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Data Acquisition & Processing Report

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Project No. OPR-P384-KR-17

Time Frame July - September 2017

LOCALITY

State Alaska

General Locality Aleutian Islands

2017

CHIEF OF PARTY

Andrew Orthmann

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DATE

Data Acquisition and Processing Report

OPR-P384-KR-17

Pavlof Islands and Vicinity

December 22nd, 2017

Project Name:	***Pavlof Islands and Vicinity***
General Locality:	***Aleutian Islands, Alaska***
Sub Localities:	***H13034 – Pavlof Corridor*** ***H13035 – South of Coal Bay*** ***H13036 – Vicinity of Beaver Bay*** ***H13037 – West of Unga Island*** ***H13038 – Vicinity of Balboa Bay*** ***H13039 – Vicinity of Zachary Bay***
Vessel(s):	***R/V Qualifier 105 and ASV C-Worker 5***
Field Unit:	***TerraSond Limited***
Lead Hydrographer:	***Andrew Orthmann***

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A. *Equipment*

A.1. Echosounder Systems

To collect sounding data, this project utilized Reson Seabat 7101 Multibeam Echosounders (MBES). There were no side scan sonar requirements for this project.

A.1.1. Multibeam Echosounder

Reson SeaBat 7101 multibeam echosounder (MBES) systems were used on this project to collect sounding data.

The Reson SeaBat 7101 MBES utilizes Reson 7k Control Center software to serve as the user interface. The 7101 is an upgraded 8101 unit, with improvements that include the ability to form additional beams.

Power, gain, depth filters and other user-selectable settings were adjusted, as necessary, through Reson 7k Control Center to monitor and maintain data quality. The system was configured to output bathymetric data via Ethernet network connection to the acquisition software (QPS QINSy), which logged DB (database format) files, a proprietary QPS format. The software also simultaneously wrote XTF (extended Triton format) files which were utilized in processing. The system was also configured to output backscatter (multibeam "snippet") data, which was logged to both DB and XTF file formats.

MBES accuracy was checked by bar check and lead line methods on the Research Vessel *Qualifier 105* (*Q105)* on JD204, with excellent results. Processed multibeam data compared to the actual bar depth to 0.008 m on average, with a standard deviation of 0.025 m. The lead line check compared to the processed multibeam data within 0.007 m.

MBES accuracy was checked on the survey vessel *ASV C-Worker 5* (*ASV-CW5)* regularly by direct comparison to the same seafloor surveyed with the *Q105* MBES. Both vessels ran the same survey area close in time (typically during patch tests), and the results were gridded and differenced. Echosounder data from the separate vessels compared well, with average results falling in a range of -0.056 m (*ASV* shoaler) to 0.021 m (*Q105* shoaler).

Both Reson Seabat 7101 systems used wet-end firmware versions 8101.1.08.C215.

Refer to Section B of this report for discussion of echosounder accuracy test methodology, with results available in *Appendix II*.

Reson SeaBat 7101	
Sonar Operating Frequency	240 kHz
Along Track Transmit Beamwidth	1.6° ± 0.3º
Across Track Receive Beamwidth	1.5°
Max Ping Rate	40 pings / s
Pulse Length	21 µsec to 225 µsec
Number of Beams	101 - 511 (511 used this project)

Reson SeaBat 7101	
Max Swath Angle	150°
Depth Range	1 – 500 m
Depth Resolution	1.25 cm

Table 1 – Reson SeaBat 7101 MBES technical specifications.

A.2. Vessels

All hydrographic data for this survey was acquired using the vessels *R/V Qualifier 105* (*Q105)* and an Autonomous Surface Vessel (ASV), the *ASV C-Worker 5 (ASV-CW5)*. Both vessels were equipped to acquire MBES data, using nearly identical survey systems.

A.2.1. R/V Qualifier 105 (Q105)

The *Q105,* owned and operated by Support Vessels of Alaska (SVA), was chartered to serve as the primary vessel for this survey. The vessel was outfit with MBES and various IT systems and operated on a 24/7 schedule for data acquisition, processing, and personnel housing. The *Q105* was also used to maintain and operate the *ASV-CW5*, collect bottom samples, and tend the project tide gauges.

The *Q105* is 32 m in length with an aluminum hull, a 9.1 m beam, and a 1.8 m draft. The vessel is powered by three Detroit D-60 engines. AC electrical power was provided by a 103 KW generator.

Figure 1 – The Q105 during survey operations outside of Sand Point, 2017.

For this survey, the *Q105* was outfit with an Applanix POSMV 320 V5 to provide attitude and positioning, with an IMU mounted at estimated center of gravity (COG), and GPS antennas on the vessels crow's nest. A Reson Seabat 7101 MBES transducer was mounted on a hydraulic-actuator arm on the port side, just aft of the main cabin. An Oceanscience RapidCAST system was installed on the starboard-stern to collect sound speed profiles.

Calibrations and quality control checks were performed on all installed systems as described in Section B of this report. Vessel drawings showing the location of major survey equipment components are included in Section C of this report.

<table>
<tr><th colspan="4">Q105 Major Survey Systems</th></tr>
<tr><th>Description</th><th>Manufacturer</th><th>Model / Part</th><th>Serial Number(s)</th></tr>
<tr><td>Echosounder, Multibeam</td><td>Teledyne Reson</td><td>7101 Head</td><td>1301045 (through JD197)
1713050 (JD198 onwards)</td></tr>
<tr><td>MB Processor</td><td>Teledyne Reson</td><td>7k Center Topside</td><td>18290413019
(through JD197)
18290114042
(JD198 and then onwards)</td></tr>
<tr><td rowspan="2">Sound Speed, Surface</td><td rowspan="2">AML Oceanographic</td><td>Micro-X</td><td>10079</td></tr>
<tr><td>SV-Xchange</td><td>206203</td></tr>
<tr><td rowspan="4">Position, Motion, Heading</td><td rowspan="2">Applanix</td><td>POSMV 320 V5</td><td>5849</td></tr>
<tr><td>IMU-200</td><td>783 (through JD197)
778 (JD198 onwards)</td></tr>
<tr><td rowspan="2">Trimble</td><td>AT1675 Antenna (1)</td><td>12695180</td></tr>
<tr><td>AT1675 Antenna (2)</td><td>12421030</td></tr>
<tr><td>Sound Speed, Deployment System</td><td>Teledyne Oceanscience</td><td>RapidCAST</td><td>8000660D</td></tr>
<tr><td>Sound Speed, Deployment System (Backup)</td><td>Teledyne Oceanscience</td><td>RapidCAST</td><td>R092038</td></tr>
<tr><td>Sound Speed, Profiler</td><td>Valeport</td><td>Rapid SV 200Bar</td><td>49911</td></tr>
</table>

Table 2 – Major survey equipment used aboard the Q105.

A.2.2. ASV C-Worker 5 (ASV-CW5)

The vessel *ASV-CW5* (model number CW76), owned and operated by ASV Global, was used to acquire MBES data on this project. The vessel was deployed from the *Q105* and operated in an unmanned but monitored mode, running adjacent survey lines alongside the larger vessel.

The *ASV-CW5* is an aluminum, unmanned vessel manufactured by ASV Global. It is 5.5 m in length with a 1.7 m beam and 0.9 m draft. The vessel is propelled by a direct drive, fixed propeller, 1 x Yanmar 57 HP diesel engine.

Figure 2 – ASV-CW5 on this project.

For this survey, the *ASV-CW5* was outfit with an Applanix POSMV Wavemaster to provide attitude and positioning, with an IMU mounted at the approximate center of gravity (COG), and GNSS antennas mounted fore-aft on the deck. A Reson Seabat 7101 MBES transducer was haul-mounted mid-ship. Calibrations and quality control checks were performed on all installed systems as described in Section B of this report. Vessel drawings showing the location of major survey equipment components are included in Section C of this report.

***ASV-CW5* Major Survey Systems**			
Description	**Manufacturer**	**Model / Part**	**Serial Number(s)**
Echosounder, Multibeam	Teledyne Reson	7101 Head	276010 (through JD206) 1301045 (JD210 onwards)
MB Processor	Teledyne Reson	7k Center Topside	18293412004
Sound Speed, Surface	AML Oceanographic	Micro-X	10239 (through JD206) 10276 (JD210 onwards)
		SV-Xchange	206207 (through JD206) 203259 (JD210 onwards)
Position, Motion, Heading	Applanix	POSMV Wavemaster	7793
		IMU	3171
	Trimble	AT1675 Antenna (1)	9861
		AT1675 Antenna (2)	9857

Table 3 – Major survey equipment used aboard the ASV-CW5.

A.3. Speed of Sound

An Oceanscience RapidCAST system – equipped with a Valeport Rapid SV sensor – was utilized aboard the *Q105* for collection of sound speed profiles. Profiles or "casts" were collected as deep as possible while underway, targeting at least 80% of the surveyed water depth during each cast, and reaching 95% minimally once per day.

Figure 3 – Valeport Rapid SV sensor aboard the Q105. Deployment of the Oceanscience RapidCAST.

For most of the survey (JD195 and JD208 through JD226), sound speed casts were approximately every 2 hours. However, the interval used was 4 hours from JD196 until late on JD207. This interval was determined in the field by examining subsequent sound speed profiles for variance and deemed sufficient to correct for changes in sound speed, while also limiting the required volume of profiles. After the initial collection on a 2-hour interval, the switch to a 4-hour interval on JD196 was made due to a lack of variability noted between profiles. An interval of 2 hours was resumed on JD207 when it was determined that the 4-hour interval was not adequately accounting for water column sound speed variation in some areas.

Additionally, line lengths were limited (less than 20 km) before completing a line turn to keep the survey vessels in the same general geographic proximity as the casts. This led to a collection of normally 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 capture as much of the water column profile as possible.

Sound speed profiles were not collected by the *ASV-CW5*. Instead, profiles collected aboard the *Q105* were used to correct the ASV's data. This was possible because the ASV was operated in close range (normally within 3 km of the *Q105)* and profiles were obtained simultaneous with ASV operations.

A formal confidence check on the Valeport Rapid SV sound speed profiler was accomplished by comparing the results with a simultaneous deployment of a separate calibrated probe, a Valeport Rapid CTD. This check was accomplished on JD226. Comparison results (available in the Descriptive Reports (DRs), *Separate II*) were good, with the probes comparing to each other within 0.3-0.5 m/s in depths up to 19 m and 0.5-0.8 m/s in depths from 19-45 m. Sound velocity determined by the Rapid CTD (computed using the Chen-Millero equation) is consistently higher than the Rapid SV, but within an acceptable margin. A difference outlier of 1.1 m/s is present at 38 m due to a strong thermocline that caused rapid change in sound velocity over a 0.4 m depth range. The difference drops to 0.6 m/s immediately above and below the thermocline, indicating that the rapid change in sound velocity over a short depth range amplified the offset between the probe's sensors.

Refer to the CARIS HIPS SVP files submitted with the deliverables for positions, collection times, and processed profile data. Processed profile data has also been submitted to NCEI for archival and oceanographic research purposes. Raw SVP data is available with the raw data deliverables. Copies of the manufacturer's calibration reports are included in *Appendix IV* of this report.

The MBES heads on both vessels were equipped with AML Micro-X SV-XChange sensors to continually monitor sound speed at the head for automatic beam-forming purposes.

The instruments listed in the following table were used to collect sound speed data on this project.

A.3.1. Sound Speed Sensors

Project Sound Speed Sensors					
Vessel	**Sound Speed Device**	**Manufacturer**	**Serial Number(s)**	**Cal Date**	**Purpose**
Q105	Rapid SV	Valeport Limited	49911	5/23/2017	Primary sound speed profiler
	Rapid CTD		52756	5/24/2017	Backup & comparison only
	Micro-X with SV-XChange Sensor	AML Oceanographic	MicroX: 10079 SV-X: 206203	6/2/2017	MBES head
ASV-CW5			MicroX: 10239 SV-X: 206207	6/2/2017	MBES head (through JD206)
			MicroX: 10276 SV-X: 203259		MBES head (JD210 onwards)

Table 4 – Sound speed sensors used on this project.

A.3.2. Sound Speed Sensor Technical Specifications

AML Oceanographic Micro-X (SV-XChange)	
SV Range	1375 – 1625 m/s
SV Precision	+/- 0.006 m/s
SV Accuracy	+/- 0.025 m/s
SV Resolution	0.001 m/s

Table 5 – AML Oceanographic SV-XChange specifications.

Valeport Rapid SV (200Bar)	
SV Range	1375 – 1900 m/s
SV Accuracy	0.02 m/s
SV Resolution	0.001 m/s
Pressure Range	200 bar
Pressure Accuracy	0.05% of range
Pressure Resolution	0.001% of range

Table 6 – Valeport Rapid SV specifications.

Valeport Rapid CTD (200Bar)	
Conductivity Range	0 – 80 mS/cm
Conductivity Resolution:	0.001 mS/cm
Conductivity Accuracy:	0.01 mS/cm
Conductivity Response:	30 milliseconds
Pressure Range	200 Bar
Pressure Resolution	0.001% of range
Pressure Accuracy:	0.01% of range
Pressure Response:	1 millisecond

Table 7 – Valeport Rapid CTD specifications.

A.4. Positioning and Attitude Systems

Both survey vessels utilized Applanix POSMV systems as the source of vessel positioning, motion, and heading data.

The POSMV system consists of two dual-frequency GPS antennas and an inertial measurement unit (IMU) interfaced with a topside processor. For real-time GPS position corrections, the POSMV was configured to receive Wide Area Augmentation System

(WAAS) correctors. However, the real-time WAAS data was replaced in processing by application of post-processed kinematic (PPK) corrections to the dataset.

The POSMV also provided time synchronization for the acquisition systems. The unit output 1-PPS (pulse per second) and a ZDA data string to sync the Reson 7k Control Center software and QPS QINSy systems to UTC time, at a rate of 1 Hz.

Additionally, the POSMV was configured to continuously log raw data during survey operations. Data was logged over network to POS format (.000) files. These raw files enabled post-processing of the GPS and inertial data in Applanix POSPac MMS software in conjunction with simultaneously logged GPS data at a nearby GPS base station to produce higher quality PPK position, motion, and heading. POS files also enabled application of delayed heave (Applanix TrueHeave) to sounding data during processing.

A.4.1. Q105

The Applanix POSMV system used aboard the *Q105* was a POSMV 320 V5.

In addition to the configuration described previously, the *Q105* system was configured to output a GGA string to provide positions to TerraLOG software (general note keeping), and to the Valeport SV acquisition software. Additionally, the V5 was used to log POS data continuously to USB thumb drive as a backup to network-logged POS files.

During this project, the POSMV 320 V5 ran firmware version SW07.92-Apr08/14.

<table>
<tr><th colspan="3">POSMV 320 (V5)</th></tr>
<tr><td rowspan="2">DGPS Positioning</td><td>Positioning Accuracy</td><td>0.5 – 2 m</td></tr>
<tr><td>Roll, Pitch Accuracy</td><td>0.02 degrees</td></tr>
<tr><td rowspan="2">Kinematic Surveying</td><td>Positioning Accuracy</td><td>Horizontal: +/- (8 mm + 1 ppm x baseline length)
Vertical: +/- (15 mm + 1 ppm x baseline length)</td></tr>
<tr><td>Roll, Pitch Accuracy</td><td>0.01 degrees (1 sigma)</td></tr>
<tr><td colspan="2">Heave Accuracy</td><td>Real-time Heave: 5 cm or 5%
TrueHeave: 2 cm or 2%
(whichever is greater) for periods of 20 seconds or less</td></tr>
<tr><td colspan="2">Heading Accuracy</td><td>0.02 degrees (1 sigma, 2 m baseline)</td></tr>
<tr><td colspan="2">Velocity Accuracy</td><td>0.03 m/s horizontal</td></tr>
</table>

Table 8 – Applanix POSMV 320 technical specifications.

A.4.2. ASV-CW5

The Applanix POSMV system used aboard the *ASV-CW5* was a POSMV Wavemaster II.

During this project, the POSMV Wavemaster II ran firmware version SW09.03-Nov21/16.

POSMV Wavemaster II		
DGPS Positioning	Positioning Accuracy	0.5 – 2 m
	Roll, Pitch Accuracy	0.03 degrees
Kinematic Surveying	Positioning Accuracy	Horizontal: +/- (8 mm + 1 ppm x baseline length) Vertical: +/- (15 mm + 1 ppm x baseline length)
	Roll, Pitch Accuracy	0.02 degrees (1 sigma)
Heave Accuracy		Real-time Heave: 5 cm or 5% TrueHeave: 2 cm or 2% (whichever is greater) for periods of 20 seconds or less
Heading Accuracy		0.03 degrees (1 sigma, 2 m baseline)

Table 9 – Applanix Wavemaster II Technical Specifications

A.5. Dynamic Draft Corrections

Dynamic draft corrections for speed and engine RPM were determined using PPK GPS methods for both vessels using squat settlement tests. Corrections were determined for a range that covered normal survey speeds and engine RPMs.

On the *Q105,* a purpose-built TerraSond TerraTach system was utilized. The TerraTach system was designed in-house and utilized sensors on the port and starboard engine main drive shafts to directly count engine RPMs. Time-tagged values with a resolution of 1 RPM were computed at a rate of 1 Hz by TerraTach software, which received a GGA string from the POSMV for time synchronization. TerraTach also logged the data to file for later processing. Note that only two engines were monitored for RPMs by TerraTach; the third central engine was not monitored because it was deemed unnecessary since all three engines were normally operated at very similar RPM settings.

On the *ASV-CW5,* RPM data was continually logged whenever the system was operational. The data was recorded and time-tagged by the on-board control computer as part of general system diagnostics. The data was extracted from the system diagnostics following the project and processed to produce RPM-based dynamic draft correctors.

See Section B of this report for processing methodology and Section C for results.

A.6. GPS Base Stations

Two GPS base stations were installed to support the project. The stations were installed on a house in Sand Point—the closest community to the survey area—where electricity was available as well as a clear view of the sky.

Figure 4 – Project GPS base station at Sand Point. Zephyr GPS antennas are visible on the roof.

Trimble 5700 (T5700) GPS receivers with dual-frequency Trimble Zephyr Geodetic antennas were utilized. These were configured to log raw GPS data continuously to data card at a rate of 1 Hz.

Project Base Station 1: Sand Point T5700 0056					
Station ID	**Site**	**GPS Receiver**	**Antenna**	**Type**	**Position (NAD83)**
0056	Sand Point 1	Trimble 5700 SN# 220320056	Trimble Zephyr Geodetic (TRM41249) SN# 60001964	Logging (PPK) 1 Hz	55-21-05.58821 N 160-28-15.74357 W Height: 85.906 m
Project Base Station 2: Sand Point T5700 5240					
5240	Sand Point 2	Trimble 5700 SN# 0220275240	Trimble Zephyr Geodetic (TRM41249) SN# 12469585	Logging (PPK) 1 Hz	55-21-05.34463 N 160-28-15.89934 W Height: 85.256

Table 10 – GPS base station position and configuration.

Confidence checks on the stability of the GPS base stations as well as repeatability of the position solutions were accomplished by upload of 24-hour data series to NGS OPUS (Online Positioning User Service), which returned results comparing to 0.014 m vertically and 0.016 m horizontally (or better) of the original position. See Section B of this report for more information regarding base station position confidence checks, which are available in *Separate I* of the project DRs.

Trimble 5700		
Accuracy (Static)	Horizontal Positioning Accuracy	5mm + 1 ppm RMS
	Vertical Positioning Accuracy	5mm + 2 ppm RMS

Table 11 – Trimble 5700 technical specifications.

Note that data from the project GPS base stations were not used in post-processing other than for QC and comparison purposes. The Continuously Operating Reference Station (CORS) site AB07 in Sand Point was utilized instead. This was done because AB07 proved readily accessible and yielded excellent final positioning results in PPK processing, especially when used as part of an Applanix Smart Base (ASB) network.

Power issues at the site caused a break in base station data from approximately JD213 until JD219 on station 0056, and JD189 until JD219 on station 5240. Data was not adversely affected since the sites were used for QC and comparison purposes only; the CORS site AB07 covered the entire project period.

Refer to Section B of this report for further discussion on PPK processing methodology, and the accompanying Horizontal and Vertical Control Report (HVCR) for more detail on the CORS sites used.

A.7. Tide Gauges

A.7.1. NWLON Stations

The NWLON station at Sand Point (station number 9459450) was used for final tidal correctors for this project.

A.7.2. Subordinate Stations

Per the tides SOW, a subordinate zoning tide station was deployed in Zachary Bay. Tidal data from this station (station number 9459465) was utilized for zoning purposes only, and leveling was not required for this station.

The tide gauge was deployed as a BMPG (bottom-mounted pressure gauge) consisting of a mooring with a single Sea-Bird SBE 26plus Wave and Tide Recorder to log pressure data, a Sea-Bird SBE 37-SMP MicroCAT C-T (P) Recorder for conductivity and temperature measurements, and a Linquest UWM1000 acoustic underwater modem as a backup data recovery method.

Each Sea-Bird unit was synced to UTC and set to log at a 6-minute interval using a 180 second averaging period. The Sea-Bird was mounted in a specially fabricated mooring (with approximately 500 lbs. of weight) and gently lowered to the bottom at the deployment location by the survey vessel. For backup recovery methods, a non-floating (ground) line was deployed that stretched approximately 300’ from the BMPG mooring to an auxiliary mooring.

Following the deployment period, the Sea-Bird was pulled, and the logged data was downloaded.

All Sea-Bird equipment were factory calibrated prior to the start of the survey season.

Additionally, a custom GPS Tide Buoy *"Apple Jack"* was attached to the Sea-Bird BMPG's auxiliary anchor mooring line. This GPS buoy was fabricated by TerraSond and consisted of a sea kayak outfitted with a T5700 GPS receiver set to log kinematic GPS data, powered by two 12V batteries recharged via a 20w solar panel. The T5700 utilized a Trimble Zephyr antenna with a phase center elevated 0.824 m above the waterline. The GPS buoy remained deployed for the entire duration as the Sea-Bird deployment. GPS buoy data was post-processed in POSGNSS software and used for quality control and comparison purposes only.

Figure 5 – GPS Tide Buoy in Zachary Bay, moored to the BMPG's auxiliary anchor.

The BMPG tide equipment performed well with no major equipment-related issues or outages encountered. The GPS buoy experienced power outages due to insufficient solar input on the solar panel during long stretches of cloudy/foggy weather, but this had no effect on final tidal data because its data was used for quality control and comparison purposes only.

More information about the tide stations is available in the HVCR.

Sea-Bird SBE 26plus Wave & Tide Recorder	
Pressure Sensor Accuracy	0.01% of full scale
Pressure Resolution	0.2 mm for 1-minute integration
Repeatability	0.005% of full scale

Table 12 – Sea-Bird SBE 26plus specifications.

Sea-Bird SBE 37-SMP MicroCAT C-T (P) Recorder	
Conductivity Accuracy	0.0003 S/m (0.003 mS/cm)
Conductivity Resolution	0.00001 S/m (0.0001 mS/cm)
Conductivity Stability	0.0003 S/m (0.003 mS/cm) per month
Temperature Accuracy	0.002 °C (-5 to +35 °C); ± 0.01 (+35 to +45 °C)
Temperature Resolution	0.0001 °C
Temperature Stability	0.0002 °C per month

Table 13 – SBE 37-SMP C/T sensor specifications.

A.8. Software Used

Multiple software packages were used for acquisition and processing purposes on this project. All were executed on Intel-based quad-core PCs running Microsoft Windows 7.

A.8.1. Acquisition Software

Acquisition software was setup nearly identically on both survey vessels. The major software packages used on this project are summarized below.

- QPS QINSy hydrographic data acquisition software was used for navigation, and to log the bathymetric, positioning, and attitude data to DB (and XTF) format files.
- Reson 7k Control Center served as the interface with the Reson Seabat 7101 multibeam system, allowing the system to be tuned and operated.
- Trimble Configuration Toolbox was used, as necessary, to configure common options in the T5700 receivers
- Sea-Bird Seasoft was used to configure the Sea-Bird tide gauges prior to deployment, and to download and convert the data after retrieval.
- POSMV POSView was used as the interface with the POSMV. The software was used to log raw POS data as well as configure and monitor the POSMV system.
- TerraLog, an in-house software package, was used to keep digital logsheets for all echosounder, POSMV, and sound speed files.
- TerraTach, an in-house software package, was used to configure, monitor, and log data from the custom-designed RPM logging system used on the *Q105.*
- Oceanscience RapidCAST Interface software was used in conjunction with Valeport RapidSVLog software to control the RapidCAST deployment system and configure/download profiles from the Valeport sound speed sensor.

- VNC Server (on the *ASV-CW5*) and VNC Viewer (on the *Q105*) software was used to remotely view and interface with the *ASV-CW5* acquisition computers from the *Q105* over a wireless network link between the vessels.
- ASView was proprietary software developed by ASV Global to monitor and control the autonomous *ASV-CW5* vessel. Unlike all other software packages utilized on the project, ASView ran on a Linux-based computer.

Software Name	Version	Year	Primary Function
QPS QINSy	8.16.1 (Build 2017.05.03.1)	2017	Acquire MBES data and provide vessel navigation
Reson 7k Control Center	4.5.10.7	2012	Interface with Reson 7101 MBES
Reson Seabat 7k	4.5.10.9	n/a	Reson 7101 MBES communications
Oceanscience RapidCAST Interface	1.5.1	2016	Interface with RapidCAST system
Valeport RapidSVLog	0400/7158/B1 27/03/2013	2013	Interface with Valeport RapidSV probe
Trimble Configuration Toolbox	6.9.0.2	2010	Interface with Trimble 5700 receiver
Sea-Bird Seasoft	2.0	2011	Interface with Sea-Bird SBE26 Plus tide gauges
Applanix POSView	7.92	2014	Interface with POSMV 320 V5 (*Q105*)
	9.03	2016	Interface with POSMV Wavemaster (*ASV-CW5*)
TerraLog	1.2.0.1	2014	Record keeping
TerraTach II	3.1.1	2016	Interface with TerraTach sensors (*Q105*)
ASView	n/a	2017	Interface with ASV

Table 14 – Software used for data acquisition.

A.8.2. Processing and Reporting Software

A summary of the primary software used to complete planning, processing, and reporting tasks follows:

- CARIS HIPS and SIPS was used as the primary MBES processing system. CARIS HIPS was used to apply all necessary corrections to soundings including corrections for motion, sound speed and tide. CARIS HIPS was used to clean and review all soundings and to generate the final BASE surfaces and generate S-57 deliverables.
- ESRI ArcGIS was used for line planning pre-plots during survey operations to assist with tracking of work completed, generation of progress sketches, and during reporting for chartlet creation and other documentation.

- Applanix POSPac MMS was used for post-processed kinematic (PPK) processing of POSMV data.
- TerraLog, an in-house multi-purpose software package, was used to process sound speed profiles and keep track of processing work completed on lines, drafts, depth checks, PPK files, and others.
- Agisoft Photoscan Professional was used to process aerial imagery for shoreline verification.

Program Name	Version	Date	Primary Function
CARIS HIPS and SIPS	10.3.3	2017	Process multibeam data and compile S-57 deliverables (field processing in 10.3.2)
ESRI ArcGIS ArcMap	10.2.1	2013	Produce chartlets for reports and track survey progress
Applanix POSPac MMS	8.1	2017	Post-processing of POSMV data (initial processing completed in V7.2)
Microsoft Office	365	2017	Logsheets, reports, and various processing tasks
TerraLog	2014	2014	Keeping notes, reporting, process SVP casts, produce PDF logsheets
Ultimate Underway Converter	2016	2016	Auto-convert Valeport Rapid SV files to MVP format prior to processing
Microsoft Infopath	2013	2013	Populate DR XML schemas
Altova XMLSpy	rel4 sp1	2015	Edit DR XMLs
Agisoft Photoscan Professional	1.3.4.5067	2017	SfM processing of aerial imagery. 1.3.2.4205 was used for preliminary, field processing
HydrOffice QC Tools	2.1	2017	Conformance checks on deliverables

Table 6 – Software used for processing and reporting.

A.9. Bottom Samples

A Van Veen grab sampler was used to collect bottom samples.

At locations assigned by NOAA via the Project Reference File (PRF), the grab sampler was dropped to the bottom from the survey vessel to collect a sample. Once aboard, the sample was examined and its S-57 (SBDARE object) attributes noted along with time and position in a logsheet. Samples were not retained, but a photo of each was taken. Description, attributes, and photos are available with the S-57 deliverables.

Refer to Section B for more information on bottom sampling methodology.

A.10. Shoreline Verification

Limited shoreline verification was assigned for this project. To investigate assigned features, UAS (unmanned aerial system) units (or drones) were deployed, acquiring low-altitude, high-resolution photogrammetry data over the assigned feature locations. DJI Phantom 4 Professional (P4P) units were utilized for this purpose.

The P4P is a small UAS introduced in 2017 weighing approximately 1.39 kg (3 lbs) with a diagonal size of 0.35 m (13.8 inches). The UAS is outfit with a gimbal-stabilized 1” CMOS camera with an effective pixel count of 20 megapixels.

Processed imagery data was checked against assigned features to ensure coverage and data quality. Ortho-photomosaics were overlaid with assigned features in CARIS HIPS to check for coverage and quality. Point-clouds were generated to obtain heights on exposed features. Questionable or incomplete imagery data was re-acquired. Ground-truthing was done with periodic checks against the survey vessel positions and features visable in both the multibeam and ortho-photomosaics, with positions agreeing to within 5 meters.

Refer to Section B of this report for additional discussion on UAS data acquisition and processing methodology.

DJI Phantom 4 Professional (P4P) Specifications			
Aircraft		**Camera**	
Weight	1388 g (3 lbs)	Sensor	1” CMOS, 20 MP
Diagonal Size (minus props)	350 mm (13.8”)	Lens	FOV 84° 8.8 mm/24 mm (35 mm format equivalent) f/2.8 - f/11 auto focus at 1 m - ∞
Max Speeds	6 m/s ascent, 4 m/s descent, 39 knots horizontal	ISO Range	Photo: 100 - 3200 (Auto) 100- 12800 (Manual)
Max Ceiling (MSL)	6000 m	Shutter Speed	8 - 1/2000 s (Mechanical) 8 - 1/8000 s (Electronic)
Max Wind Resistance	19.4 knots	Image Size	3:2 Aspect Ratio: 5472 × 3648 4:3 Aspect Ratio: 4864 × 3648 16:9 Aspect Ratio: 5472 × 3078
Satellite Positioning System	GPS with GLONASS	Formats	JPEG, DNG (RAW), JPEG + DNG

Table 16 – P4P specifications

B. *Quality Control*

B.1. 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.

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.

B.2. Data Collection

B.2.1. General Acquisition Systems Configuration

Q105 and *ASV-CW5* acquisition systems were configured nearly identically. Both vessels utilized Intel-based Windows 7 PCs for acquiring data. On the *Q105*, two PCs were used: One PC devoted to notetaking, logging RPM data, monitoring deck cameras, and acquiring POSMV data running Applanix POSView, with the other PC to acquire multibeam data using QPS QINSy and Reson 7k Control Center software. On the more space-limited *ASV-CW5*, one PC was used for data acquisition.

B.2.2. ASV-CW5 Operations

Operations on the unmanned *ASV-CW5* vessel were semi-autonomous, whereby the vessel would be directed to follow pre-defined survey lines without human intervention. However, the vessel was still monitored constantly, with two technicians dedicated to it at all times: One technician was responsible for monitoring and directing the vessel's operations, the other for monitoring and controlling the survey systems.

Obstacle avoidance, including avoidance of other vessels, depended on constant monitoring and frequent intervention by the remote vessel operator. Tools for this purpose included a streaming camera view from ASV, on-board radar, and an AIS system. The MBES system was relied upon for water depth under the vessel. In addition, the bridge crew on the *Q105* would monitor the area in front of the ASV for potential interactions, informing the ASV crew and communicating with other vessels as necessary.

The *ASV-CW5* worked in a normal range of 3 km or less of the Q105. This facilitated visual monitoring and radio link strength for streaming of vessel and survey system data. The proximity also made it possible to perform all sound speed profile casts from the *Q105,* that the *ASV-CW5* was not configured to collect.

Figure 6 – ASV-CW5 working near the Q105 in Balboa Bay.

Since the survey PC aboard the *ASV-CW5* was not directly accessible, their displays were continuously streamed via wireless network to the *Q105* via a remote desktop connection. This allowed the survey technician to monitor and control the systems in a manner similar to the conventional setup aboard the *Q105*. Raw files (XTF, DB, and POSMV) were logged locally on the ASV survey computer, which made data logging immune to radio dropouts.

Transfer of a survey line's associated raw data files (XTF, DB) from the *ASV-CW5* to the *Q105* commenced soon after the collection of each line was completed. Radio bandwidth was sufficient to transfer data as fast (or faster) than new data was being acquired. This made it possible to process data soon after acquisition without the need to wait to physically download it later, allowing potential data quality issues to be caught and addressed quickly. Occasionally, in shallow water with high MBES ping rates, the rate of data transfer could fall behind the rate of data acquisition, creating a backlog of un-transferred raw data aboard the ASV. When occurred, the survey crew prioritized transfer of file types to only those necessary for immediate processing (XTF), and queue DB and POSMV files for later transfer--either by radio, or by USB hard drive when the ASV was physically accessible.

Although the ASV-CW5 could autonomously follow pre-defined (and relatively straight) survey lines, the current generation of the technology used on this project did not have the capability to autonomously navigate based on water depth. Therefore, in nearshore shallow/complex areas where straight survey lines were not possible, constant intervention by the remote operator was necessary, with the ASV effectively operating as a remote-controlled vessel. In the data records, straight tracklines (offshore, generally deeper water) were collected in autonomous mode, while sinuous and/or nearshore tracklines were collected in remote-controlled mode.

Figure 7 – Q105 data acquisition station, with direct interfaces to survey hardware.

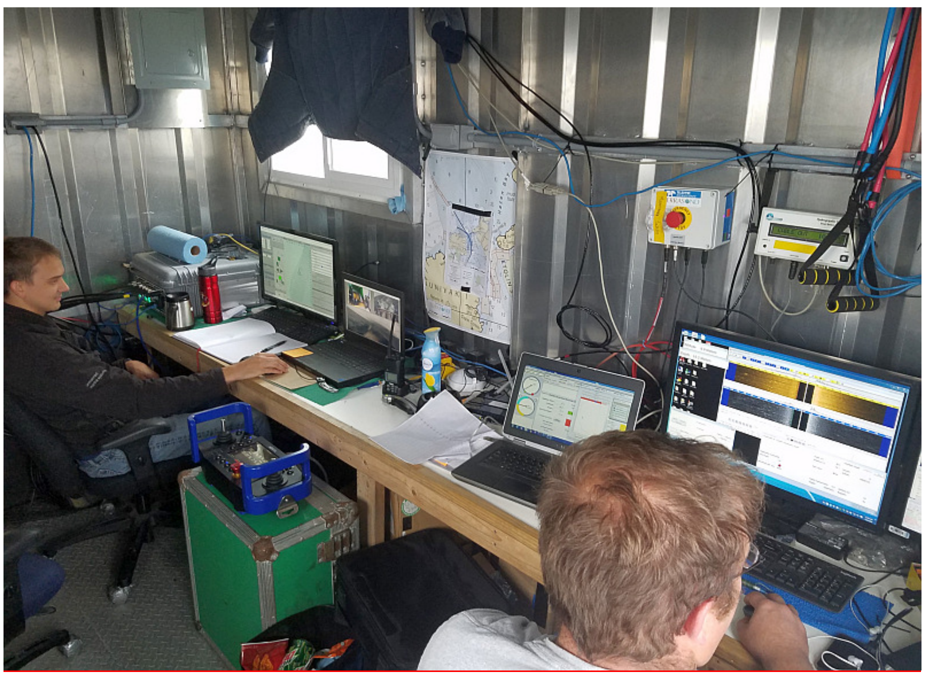


Figure 8 – Station aboard the Q105 for remotely controlling and monitoring the ASV-CW5. Displays are transmitted wirelessly from the unmanned vessel.

B.2.3. QPS QINSy Navigation and MBES Collection

QPS QINSy data acquisition software was used to log all bathymetric data and to provide general navigation for survey line tracking. 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.

B.2.4. Data Coverage and Density

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

This project spans multiple coverage types. Coverage types required were “Complete Coverage Multibeam” (Section 5.2.2.3 in the HSSD), and “Set Line Spacing” (section 5.2.2.4, option “A” in the HSSD). Per the work instructions, line spacing for set-line spacing areas was 100 m. MBES backscatter collection was required during all MBES data acquisition.

A line plan designed to meet these requirements was developed prior to commencement of operations. During operations, the line plan was modified on the fly as necessary.

Complete coverage areas were surveyed by executing the line plan, with adjustments to line spacing based on 2.5x to 3x the shoalest depth observed on the line. Or, when there were drastic changes in water depth along lines, line running was abandoned in favor of coverage running, whereby the survey vessels would follow near the edge of the real-time coverage plot plotted in the acquisition software, “painting” the seafloor. In both cases, line spacing favored substantial overlap (normally at least 50%) to achieve complete coverage with considerable extra data to allow for rejection of erroneous outer beams, when necessary.

For set-line spacing areas, a line plan with 100 m spaced lines was used. 100 m spaced lines with little across-track variation was possible in offshore areas. As the survey vessel approached the rugged shoreline areas with many underwater rocks, straight lines were not feasible. In these rocky nearshore areas, the survey vessel no longer utilized the line plan and ran sinuous routes, adjusted on the fly holding an estimated 100 m distance to nadir on adjacent lines. In attempts not to strike rocks, this mode of operation required constant steering adjustments due to the common sudden variations in water depth. The difficulty with navigating sinuous lines in this complex nearshore region caused line separation to exceed 100 m in many cases.

Note that throughout the project, many areas assigned to set-spaced 100 m lines received complete coverage. This commonly occurred in depths of 30 to 40 m and deeper, where outer beams of 100 m spaced lines would overlap. In these cases--depending on depth and coverage quality--either the 100 m plan was continued, or where overlap was extremely generous, the 100 m set-spaced line plan was abandoned in favor of collecting to complete coverage standards. Since complete coverage is considered a higher standard of coverage than set-spacing, complete coverage collection in set-spaced areas was approved in advance by the project COR (see correspondence included with the DRs).

Coverage was monitored relative to the assigned survey area boundaries in real-time in the QPS QINSy acquisition software. When running lines, each vessel navigated the line as closely as possible while surveying, with the *Q105* able to maintain average off-track errors of 5 m or less, and the *ASV-CW5* 1 m or less. When running the edge of coverage, each vessel would navigate on the edge of the coverage plotted in QPS QINSy, ensuring substantial overlap with the previous line. Care was taken during run-ins and run-outs to collect data at least to the survey boundaries.

Data density requirements were met by utilizing adequate ping rates to address along-track density, generating maximum beams to improve across-track density, and providing substantial overlap between adjacent lines in full coverage areas. Ping rate was capped at a relatively high rate (10/second where the range scale allowed) while vessel speeds were moderated (less than 8 knots, but usually 6 to 6.5 knots, and 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 7101 sonar, which generated 511 beams spaced equidistant across the swath for every ping, which was the maximum capability of the 7101 MBES system. This combination of ping rate and beam mode caused the system to generate up to 5,110 soundings per second and—at the speeds used—meet density specifications for the resolutions required. Substantial overlap between adjacent lines improved data density, especially in cases where erroneous data required rejection.

Coverage and density was 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.

B.2.5. Q105 MBES Cable Issue

On the *Q105*, abnormal noise was observed in the MBES data immediately at the start of the project on JD195. Good bottom detection was intermixed with intermittent loss of bottom detection and elevated levels of erroneous, noisy soundings. Troubleshooting revealed the cause to be a frayed MBES sonar cable at the MBES actuator arm. The cable was replaced with a spare on JD196 at approximately 03:00. This affected approximately 24 hours of sounding data during survey H13035.

The data collected in the area surveyed with the cable problem was closely examined and it was deemed unnecessary to re-run the affected survey lines. This was largely due to tight line spacing resulting in generous overlap from the MBES system on the *ASV-CW5* vessel, which was unaffected.

B.2.6. Q105 MBES Actuator Arm Issue

On JD211, the Q105 MBES actuator arm experienced a hydraulic failure. At approximately 22:00, an alarm indicated a sudden loss of pressure of the arm's hydraulic system. Repairing the hydraulic system required detaching the entire MBES arm assembly from the vessel and reinstalling it following repair. Since this had the potential to change the MBES to POSMV alignment, an additional patch test was completed to establish new calibration values (see Section C for results).

Despite the failure, data quality was not adversely affected because the vessel was not surveying at the time of the failure and the issue was fully addressed before collecting additional MBES data.

B.2.7. 7101 Errant Pings

Errant or bad pings are evident periodically in the multibeam swath data. This occurred regularly on both vessel 7101 systems. The issue manifests as a single ping, or swath, that is skewed (or rolled) from the seafloor at an angle. The cause is unknown, and does not correlate to any spikes in attitude data. These were normally rejected manually during swath edit review, resulting in small along-track gaps as viewed in swath editor plan view. However, since only single pings were affected, and ping rates were high (10 pings/second if range scale allowed) there was no significant detrimental effect on data density. During surface review in CARIS subset editor, remaining errant pings were rejected if they adversely affected the surface. Un-rejected errant pings in the dataset may remain, but do not have significant detrimental effect on final surface quality.

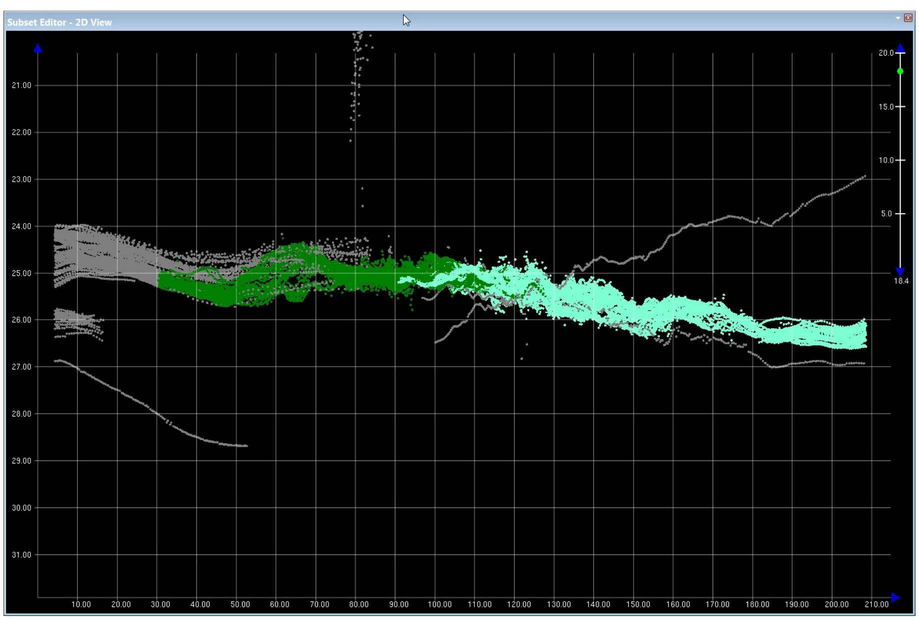


Figure 9 – Errant pings, skewed single swaths (rejected, in grey) shown in CARIS subset mode

B.2.8. ASV-CW5 MBES Lost Sonar & Rotated Head

On JD206, at approximately 19:25, the ASV-CW5 struck a rock while working on developing the 8 m curve in an uncharted area on the west side of Coal Bay (H13035). Although there was no apparent damage to the vessel itself, the transducer mount took most of the hit. This caused it to separate from the vessel, taking with it the 7101 MBES sonar head and accompanying AML MicroX sensor. Unfortunately, the separation did not occur immediately in the shallow water near the rock; instead, the ASV had navigated a short distance out into relatively deep water (~27 m) before the equipment separated. Although a brief search of the estimated drop location was conducted using the *Q105*'s MBES sonar system, nothing obvious was observed and no further efforts were made to find or recover the units.

The incident had no effect on data quality since no data was collected with the damaged / lost unit. However, no data was acquired aboard the ASV from JD208 – JD209 while a new mount was being sourced.

A new mount and the project's spare 7101 MBES head with MicroX probe were installed on the ASV at approximately 01:10 on JD210 and ASV operations recommenced shortly after.

To reduce the likelihood of a repeat incident in the rocky seafloor prevalent on this project, the ASV's sonar head was rotated 30 degrees to starboard (starboard-up) on JD211 at approximately 00:50. The sonar was left in the rotated configuration for the remainder of the project.

The rotated configuration facilitated near-shore operations and development of rocks and the 8 m curve by providing more coverage on the starboard side in shallow water. However, the additional coverage came at the expense of reduced coverage on the port side resulting in semi-unidirectional survey direction (best with starboard-side towards shore) in shallow areas, and increased susceptibility to sound speed refraction. Coverage concerns were addressed by tightening line spacing. Sound speed refraction was addressed by applying additional filters on outer beams in areas where excessive refraction was observed, combined with manually editing/rejection of erroneous data during subset review.

B.2.9. MBES Backscatter

MBES backscatter was collected continuously during MBES operations, but not processed. Presence of backscatter records in the raw MBES files was confirmed by periodic random checks through the Geocoder process in CARIS HIPS Mosaic Editor.

Although the project instructions exempted this project from the HSSD requirement that backscatter be in a format readable by IVS Fledermaus Geocoder Toolbox, a query placed with QPS during the project returned a response from their support that the DB files should indeed be compatible with IVS Fledermaus Geocoder Toolbox, though processing of the DB files to extract backscatter may require replay to generate QPS "result" files.

If backscatter data is processed in the future, it is important to note that the backscatter format was changed starting on JD202, on both vessels: DB and XTF files logged from the start of the project up through JD201 contain "new" style (7027) Reson-records, with "old" style (7004/7006) Reson-records from JD202 onwards. The reasoning for the transition of record types is discussed in more detail in the processing section of this report.

B.2.10. Draft Measurements

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 undertaken whenever a situation was experienced with the potential to significantly change the draft, such as after fueling or adjustments in ballast.

On the *Q105*, with the vessel at rest, a calibrated "measure-down" pole was used to measure the distance from a measure-down point on the vessel gunwale to the waterline. The measurement was taken on both sides of the vessel, and then averaged to calculate the value at the vessel center reference point (CRP), which was near the vessel keel. The relationship between the measure-down point and CRP had been previously determined by vessel survey, allowing computation of the CRP to waterline offset for application in processing.

On the *ASV-CW5*, draft measurements were made by visual observation of the intersection of the waterline and draft marks on the starboard side of the hull when the vessel was near the *Q105*. The draft marks represented the measured vertical distance from the deck near the CRP. The relationship between the deck and vessel CRP had been previously determined by vessel survey, allowing computation of the CRP to waterline offset for application in processing. Note that only one measurement is applied in processing to the *ASV-CW5* data. This is because no perceptible change in the draft mark – waterline intersection was observed during operations.

Draft values were logged with the time of acquisition and checked to ensure they fell within the normal range for the survey vessel. Questionable values were discarded. Values with high-confidence were entered into the CARIS HIPS Vessel Files (HVF) by processing (included with the survey deliverables) and then applied to all soundings. Static draft logsheets are available with the survey deliverables.

B.2.11. Sound Speed Measurements

Casts were taken from the *Q105* using an Oceanscience RapidCAST system, which utilized a Valeport Rapid SV sensor.

Note the *ASV-CW5* was not equipped to acquire SV profiles – all *ASV-CW5* MBES data was corrected using the profiles acquired aboard the *Q105*. This was possible because the unmanned vessel always worked near the *Q105* (usually within 1 km, but almost always within 3 km).

When deployed, the sensor free-falls through the water column at a rate of about 2-3 m/s. The fall is arrested when the brake is automatically applied by the winch software. The sensor is then winched back aboard the vessel, and the stored profile data downloaded wirelessly by Valeport Rapid SV software.

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.

Downloaded sound speed profiles were automatically assigned position and UTC timestamps by the Valeport RapidSVLog software, which was interfaced with a GGA position/time string from the POSMV. These fields were then carried through to the CARIS SVP files during processing in TerraSond's TerraLog software. Automatic time and position stamps helped reduce the possibility of assigning incorrect time or positions to profiles. Occasionally a sound speed cast would not receive a position stamp – when this was observed, a position was manually entered into the file by acquisition personnel based on an estimate of where the cast occurred.

Note that TerraLog did not natively support the Valeport RapidSV format; therefore, an in-house software program (Ultimate UnderwaySV Converter, or UUC) was developed and utilized to convert the UnderwaySV files to a TerraLog supported format ("MVP"), which maintained the original position and timestamps. UUC also converted the depth data, stored as pressure in decibars in the original UnderwaySV file, to depth in meters (using empirical formulas from UNESCO Technical Papers in Marine Science No. 44) and filtered out measurements of depths less than 0.5 m, sound speed values less than 1400 m/s, and sound speed values greater than 1520 m/s. Both formats, original and "MVP," are included with the raw survey data deliverables.

For most of the survey (JD195 and JD208 through JD226), sound speed casts were approximately every 2 hours. However, the interval used was 4 hours from JD196 until late on JD207. This interval was determined in the field by examining subsequent sound speed profiles for variance and deemed sufficient to correct for changes in sound speed while also limiting the required volume of profiles. After the initial collection on a 2-hour interval, the switch to a 4-hour interval on JD196 was made due to a lack of variability noted between profiles, but was returned to 2 hours on JD207 when it was determined that the 4-hour interval was not adequately accounting for water column sound speed variation in some areas.

Additionally, line lengths were limited (generally 20 km or less) before completing a line turn to keep the survey vessels in the same general geographic proximity as the casts. 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.

Sound speed profiles were applied in CARIS HIPS using the methodology by nearest in distance, with a time interval that generally matched the acquisition interval. Exceptions were rare and are described in the applicable DR.

To check data quality, profile results from independent sound speed sensors logged simultaneously were compared to each other. The comparison methodology is described in more detail in Section B.5. Comparison results are available in the DRs, *Separate II*.

B.2.12. Logsheets

TerraLog, an in-house software package, was utilized during survey operations for log keeping during both acquisition and processing phases.

TerraLog was designed to replace Excel-based logsheets for common log keeping tasks. Its primary purpose is to simplify acquisition and processing logsheet entries, provide a more seamless and consistent flow of user-entered log data from acquisition to processing, and output standardized logsheets in PDF format. Since TerraLog automatically records time- and position-tag (with GGA input) events, it largely eliminates errors associated with manually entered time and position. On this survey (on the Q105 only), *TerraLog* was configured to receive a GGA data string from the POSMV, enabling the software to position-tag events.

On-board the vessel, events pertinent to surveying, including start/stop of lines, start/stop of POS files, surveyors' initials, weather conditions, draft and sound speed casts, were entered into TerraLog, which recorded events to a SQL database file. It should be noted that although TerraLog time-tagged events like start of line and end of line, it had no automatic synchronization capabilities with the acquisition software. Time-tagged events relied on operator entry and a small-time difference (usually on the order of seconds), is common between the TerraLog entry and the actual data file start and end. However, log keeping, the time difference was deemed to be of no consequence. Additionally, the acquisition software (QINSy) would automatically split files when they became too large resulting in two files for the same line – though only one line entry appears in TerraLog.

The following common events, with their time and position when applicable, were recorded by the survey crew:

- Generic line information including line name
- Sonar settings, RPM data, vessel speeds
- Generic POS file information including approximate start and stop times
- DGPS base station in use and status
- Static draft measurements
- Sound speed cast events
- Sea and wind state, especially when adversely affecting operations
- Comments on any unusual observations or problems

On-board the *Q105*, the SQL database was simultaneously accessible by acquisition and processing personnel. Following acquisition of a line, data processing personnel would examine acquisition's comments and take the raw data through the processing workflow, tracking edits and corrections in TerraLog in context of the readily accessible acquisition-recorded information.

Task completion and details of common processing tasks tracked in TerraLog included:

- Common CARIS HIPS processes including conversion, SVP correction, tide correction, SBET and TrueHeave application, TPU computation, merge, cleaning, and general processing comments
- POS file processing including base station selection and processing methods
- SVP file processing

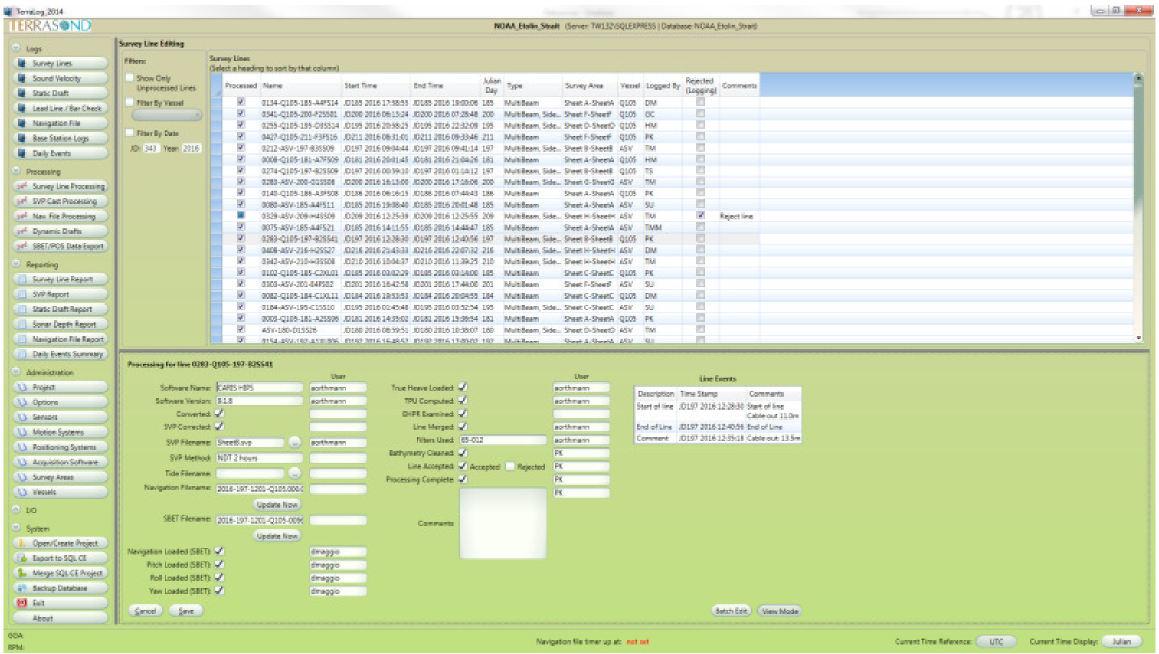


Figure 10 – TerraLog interface for line processing.

Following processing and application of final corrections, logsheets were exported from TerraLog to PDF. Logsheets include logs for lines, draft measurements, sound speed profiles, depth checks, navigation file processing, and daily events. The PDFs are available in the DRs, *Separate I: Acquisition & Processing Logs*.

B.2.13. Base Station Deployment

As described in Section A of this report, two GPS base stations were established on the roof of a private residence in the community of Sand Point, which is near the project area. The base station data was not used for data processing because excellent positioning results were obtained using the CORS site AB07 in an Applanix Smart Base configuration (detailed below in this report).

The base stations' location was chosen for its clear view of the sky and availability of power. Trimble Zephyr Geodetic antennas were firmly mounted on all-thread at a height sufficient to clear the roof structure. The units were set to log dual-frequency GPS data (Trimble T01 format) at a rate of 1 Hz to a Compact Flash (CF) card, which was swapped periodically during operations. Data was checked for continuity, with breaks in continuity noted in base station data from approximately JD213 until JD219 on station 0056, and JD189 until JD219 on station 5240 due to power loss issues at the residence.

Confidence checks on the stability of the GPS base stations as well as repeatability of the position solutions were accomplished by upload of 24-hour data series to NGS OPUS (Online Positioning User Service), which returned results comparing to 0.014 m vertically and 0.016 m horizontally (or better) of the original position. Base station confidence checks are available in *Separate I* of the project DRs.

Although not used to correct final data, the base data was used to perform vessel positioning confidence checks, described in Section B.5.

B.2.14. Bottom Samples

Locations for bottom samples were assigned by NOAA via the S-57 format Project Reference File (PRF). Assigned locations were assigned a name for reference, and imported and displayed on the *Q105* ship chart plotter.

To collect the samples, the *Q105* 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 then 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.

Figure 11 – Bottom sample collection with Van Veen sampler on back deck of the Q105.

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, 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 all but one assigned location, which is noted in the applicable DR and encoded with a "NATSUR" as "Unknown".

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 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, version 2.1.

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

Figure 12 -- Example bottom sample from this survey – 1st constituent broken brown shells, 2nd medium black sand, 3rd fine brown pebbles.

Bottom sample results are available in the S-57 FFF submitted with the survey deliverables. Sample photos are included in the FFF "multimedia" directory. Bottom samples were encoded at the actual position of acquisition, which may differ slightly from the assigned locations.

B.2.15. File Naming and Initial 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.

The following table lists raw data files commonly created in acquisition and transferred to data processing.

Raw File Naming Conventions		
Type	**Description**	**Example / Format**
DB, XTF	MBES Mainscheme and Crossline Data from QPS QINSy	**1165-ASV-224-A4MS01600 (.DB, .XTF)** [Index]-[Vessel]-[JD]-[Area][Type][Line#]_ -_[FileSequence#]. Area denotes sheet and block, type includes MS as mainscheme, and XL as a crossline
	MBES Patch Test or Depth Check from QPS QINSy	**0764-Q105-225-Yaw (.DB, .XTF)** [Index]-[Vessel]-[JD]-[Purpose]_-_[FileSequence#], where purpose is calibration type such as “yaw”
SVP	Text File from Valeport SV	**2017-07-16-14-13-24 (.TXT)** [Year]-[Month]-[Day]-[Hour]-[Minute]-[Second]
	UUC-Converted Version of Valeport SV file	**2017-07-16-14-13-24_MVPFormat (.RAW)** [Year]-[Month]-[Day]-[Hour]-[Minute]-[Second]_
Tide - Pressure	Raw File from Sea-Bird Tide Gauge	**2015_178-207_SN1131_Zoning1-SE (.HEX)** [Year]_[StartJD]-[EndJD]_[SN]_[Name]
T01	Trimble 5700 Binary File (navigation / base)	**00562340 (.T01)** [ReceiverSN][StartJD][FileSequence#]
POS	Raw Positioning Data (.000 file) from POSMV POSView	**2016-183-1245-Q105 (.000)** [Year]-[JD]-[Start time HHMM]-[Vessel]
RPM	Q105 engine RPM data (.RPM) written by TerraTach software	**2016-183-1245-Q105 (.RPM)** [Year]-[JD]-[Start time HHMM]-[Vessel]

Table 17 – Common raw data files and their naming convention on this 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 and processing began.

ASV-CW5 data was transferred over a radio link after each line, or on rare occasion transferred to the *Q105* server via USB drives whenever the unmanned vessel was back aboard. Deletion of files on the acquisition PCs was done only when necessary and only following confirmation of successful transfer to the *Q105* vessel file server as well as backup to secondary USB hard drives.

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.

B.3. Bathymetric (MBES) Data Processing

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 rapid coverage and quality determination.

Following the completion of field operations and prior to deliverable creation, 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 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 database file using the TerraLog interface. Log files were then output to PDF. These are available in each DR, *Separate I: Acquisition and Processing Logs.*

B.3.1. 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 timestamping, 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.

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

B.3.2. Standard and "DH" type HIPS Vessel Files

In the CARIS project, two HVFs exist for each vessel: "ASV" and "ASV-DH" corresponding to the *ASV-CW5* vessel, with "Q105" and "Q105-DH" corresponding to the *Q105* vessel. "DH" denotes a dual-head configuration HVF: Although dual-head sonars were not used on this project, the HVF configuration was necessary to address changes in raw MBES record types, as explained below.

Due to updated version of QPS QINSy being used on the project that included a change in terminology utilized for some options under the Reson MBES 7k drivers, early lines on the project were inadvertently acquired using "new" style (Reson 7027) records. From JD202 onwards, QINSy was reconfigured to acquire the desired "old" style (Reson 7004/7006) records. Old-style records were favored in this project's workflow because they simplify the HVF while also making the backscatter data in the XTF readable by CARIS HIPS' Geocoder.

Data collected at the start of the project on the *Q105* initially exhibited oddities (S-shaped seafloor in flat areas) in the seafloor profiles. CARIS was consulted, and the cause determined to be a misconfiguration of the HVF stemming from the incorrect assumption of MBES record types from the raw XTFs. Utilizing a correct HVF configuration based on the record types logged resolved the issue.

The known issue is addressed in CARIS' technical bulletin "HIPS and SIPS Technical Note for Sound Velocity Correction for Teledyne Reson 7k Data". Although the technical bulletin specifically references Reson S7k records, CARIS confirmed that the XTFs contain the same record types and should be processed the same way.

To address the issue, HVFs were created based on instructions laid out in the technical bulletin, depending on the type of Reson record used:

1. Data collected prior to JD202 inadvertently used Reson 7027 records. For each vessel, this required a "dual-head" configuration HVF (ASV-DH and Q105-DH), even though a single-head sonar was used. "DH" HVFs were configured according to instructions in the technical bulletin for "HVF for Sound Velocity Correction 7027 Records (Single Head). Separate Tx and Rx arrays are defined in this configuration, offsets for which were determined based on the Reson 7101 MBES transducer specifications.

2. Data collected from JD202 onwards used Reson 7004/7006 records. For each vessel, the HVF was setup according to instructions in the technical bulletin for "HVF for Sound Velocity Correction 7004/7006 Records".

Exact time of the change from 7027 to 7004/7006 records was JD201 23:50 on the *Q105*, and JD202 00:54 on the *ASV-CW5*.

Note that this is provided for documentation purposes only. The issue was fully resolved by using the correct HVF configuration and there was no adverse effect on final data.

B.3.3. 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.

The static draft PDF logsheet exported from TerraLog is available in each DR, *Separate I: Acquisition and Processing Logs.*

B.3.4. Load Delayed Heave

The POSMVs on both vessels were configured to compute and record Delayed Heave (also known as Applanix "TrueHeave") to POS file. Delayed Heave provides improved heave corrections over real-time heave, especially at the start of lines where the real-time heave filter may not have had adequate time to filter new sea-state conditions after a line turn to compute a zero-reference point. POS files were logged continually during survey operations, with rare exceptions.

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 rates (25 Hz).

Along with the Delayed Heave data, Delayed Heave RMS error records were also imported during this process so that final TPU values would reflect actual computations of RMS error for heave by the POSMV over the fixed values specified in the HVF.

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) where lines do not have a POS file (and hence Delayed Heave coverage), CARIS defaulted to utilizing the real-time heave corrections.

In CARIS HIPS, options to apply Delayed Heave were utilized during both Sound Velocity Correction and Merge.

B.3.5. Load Attitude / Navigation 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, and all available records were imported (navigation, gyro, pitch, roll, and GPS height). 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.

Through this process, each line's original, real-time attitude and navigation records were superseded in CARIS HIPS by the records in the SBET files. In rare cases where SBETs were not available (noted in the applicable DRs), CARIS HIPS reverted to using real-time records.

The name of the SBET file applied to each survey line was noted by the data processors in the line processing logsheet.

B.3.6. Dynamic Draft Corrections

Dynamic draft corrections, determined by using squat-settlement tests, were computed and applied for this survey. Corrections were RPM-based for both vessels. These corrections, in the format of time-correction, were loaded into each line using CARIS HIPS' "Load Delta Draft" utility.

Note that the "Load Delta Draft" utility was removed from CARIS HIPS starting with HIPS V10. CARIS was contacted and confirmed they intend to reinstate the option in a future version. Meanwhile, for this project, "Load Delta Draft" was accomplished by using prior version of HIPS, V9.1. CARIS confirmed this is an acceptable approach. It appears the HIPS "Log Viewer" does not show that the process was run because it was done in a prior version. However, querying the lines for the presence of Delta Draft confirms the records exist.

Speed-based corrections, with rare exceptions, were not used for this survey. RPM-based corrections were used because they more accurately reflect vessel vertical response from changes in engine loading than speed-based corrections. A speed-to-draft correction table exists in each HVF, but was disregarded by CARIS during merge because of the presence of the loaded Delta Draft data, except in rare cases where RPM-based corrections were not available. Specific cases where speed-based corrections were used are documented in the respective DR.

Engine RPM data was logged and processed slightly differently depending on the vessel:

On the *Q105,* a TerraTach system was used to continuously compute, time tag, and log engine RPM data at 1 Hz with a resolution of 1 RPM to .RPM file (text format). On the ASV-CW5, data was similarly logged, but by the on-board control computer. In processing, the dynamic draft results were interpolated to 1 RPM to match the resolution of the RPM systems (1 RPM). A VB.NET utility was written that averaged port and starboard readings and then paired each RPM value logged with the corresponding settlement value determined by a squat settlement test. Rare instances of missing RPM data from the logged files were filled using RPM data saved by TerraLog, which was also configured to record RPM values. A draft correction file consisting of time and settlement value was then produced.

Dynamic Draft correction files are provided with the deliverables for the survey in the "Water_Levels" subdirectory. Raw RPM data is included with the raw data deliverables. Section C of this report summarizes the dynamic draft results.

B.3.7. Sound Speed Corrections

Sound speed profiles (also known as "SV casts") were processed using TerraLog, an in-house software package. During import into TerraLog, the software assigned the cast, the UTC timestamp, and geographic position that was recorded in the raw SVP file.

During processing, TerraLog separated the profile into its up and down components and graphed the data points, allowing erroneous points to be rejected by data processing personnel. Once checked and cleaned, the software exported the combined (average of up and down components) profile to CARIS HIPS SVP format at a regular 0.10 m interval. The output was checked for incorrect timestamps and positions, and appended to the appropriate master CARIS HIPS SVP file based on the survey sheet.

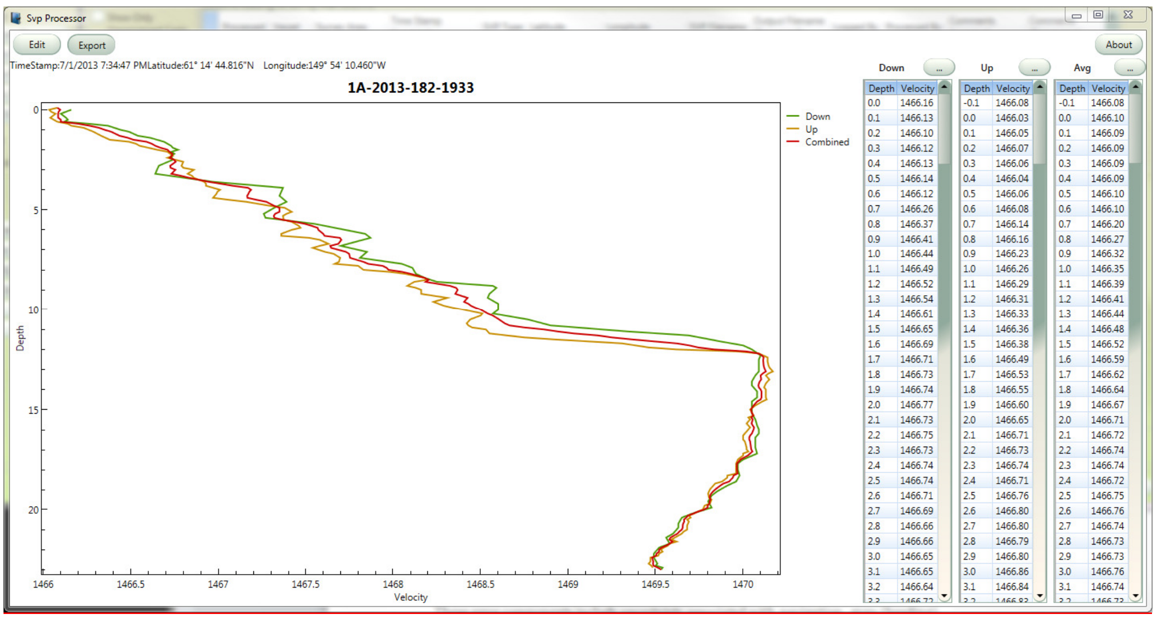


Figure 13 – Example SVP profile editing interface in TerraLog.

As described previously in this report, TerraLog did not natively support the Valeport RapidSV format and an in-house program was used to convert raw Valeport casts to a TerraLog supported format ("MVP"). The MVP-format files were the files utilized by TerraLog.

Each line was corrected for sound speed using CARIS HIPS "Sound Velocity Correct using CARIS Algorithm" utility. 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, 4 hours was used through JD206. From JD207 onwards, 2 hours was used. The value was chosen to match the cast interval in data acquisition (described previously in this report). Deviations to the selection interval are rare and are noted in the applicable DR. Each line logsheet is also marked with the correction method, such as "NDT 2" (for nearest-in-distance within 2 hours).

In addition to the profile selection method, options applied during sound velocity correction included setting heave source to "Delayed" and including the option to "Use Surface Sound Speed" (if available).

Note that the same profiles used to correct *Q105* data were also used to correct *ASV-CW5* data because the *ASV-CW5* always worked near the *Q105*.

B.3.8. Total Propagated Uncertainty

CARIS HIPS was used to compute total propagated uncertainty (TPU). The CARIS HIPS TPU calculation 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). The following table describes the TPU values entered in the HVF. Note that all values entered are at 1-sigma, per CARIS guidance, while CARIS reports TPU at 2-sigma.

HVF TPU Entries			
HVF TPU Entry	***Q105***	***ASV-CW5***	**Source**
Sonar Type	Teledyne Reson Seabat 7101 (511 beams)		Entry in HVF for Swath1 (sonar model). Uses the sonar parameters from the CARIS device models .XML file to model sonar error based on manufacturer-provided estimates
Motion Gyro*	0.02°		CARIS TPU values for Applanix POSMV 320 (2 m baseline)
Heave*	5% or 0.05m		CARIS TPU values for Applanix POSMV 320
Roll and Pitch*	0.010°	0.010°	CARIS TPU values for Applanix POSMV 320 (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)	0.01 sec.		Estimated overall synchronization error
Offset X	0.1 m	0.02 m	Accuracy estimate of the X offset measurement of the transducer acoustic center relative to the vessel CRP
Offset Y	0.05 m	0.02 m	Same as above
Offset Z	0.02 m	0.02 m	*Q105:* Variance of bar check results *ASV-CW5*: Estimated accuracy of measured Z
Vessel Speed	1 m/s		Estimated average max current experienced in survey area

HVF TPU Entries			
HVF TPU Entry	***Q105***	***ASV-CW5***	**Source**
Loading	0.05 m	0.01 m	Standard deviation of the difference between subsequent static draft measurements
Draft	0.02 m	0.03 m	Estimated accuracy of static draft measurements
Delta Draft	0.02 m		Overall estimated uncertainty of squat-settlement test results
MRU Align StdDev Gyro, Roll/Pitch	0.03°		Estimate of accuracy of patch test results for the applicable sensors
MRU to Trans and Nav to Trans Offsets	IMU to Transducer X, Y, Z offset		Offsets are from the POSMV IMU top-center (vessel CRP)
* These static HVF error estimates for gyro, heave, pitch, roll, and positioning were superseded by real-time error estimates loaded into lines during processing			

Table 18 – HVF TPU values used.

Other TPU computation parameters:

- **Tide error uncertainty**: "Real-time" tide error estimates were used. The final tide zone definition file (ZDF) includes error estimates for the project tide gauge and each individual zone. When loading the final tide data from the ZDF, the option to "Compute errors" was used, resulting in more customized and presumably more accurate tidal error estimates. During TPU computation, a tide measurement error of 0.10 m was entered but was ignored by the software in favor of the real-time error estimates.

- **Real-time Error for Navigation and Attitude Data**: Real-time estimates of navigation and attitude error were loaded into all MBES lines with few exceptions (noted in applicable DRs) through CARIS HIPS' "Import Auxiliary Data" utility.

  Real-time error estimates for Delayed Heave were loaded from POS files when importing Delayed Heave, and real-time error estimates for navigation, gyro, pitch, roll, and GPS height were loaded from SMRMSG files that were produced concurrently with SBET files during the POSPac PPK process. During final TPU computation, real-time error was selected as the error source to override the static values entered the HVF whenever applicable.

  Note that this means the static error estimates for these specific sensors in the HVF were ignored by HIPS during TPU computation for most survey lines. The associated static error estimate in the HVF was only used by CARIS HIPS as a backup for when the real-time error data was not available.

- **Sound speed error**: For estimated sound speed error, a value which varied by survey sheet was entered. The value for each survey sheet was derived by comparing subsequent profiles side-by-side according to the cast interval in use, differencing the change in sound speed at each depth, and calculating the standard deviation of the differences. This standard deviation (at 1-sigma) was considered the measured sound speed error for CARIS TPU computation purposes. Values ranged from 1.336 to 2.162 m/s. The specific value used for each sheet can be found in the applicable DR.

Other TPU Settings			
TPU Setting	***Q105***	***ASV-CW5***	**Description**
Sound Speed - Measured	Varied by sheet, from 1.336 to 2.162 m/s		Unique value determined for each sheet based on an analysis of sound speed variance between casts. See each DR for values used
Sound Speed - Surface	0.025 m/s		Manufacturer-specified accuracy of the surface sound-speed probe
Tide	Gauge error 0.034 m, plus zonal errors ranging from 0.034 to 0.061 m		Computed during “Compute Error” while loading final tides via ZDF, applied by using “Realtime” tide error. Note that a static value of 0.10 m entered for zone error was superseded by using real-time error.
Uncertainty Source	Position: Realtime Heading: Realtime Pitch: Realtime Roll: Realtime Tide: Realtime Vertical: Delayed Heave Sonar: Vessel		Caused HIPS to use the real-time estimates of error loaded into survey lines whenever available, falling back to the static HVF values in rare instances when real-time errors were not available. Real-time error data was not available for the sonar, so the HVF entry was used

Table 19 – Other TPU computation settings.

B.3.9. 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. FAA WAAS (Wide Area Augmentation System) corrections were used for real-time positioning but were replaced in final processing with PPK positions.

PPK processing for this project utilized Applanix POSPac MMS software. POSPac made use of dual-frequency GPS data logged at the nearby CORS site AB07 (Sand Point) and the raw POSMV data logged on-board the vessels to produce post-processed positioning files. These PPK files (SBET format .OUT files) were loaded into all lines in processing, with few exceptions. This replaced navigation (position and GPS height) as well as attitude data (gyro, pitch, and roll) logged in real-time with the post-processed version. The process also produced SMRMSG files, which contained root mean square (RMS) error estimates for the post-processed solution at 1 Hz that were loaded and used for dynamic (real-time) TPU estimates described previously in this report.

To process POS files to produce an SBET, a POSPac MMS project was first established based on a pre-defined 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 Applanix Smart Base (ASB) functionality was utilized for the majority of the POSPac processing. ASB requires the project area be fully encompassed by base stations, a requirement that this project met due to the fortunate placement of CORS sites in the region. Early in the project, single-base and ASB modes were tested and it was determined ASB provided a slightly improved RMS error results over single-base mode.

In ASB processing, POSPac typically utilized AB07 (Sand Point) as the primary base station. Neighboring stations up to 100 km away were used in the ASB network, with sites ranging from Cold Bay and Sanak Island to Port Moller and Perryville. A common ASB network is shown in the figure below.

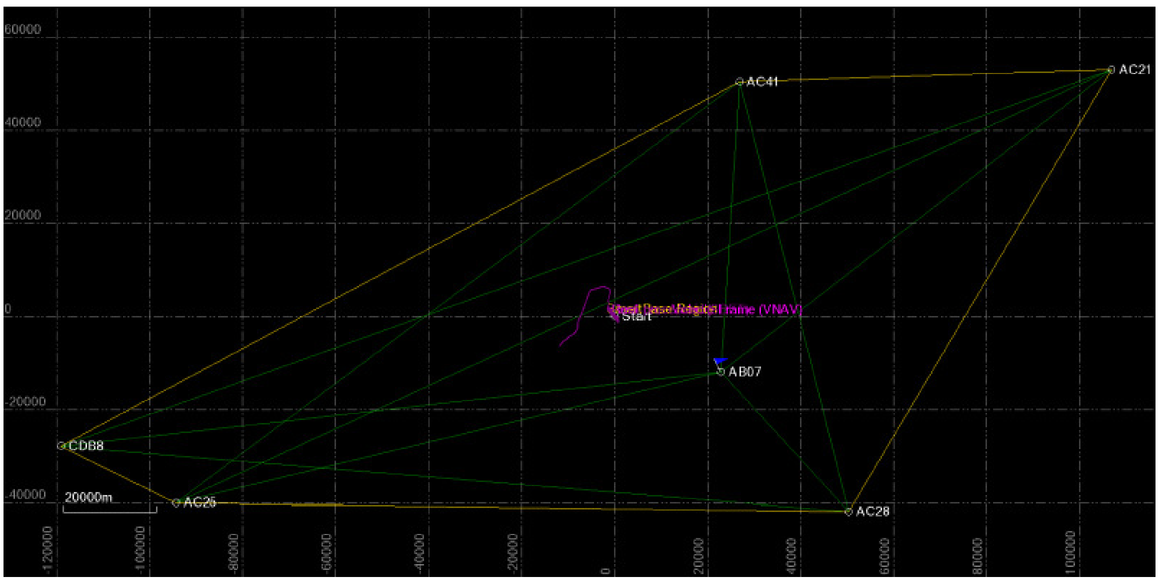


Figure 14 – Typical ASB network for PPK. Vessel trackline is purple. AB07 (Sand Point) is flagged.

Following importation of the base stations as well as precise ephemeris data via the "Find Base Stations" function, the "SmartBase Quality Check" process was run and performed a positioning check on each station in the network by comparing computed positions of the base stations to reported positions. The "Applanix SmartBase (ASB)" process was run next, which generated a virtual reference station (VRS) for each vessel position using interpolation across the ASB region. Finally, the "GNSS-Inertial Processor" was run, which utilized the VRS as the base station and post-processed the inertial navigation data.

Note in rare cases POS files would not process with ASB. When this occurred, single-base mode (using AB07) was used instead. These cases are noted in the PPK processing logs. Additionally, SBET (and SMRMSG) filenames include the processing method utilized: "_ASB" to denote Applanix SmartBase, but on occasion "_AB07" to denote single-base mode utilizing AB07.

Following completion of the inertial processor, QC plots were examined within POSPac for spikes and other anomalies. Smoothed performance metrics for north, east, and down position error RMS were reviewed and exported for inclusion in the project HVCR. On this project, no significant issues were observed with the PPK data.

Lastly, SBETs were exported from POSPac. The option to produce "Custom Smoothed BET" was used to produce an SBET in the NAD83 (2011) reference frame at 50 Hz. This made it so that all final positions were NAD83 (2011) per the 2017 HSSD.

The flow chart shown below is a generalized overview of the POSPac workflow used on this project. Steps are similar for projects that used single-base mode, with the exception that single-base options were used in place of SmartBase options.

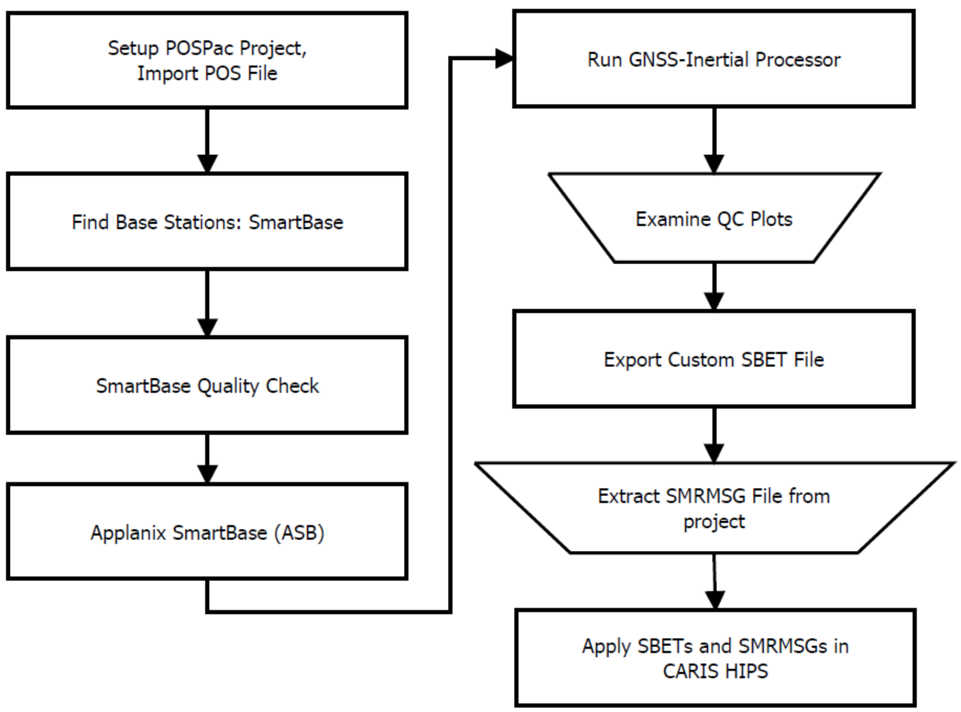


Figure 15 – Flow chart overview of POSPac workflow used on this project.

SBET .OUT and SMRMSG .OUT files were then applied in CARIS HIPS to lines using the Import Auxiliary Data process, as described elsewhere in this report. All .OUT files that were applied to the data are included with the survey deliverables, as well as RMS error graphs.

Note that while SBETs were produced in NAD83 (2011), CARIS HIPS projects were set to NAD83 without the 2011 epoch designation. This was done intentionally because of a known issue in CARIS HIPS 10.3.3, whereby if the project were set to an epoch of 2011 the software may perform a potentially detrimental, albeit minor, conversion on the imported navigation which is already on the 2011 epoch. This would happen because only "NA83" is available (without a 2011 epoch designation) as the applicable datum under the navigation sensor in the HVF. If a CARIS project is set to NAD83 (2011) but assumes the NAD83 (2011) navigation is standard NAD83 due to the "NA83" setting in the HVF, the unwanted conversion would be triggered.

B.3.10. Compute GPSTide

Following loading of PPK altitude data, CARIS HIPS' "Compute GPSTide" function was run on all lines. This created a GPSTide record within each survey line. Options to apply dynamic draft, dynamic heave, and vessel waterline were used so that the GPSTide record reflects the elevation of the vessel waterline above the NAD83 (2011) ellipsoid. Rare lines without PPK data loaded (noted in the applicable DR) will not have accurate GPSTide records.

Note that GPSTide was computed for reference only, including troubleshooting and in case ellipsoid-based water levels are useful for future purposes. They were NOT applied to final survey deliverables. Final deliverables utilized discrete tide zones.

B.3.11. Load Tide and Merge

Discrete tide zones were used for final tide corrections. NWLON gauges in Sand Point (9459450) and King Cove (9459881) were used in conjunction with a zoning tide station deployed for the project in Zachary Bay (9459465) to derive time and range correctors for discrete zones across the survey area.

Zoned tidal data, in CARIS HIPS ZDF format, was loaded to all survey lines through CARIS HIPS' "Load Tide" utility. The ZDF (Zone Definition File) utilized smoothed, verified 6-minute tide data on MLLW from the Sand Point NWLON station in conjunction with the computed time and range offsets. During loading of tide, the option to "Compute Errors" was selected so that individual "real-time" error estimates by zone were available for TPU computation.

Following application of final tide data, CARIS HIPS "Merge" function was run. Heave Source was selected as "Delayed". Tide source was set to "Observed" so that the tidal data loaded via ZDF would be utilized, bringing final sounding data to chart datum (MLLW).

The ZDF and Sand Point gauge tide file are available with the survey deliverables. Refer to the project HVCR for more information on the tidal data deliverables including derivation of the tide zones.

B.3.12. 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. Soundings flagged as 0, 1, and 2 were flagged as "rejected" automatically in filtering. Only high quality (3, being both co-linear and bright) soundings passed. This removed a large amount of water column noise.

Beam-based filters were also run based on the vessel and sonar configuration: In the field, all *Q105* lines received an initial beam filter of 70°, which removed the outer 5° of the swath--port and starboard--that was most subject to sound speed and motion error. *ASV-CW5* lines prior to JD211 also received an initial beam filter of 70°.

From JD211 onwards the ASV-CW5 sonar was configured with a 30° to starboard tilt (starboard up). Since it was advantageous to retain the outer starboard beams in this configuration, a beam filter was not initially used on these lines.

During office processing, data quality was reviewed, and filtering revisited on an area-by-area basis. More aggressive filters were run as necessary on groups of lines that exhibited higher error due to sound speed refraction or motion. This included commonly running a 65° beam filter on standard (non-tilted) configuration lines, and starboard beam-only (beams 350 to 511 for example) on tilted-head lines that showed sound speed error. Minimum depth filters of 1-2 m were also utilized occasionally in deeper water to reduce the incidence of "fliers" high in the water column. Filter settings used were recorded on the individual line logsheets (included with the project DRs) as well as in the CARIS HIPS "Process" log.

On occasion, filtering—especially outer beam filters—widened or opened gaps in coverage between parallel lines. In areas requiring complete multibeam coverage, these gaps were manually reviewed in subset mode and filled by reaccepting filtered data that appeared to be of high quality based on collinearity with adjacent soundings. In survey areas not requiring complete coverage (set-spaced areas) gaps were generally not filled with rejected data (if available), except where shoaling was evident between survey lines.

B.3.13. Multibeam 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 erroneous soundings were rejected. Cleaning status was tracked in the processing section of TerraLog, along with the processors' comments or notes, if any.

In the office, following application of final correctors including final tides, an examination of all soundings was completed in CARIS HIPS Subset Editor, in context of bathymetric surfaces generated using the CUBE (Combined Uncertainty and Bathymetric Estimator) algorithm.

In CARIS HIPS, CUBE surfaces were first generated based on the depth resolution standards and CUBE parameters conforming to the 2017 Hydrographic Surveys Specifications and Deliverables (HSSD). The CUBE surfaces were "finalized" using depth ranges for resolution specified in the HSSD. Surfaces were then loaded as a reference layer, and examined in subset mode simultaneous with the contributing soundings. Only the CUBE surface appropriate for the depth and coverage type being examined was loaded (4 m, 8 m, or 16 m surfaces for all set-spaced areas, 1 m, 2 m, 4 m, 8 m, and 16 m surfaces for complete coverage areas).

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), which meets TVU specifications.

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 features 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 80 m (2 mm at survey scale) of a shoaler part of the surface (or a shoaler designated sounding), it was not designated.

For editing consistency, the data was reviewed in subset with set visualization parameters. Data was examined looking along-track through the data, which is standard practice for examining bathymetry in subset. The subset view slice length was constrained to approximately 5-8 lines, and slice width was constrained to about 25-50 m, based on ruggedness of the seafloor being examined. Vertical exaggeration in the subset window was manually set so the vertical scale graticule displayed in increments of 0.50 m. Subset tiles were used to track editing progress, with care taken to ensure all data was examined.

Following editing, the “Depth” and “Shoal” layers of the CUBE surface were examined. These layers readily portrayed extreme fliers, which were subsequently loaded into subset and rejected to ensure they were not included in future re-computations of the CUBE surfaces.

B.3.14. Final BASE Surfaces

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 10.3.3 in CSAR format, and represent the seafloor at the time of survey, relative to chart datum (MLLW).

This project spans multiple coverage types. Resolutions of the BASE surfaces were created in accordance with the HSSD based on coverage type and depth. Coverage types required on this survey were “Complete Coverage Multibeam” (Section 5.2.2.3 in the HSSD), and “Set Line Spacing” (section 5.2.2.4, option “A” in the HSSD). Resolutions ranged from 1 m to 16 m for complete coverage areas, and 4 m to 16 m for set spaced areas.

For all surfaces, “CUBE” was selected as the gridding algorithm. “Density and Locale” was chosen as the disambiguity method and NOAA CUBE parameters appropriate to the resolution were selected. The CUBE parameters (XML format) are included with the CARIS HIPS digital data deliverables. “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 that resolution. Designated soundings were applied, which forced the final surfaces to honor these soundings where applicable.

B.3.15. Final Feature Files

A final feature S-57 file (FFF) and supporting files was submitted in conjunction with each survey. The FFF contains information on objects not represented in the depth grid, including bottom samples, features, and metadata. Each feature object includes the mandatory S-57 attributes (including NOAA extended attributes) that may be useful for chart compilation. The FFF was created in CARIS HIPS 10.3.3 by importing all applicable features and assigning mandatory attributes as necessary.

"CARIS Support Files V5.6" were used as NOAA extended attributes, which added custom NOAA attributes to the standard S-57 library. V5.6 was the latest provided by NOAA (October 2017) at the time of deliverables preparation for this survey. During feature attribution, effort was taken to ensure required attributes described in the HSSD were applied.

B.3.16. Crossline Analysis

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 surfaces 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 Order 1, 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. Note that although IHO Order 2 standards are acceptable for depths greater than 100 m, Order 1 parameters were used for all depths for simplicity.

Overall, there was excellent agreement between crosslines and mainscheme on this project, with the vast majority of crosslines comparing to mainscheme well within IHO Order 1.

A discussion concerning the methodology of crossline selection, as well as a summary of results for each sheet, is available in the project DRs. The crossline reports are included in the DRs, *Separate II.*

B.3.17. Bathymetric Processing Flow Diagram

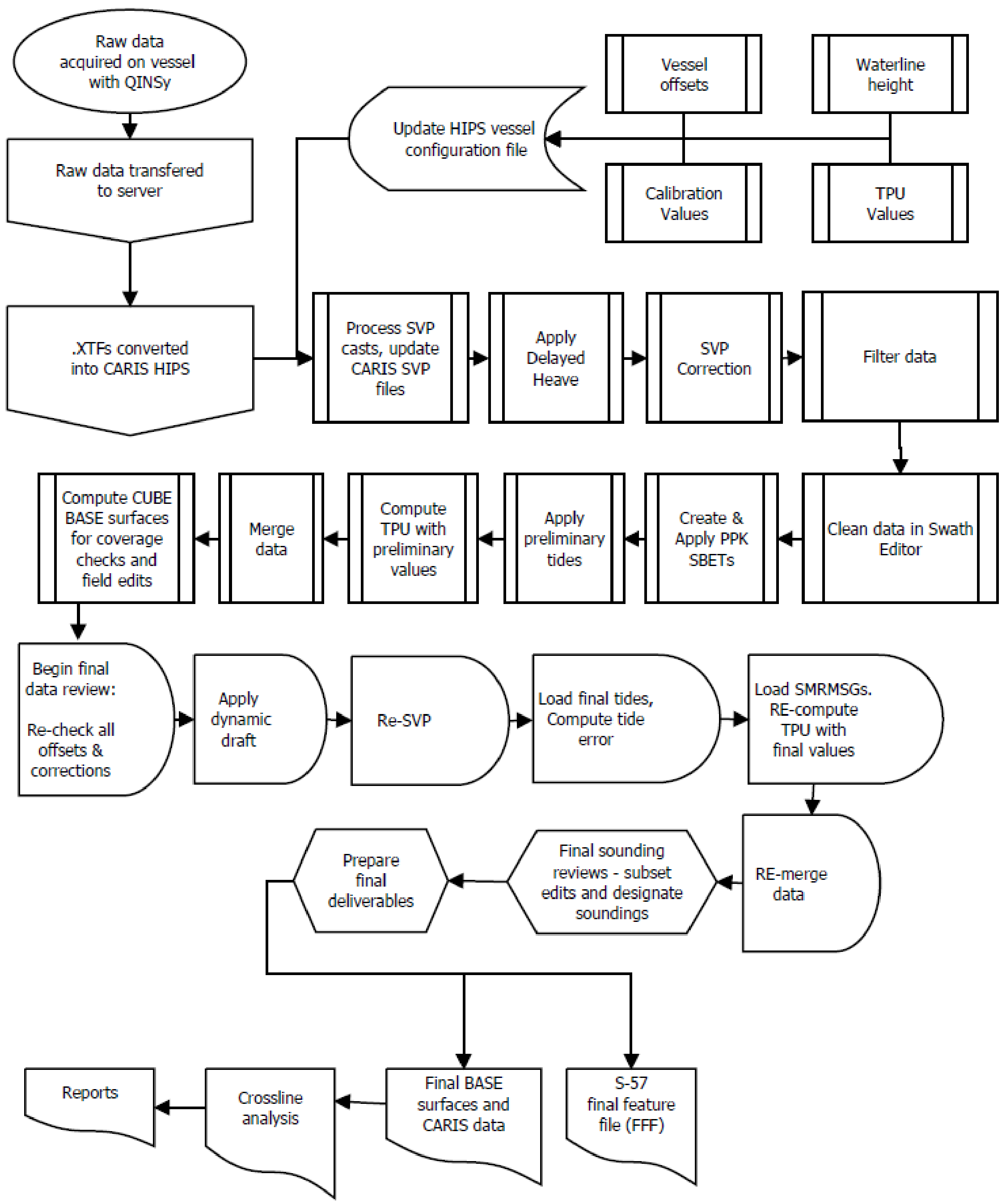


Figure 16 – Generalized flow chart of processing steps used on this project.

B.4. Limited Shoreline Verification

Limited shoreline verification was assigned and accomplished for this project.

A Composite Source S-57 File (CSF) was provided with the project instructions that included "Assigned" features for investigation (Acronym "asgnmt", name "Assignment flag", Value="Assigned"). Assigned features were extracted from the CSF and investigated.

B.4.1. Shoreline Data Acquisition

The vast majority of shoreline features were investigated via Unmanned Aerial System (UAS) on this project. DJI Phantom 4 Professional (P4P) units were used on this project (see specifications in Section A of this report).

Use of UAS to investigate assigned features instead of from surface vessel (skiff) improved safety while simultaneously allowing a more accurate, comprehensive, and quantitative shoreline dataset to be acquired. The skiff-based approach, which has inherent safety concerns, relies heavily on visually estimated heights for features as well as estimated positions since most features cannot be approached directly. In addition, inspection of the coastline by skiff can miss potentially hazardous uncharted or new features just at or under the water surface that are clearly visible from the air. Water clarity in this project area was also conducive to aerial search for submerged features, with rocks readily visible at 8 m water depth in most areas.

To investigate features with UAS, “missions” of approximately 1 to 2 nautical miles of coastline were first pre-defined. Missions routes were best-fit to intersect assigned features, with consideration for photo coverage and overlap. Altitudes were set to 400' or less and speeds were limited to allow at least three high-resolution (20 megapixel) geotagged photos to be taken on each feature and surrounding seafloor.

Figure 17 -- Pre-defined mission routes over assigned features shown in Google Earth.

When conditions were favorable for shoreline verification (low tide, good visibility, and winds of 20 knots or less), the missions were carried out. With the *Q105* in the general proximity of the features requiring investigation, the UAS was launched from the top deck and sent on the pre-defined mission. Camera angle was usually set to a straight-down (nadir) orientation, and the UAS was set automatically take high-resolution (typically 20 megapixel), geo-tagged JPG images every 2 seconds. Images were saved to an on-board SD card for later processing.

Figure 18 -- A P4P drone (UAS) is launched from the Q105 to investigate shoreline features.

Except for launch and recover from the *Q105*, the vast majority of UAS missions were executed autonomously. This allowed for consistent altitude, speed control, and positioning along the pre-defined route. Care was taken to time missions for good weather and visibility as well as low tide (usually 0.5 m or less).

Figure 19 -- UAS (center of image, white) in flight photographing assigned features (ledges and rocks), including ATON inspection (lower left corner)

B.4.2. Shoreline Data Processing

The UAS data acquisition process generated thousands of overlapping images of the assigned feature areas and surrounding shoreline. Instead of analyzing images individually, Structure from Motion (SfM) methodology was utilized to create ortho-rectified photo-mosaics and digital elevation models (DEMs) over assigned features. For this purpose, Agisoft PhotoScan software was utilized. Final products from PhotoScan were high resolution photo-mosaics and DEMs for correlation with assigned features and identification of new (uncharted) features.

SfM is a technique of photogrammetry that allows 3D modeling from 2D image sequences. Using multiple photos of features, SfM utilizes changes in perspective to determine positional relationships between matching features and model them in 3D. On this project, care was taken to ensure at least three photos were taken of each feature to allow sufficient data for good SfM results.

Each UAS mission was imported into PhotoScan as a separate photoset project. Images taken during “transit” of the UAS over open water were rejected. Remaining images were run through an automated process of photo alignment and aero-triangulation, wherein photos were matched and merged with adjacent photos based on geotags and common features identified in overlapping photos. Photos were sometimes auto-rejected by PhotoScan when insufficient tie points with adjacent photos could be computed, common when open water was crossed.

Initial field processing in PhotoScan was done immediately after each mission to ensure coverage and data quality. During this initial processing, PhotoScan was run with reduced quality settings to rapidly verify integrity of acquired data. Processing was separated into 'chunks' that represented UAS missions. Since SfM processing can be time intensive, lower quality settings for aero-triangulation and point cloud generation were used to compile a scene for the mission within a suitable timeframe (usually within the available tide window). Preliminary ortho-photomosaics (as georeferenced TIF images) were then output and compared to assigned features to ensure coverage.

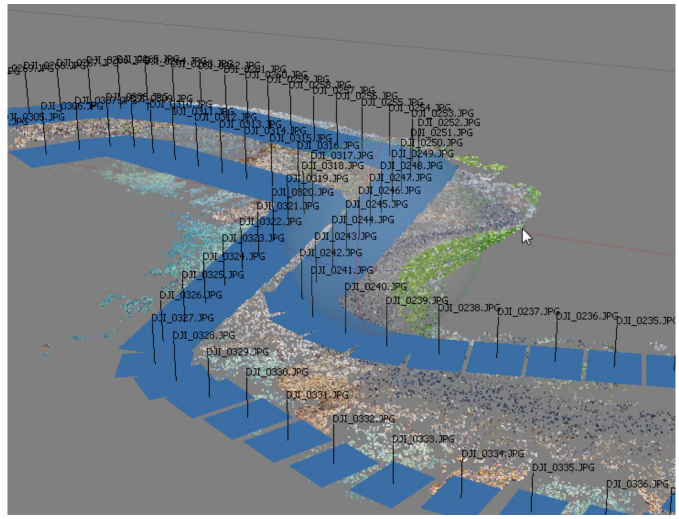


Figure 20 -- Aero-Triangulation Tie Points showing photo locations along the pre-defined mission route.

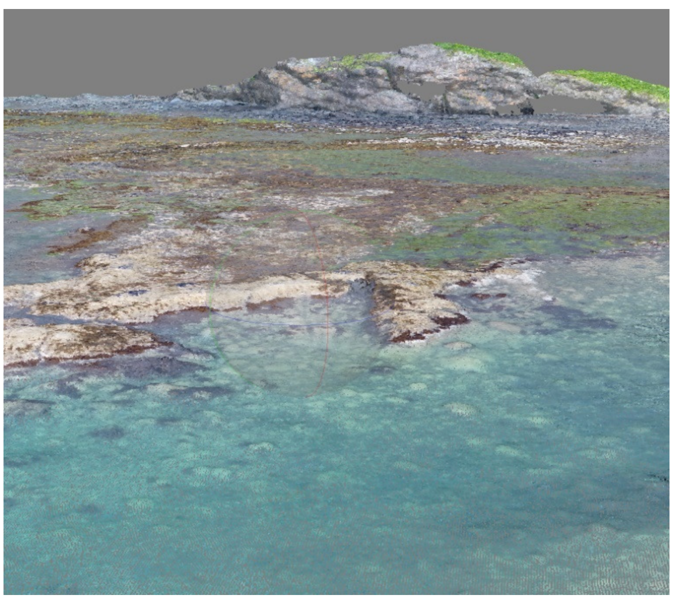


Figure 21 -- Dense Point Cloud generated through SfM

Secondary field processing involved reprocessing missions to generate densified point clouds. The point clouds were then manually reviewed to verify a 3D height could be measured on features of interest. From the dense point clouds, DEMs and ortho-photomosaics were batch processed for each mission.

In final office processing following availability of final tides, tide corrections were applied in PhotoScan to bring point cloud data to MLLW. A tide value was first computed for each mission, based on the average time of acquisition of the mission using zone-corrected tide data from the NWLON station in Sand Point. Next, vertical control points were created along the recognizable water line. The tide value was then used to shift the entire mission's point cloud and associated DEMs to MLLW for height determination.

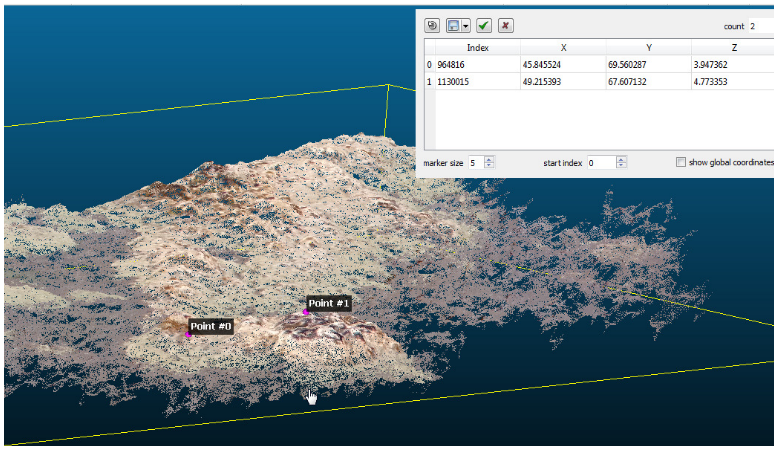


Figure 22 -- Manual height measurements in dense point cloud

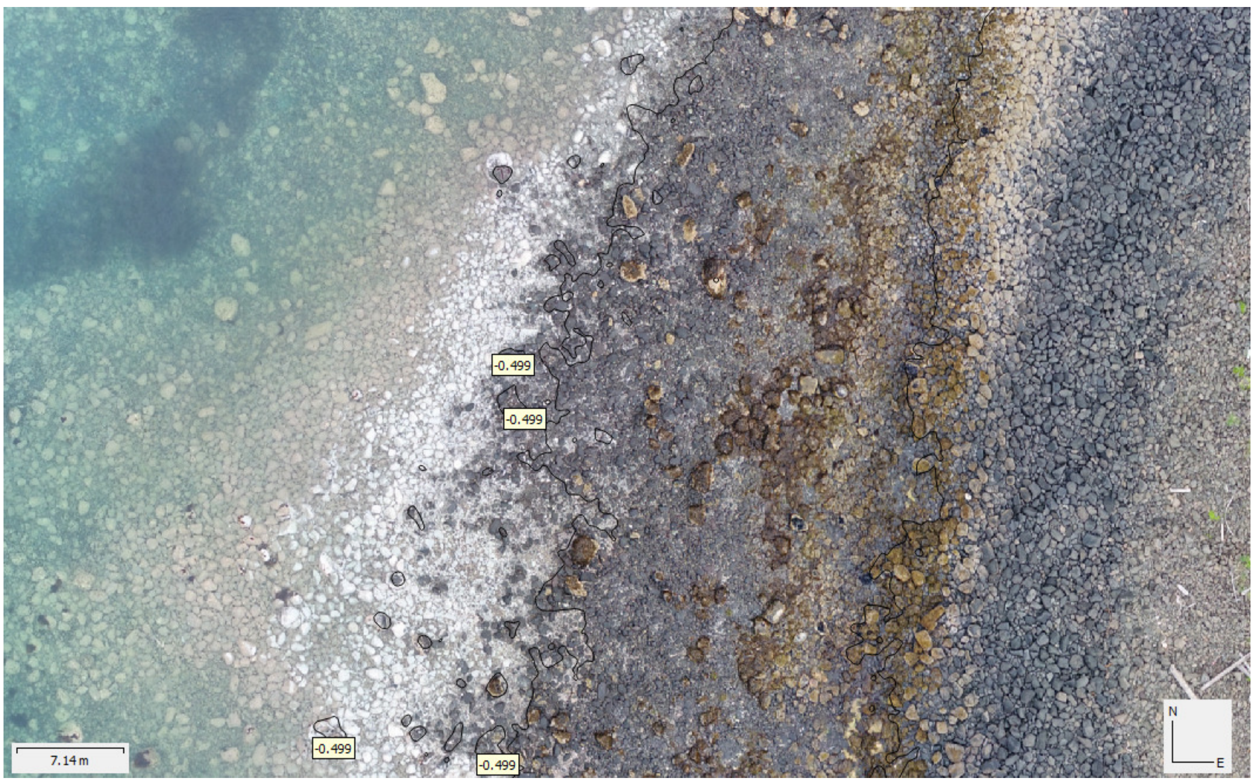


Figure 23 -- Waterline contour corrected for MLLW overlaid on DEM generated photo-mosaic in PhotoScan. A tide of -0.499 m at this mission time was assigned to the shoreline-water interface to adjust the final DEM to MLLW.

On occasion, missions were flown as “oblique”, with a camera angle of approximately 45 degrees relative to the shoreline, instead of straight down. This was advantageous when examining expansive area features, including foul coastline or ledges. An example image form one of these missions is shown below.

Figure 24 -- Oblique photo to show foul area in shallow bay at low tide.

Final products from SfM processing were ortho-rectified photo-mosaics (ortho-photomosaics) at a resolution of approximately 0.035 m and DEMs at a resolution of approximately 0.105 m. Both ortho-photomosaics and DEMs were output as GeoTIF images projected into NAD83, UTM Zone 4 N.

B.4.3. Feature Correlation

Correlation between assigned and observed features were done in CARIS HIPS. All applicable data sets were overlaid in CARIS HIPS for this process, consisting primarily of the project CSF (including assigned features), multibeam surfaces, as well as the SfM-derived ortho-photomosaic and DEM GeoTIFs. NOAA extended attributes V5.6 was used for attribution.

Each assigned feature was inspected for accuracy and attributed with applicable S-57 attributes.

Features were considered as "verified" if the actual feature could be identified within the search radius specified in the work instructions (80 m, also 1 mm at chart scale).

Most features could be readily identified within the required 80 m. However, per guidance in the "New/Delete vs Update" section (7.5.2) of the HSSD, the better positions obtained by this survey frequently required position updates for features. The increased accuracy as well as high level of detail available with the low-altitude aerial imagery led to extensive re-digitization of chart as well as GC-sourced line and area features. For this reason, many assigned features were noted in the FFF to be "verified but mispositioned" with a recommendation of "delete", to be replaced by an associated "new" feature defined nearby in the FFF.

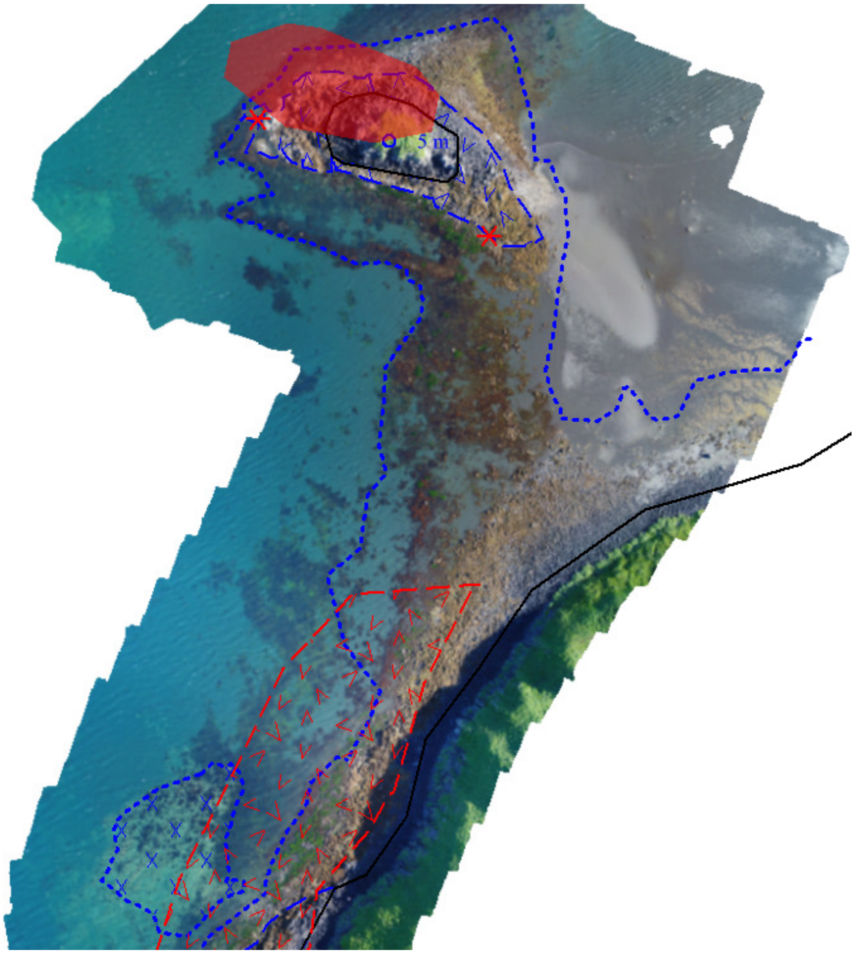


Figure 25 -- Example of shoreline feature processing -- assigned features (red) overlaid on ortho-photomosaic and correlated. New features, including a MHW height on the island derived from the SfM DEM, are shown in blue. MHW from the CSF is black.

Common scenarios encountered and important parameters used when correlating assigned features with observed features were:

- Observed location is greater than 5 m (but less than 80 m, common for chart-sourced data) from the assigned location: The assigned feature was considered “verified but mispositioned”. Recommended for deletion (Description=”Delete”). A “new” feature was then defined nearby at the actual position.

- Observed location is within 5 m of the assigned location (common for GC-source data): The assigned feature was considered verified. A height was determined for the feature. Recommended for update (Description=”Update”) because a height was added.

- Most foul lines/areas and ledges (both GC and chart-sourced) required re-digitizing based on the high-resolution ortho-photomosaics from this survey. The source data was rarely within 5 m of the observed locations. The assigned line or area feature was considered “verified, but requiring extensive modifications to geometry”. As with point-features, these were recommended for deletion but to be replaced by a "new" feature with the appropriate geometry

- 5 meters was used as the horizontal position discrepancy threshold for "new" vs "retain" on features because this was the estimated positional accuracy for the ortho-photomosaics from this survey as well as the GC source shoreline data (specified in the work instructions).

- In rare instances SfM software could not create ortho-photomosaics and/or DEMs over features, either because the features were fully submerged, or not enough correlating points could be computed between overlapping photos. In these cases raw images were extracted at the feature location and examined to complete the correlation manually.

- In a few instances features were investigated with conventional (vessel-based) methods. These do not have ortho-photomosaic coverage and are noted in the remarks for the feature in the FFF

- The published MHW value of 1.988 m for Sand Point NWLON was used for rock – islet determination. Therefore, feature heights determined to be greater than 2.598 m above MLLW were considered to be an islet and referenced to MHW.

Heights for most features were pulled from the associated DEM output from PhotoScan. DEM heights were adjusted to MLLW prior to height extraction, as described previously. PhotoScan was able to generate 3D heights for exposed features in most cases, and in some cases submerged features as well--though DEM quality rapidly degraded with increasing water depth. An example is shown below.

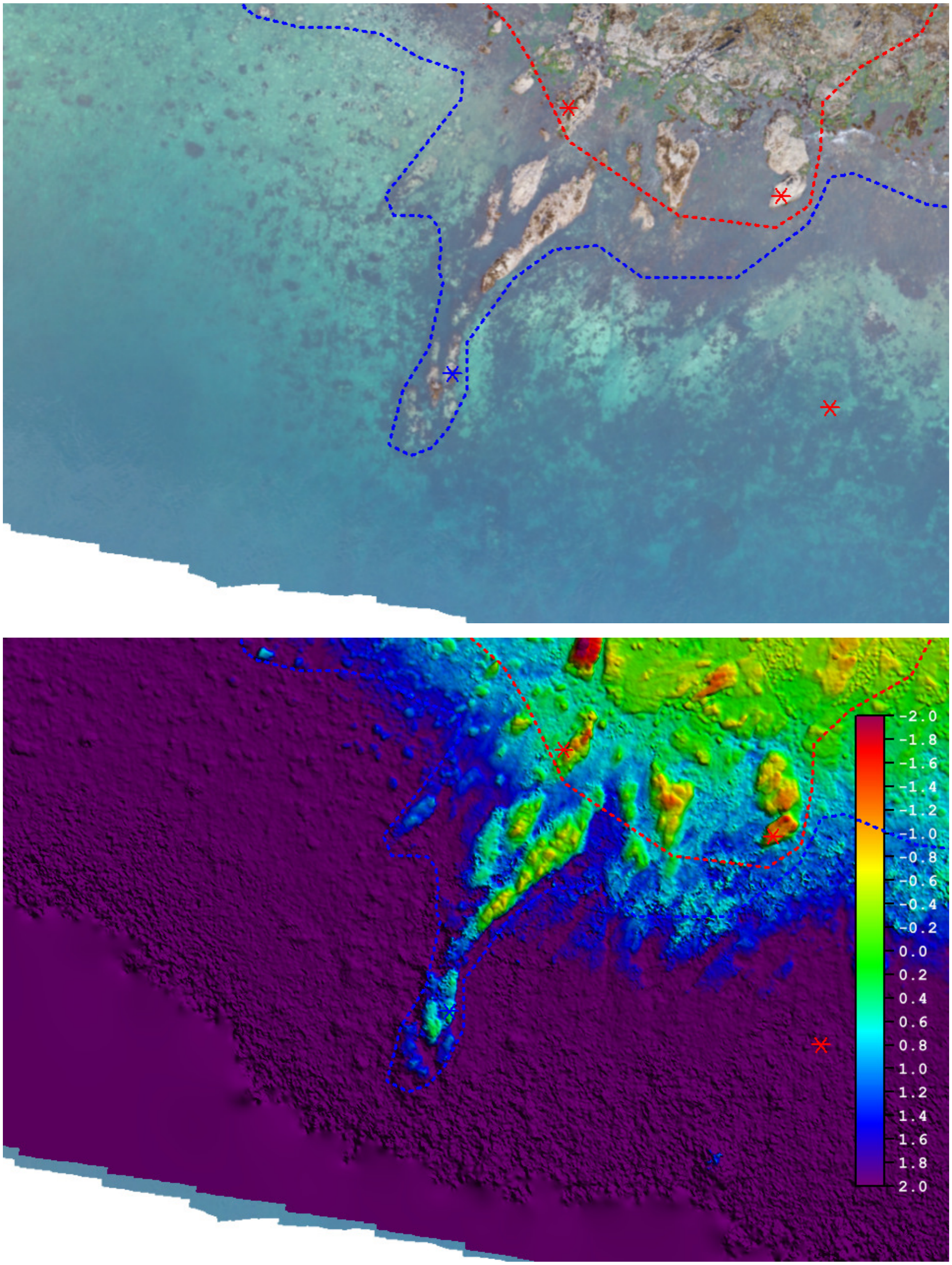


Figure 26 -- Example of DEM usage for height extraction – SfM ortho-photomosaic (top) clearly shows shoreline detail. DEM (bottom, scale in meters relative to MLLW) shows heights. Note smooth-appearing area in lower part of DEM is where heights could not be computed by the SfM algorithm due to water depth.

The following figure shows mission numbers and their relative location in the overall project area:

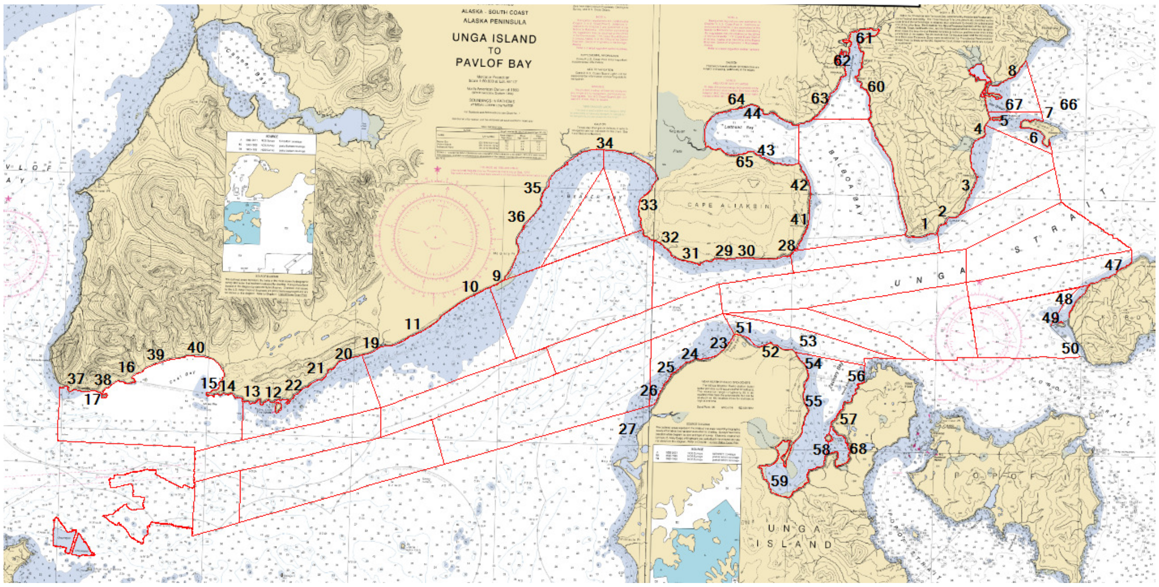


Figure 27 -- Mission number locations relative to the project area

The following table describes filenames for the GeoTIFs, tide at the time of the imagery (and applied to DEMs), and any comments:

Mission#	Ortho-photomosaic (.TIFs) names	DEM (.TIFs) names	Tide	Comments
M1	Mission1_Ortho_Nad83akz4	M1_MLLW_OPT	1.018784	
M2	Mission2_Ortho_Nad83akz4	M2_MLLW_OPT	0.910164	
M3	Mission3_Ortho_Nad83akz4	M3_MLLW_OPT	0.791718	
M4	Mission4_Ortho_Nad83akz4	M4_MLLW_OPT	0.750158	
M5	Mission5_Ortho_Nad83akz4	M5_MLLW_OPT	0.744963	
M6	Mission6_Ortho_Nad83akz4	M6_MLLW_OPT	0.764704	
M7	Mission7_Ortho_Nad83akz4	M7_MLLW_OPT	0.822888	
M8	Mission8_Ortho_Nad83akz4	M8_MLLW_OPT	0.921593	
M9	Mission9_Ortho_Nad83akz4	M9A_MLLW_OPT	-0.587656	
M10	Mission10A_Ortho_Nad83akz4-0-0 Mission10A_Ortho_Nad83akz4-0-1 Mission10A_Ortho_Nad83akz4-1-0 Mission10A_Ortho_Nad83akz4-2-0	M10A_MLLW_OPT	-0.572866	
M11	Mission11_Ortho_NAD83akz4	M11_MLLW_OPT	0.125222	
M12	Mission12_Ortho_NAD83akz4	M12_MLLW_OPT	-0.335966	
M13	Mission13_Ortho_NAD83akz4	M13_MLLW_OPT	-0.306836	
M14	Mission14_Ortho_NAD83akz4	M14_MLLW_OPT	-0.219446	
M15	Mission15_Ortho_NAD83akz4	M15_MLLW_OPT-A	0.007768	
M16	Mission16_Ortho_NAD83akz4	M16_MLLW_OPT	0.476761	
M17	Mission17_Ortho_NAD83akz4	M17_MLLW_OPT	0.632121	
M18	Mission not flown			
M19	Mission19_Ortho_NAD83akz4	M19_MLLW_OPT	-0.185368	
M20	Mission20_Ortho_NAD83akz4	M20_MLLW_OPT	0.294213	
M21	Mission21_Ortho_NAD83akz4	M21_MLLW_OPT	0.529195	
M22	Mission22_Ortho_NAD83akz4	M22_MLLW_OPT	0.759322	

Mission#	Ortho-photomosaic (.TIFs) names	DEM (.TIFs) names	Tide	Comments
M23	Mission23_Ortho_NAD83akz4	M23_MLLW_OPT	-0.715428	
M24	Mission24_Ortho_NAD83akz4	M24_MLLW_OPT	-0.744486	
M25	Mission25_Ortho_NAD83akz4	M25_MLLW_OPT	-0.620194	
M26	Mission26_RapidOrtho_NAD83_UTMz4-0-0 Mission26_RapidOrtho_NAD83_UTMz4-0-1 Mission26_RapidOrtho_NAD83_UTMz4-1-0 Mission26_RapidOrtho_NAD83akz4-0-0 Mission26_RapidOrtho_NAD83akz4-0-1 Mission26_RapidOrtho_NAD83akz4-1-0 Mission26_RapidOrtho_NAD83akz4-1-1	n/a	-0.444686	
M27	Mission27_RapidOrtho_NAD83_UTMz4-0-0 Mission27_RapidOrtho_NAD83_UTMz4-0-1	n/a	-0.102544	Oblique
M28	Mission28_Ortho_Nad83akz4	M28_MLLW_OPT	-0.262912	
M29	Mission29_RapidOrtho_NAD83_UTMz4-0-0 Mission29_RapidOrtho_NAD83_UTMz4-1-0 Mission29_RapidOrtho_NAD83_UTMz4-2-0	n/a	-0.508014	Foggy, not used
M30	Mission30_Ortho_NAD83akz4	M30_MLLW_OPT	-0.569136	
M31	Mission31_Ortho_NAD83akz4	M31_MLLW_OPT	-0.717432	
M32	Mission32_Ortho_NAD83akz4-0-0 Mission32_Ortho_NAD83akz4-0-1 Mission32_Ortho_NAD83akz4-1-0 Mission32_Ortho_NAD83akz4-1-1 Mission32_Ortho_NAD83akz4-2-1 Mission32_Ortho_NAD83akz4-2-2	M32_MLLW_OPT	-0.704406	
M33	Mission33_Ortho_NAD83akz4	M33_MLLW_OPT	-0.501	
M34	Mission34_Ortho_NAD83akz4	M34_MLLW_OPT	-0.168336	
M35	Mission35_Ortho_NAD83akz4	M35_MLLW_OPT	0.322644	
M36	Mission36_Ortho_NAD83akz4	M36_MLLW_OPT	0.714426	
M37	Mission37_Ortho_NAD83akz4	M37_MLLW_OPT	-0.499094	
M38	Mission38_Ortho_NAD83akz4	M38_MLLW_OPT	-0.566093	
M39	Mission39_Ortho_NAD83akz4	M39_MLLW_OPT	-0.472877	
M40	Mission40_Ortho_NAD83akz4	M40_MLLW_OPT	0.083506	
M41	Mission41_Ortho_NAD83akz4	M41_MLLW_OPT	-0.180752	
M42	Mission42_Ortho_NAD83akz4	M42_MLLW_OPT	0.210535	
M43	Mission43_Ortho_NAD83akz4	M43_MLLW_OPT	0.378256	
M44	Mission44_Ortho_NAD83akz4	M44_MLLW_OPT	0.288722	
M45	Mission not flown			
M46	Mission not flown			
M47	Mission47_Ortho_NAD83akz4	M47_MLLW_OPT	-0.16624	
M48	Mission48_Ortho_NAD83akz4	M48_MLLW_OPT	-0.19741	
M49	Mission49_1_Ortho_NAD83akz4 Mission49_2_Ortho_NAD83akz4 Mission49_3_Ortho_NAD83akz4	M49_1_MLLW_OPT M49_2_MLLW_OPT	-0.168318	Processed in 3 sections
M50	Mission50_Ortho_NAD83akz4	M50_MLLW_OPT	-0.059223	
M51	Mission51_Ortho_NAD83akz4	M51_MLLW_OPT	0.170482	
M52	Mission52_Ortho_NAD83akz4	M52_MLLW_OPT	0.478582	
M53	Mission53_Ortho_NAD83akz4	M53_MLLW_OPT	0.430313	
M54	Mission54_Ortho_NAD83akz4	M54_MLLW_OPT	0.855491	
M55	Mission55_Ortho_NAD83akz4	M55_MLLW_OPT	0.799006	
M56	Mission56_Ortho_NAD83akz4 Mission56B_Ortho_NAD83akz4	M56_MLLW_OPT M56B_MLLW_OPT	1.24267	Processed in 2 sections
M57	Mission57_Ortho_NAD83akz4-0-0 Mission57_Ortho_NAD83akz4-0-1	M57_MLLW_OPT	1.189266	
M58	Mission58_Ortho_NAD83akz4	M58_MLLW_OPT	1.638405	

Mission#	Ortho-photomosaic (.TIFs) names	DEM (.TIFs) names	Tide	Comments
M59	Mission59_Rapidortho_NAD83_UTMz4-0-0 Mission59_Rapidortho_NAD83_UTMz4-0-1 Mission59_Rapidortho_NAD83_UTMz4-1-0	n/a	1.59597	
M60	Mission60_Ortho_Nad83akz4	M60_MLLW_OPT	0.24687	
M61	Mission61_Ortho_Nad83akz4	n/a	0.205725	
M62	Mission62_Ortho_Nad83akz4	M62_MLLW_OPT	0.19201	
M63	Mission63_Ortho_Nad83akz4	M63_MLLW_OPT	0.30806	
M64	Mission64_Ortho_Nad83akz4	M64_MLLW_OPT	0.597564	
M65	Mission65_Ortho_Nad83akz4	M65_MLLW_OPT	0.813854	
M66	Mission66_Ortho_Nad83akz4	M66_MLLW_OPT	0.408327	
M67	Mission67_Ortho_Nad83akz4	M67_MLLW_OPT	0.397937	
M68	Mission68_Ortho_Nad83akz4	M68_MLLW_OPT	1.44486	
R2	ReconFlight2_Ortho_NAD83akz4	Recon2_MLLW_OPT	0.960319	ReconFlight2

Table 20 – Ortho-photomosaic filenames and tide corrections.

Note that for reference, features in the FFFs have additional information added to assist during review. Where applicable, these are:

- Mission numbers are added to the feature "remarks" field. For example, "New rock, M6" refers to Mission 6 (from the table above) as the primary source for making the determination/recommendation. If the feature appears in an overlapping mission, the secondary mission is included in parentheses. For example, M6 (M7).
- The tide value for the time of the mission imagery is entered into the "Tidal adjustment" field for each feature. For example, a tidal adjustment of -0.014 meters means the imagery associated with the feature was flown at a negative 0.014 m tide.
- The observed (at time of observation) depth of the feature was entered into the "observed depth" field.

Ortho-photomosaics and DEM GeoTIF images are included in the Multimedia directory with the survey deliverables. These are projected as NAD83, UTM Zone 4 north. GeoTIF images are named for the associated mission, and split where necessary to minimize file size. GeoTIF DEMs open as BASE surfaces with associated elevation data in CARIS HIPS. Note that the accuracy of ortho-photomosaics and DEMs degrades towards the outside edges. Raw aerial images are included with the survey deliverables as well, organized by mission in the raw data directory.

B.4.4. SfM Quality Control

Ground control for positioning aerial imagery was not established or utilized on this project.

Instead, positioning results received reality checks by comparison to overlapping multibeam data on coincident features, as well as vessel track-line positions. Positions on features computed from overlapping, independent missions were also checked. These checks compared to within 5 m or better, on average. This was considered more than sufficient given that the alternative method of investigation (visual estimations based on range and bearing from skiff for most features) would result in much lower confidence for final positions. Some examples of these checks are shown below.

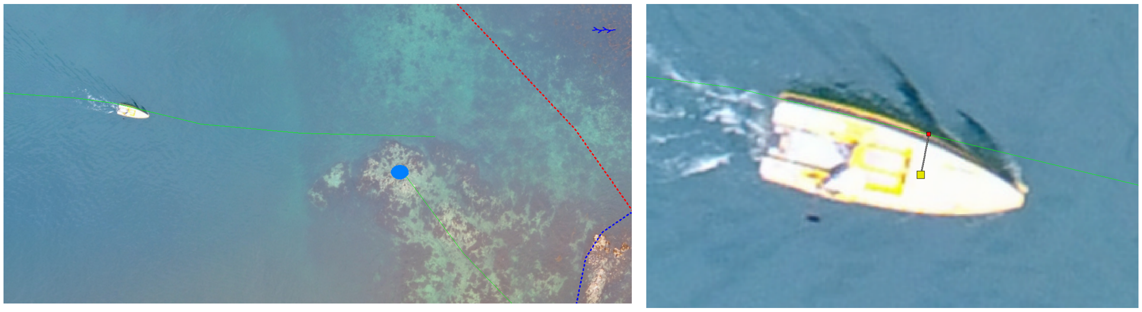


Figure 28 -- Example imagery check, compared to vessel: Ortho-photomosaic computed position of ASV vessel is displaced from its actual position (green trackline in CARIS) by about 0.9 m. The navigation center is mid-ship on the vessel, so perfect alignment would place the trackline dead-center in the imagery.

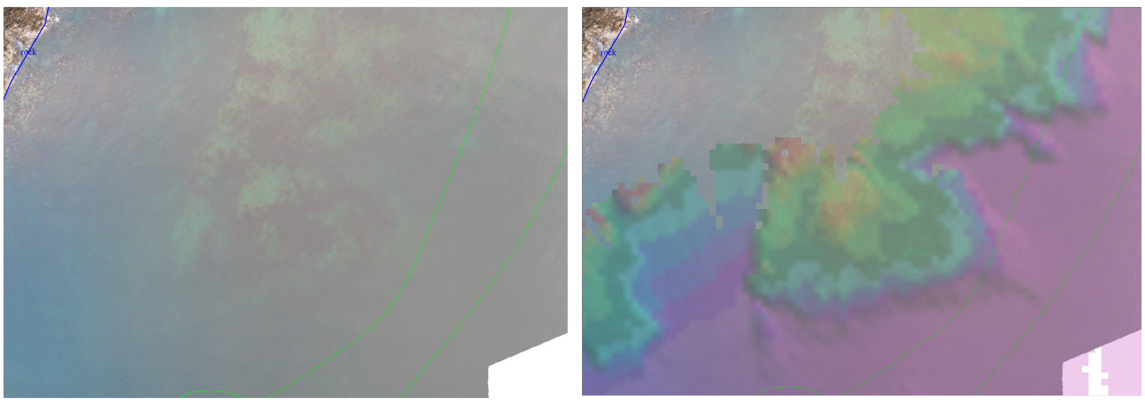


Figure 29 -- Example of common multibeam/imagery agreement: Submerged rock in imagery (left) lines up well with multibeam (overlaid on the right), to 2 m or better in this example. Rock depth at center of image is about 6 m.

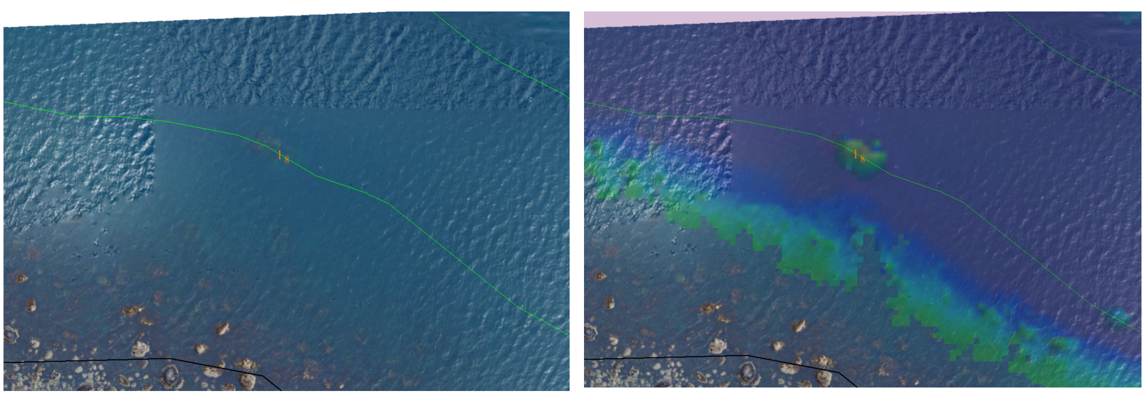


Figure 30 -- Example of common multibeam/imagery agreement: Submerged rock in imagery (left) lines up well with multibeam (overlaid on the right), to within about 3 m in this example. Rock depth (orange designated sounding) is 1.8 m.

Vertical positioning for SfM generated DEM's was reality checked by examining the waterline interface in CARIS HIPS. Assuming a proper adjustment to MLLW, the value of the DEM at the interface should match the tide value at the time of the mission (as shown in the table above). These returned results generally within +/- 0.5 m. Relative heights of features were also considered for reasonableness. This approach was considered sufficient given the alternative method of investigation (visually estimated heights from a distance from a skiff) which would result in much lower confidence for final heights.

The following table lists, by mission, statistics including image quantities and error estimates as reported by the PhotoScan software.

M#	images	stations	alt	tie pts	gsd	area km^2	proj error px	x err	y err	z err	xy err	3d err	eff overlap
m1	259	185	130	93053	3.28	0.139	0.945	3.443	2.250	0.703	4.113	4.173	4.595
m2	165	143	128	83908	3.25	0.140	0.936	2.126	2.340	1.382	3.162	3.451	3.709
m3	495	251	132	83649	3.2	0.235	0.661	3.898	5.136	1.652	6.447	6.656	3.091
m4	576	236	130	148101	3.21	0.423	0.731	4.012	2.238	1.286	4.594	4.771	3.088
m5	398	177	128	110498	3.2	0.217	0.598	4.957	2.796	1.172	5.691	5.811	3.954
m6	556	436	124	265018	3.18	0.376	0.668	4.505	3.487	0.876	5.697	5.764	6.045
m7	305	42	123	12212	3.18	0.042	0.573	1.061	0.907	0.358	1.396	1.441	3.237
m8	186	135	123	85164	3.14	0.150	0.630	3.277	2.182	0.915	3.937	4.042	5.929
m9	213	176	123	174955	3.13	0.566	0.458	5.661	5.504	1.793	7.895	8.096	3.226
m10	263	223	124	238594	3.19	0.809	0.412	3.510	2.147	1.205	4.114	4.287	3.295
m11	287	258	122	229505	3.2	0.848	0.571	6.094	4.406	1.470	7.520	7.662	4.057
m12	261	210	122	186096	3.14	0.459	1.000	4.636	4.600	2.732	6.531	7.079	3.569
m13	201	150	125	175808	3.26	0.505	0.936	1.848	2.863	1.057	3.407	3.567	3.158
m14	258	218	125	157533	3.22	0.529	0.920	7.145	4.303	5.164	8.341	9.810	4.226
m15	271	113	121	115138	3.09	0.228	0.457	1.176	1.620	1.714	2.002	2.635	3.188
m16	191	123	127	77758	3.16	0.180	0.816	7.312	3.764	2.201	8.224	8.513	3.520
m17	208	169	125	127907	3.16	0.479	0.818	2.149	1.568	1.630	2.660	3.120	2.772
m19	241	228	123	203593	3.19	0.866	0.738	2.641	1.422	1.173	2.999	3.221	3.179
m20	269	249	125	171111	3.18	0.641	1.110	2.595	1.907	2.102	3.221	3.846	2.745
m21	179	92	128	67611	3.21	0.214	0.749	2.224	1.360	1.097	2.607	2.828	2.466
m22	184	178	127	86912	3.24	0.296	1.400	6.859	4.324	2.505	8.108	8.486	3.054
m23	218	198	122	212474	3.2	0.650	0.811	4.615	3.745	0.663	5.943	5.980	2.987
m24	326	227	126	147890	3.22	0.507	0.892	7.208	4.002	0.995	8.244	8.304	3.116
m25	378	355	127	249212	3.21	0.801	0.738	1.312	1.353	0.944	1.884	2.107	4.191
m26	408	377	120	361179	3.12	1.220	0.629	4.724	6.412	1.847	7.964	8.175	3.167
m27o	302	298	435	70210	7.93	9.900	2.770	7.374	4.635	1.448	8.710	8.830	3.826
m28	374	356	123	296066	3.14	0.872	1.220	6.962	5.734	2.335	9.019	9.317	4.185
m29	384	272	121	174751	3.18	0.675	0.868	10.049	3.241	1.554	10.55	10.672	2.680
m30	314	293	91.7	353733	2.39	0.602	0.691	8.676	3.619	0.799	9.401	9.434	2.808
m31	354	345	94.2	361707	2.45	0.661	0.796	6.187	3.338	0.971	7.030	7.098	3.636
m32	427	405	89.7	434379	2.34	0.749	0.823	4.869	4.048	1.160	6.332	6.438	3.199
m33	373	345	125	287454	3.16	0.746	0.659	2.139	4.687	0.087	5.152	5.224	3.717
m34	355	307	128	311049	3.2	0.782	0.595	3.288	1.301	1.170	3.536	3.724	3.117
m35	285	229	127	221208	3.2	0.581	0.741	2.490	3.965	1.068	4.682	4.802	3.019
m36	442	346	125	373269	3.23	1.200	0.907	5.347	7.746	1.067	9.413	9.473	2.715
m37	295	269	94.6	251794	2.43	0.369	0.860	1.371	0.740	0.287	1.558	1.584	3.731
m38	437	247	125	199757	3.16	0.452	0.620	1.414	1.172	0.832	1.836	2.016	3.837
m39	451	355	124	311758	3.2	0.878	0.548	4.369	2.784	1.758	5.180	5.470	3.945

M#	images	stations	alt	tie pts	gsd	area km^2	proj error px	x err	y err	z err	xy err	3d err	eff overlap
m40	336	300	122	228354	3.17	0.414	1.040	2.339	0.913	1.295	2.511	2.826	3.672
m41	343	271	124	196176	3.2	0.506	0.472	2.288	5.702	0.815	6.144	6.198	4.324
m42	365	265	125	137677	3.25	0.482	1.190	1.639	1.849	1.208	2.471	2.750	3.119
m43	296	207	122	197375	3.11	0.413	0.425	0.828	1.133	0.774	1.403	1.602	3.220
m44	251	116	99.3	90663	2.44	0.150	1.300	4.133	2.044	2.320	4.611	5.161	3.558
m47o	447	332	271	197347	6.43	1.070	0.554	6.199	4.805	3.185	7.843	8.465	6.320
m48o	250	133	335	117135	8.21	1.450	0.517	3.090	3.024	1.530	4.323	4.586	4.449
m49	361	140	148	84011	2.69	0.662	0.721	0.375	0.498	1.832	0.624	1.935	2.588
m50	369	159	141	165474	3.43	0.390	0.625	2.682	3.975	1.903	4.795	5.159	2.948
m51	447	283	115	275457	2.84	0.623	0.811	4.740	2.463	1.705	5.428	5.690	3.851
m52	506	385	157	278384	3.55	0.688	0.752	2.352	1.626	2.755	2.860	3.970	4.086
m53	388	176	130	73658	3.17	0.172	0.759	4.699	3.144	1.001	5.653	5.741	3.296
m54	542	375	168	317617	3.55	0.577	0.636	3.000	4.385	2.515	5.313	5.878	4.069
m55	335	177	130	75454	3.19	0.238	1.090	1.203	1.579	1.258	1.985	2.350	3.836
m56	143	68	143	52424	3.12	0.149	0.691	8.694	3.830	3.140	9.500	10.005	3.091
m57	419	166	129	107008	3.13	0.196	0.748	4.004	6.326	0.698	7.487	7.519	2.956
m58	375	177	131	293880	3.01	0.131	0.419	1.847	1.136	1.153	2.168	2.456	3.128
m59	523	125	138	60334	3.07	0.183	0.492	8.287	7.760	3.180	11.35	11.790	3.008
m60	421	355	185	292234	3.4	0.615	0.528	1.892	2.675	3.220	3.276	4.594	4.075
m62	282	213	325	124217	5.15	0.745	0.573	2.558	2.515	1.905	4.347	4.746	3.798
m63	384	324	83.3	302183	2	0.182	0.368	2.384	3.954	1.853	4.617	4.975	3.547
m64	260	190	123	111356	3.13	0.240	1.430	2.922	1.778	2.911	3.421	4.494	3.884
m65	286	88	130	7138	3.2	0.099	2.580	4.896	4.456	2.913	6.620	7.232	2.353
m66	453	140	213	136027	4.35	0.199	0.472	2.898	3.917	1.876	4.873	5.222	3.483
m67	430	125	106	2.65	57063	2.650	0.049	3.559	0.883	1.492	3.667	3.959	4.017
m68	292	204	112	75854	2.68	0.060	0.942	1.276	1.744	2.580	2.161	3.653	6.076
R2	44	33	119	13712	2.95	9.880	0.403	4.330	3.743	3.961	5.723	6.961	3.410
Avg	**332**	**226.8**	**139.3**	**177279**	**881**	**0.818**	**0.798**	**3.887**	**3.162**	**1.664**	**5.143**	**5.505**	**3.602**
stdev	**108**	**94.8**	**57.4**	**102979**	**7077**	**1.679**	**0.423**	**2.226**	**1.701**	**0.925**	**2.567**	**2.527**	**0.819**

m# = Mission number
images = Number of photos submitted to the processing chunk. More photos may have been collected, but manually excluded.
stations = Number of camera positions retained for alignment by PhotoScan for processing chunk
alt = Avg GPS altitude of camera positions
tie pts = Aero-Triangulation points created
gsd = Average ground sample distance (pixel resolution)
area km^2 = Area modeled by station images
proj error px = SfM projection error for Aero-Triangulation process
x err = Average Longitude camera location error
y err = Average Latitude camera location error
z err = Average vertical camera location error
xy err = Average horizontal camera location error
3d err = Average total camera location error
eff overlap = Effective overlap of station images used for SfM reconstruction.

Table 21 – Summary of SfM processing statistics.

B.5. Confidence Checks

In addition to the crossline comparisons and daily QC efforts utilized during acquisition and processing described previously in this report, formal confidence checks were also completed throughout the survey.

The table below summarizes the formal confidence checks. Planned intervals (for example, the weekly SVP comparison) were not always achieved on schedule due to weather or operational concerns. However, planned confidence checks were accomplished as soon as possible when conditions allowed.

Confidence Check	Purpose	Frequency
Depth Checks (Bar and/or Lead Line)	Check depth accuracy Determine and refine Z offsets	Once per project
Echosounder Depth Comparison (Multiple Vessels)	Overall check of consistency of survey systems between independent vessels	No planned frequency; generally weekly, but done when operationally convenient
SVP Comparison	Check SVP sensor for consistency	Once per project
Base Station Position Check	Ensure stable and repeatable base station position	Weekly
Vessel Position Confidence Check – Alternate Base Station	Check for accurate and consistent vessel positioning regardless of base station used (CORS versus project base)	Weekly
Staff Shots	Check of tide gauge stability	N/A for this project
SSS Confidence Check	Confirm SSS contact detection capabilities	N/A for this project
Shoreline Feature Positioning Check	Confirm positioning results obtained from SfM methodology for shoreline features	Periodically, as convenient

Table 22 – Summary of formal confidence checks.

B.5.1. Bar Checks

For this survey, 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* only. The *ASV-CW5* did not receive a bar check – MBES data was compared directly to *Q105* data instead (see multi-vessel echosounder comparisons below).

MBES accuracy was checked by bar check methods on *Q105* on JD204. The test was done while alongside the dock in Sand Point, under excellent conditions.

To perform the bar check, a rectangular steel grate was hung by cable from the vessel's gunwale. The cable was marked at an interval of 0.5 m from the bar and measured carefully by tape. A sound speed profile was collected, and static draft was measured.

With QINSy logging and the sonar tuned to track the bar instead of the bottom, the bar was lowered in 0.5 m increments directly below the transducer while bar depth and time were noted in the log. Bar check depths ranged from 3-8 m and were limited by the ability to track the bar and the depth in the harbor under the sonar.

The bar depth was read relative to the waterline for later comparison to the CARIS HIPS results, as well as from the gunwale for checking the acoustic center offset.

Bar checks were processed in CARIS HIPS. The heave data record was removed, and the MBES data was sound speed corrected using the associated profile, and waterline measurement 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.

Comparison results were excellent: Actual bar depths compared to processed bar depths within 0.008 m on average, with a standard deviation of 0.025 m.

Bar check logs (processing and sonar depth check logsheet) are available with the echosounder accuracy test results, in *Appendix II* of this report.

B.5.2. Lead Line Check

A lead line check was deployed to check for gross error in the absolute accuracy for the echosounder and processing systems. This check was done for the *Q105* on JD204 concurrent with the bar check described previously, under excellent conditions in the Sand Point harbor.

The check was accomplished by lowering a measuring tape outfit with a 3 lb. weight to the seafloor and noting the waterline level on the tape. This was done as close as possible to the echosounder mount location to help minimize the effect of slope, although no slope was apparent on the seafloor at the test position.

A sound speed profile and static draft was taken near in time to the lead line check, and QINSy recorded the echosounder data during the test. Later in processing, the CARIS HIPS-computed depth was compared to the lead line depth in a sonar depth check log.

Results were excellent: The lead line read 7.80 m, while processed CARIS data returned 7.807 m, a difference of 0.007 m.

The sonar depth check logsheet, which includes the lead line results, are available in *Appendix II* of this report.

B.5.3. Echosounder Depth Comparison (Multi-Vessel)

Echosounder depth comparison lines were completed regularly during the project. During these checks, both vessels ran survey lines as close as possible in time, usually minutes apart. This allowed for a comprehensive comparison of results obtained by independent survey platforms for the same seafloor while minimizing the potentially confounding temporal factors of tide or bottom change.

On this project, patch tests were used for the depth comparisons. The patch tests were completed by both vessels in order to check calibration values as well as provide data for a good inter-vessel comparison.

Comparison data was processed identically to mainscheme, following the procedures described previously in this report, including application of all final correctors. Using the data, CARIS BASE CUBE surfaces at 2 m or 4 m resolution (depending on depth) were created for each vessel, and differenced from each other. The difference surfaces were exported to text and analyzed in Excel.

Echosounder data from the separate vessels compared well, with average results falling in a range of -0.056 m (*ASV* shoaler) to 0.021 m (*Q105* shoaler).

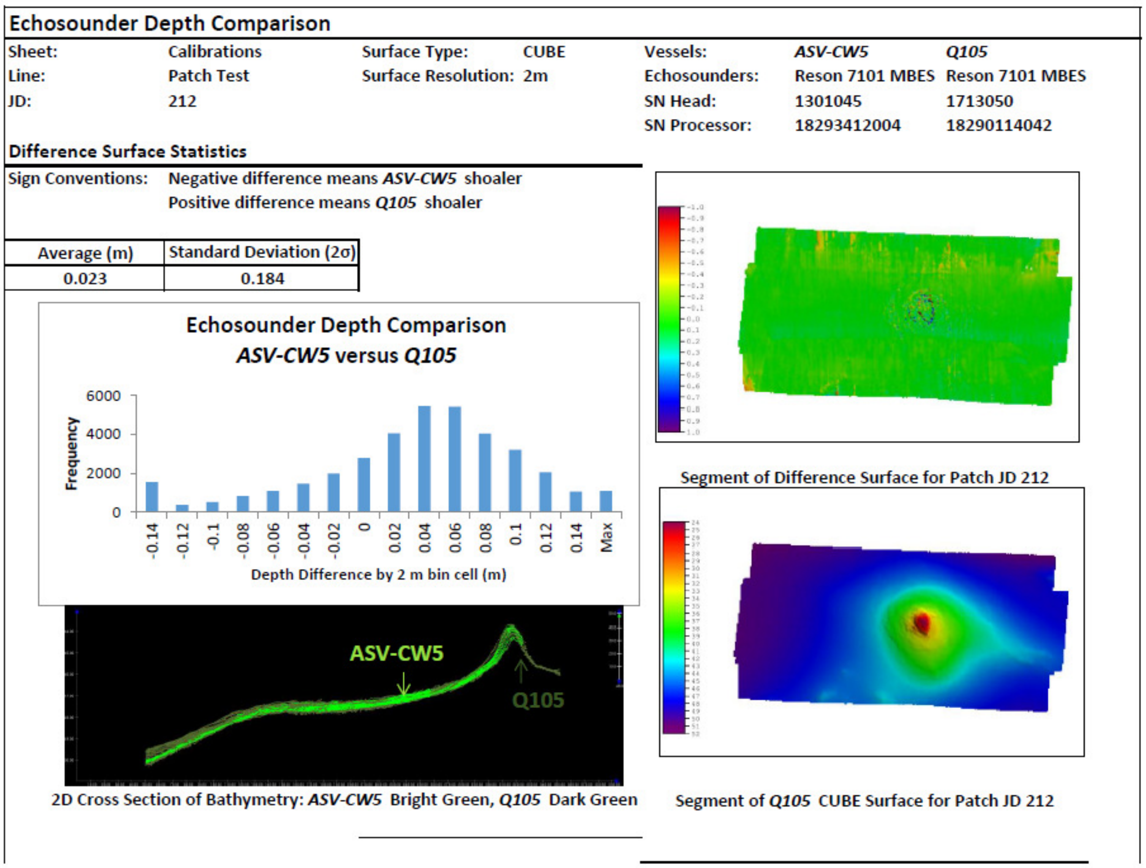


Figure 31 – Example Echosounder Depth Comparison report from this project.

Good agreement between the vessels – each with completely independent sonar and positioning systems – helps demonstrate the lack of significant systematic biases.

Echosounder depth comparison reports are available in Appendix II.

B.5.4. SVP Comparison

SVP comparisons were 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 one other independent, recently calibrated sound speed profiler. Both 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.

On this project, one formal confidence check was completed in this manner. The Valeport Rapid SV sound speed profiler—the primary profiler used on this project—was compared to Valeport Rapid CTD. This check was accomplished on JD226 and extended to a depth of approximately 46 m. Comparison results were good, with the probes comparing to each other within 0.3-0.5 m/s in depths up to 19 m and 0.5-0.8 m/s in depths from 19-45 m. Sound velocity determined by the Rapid CTD is consistently higher than the Rapid SV, but within an acceptable margin. A difference outlier of 1.1 m/s is present at 38 m due to a strong thermocline that caused rapid change in sound velocity over a 0.4 m depth range. The difference drops to 0.6 m/s immediately above and below the thermocline, indicating that the rapid change in sound velocity over a short depth range amplified the offset between the probe's sensors. Some offset is likely due to the different sensing technology used by the two profilers (direct sound speed measurement of the RapidSV, versus C/T-computed from the RapidCTD).

SVP confidence checks / comparison results are available in *Separate II* of the DRs.

SV Probe Results		
Sensor:	Valeport RapidSV	Valeport RapidCTD
SN:	49911	52756
Date of Cal.	5/22/2017	5/24/2017
Date/Time:	2017-226 03:25:56	2017-226 03:25:56
Depth	Sound Speed (m/s)	
0.6	1495.18	1495.54
0.7	1495.2	1495.53
0.8	1495.2	1495.55
0.9	1495.16	1495.56
1	1495.15	1495.54
1.1	1495.15	1495.54
1.2	1495.16	1495.55
1.3	1495.15	1495.55
1.4	1495.15	1495.54
1.5	1495.15	1495.55
1.6	1495.15	1495.55
1.7	1495.16	1495.56
1.8	1495.15	1495.55
1.9	1495.12	1495.55
2	1495.1	1495.55
2.1	1495.1	1495.54
2.2	1495.14	1495.54
2.3	1495.15	1495.54
2.4	1495.14	1495.54
2.5	1495.12	1495.53
2.6	1495.12	1495.53
2.7	1495.09	1495.53
2.8	1495.08	1495.53
2.9	1495.06	1495.52
3	1495.06	1495.52
3.1	1495.05	1495.53
3.2	1495.05	1495.52
3.3	1495.06	1495.53
3.4	1495.07	1495.53
3.5	1495.07	1495.52

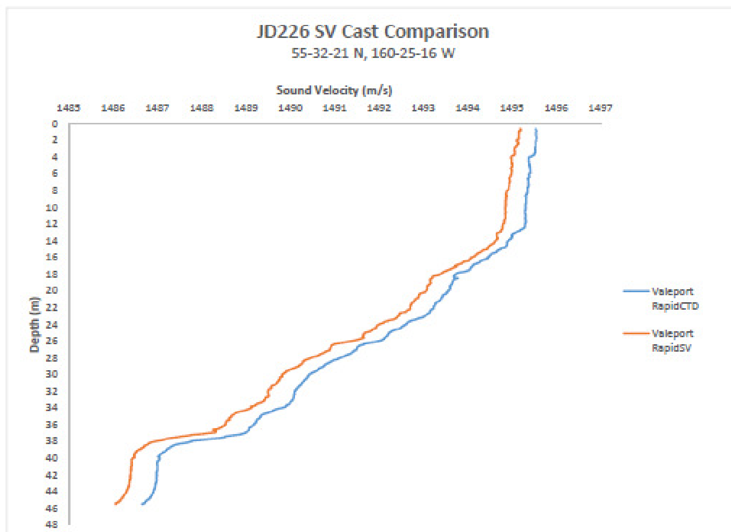


Figure 32 – Example of SVP confidence check (comparison results).

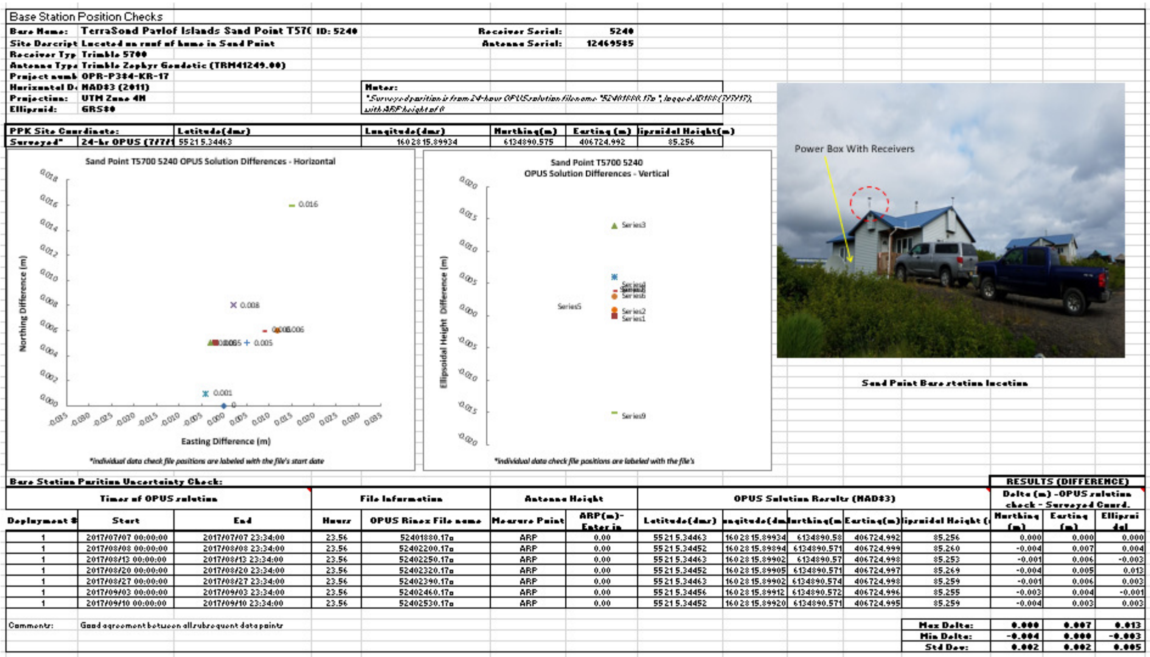
B.5.5. Base Station Position Checks

For the project base stations, the precise geographic position was established using NOAA NGS Online Positioning User Service (OPUS) by upload of the initial 24-hour GPS static session logged at the sites. This position became the accepted, surveyed position that was used for data processing, as well as the position against subsequent measurements were compared.

Confidence checks on the stability of the GPS base stations, as well as repeatability of the position solutions, were accomplished by weekly upload of 24-hour data series to NGS

OPUS (Online Positioning User Service). Base data was converted to Rinex using the Trimble Convert to Rinex utility within Applanix POSPac. The Rinex observation file was zipped and uploaded to OPUS at https://www.ngs.noaa.gov/OPUS/. Antenna type was selected as “TRM41249” to correspond to the Trimble Zephyr Geodetic antenna used for each base. An ARP of 0 m was intentionally entered for antenna height so that results would be returned for the ARP instead of a survey mark, which was not applicable to the rooftop placement of the base stations on this project.

Results returned by OPUS compared to 0.014 m vertically and 0.016 m horizontally (or better) of the original position, which demonstrates excellent stability of the initial ARP positions for the base stations. Results were recorded in a base station confidence check logsheet, available in *Separate I* of the project DRs. Base data in Rinex format available with the project HVCR.



Base Station Position Checks

Base Name:	TerraSond Pavlof Islands Sand Point T57(ID: 5240	Receiver Serial:	5240
Site Descript	Located on roof of home in Sand Point	Antenna Serial:	12469585
Receiver Typ	Trimble 5700		
Antenna Type	Trimble Zephyr Geodetic (TRM41249.00)		
Project numb	OPR-P384-KR-17		
Horizontal D	NAD83 (2011)	Notes:	
Projection:	UTM Zone 4N	*Surveyed position is from 24-hour OPUS solution filename "52401880.17o", logged JD188 (7/7/17), with ARP height of 0	
Ellipsoid:	GRS80		

PPK Site Coordinate:		Latitude(dms)	Longitude(dms)	Northing(m)	Easting (m)	Ellipsoidal Height(m)
Surveyed*	24-hr OPUS (7/7/1	55 21 5.34463	160 28 15.89934	6134890.575	406724.992	85.256

Base Station Position Uncertainty Check:

Times of OPUS solution			File Information		Antenna Height		OPUS Solution Results (NAD83)					RESULTS (DIFFERENCE) Delta (m) - OPUS solution check - Surveyed Coord.		
Deployment #	Start	End	Hours	OPUS Rinex File name	Measure Point	ARP(m)-Enter in	Latitude(dms)	Longitude(dms)	Northing(m)	Easting(m)	Ellipsoidal Height (m)	Northing (m)	Easting (m)	Ellipsoidal
1	2017/07/07 00:00:00	2017/07/07 23:34:00	23.56	52401880.17o	ARP	0.00	55 21 5.34463	160 28 15.89934	6134890.58	406724.992	85.256	0.000	0.000	0.000
1	2017/08/08 00:00:00	2017/08/08 23:34:00	23.56	52402200.17o	ARP	0.00	55 21 5.34452	160 28 15.89894	6134890.571	406724.999	85.260	-0.004	0.007	0.004
1	2017/08/13 00:00:00	2017/08/13 23:34:00	23.56	52402250.17o	ARP	0.00	55 21 5.34463	160 28 15.89902	6134890.57	406724.998	85.253	-0.001	0.006	-0.003
1	2017/08/20 00:00:00	2017/08/20 23:34:00	23.56	52402320.17o	ARP	0.00	55 21 5.34452	160 28 15.89905	6134890.571	406724.997	85.269	-0.004	0.005	0.013
1	2017/08/27 00:00:00	2017/08/27 23:34:00	23.56	52402390.17o	ARP	0.00	55 21 5.34463	160 28 15.89902	6134890.574	406724.998	85.259	-0.001	0.006	0.003
1	2017/09/03 00:00:00	2017/09/03 23:34:00	23.56	52402460.17o	ARP	0.00	55 21 5.34456	160 28 15.89912	6134890.572	406724.996	85.255	-0.003	0.004	-0.001
1	2017/09/10 00:00:00	2017/09/10 23:34:00	23.56	52402530.17o	ARP	0.00	55 21 5.34452	160 28 15.89920	6134890.571	406724.995	85.259	-0.004	0.003	0.003
Comments:	Good agreement between all subsequent data points										Max Delta:	0.000	0.007	0.013
											Min Delta:	-0.004	0.000	-0.003
											Std Dev:	0.002	0.002	0.005

Figure 33 – Example Base Station Position Check logsheet.

B.5.6. Vessel Positioning Confidence Checks – Alternate Base Station

To ensure vessel positioning was consistent regardless of the base station in use, and as an accuracy check of vessel positioning, vessel position confidence checks were accomplished by using an alternate base station independent of the base station primarily used for PPK processing. 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 re-processed with one of the project base stations, 0056. This was compared to the POS file originally processed using the CORS site AB07 in Sand Point. 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 (see example below) along with the comparison parameters and observations.

Results were good, with average differences agreeing to 0.1 m or better, demonstrating consistent results regardless of the base station used. However, a shift of approximately 0.06 m horizontally and 0.02 m vertically is evident in the checks for both vessels (see figure below) demonstrating a small systematic bias depending on the base station used. The bias was not extensively investigated since it is well within positioning specifications.

The vessel positioning confidence check logs are available in *Separate I* of the DRs.

TerraSond Limited | Vessel Positioning Confidence Check | NOAA Pavlof Islands and Vicinity

Vessel Positioning Confidence Check

(Comparison of PPK vessel position results using primary and alternate base station)

POS file: 2017-208-0204-Q105.POS	**Date:** July 27, 2017 (JD208)	**Vessel:** Qualifier 105

Base Stations Used

Base Station Name	Operating Agency	Function	Data Rate	Min. Baseline Distance (m)	Max. Baseline Distance (m)
AB07 (ASB)	UNAVCO/PBO	Project Primary	15 Second	200	5,300
0056	TerraSond	Backup/Comparison	1 Second	14,000	24,000

Table 1- Base stations used for comparison

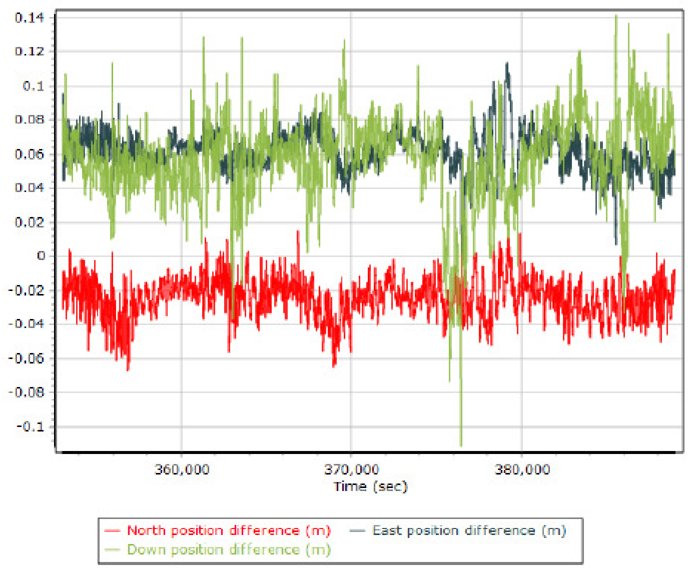


Figure 1 - Results of position difference between 2017-208-0204-Q105.POS processed with AB07 and 0056

Result Statistics

Position	Min. Difference (m)	Max. Difference (m)	Mean Difference (m)
North	-0.067	0.016	-0.025
East	-0.002	0.014	0.006
Down	-0.110	0.140	0.015

Table 2 - Approximate minimum, maximum and mean differences

Comments: *Agreement is excellent for both horizontal and vertical.*

Figure 34 – Example of Vessel Positioning Confidence Check (alternate base station), from JD208.

B.5.7. Tide Station Staff Shots and Operation

Per the tides SOW, a subordinate zoning tide station was deployed in Zachary Bay. Tidal data from this station (station number 9459465) was applied for zoning purposes only, and leveling was not required.

The gauge was installed in a BMPG configuration with a surface GPS buoy for quality control. Refer to Section A of this report for photos and more information on the equipment used at the site, as well as the HVCR.

C. ***Corrections to Echo Soundings***

The following methods were used to determine, evaluate, and apply corrections to instruments and soundings.

C.1. Vessel Offsets

Sensor locations were established with a pre-season survey of the vessels using conventional survey instruments.

A Center Reference Point (CRP), or point from which all offsets were referenced, was selected for each vessel. The top-center of each vessel's POSMV IMU was selected for this purpose.

On both vessels, the primary POSMV GNSS antenna to POSMV IMU offset was applied automatically during data collection (and subsequent post-processing) through the POSMV lever arm settings. Therefore, navigation and attitude values in the raw data as well as CARIS HIPS were already reduced to the CRP. Remaining offsets such as the CRP to transducer and CRP to waterline were applied by way of the HVF.

It is important to note that X, Y, and Z offsets were entered only under the SV1 sensor in the HVF. Per consultation with CARIS, this configuration is necessary to allow correct application of the offsets during sound velocity correction when using S7k data from Reson 71xx-series sonars, including those used on this project.

Offsets received checks including gross error reality checks by survey tape and bar check. Offset uncertainties varied, and are described previously in the TPU section of this report. Vessel outlines and offset descriptions are provided in the following figures and tables.

C.1.1. Q105 Vessel Offsets

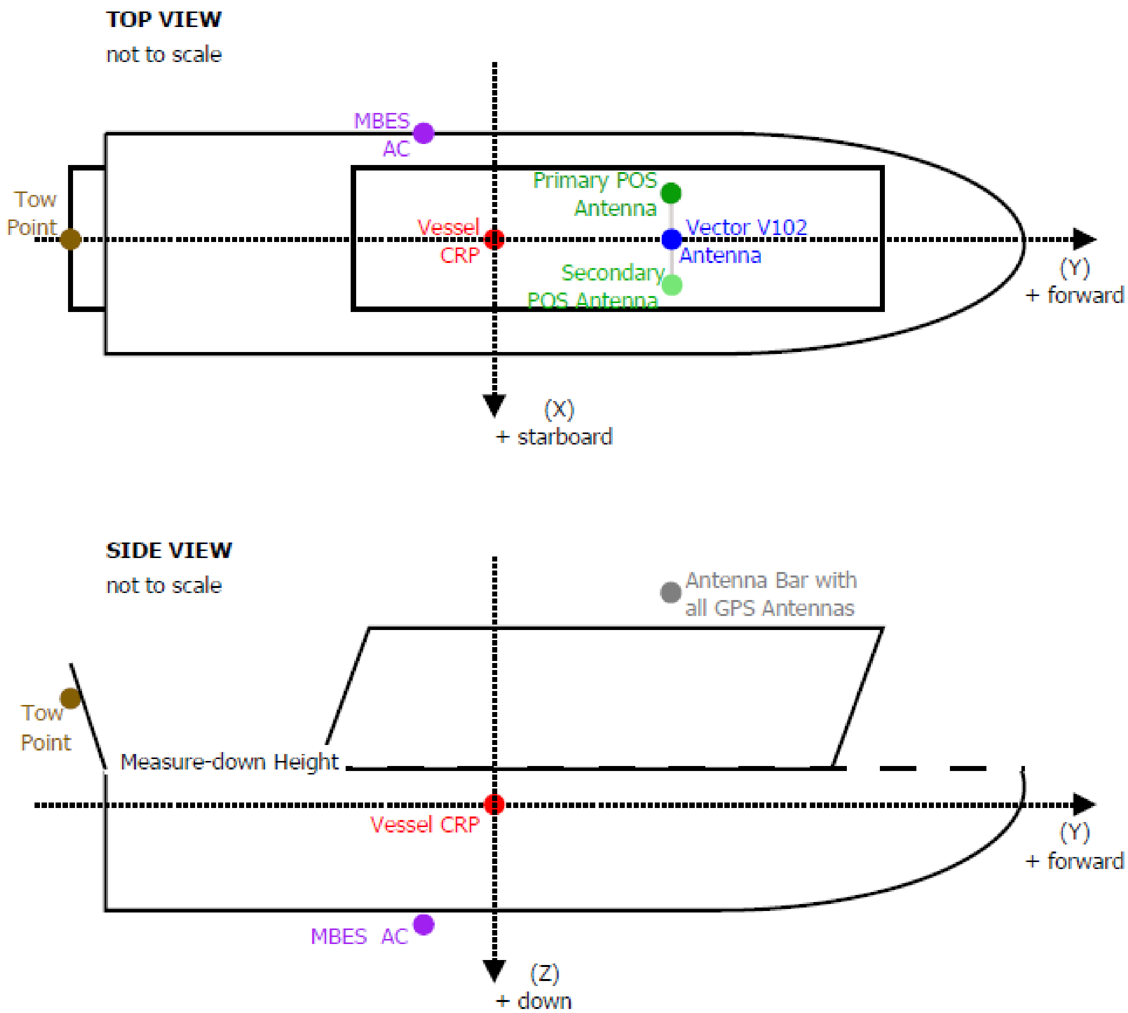


Figure 35 – Q105 vessel survey showing relative positions of installed survey equipment.

Equipment	X (m) (+ stbd)	Y (m) (+ fwd)	Z (m) (+ down)	Comments
CRP	0.000	0.000	0.000	Top-center of POSMV IMU
MBES Acoustic Center (AC)*	-4.178	-3.380	1.120	X, Y from vessel survey, Z value derived from bar checks
Primary POS Antenna	-0.998	5.093	-13.903	X, Y from vessel survey, Z value derived from POSPac calibration
Secondary POS Antenna	0.998	5.096	-13.954	Primary position corrected by GAMS computed A-B vector
Stern Tow Point	0.000	-14.940	-4.00	A-frame block in tow position. Not used this project.
Draft Measure-down Point (port side)	-	-	-2.551	
Draft Measure-down Point (stbd side)	-	-	-2.551	
(*) As described in Section B of this report, data collected prior to JD202 required a "dual-head" type setup of the HVF despite use of a single head sonar. Therefore the "DH" version of the HVF includes separate offsets computed for the Tx and Rx portions of the 7101 MBES transducer. For Tx (SV1 in the HVF) these are X=-4.178, Y=-3.509, Z=1.204. For Rx (SV2 in the HVF), these are X=-4.178, Y=-3.208, Z=1.120.				

Table 7 – Q105 offset measurements relative to CRP.

C.1.2. ASV-CW5 Offsets

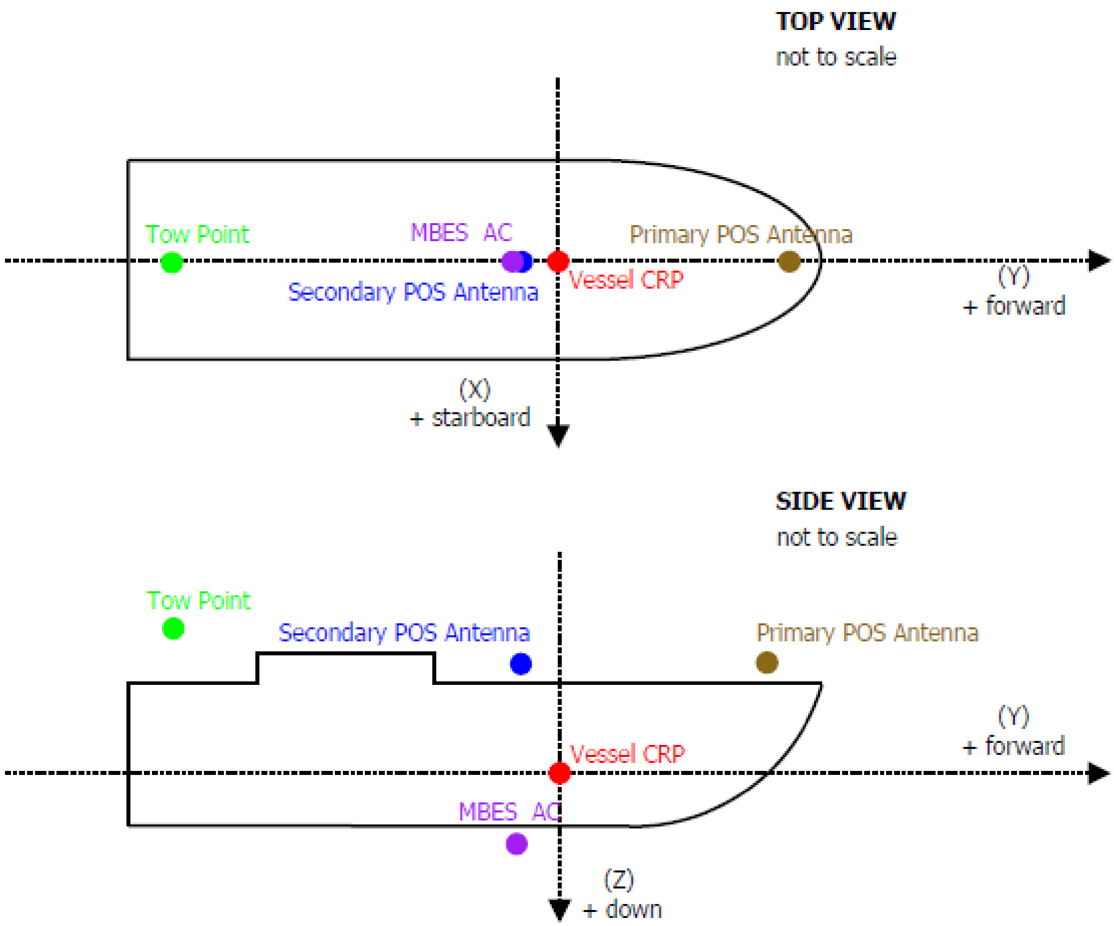


Figure 36 – ASV-CW5 vessel survey showing relative positions of installed survey equipment.

Equipment	X (m)	Y (m)	Z (m)	Comments
	(+ stbd)	(+ fwd)	(+ down)	
CRP	0.000	0.000	0.000	Top-center of POSMV IMU
MBES Acoustic Center (AC)	0.026	-0.526	0.663	Start of project until JD210 (01:10)*
	0.026	-0.526	0.613	JD210 (01:10) to JD211 (00:50)
	0.106	-0.526	0.638	JD211 (00:50) to end of project (rotated head)
Primary POS Antenna	0.000	1.115	-1.080	POSPac - Computed
Secondary POS Antenna	-0.005	-0.398	-1.049	Primary position corrected by GAMS computed A-B vector
Stern Tow Point	0.000	-3.17	-0.91	A-frame block in tow position (not used this project)
Draft Measure-down Point (port side)	-	0.000	-0.808	ASV deck above CRP
Draft Measure-down Point (stbd side)	-	0.000		
(*) As described in Section B of this report, data collected prior to JD202 required a “dual-head” type setup of the HVF despite use of a single head sonar. Therefore the “DH” version of the HVF includes separate offsets computed for the Tx and Rx portions of the 7101 MBES transducer. For Tx (SV1 in the HVF) these are X=0.026, Y=-0.649, Z=0.747. For Rx (SV2 in the HVF), these are X=0.026, Y=-0.354, Z=0.663.				

Table 24 – ASV-CW5 offset measurements relative to CRP.

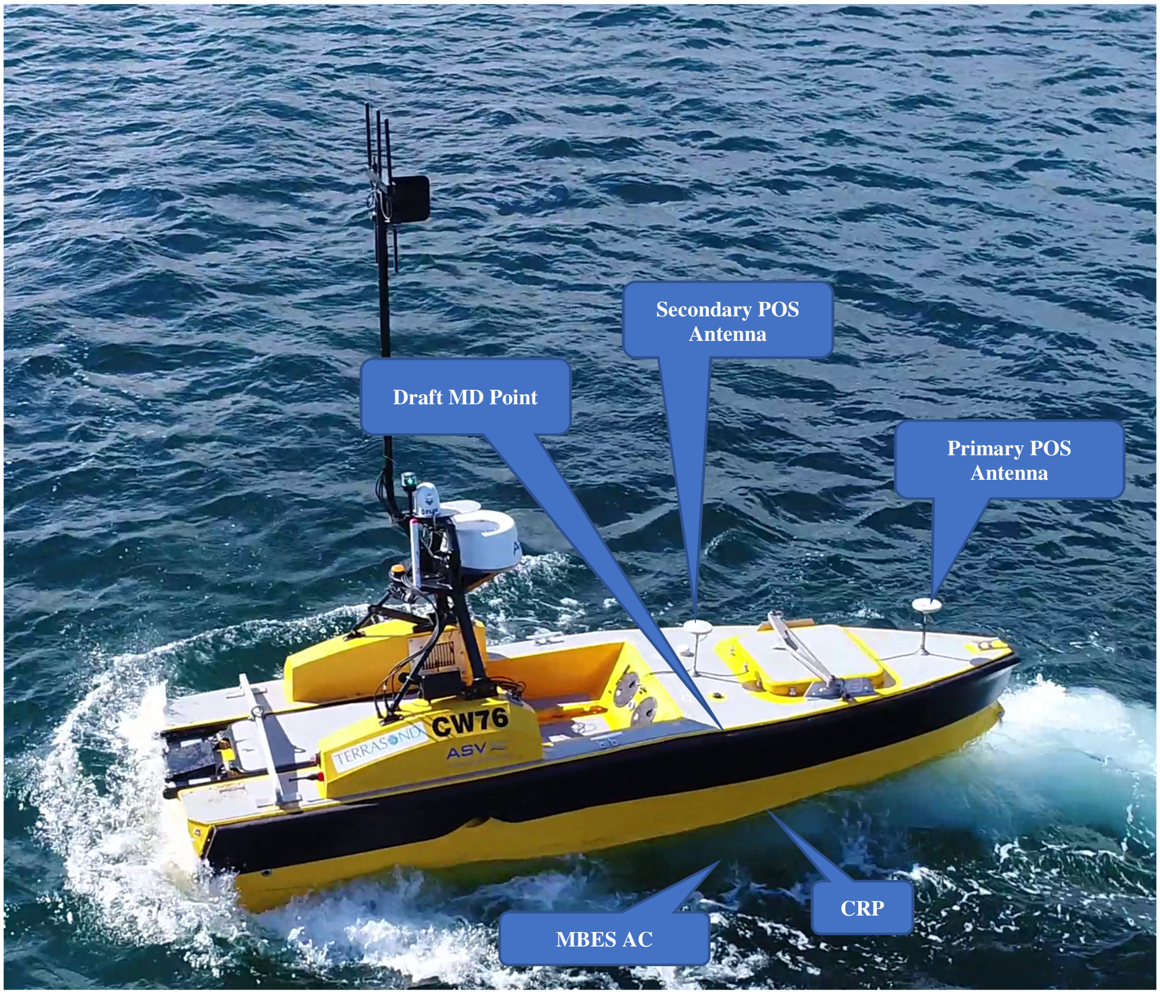


Figure 37 – ASV-CW5 primary sensors and offset measurement points.

C.2. Attitude and Positioning

As described in previous sections of this report, positioning, heave, roll, pitch, and heading (gyro) data were measured on both vessels with Applanix POSMV systems. On each vessel, the system was configured to output attitude and position for the top-center of the system's IMU, which was also used as the vessel CRP. POSMV data was output to QINSy as a UDP network stream and logged to DB and XTF file while online. During survey operations, raw POSMV data was continually recorded to a POS file via a TCP network stream, which was post-processed to improve position and attitude accuracy, as well as to apply TrueHeave (Delayed Heave) data.

A GAMS (GPS azimuth measurement subsystem) calibration was done per POSMV manufacturer recommendations to ensure correct heading output. The results are shown below.

Vessel	Date (JD)	A-B Antenna Separation (m)	Baseline Vector (m)		
			X (+ stbd)	Y (+ fwd)	Z (+ down)
Q105	2017-195	1.997	1.996	0.003	-0.051
ASV-CW5		1.513	-0.005	-1.513	0.014

Table 25 – POSMV GAMS calibration results.

Refer to Section B of this document for descriptions of uncertainties associated with each system.

C.2.1. Q105 Pitch Error Adjustment

A pitch error of 3.3° was identified and quantified via bar check results on the *Q105,* and applied via the HVF to all multibeam data. This was done because CARIS bar check results exhibited a discrepancy of about 0.20 m, with the *Q105* soundings shoaler than the actual bar depth when pitch and roll was applied. The value of 3.3° was computed using the difference between the bar depth and the CARIS value and the horizontal distance between the vessel measure down point and bar check point. The value represents the angle that aligns the vessel reference frame (vessel survey) and the motion sensor reference frame. The correction was first identified on this vessel in 2014 and reconfirmed annually, including on this project.

With the correction applied to the bar check data, agreement was improved to better than 0.008 m on average. Agreement with the *ASV-CW5* was also excellent, with the two sets agreeing within 0.056 m or better on average.

C.3. Calibration / Patch Tests

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

After arriving on site on JD195, an initial patch test was completed as soon as a definite bottom feature was observed in the MBES data.

Additional patch tests were completed whenever major configuration changes occurred that could affect the alignment between the POSMV and MBES systems (for example, after remounting MBES sonar heads) as well as occasional quality control checks on the stability of calibration values.

Configuration changes (and therefore patch tests) were more common than usual on this project due to MBES issues discussed previously in this report. Additionally, if one vessel required a new patch test because of a configuration change, the other would typically also patch test over the same feature to provide data for an inter-vessel depth check comparison while simultaneously providing a calibration value stability check.

Although patch tests were prioritized following configuration changes, it was not always practical to patch test immediately following the change. Therefore, patch test results are back-dated when necessary in the HVFs to coincide with the configuration change.

Patch test data received standard corrections and processing prior to examination. This included sound speed correction, filtering, corrections for tide and delta draft, and application of PPK (SBET) and Delayed Heave data.

The calibration test data for each vessel is available for review with the CARIS HIPS deliverables in the “Calibrations” project.

C.3.1. Latency, Pitch, Roll, and Yaw

Industry-standard patch test procedures were used to determine latency, pitch, roll, and yaw correctors.

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 in to the HVF.

Note that the timing correction (if any) was entered in to 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. Note that as described previously in this report, a pitch error of 3.3° was identified via bar checks in the *Q105* data, and was corrected prior to determining the pitch offset.

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 in to 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 in to the HVF.

Refer to Section B of this report for uncertainties associated with patch test results. Results are summarized below.

<table>
<tr><th>Vessel</th><th>Patch Test Time</th><th>Valid Start Time in HVFs</th><th>Latency (seconds)</th><th>Pitch</th><th>Yaw</th><th>Roll</th><th>See Note</th></tr>
<tr><td rowspan="5">Q105</td><td>2017-195 21:00</td><td>2017-191 00:00</td><td>0.000</td><td>-0.300</td><td>1.800</td><td>-0.235</td><td>1</td></tr>
<tr><td>2017-203 07:30</td><td>2017-197 19:20
2017-201 23:50</td><td>0.000</td><td>-0.900</td><td>2.500</td><td>1.750</td><td>2</td></tr>
<tr><td colspan="2">2017-210 05:20</td><td>0.000</td><td>-1.700</td><td>1.900</td><td>1.625</td><td>3</td></tr>
<tr><td>2017-212 15:19</td><td>2017-212 00:00</td><td>0.000</td><td>-1.450</td><td>2.050</td><td>1.665</td><td>4</td></tr>
<tr><td colspan="2">2017-225 13:29</td><td>0.000</td><td>-1.770</td><td>2.400</td><td>1.665</td><td>5</td></tr>
<tr><td rowspan="5">ASV-CW5</td><td>2017-195 21:23</td><td>2017-191 00:00</td><td>0.000</td><td>-0.790</td><td>0.370</td><td>0.190</td><td>1</td></tr>
<tr><td>2017-203 08:37</td><td>2017-202 00:54</td><td>0.000</td><td>-0.790</td><td>0.370</td><td>0.190</td><td>6</td></tr>
<tr><td>2017-210 05:55</td><td>2017-210 01:10</td><td>0.000</td><td>-0.940</td><td>-1.850</td><td>0.530</td><td>7</td></tr>
<tr><td>2017-212 16:02</td><td>2017-211 00:50</td><td>0.000</td><td>-1.100</td><td>-3.050</td><td>0.220</td><td>8</td></tr>
<tr><td>2017-225 13:11</td><td>n/a</td><td>0.000</td><td>-1.100</td><td>-3.050</td><td>0.220</td><td>9</td></tr>
</table>

Patch Test Notes:

1. JD195 patch test was initial patch test on site. Back-dated to JD191 cover test data collected in Homer, AK following mobilization
2. JD203 patch test back-dated to cover Q105 sonar-head swap-out which was completed on JD197 (Q105-DH HVF file). Also, back-dated to JD201 in the Q105 HVF file.
3. JD210 was a check patch test on the Q105. Slightly different values were obtained for unknown reasons, and applied at this time.
4. JD212 was done following a removal and reinstall of the entire Q105 MBES arm assembly to address issues with the arm's hydraulic deployment system
5. JD225 was a check patch test on the Q105. Slightly different values were obtained on pitch and yaw for unknown reasons, and applied starting at this time.
6. JD203 patch test was a check for the ASV-CW5. Prior values reconfirmed. Applied beginning on JD202 for ASV HVF.
7. JD210 patch test was done following re-install of ASV-CW5 MBES sonar head.
8. JD212 patch test was done following re-install of ASV-CW5 MBES sonar head in a tilted configuration. Note a course correction for the tilt of -30 degrees, denoting port-down/starboard-up, was applied as a roll correction under the SVP1 sensor in the HVF.
9. JD225 patch test was a check patch test on the ASV-CW5. Prior values reconfirmed; not entered HVF since no change was necessary.

Table 8 – Patch Test calibration results.

C.4. Speed of Sound Corrections

A Valeport RapidSV sensor deployed using a Teledyne Oceanscience RapidCAST system was used to acquire the majority of sound speed profiles for data corrections. The profiler was factory calibrated prior to commencement of survey operations.

For the majority of the survey (JD195 and JD208 through JD226), sound speed casts were approximately every 2 hours. However, the interval used was 4 hours from JD196 until late on JD207.

As described previously in this report, casts were converted and then processed in TerraSond's TerraLog software producing a CARIS HIPS-compatible format at 0.1 m depth intervals. The output was appended to the master CARIS HIPS SVP file by survey area, occasionally being placed in two survey areas when applicable to both by time and distance. Sound speed corrections were then applied in processing to the raw sounding data through CARIS HIPS "Sound Velocity Correction" utility.

Refer to Section B of this report for more information on acquisition and processing methodology and uncertainties. Refer to the project DRs, *Separate II* for sound speed confidence checks (comparisons). Refer to *Appendix IV* of this report for calibration reports. Individual processed profile data including time and position can be found in the CARIS HIPS SVP file submitted with the digital CARIS HIPS data for the survey. Unprocessed profile data is available with the raw data deliverables.

C.5. Static Draft

Vessel static draft (waterline) was measured when sea conditions allowed on the survey vessels. Measurements were taken whenever a situation had the potential to significantly change the draft, such as after fueling or adjustments in ballast.

On each vessel, static draft was observed from a measure-down point (gunwale rail on the *Q105*, deck on the *ASV-CW5*) to the waterline. The relationship between the measure-down point and the CRP, previously determined by vessel survey, was used to compute the CRP to waterline offset, which was then applied via the HVF as a waterline entry.

Refer to Section B for uncertainties associated with static draft measurements and more information regarding acquisition and processing of static draft. Static draft tables are available in the HVFs with the CARIS HIPS deliverables. Logsheets exported from TerraLog are available with the project DRs, *Separate I*.

C.6. Dynamic Draft Corrections

Dynamic draft corrections on this project are primarily engine RPM-based, not speed-based.

Corrections were determined for each vessel by means of a squat settlement tests. PPK GPS methods were used to produce and extract the GPS altitudes from the test. Corrections were determined for a range that covered normal engine RPMs and vessel speeds experienced while surveying. Results were also compared to prior year's results.

C.6.1. Squat Settlement Test Procedure

During the squat settlement test, the vessel logged raw POSMV attitude and positioning data to a POS file while the nearby shore base station logged dual-frequency GPS data at 1 Hz. 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 2 minutes. The survey crew would note the time and speed of each event.

The POS file was post-processed concurrent with the nearby base station data in Applanix POSPac software (using the workflow described previously in this report) to produce the PPK positioning data, which was exported to text and brought into Excel. Using the event notes, the positioning data was separated and grouped according to RPM/speed range and static. Each range was averaged to remove heave and motion. A polynomial equation was computed that best fit the static periods and then used to remove the tide component from each altitude. The residual result was the difference from static or dynamic draft. Finally, the results were averaged for each direction to eliminate any affect from the current, wind or other factors.

RPM data was time-tagged and logged continuously during survey operations. In processing, this data was correlated with the results of the squat-settlement tests to create a time-based dynamic draft correction file for each vessel and applied to the survey data. Refer to Section B of this report for more information on the acquisition and processing of the RPM data. The dynamic draft correction file is located in the “Tide” directory with the CARIS deliverables. The logged RPM data is located with the raw data deliverables.

C.6.2. Q105 Dynamic Draft Corrections

To determine the dynamic draft corrections, a squat settlement test was completed on JD227. RPM values between 800 and 1200 were tested at 100 RPM increments. This range encompassed the RPM settings used during survey operations. Speed was also noted during the tests. Squat settlement tests obtained on this vessel in 2013, 2014, and 2015 were compared to this test, with results showing good consistency between years, comparing on average to 0.01 m at each RPM point.

Q105 Squat Settlement Results (2017)		
RPM	**Speed (m/s)***	**Measured Dynamic Draft (m) (positive down)**
<800	<3.20	0.000
800	3.20	0.001
900	3.55	0.019
1000	3.90	0.036
1100	4.30	0.063
1200	4.70	0.090
>1200	>4.70	0.090

Table 9 – Q105 squat settlement results.

*Note that speed-based corrections are listed for reference only, but were not applied to final data, except in rare cases noted in the applicable DR. The speed-based corrections, present in the HVF were overridden for final data by loading RPM-based draft corrections through CARIS HIPS "Load Delta Draft" utility, as described in Section B of this report. Additionally, speed-based corrections in the HVF were smoothed and interpolated to a 0.1 m/s increment and therefore may vary slightly from those shown in this table, and have a maximum value of 10 m/s entered to cover any potential speeds above the top measured.

A 3rd order polynomial was used to smooth the 100-RPM results and create a correction for every 1 RPM of change, as shown in the following figure. The interpolated data—not measured data—was used for final corrections.

Figure 38 – Q105 squat settlement results (2017).

C.6.3. ASV-CW5 Dynamic Draft Corrections

To determine the dynamic draft corrections, a squat settlement test was completed on the *ASV-CW5* on JD227. RPMs of 1200 through 2600 were tested, in 100-RPM increments, a range which encompassed engine settings used during survey operations. Speed was also noted for each RPM.

***ASV-CW5* Squat Settlement Results (2017)**		
RPM	**Speed (m/s)***	**Measured Dynamic Draft (m) (positive down)**
<1200	<1.85	0.000
1200	1.85	0.022
1300	1.90	0.010
1400	1.95	-0.001
1500	2.18	0.009
1600	2.40	0.020
1700	2.51	0.020
1800	2.63	0.020
1900	2.83	0.018
2000	3.03	0.015
2100	3.11	0.011
2200	3.20	0.006
2300	3.32	-0.002
2400	3.44	-0.010
2500	3.50	-0.024
2600	3.55	-0.038
>2600	>3.55	-0.038

Table 10 – ASV-CW5 squat settlement results.

*Note that speed-based corrections are listed for reference only, but were not applied to final data, except in rare cases noted in the applicable DR. The speed-based corrections, present in the HVF were overridden for final data by loading RPM-based draft corrections through CARIS HIPS "Load Delta Draft" utility, as described in Section B of this report. Additionally, speed-based corrections in the HVF were smoothed and interpolated to a 0.1 m/s increment and therefore may vary slightly from those shown in this table, and have a maximum value of 10 m/s entered to cover any potential speeds above the top measured.

A 3rd order polynomial was used to smooth the 100-RPM results and create a correction for every 1 RPM of change, as shown in the following figure. This also had the effect of smoothing out inconsistent data points obtained for the 1200, 1400, and 1500 RPM levels that were not observed on the 2016 tests done on the same vessel. The interpolated data—not measured data—was used for final corrections.

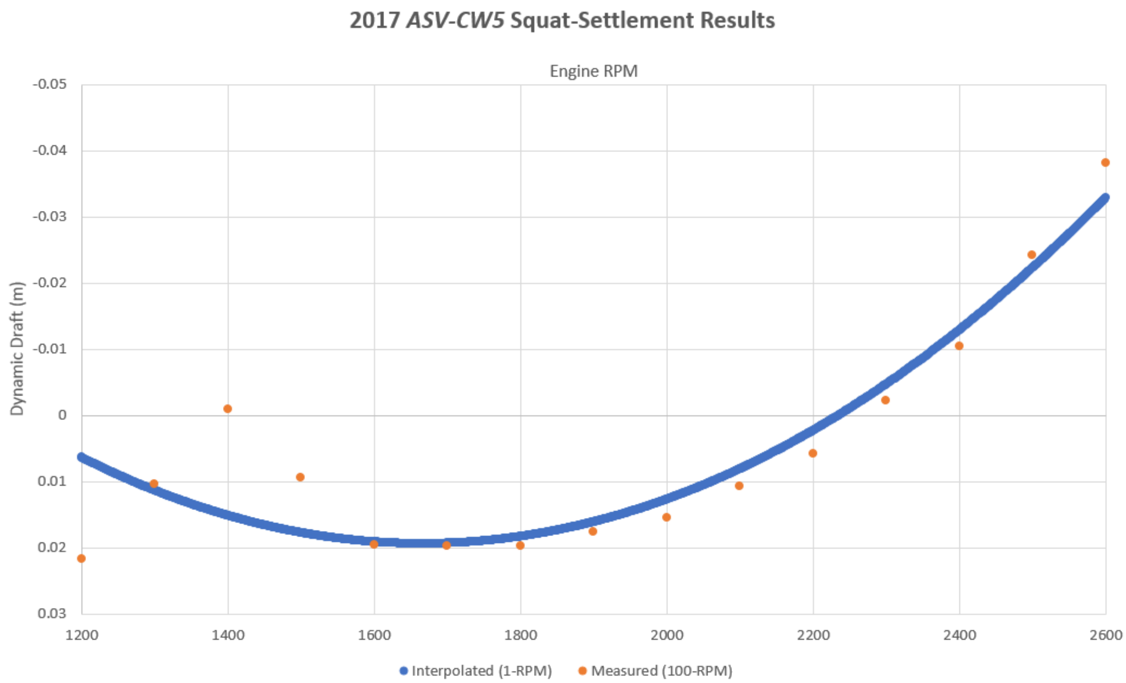


Figure 39 – ASV-CW5 squat settlement results (2017).

C.7. Tide Correctors and Project Wide Tide Correction Methodology

Final tides were based on discrete tide zones.

Time and range corrections were applied via Zone Definition File (ZDF) within CARIS HIPS to reduce all soundings to chart datum (MLLW). The ZDF applied time and range correctors for smoothed, verified data from the NWLON station at Sand Point, Alaska (9459450) using discrete geographic zones defined for the survey area.

A TCARI tide model file (P384KR2017Rev.tc) was provided for this project but was not used.

Refer to the project HVCR for additional information regarding tidal correction methodology, including tide processing and derivation of tide zones.

APPROVAL SHEET

For

Data Acquisition and Processing Report: H13034 through H13039

This report and the accompanying digital data are respectfully submitted.

Field operations contributing to the completion of this project were conducted under my direct supervision with frequent personal checks of progress and adequacy. This report, digital data, and accompanying records have been closely reviewed and are considered complete and adequate per the Statement of Work and Project Work Instructions. Other reports submitted for this survey include the Descriptive Report (one for each survey sheet) and the Horizontal and Vertical Control Report.

This survey is complete and adequate for its intended purpose.

Andrew Orthmann

Digitally signed by Andrew Orthmann
Date: 2017.12.22 15:30:44 -09'00'

Andrew Orthmann

NSPS/THSOA Certified Hydrographer (2005), Certificate No. 225

Charting Program Manager

TerraSond Limited