applicable, was linked.

D. Data Quality Management

D.1 Bathymetric Data Integrity and Quality Management

D.1.1 Directed Editing

Initial field cleaning of multibeam data was done in the field using CARIS HIPS Swath Editor. Following application of filters, soundings were examined for spikes, fliers, or other abnormalities, and obviously erroneous soundings (fliers) were rejected. Cleaning status was tracked in a processing log along with processing comments or notes, if any. Log sheets are available with the project DRs.

Following review and application of final correctors in the office, an examination of soundings was completed in CARIS HIPS Subset Editor, in context of bathymetric surfaces generated using the CUBE (Combined Uncertainty and Bathymetric Estimator) algorithm. The surfaces were examined for fliers, holidays, and artifact such as vertical busts or motion error, and examined in HIPS subset mode where possible issues were noted.

To prevent unnecessary and excess rejection of soundings, requirements in the HSSD were adhered to during the subset editing process. Specifically, only soundings that caused the CUBE surface to error from the obvious seafloor position by an amount greater than the allowable TVU (total vertical uncertainty) at that depth were rejected. It is important to note that this surface-focused approach leaves noisy ‘accepted' soundings that can exceed the TVU allowance, however, the final deliverable is the surface (not the soundings) and meets TVU specifications.

D.1.2 Designated Sounding Selection

On occasion, designated soundings were flagged on the shoalest point of features not well modeled by the CUBE surface during subset editing. As specified in the HSSD, the shoalest sounding on a feature was designated only when the difference between the CUBE surface and reliable shoaler sounding(s) was more than 1 m as well as at least the maximum allowable TVU at that depth. Additionally, if a sounding on a feature was within 2 mm at survey scale (80 meters for most of the project's surveys) of a shoaler part of the surface (or a shoaler designated sounding), it was not designated.

D.1.3 Holiday Identification

Requirements for holidays in for "Set Line Spacing, Option A" were followed under this survey, referencing Section 5.2.2.4 of the 2020 HSSD. In survey areas where complete coverage was required, holiday requirements were followed based on "Complete Coverage Multibeam, Option A", referencing Section 5.2.2.3 of the 2020 HSSD.

Following application of preliminary correctors, filtering, and the first pass of manual edits in CARIS Swath Editor, 4 m resolution CUBE surfaces were generated and systematically examined for holidays in Set Spacing areas. 1 m resolution surfaces were generated for holidays in Complete Coverage areas.

Holidays were considered to be along-track gaps on mainscheme lines of at least 12 m in set spacing coverage. This corresponded to the requirement that no holidays may span more than 3 nodes along-track in depths less than 20 m. When identified these holidays were recollected in the field if depths were greater than NALL and it was safe to do so.

Holidays in Complete Coverage areas had to meet the requirement of being equal to or greater than a square with the side length equal to the coarsest resolution for that depth. For this project 1 m resolution between 0 and 20 m depth covered all of the Complete Coverage survey areas. Therefore, holidays defined as a data gap equal to a 3 m by 3 m square or larger. When identified these holidays were recollected in the field if depths were greater than NALL and it was safe to do so.

D.1.4 Uncertainty Assessment

Uncertainty of final grids was assessed through use of QCTools v3.5.14 "Grid QA v6" utility. For each grid cell in the final surfaces, the utility examined the uncertainty value and determined if it fell within allowable TVU for the depth. It then presented statistics that included the percentage of grid cells with allowable TVU as well as the minimum and maximum values for uncertainty found. Areas of higher than allowable uncertainty, if any, were examined in CARIS HIPS. Results are available with each project DR.

D.1.5 Surface Difference Review

D.1.5.1 Crossline to Mainscheme

Crossline to Mainscheme comparisons did not utilize difference surface methodology. Instead, crossline soundings were compared to a surface that consisted only of mainscheme lines. The crossline analysis was conducted using CARIS HIPS “Line QC report” routine. Each crossline was selected and run through the process, which calculated the depth difference between each accepted crossline sounding and a “QC BASE” surface created from the mainscheme data. The QC BASE surface was created as a CUBE surface at 4 m resolution in the same manner as the final surfaces, but with the important distinction that the QC BASE surface excluded crosslines to not bias the QC report results. Differences in depth were grouped by beam number and statistics computed, which included the percentage of soundings with differences from the BASE surface falling within IHO Order 1. When at least 95% of the soundings exceed IHO Order 1, the crossline was considered to “pass,” but when less than 95% of the soundings compare within IHO Order1, the crossline was considered to “fail.” A 5% (or less) failure rate was considered acceptable since this approach compares soundings to a surface (instead of a surface to a surface), allowing for the possibility of noisy crossline soundings that adversely affect the QC results while not necessarily affecting the final surfaces. Results were placed into Excel spreadsheets, amended with applicable line names and surface resolutions, and exported to PDF reports. Results of crossline comparison and the reports are available with each project DR. Note that crosslines can be any line that transects mainscheme data. They were usually intentionally ran as crosslines and as a result have "XL" in their filename in the survey records. However, on some occasions a recon or a line originally intended as mainscheme was determined to be a good crossline due to significant numbers of crossings, and was selected in processing for crossline comparison purposes. These "crosslines" may not have "XL" in their filename, but all lines used as crosslines are itemized by name in each DR.

D.1.5.2 Junctions

Junction comparison was completed using difference surface methodology. Pydro's "Compare Grids" utility (v19.4r12570) was utilized to complete the comparison. For each Current survey, overlapping final surfaces for junctioning surveys (both Current and Prior) were selected and ran through the utility. For each intersecting grid cell, the utility computed the difference between the depth values and then determined if the difference fell within the allowable TVU for the depth, and presented the results in graphical format. Junction results are available with each DR.

D.1.5.3 Platform to Platform

Echosounder Depth Comparison (Multi-Vessel)

MBES data collected with the Sealegs was compared to MBES data collected with the Q105 using difference surface methodology in the same manner described above for Junction comparisons. These echosounder depth comparisons were completed regularly during the project, normally at least one per week. During these checks, overlapping data from each vessel that was collected as close in time as possible was selected and examined. This allowed for a direct comparison of results obtained by independent survey platforms for the same seafloor while minimizing the potentially confounding temporal factors of tide or bottom change.

In addition to differencing the results in the "Compare Grids" utility, the overlap was examined in CARIS Subset mode.

Results: The vessels compared well to each other. Each comparison resulted in a mean difference between the two vessels of 0.00 m (no difference) to 0.05 m (maximum difference), with the Q105 showing slightly deeper in most comparisons than the Sealegs.

Results were summarized in a "Echosounder Depth Comparison" logsheet, which is available in Appendix V, as well as with the Project DRs.

D.1.6 Other Validation Procedures

Traceability and Integrity Overview

The traceability and integrity of the echosounder data, position, and other supporting data was maintained as it was moved from the collection phase through processing. Consistency in file naming combined with the use of standardized data processing sequences and methods formed an integral part of this process.

CARIS HIPS and SIPS was used for bathymetric data processing tasks on this project. CARIS HIPS was designed to ensure that all edits, adjustments and computations performed with the data followed a specific order and were saved separately from the raw data to maintain the integrity of the original data. CARIS HIPS also maintains a running log of all processes that were run on each survey line.

Quality control checks were performed throughout the survey on all survey equipment and survey results. The following sections outline the quality control efforts used throughout this project in the context of the procedures used, from acquisition through processing and reporting.

D.1.7 Other Validation Procedures

File Handling

A file naming convention was established prior to survey commencement for all raw files created in acquisition. Files were named in a consistent manner with attributes that identified the originating vessel, survey sheet, and Julian day. The file naming convention assisted with data management and quality control in processing. Data was more easily filed in its correct location in the directory structure and more readily located later when needed. The file naming system was also designed to reduce the chance of duplicate file names in the project.

Files that were logged over Julian day rollovers were named (and filed) for the day in which logging began. This convention was adhered to even if most of the file was logged in the “new” day.

During data collection, the raw data files were logged to a local hard drive in a logical directory structure (based on file type and Julian day) on the acquisition PCs. On the Q105, after logging of each file was complete it was copied to a network share on the vessel server that was available to the processors. Data processors then moved the files to their permanent storage location on the server, where the data was backed up to a secondary server and processing began.

SeaLegs data was copied to an external hard drive and transferred to the Q105 vessel server at the end of each survey effort. Data was left on the primary SeaLegs computer for redundancy and no files were deleted as the acquisition PC onboard had ample space. Once on the Q105 servers, the data was treated similarly to Q105 data, wherein processors would move data to a permanent location on the server, back it up to a secondary server, and process the data.

At the end of the project following vessel demobilization, the vessel file server containing all project data was moved to TerraSond’s Palmer, Alaska office and integrated into the office IT system, where automated backups were configured, and processing and reporting continued.

D.1.8 Other Validation Procedures

Logsheets:

Logs were kept during survey operations by the survey crew during both acquisition and processing. On this project, logs were kept in Excel format with all times and dates in UTC.

A log entry was made for all important files and events that occurred during survey data acquisition operations, especially those with the potential to impact data quality. In addition to communicating metadata useful to data processing, acquisition logsheets tracked the existence of files to data processing personnel to help ensure files were not missed. Processing logsheets were used to track the progress of the various processes utilized during data processing and helped with hand offs between various processing personnel. Logsheets also serve as the survey records for archival purposes.

The logsheets kept during acquisition included:

MBES Acquisition Logsheet: This captured information pertaining to the online acquisition of MBES data, and included the file name, survey area, date, start and end times, vessel speed and heading, general sonar settings such as power and gain, and any comments on abnormal situations or observations such as the influence of adverse weather on data quality and equipment or software issues. Note that while only one entry was made in the logsheet for each survey line, a survey line may consist of multiple files or segments due to QPS QINSy's automatic splitting of files as they increased in size. The number of files associated with each line was noted in the logsheet as well. Separate sheets were kept for each vessel.

SVP Logsheet: Information captured included the filename of the cast, date, time, applicable survey area(s), geographic position, approximate depth of the profile, as well as comments (if any). In addition, the sound speed as measured by the MBES surface sensor at the time of the cast was noted and compared to the value obtained from the cast at the same depth, which served as reality check on both the surface sound speed sensor and SVP profiler sensor.

Event Log: Events of general importance were recorded in the Event Log. This included items such as weather conditions and crew change-outs (shift-changes), and events that document chronological gaps in the survey records such as launch and recovery of the Sealegs, weather downtime, tide gauge deployments, and transit to/from port for resupplies.

Hourly Logsheet: Survey status of vessels kept here with regards to Transit, Survey, or Down Time. Categories broken down further to help track hourly operations.

POS Acquisition Logsheet: This tracked the name of the POS file, start and end times, and any comments or observations. Separate sheets were kept for each vessel.

Vessel Draft Logsheet: This sheet recorded the static draft ("measure-down") value obtained by the survey crew along with its date, time, and any comments including the quality of the observation.

Depth Check Logsheet: This sheet recorded the results of any lead lines or bar checks. As described elsewhere in this report, these checks were completed on both the Q105 and Sealegs.

Logsheets kept during processing included:

MBES Processing Logsheet: For each survey line, this logsheet tracked the progress of processing in CARIS HIPS, including application of corrections and status of manual editing. Steps tracked included conversion, SVP correction, filtering, application of Delayed Heave and SBET, Compute GPSTide, TPU, and Merge. The status of two reviews in HIPS Swath Editor was also logged. Processing comments were kept for any abnormal situations encountered. The initials of the survey staff member completing the process or task was also kept.

POS Processing Logsheet: For each POS (POSMV) file, this logsheet tracked POSPac processing completed and any notes or observations. Times entered into logsheets were manually entered and may differ slightly from corresponding times within the digital files.

Shorthand letter identifiers for the various survey sheets were commonly used throughout the logsheets (as well as the associated raw and processed files). These were as follows:

Sheet 'A' = H13438
Sheet 'B' = H13439
Sheet 'C' = H13440
Sheet 'D' = H13441
Sheet 'E' = H13442
Sheet 'F' = H13443

Logs were exported to PDF format and included with the applicable DRs for reference.

D.1.9 Other Validation Procedures

Bar Checks

A bar check was used to determine and refine sonar Z offsets, and to check the relative accuracy of the echosounder and processing systems. This was completed on the Q105 on JD176 (6/24/20) during sea trials.

The ASV-CW5 did not receive a bar check due to the difficulty involved with this check on the unmanned vessel – MBES data was compared directly to Q105 data instead (see multi-vessel echosounder comparisons below).

To perform the bar check, a rectangular steel grate was hung by cable from the vessel’s gunwale directly above the MBES sonar on the vessel's port side. The cable was marked at an interval of 1.0 m from the bar, determined by measuring tape. A sound speed profile was collected, and static draft (gunwale to the waterline) was measured.

With QINSy logging and the sonar tuned to track the bar instead of the bottom, the bar was lowered in 1.0 m increments directly below the transducer while bar depth and time were noted in the depth check logsheet. Bar check depths ranged from 2.24 to 6.25 m and were limited by the ability to track the bar and the depth under the vessel while on anchor.

The bar depth was read relative to the gunwale, and later corrected to the waterline using the static draft measurement for comparison to the processed results.

Bar checks were processed in CARIS HIPS. The heave data record was removed, MBES data was sound speed corrected using the associated profile, and waterline measurement (static draft) applied. Depth of the bar relative to the waterline was extracted from HIPS in swath editor and compared to the actual bar depth at that time.

Processed bar depths (CARIS results) compared to actual bar depths to 0.045 m on average with a standard deviation of 0.012 m. The computed acoustic center Z value, which used the observed nadir value from the MBES corrected for known vessel offsets to the measure-down point, compared to 0.008 m on average with a standard deviation of 0.015 m.

Results were considered excellent given the variables of a bar check. The bar check processing logsheet in Appendix V of this report.

D.1.10 Other Validation Procedures

Lead Lines

A lead line check was completed on the Q105 to check for gross error in the absolute accuracy for the echosounder and processing systems. The check was done on JD261 while anchored near Dillingham, Alaska.

Note other lead line checks were attempted on multiple occasions during the project but were all compromised by the nearly constant high currents experienced in the area and therefore were rejected. None were successfully acquired on the Sealegs, and only one (JD261) was successful on the Q105.

The check was accomplished by lowering a measuring tape outfit with a 3 lb. weight to the seafloor from the static draft measure-down point and noting the value. The real-time (or raw) sonar depth at nadir was simultaneously noted. The two measurements were corrected to the water level using the established vessel offsets and the static draft measurement and compared.

The test returned a difference of 0.199 m, with the lead line reading deeper.

Results were considered acceptable as a gross error check given the variables inherent in a lead line check. The lead line logsheet is available in Appendix V of this report.

D.1.11 Other Validation Procedures

SVP Comparisons

An SVP comparison was used to check the accuracy and consistency of the sound velocity profiler data. In the test, data from the primary sound speed profiler was compared to two other independent sound speed profilers. All three profilers were lowered simultaneously to the seafloor, with the probes taped together so that the sensors were located as close as possible to each other. Results were then compared in Excel by graphical examination and computation of mean difference and standard deviation.

On this project, one formal confidence check was completed in this manner on JD157. The check was completed while on anchor near Dillingham, Alaska. The two project Valeport SWiFT sensors and the AML Minos-X sensor were used in the check. The check extended to a depth of about 8.5 meters.

All sensors compared to each other within 0.201 m/s on average, with a standard deviation of 0.205 m/s.

The SVP Comparisons were exported to PDF format and are available with the project DRs.

D.1.12 Other Validation Procedures

Vevssel Positioning Confidence Checks

As discussed elsewhere in this report, POSMV data was post-processed in Applanix POSPac MMS using Applanix SmartBase (ASB) methodology. As check on ASB positioning to ensure vessel positioning was consistent regardless of processing method used, and as an overall accuracy check of vessel positioning, vessel position confidence checks were accomplished by processing with an alternative POSPac processing method and comparing to the primary method. These checks were accomplished on a weekly basis.

To complete the check for each vessel, a random POS file was selected from each week and processed with both PP-RTX and ASB methodology. The two independent post-processed solutions were differenced in POSPac MMS’s “Navdif” utility. A difference plot was produced, which was recorded on a vessel positioning confidence form along with the comparison parameters and observations.

Results were good, with differences agreeing within horizontal and vertical positioning specifications, but usually to 0.2 m or better, demonstrating consistent results regardless of the processing method used.

The vessel positioning confidence checks were exported to PDF format and are available with the project DRs.

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 project were conducted under my direct supervision, with frequent personal checks of progress and adequacy. I have reviewed the attached survey data and reports. All field sheets, this report, and all accompanying records and data are approved. All records are forwarded for final review and processing to the Processing Branch.

The survey data meets or exceeds requirements as set forth in the 2020 NOS Hydrographic Surveys Specifications and Deliverables, Hydrographic Survey Project Instructions and Statement of Work. This data is adequate to supersede charted data in their common areas. This survey is complete and no additional work is required with the exception of deficiencies, if any, noted in the Descriptive Reports.

Approver Name	Approver Title	Date	Signature
Andrew Orthmann, C.H.	Charting Program Manager	01/08/2022	Andrew Orthmann Digitally signed by Andrew Orthmann Date: 2022.01.08 15:51:59 -09'00'

List of Appendices: