U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SERVICE

Data Acquisition & Processing Report

Type of Survey Navigable Area

Project No. OPR-P377-KR-18

Time Frame June - July 2018

LOCALITY

State Alaska

General Locality Southwestern Alaska Peninsula

2018

CHIEF OF PARTY

Andrew Orthmann

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Data Acquisition and Processing Report

OPR-P377-KR-18

Southwest Alaska Peninsula

January 11th, 2019

Project Name:	***Southwest Alaska Peninsula***
General Locality:	***Southwest Alaska Peninsula***
Sub Localities:	***H13112 – Unimak Bight Channel*** ***H13113 – Otter Cove*** ***H13114 – Northwest of Sanak Island*** ***H13115 – Main Channel Extension*** ***H13116 – Ikatan Bay (and Pankof Breaker)***
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 T50 Multibeam Echosounders (MBES). There were no side scan sonar requirements for this project.

A.1.1. Multibeam Echosounder

Reson SeaBat T50 multibeam echosounder (MBES) systems were used on this project to collect sounding data. At the time of this survey the T50 was Reson's latest in their SeaBat multibeam series, with improvements in specifications and capabilities over prior sonar model generations such as the 7125 and 7101.

The Reson SeaBat T50 MBES utilizes Teledyne RESON Sonar UI software to serve as the user interface. In the interface, power, gain, depth filters and other user-selectable settings were adjusted, as necessary, through Teledyne RESON Sonar UI 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 the DB files with accompanying DTM files in QINSy QPD format.

MBES accuracy was checked by bar check and lead line methods on the Research Vessel *Qualifier 105* (*Q105)*, with excellent results. On JD158, a bar check was completed, showing echosounder agreement to the actual bar depth at 0.005 m for real-time data and 0.061 m for processed results. Lead line comparisons were also periodically taken throughout the project (on JD158, JD171, JD183, and JD198) and showed good results, with all comparing to the echosounder to 0.03 m or better.

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 and the results were gridded and differenced. Echosounder data from the separate vessels compared well, with average results falling in a range of -0.147 m (*ASV* shoaler) to 0.076 m (*Q105* shoaler), with several comparisons averaging to 0.02 m or better.

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

Reson SeaBat T50-P*	
Sonar Operating Frequency	190 – 420 kHz (400 used on this project)
Along Track Transmit Beamwidth	1° at 400 kHz
Across Track Receive Beamwidth	0.5° at 400 kHz
Max Ping Rate	50 p/s (10 p/s used on this project)

Reson SeaBat T50-P*	
Pulse Length	15 to 300 µsec
Number of Beams	10 - 512 (512 used this project)
Max Swath Angle	Up to 165° (150° in Equi-Distant, used this project)
Depth Range	0.5 – 200 m at 400 kHz
Depth Resolution	0.006 m
**A T50-R (Rackmount) system was used on the ASV vessel while a -P (Portable) system was used on the Q105 vessel. The difference is the topside form-factor; specifications are equivalent.*	

Table 1 – Reson SeaBat T50-P 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 configured with an Applanix POSMV 320 V4 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 T50 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.

***Q105* Major Survey Systems**			
Description	**Manufacturer**	**Model / Part**	**Serial Number(s)**
Echosounder, Multibeam	Teledyne Reson	T50 Transducer	4117006 (rx array) 4817046 (tx array)
MB Processor	Teledyne Reson	T50-P	95771118259
Sound Speed, Surface	AML Oceanographic	Micro-X	11175
		SV-Xchange	206714
Position, Motion, Heading	Applanix	POSMV 320 V4	3694
		IMU Type 26	SYS-I000327-038
	Trimble	Zephyr Model 2 (1)	n/a
		Zephyr Model 2 (2)	n/a
Sound Speed, Deployment System	Teledyne Oceanscience	RapidCAST	115

Q105 Major Survey Systems			
Description	**Manufacturer**	**Model / Part**	**Serial Number(s)**
Sound Speed, Profiler	Valeport	Rapid SV 200Bar	49911

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.

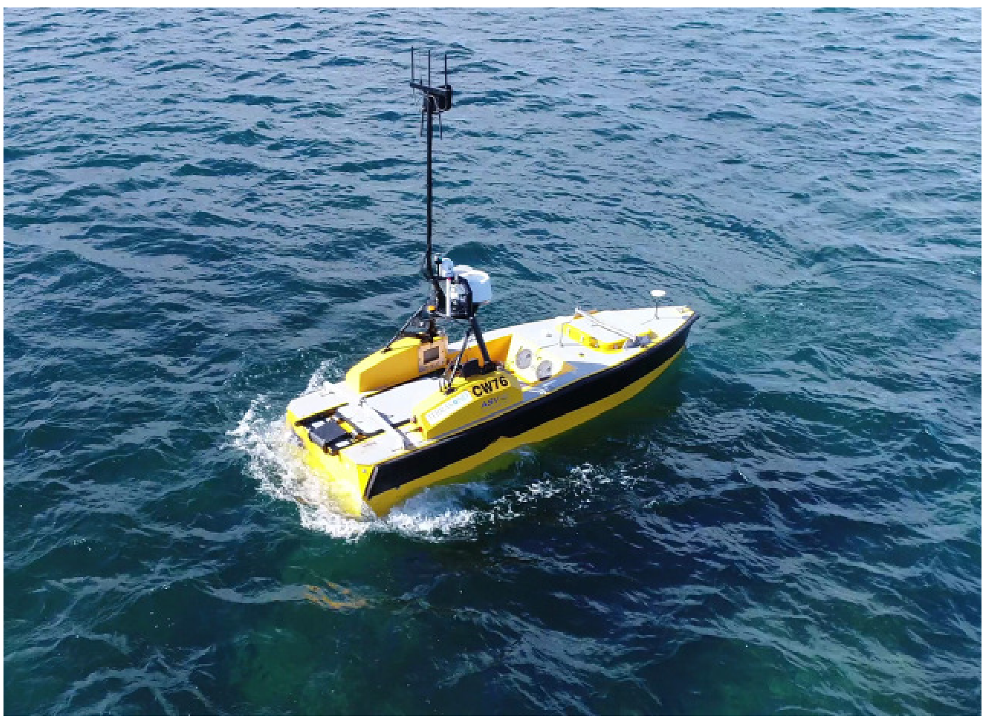

Figure 2 – ASV-CW5

For this survey, the *ASV-CW5* was configured with an Applanix POSMV Wavemaster (integrated with the T50-R multibeam) to provide attitude and positioning, with a submersible IMU mounted co-incident with the sonar head, and GNSS antennas mounted fore-aft above the deck. A Reson SeaBat T50 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	T50 Head	2316007 (rx array) 1716173 (tx array)
MB Processor	Teledyne Reson	T50-R	5216017
Sound Speed, Surface	AML Oceanographic	Micro-X	10873
		SV-Xchange	206710
Position, Motion, Heading	Applanix	POSMV Wavemaster	n/a, integrated with T50-R
		IMU Type 42	2629
	Trimble	AT1675 Antenna (1)	n/a
		AT1675 Antenna (2)	n/a

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.

Sound speed casts were taken when the difference between the sound speed at the sonar head on the *Q105* differed from the previous cast's sound speed at the depth of the sonar by more than 2 m/s. This resulted in casts approximately every 2 hours during operations.

Survey line lengths were limited to 20 km or less 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 proximity (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 AML MinosX with SV- and P- Xchange sensors. This check was accomplished on JD170. Comparison results (available in the Descriptive Reports (DRs), *Separate II*) were good, with the probes comparing to each other within 0.3 m/s on average with a standard deviation of 0.25 m.

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 sonar heads on both vessels were also equipped with AML Micro-X SV-XChange sensors (listed previously under vessel survey equipment) 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 profiles on this project.

A.3.1. Sound Speed Profilers

Project Sound Speed Sensors					
Vessel	**Sound Speed Device**	**Manufacturer**	**Serial Number(s)**	**Cal Date**	**Purpose**
Q105	Rapid SV	Valeport Limited	49911	4/20/2018	Primary sound speed profiler
	AML Minos-X	AML Oceanographic	30421 (Minos-X)	n/a	Backup / comparison
			204167 (SV-Xchange)	4/10/2018	
			305722 (P-Xchange)	5/17/2018	

Table 4 – Sound speed profilers used on this project.

A.3.2. Sound Speed Sensor Technical Specifications

AML Oceanographic Micro-X (SV- and P-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
P Response Time	10 ms
P Accuracy	0.05% FS
P Precision	0.03% FS
P Resolution	0.02% FS

Table 5 – AML Oceanographic SV- and P- 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.

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 provided by the Federal Aviation Administration (FAA). 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 Teledyne RESON Sonar UI 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 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 V4.

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.

During this project, the POSMV 320 V4 ran firmware version SW05.03-Mar10/10.

POSMV 320 (V4)		
DGPS Positioning	Positioning Accuracy	0.5 – 2 m
	Roll, Pitch Accuracy	0.02 degrees
Kinematic Surveying	Positioning Accuracy	Horizontal: +/- (8 mm + 1 ppm x baseline length) Vertical: +/- (15 mm + 1 ppm x baseline length)
	Roll, Pitch Accuracy	0.01 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		0.02 degrees (1 sigma, 2 m baseline)
Velocity Accuracy		0.03 m/s horizontal

Table 7 – Applanix POSMV 320 technical specifications.

A.4.2. ASV-CW5

The Applanix POSMV system used aboard the *ASV-CW5* was a POSMV Wavemaster II. This was an integrated system, meaning the topside was combined into the same physical housing as the T50-R sonar topside. The IMU for this system was a submersible unit secured directly onto the sonar head mount.

The primary POSMV antenna for this unit was mounted as the forward-most antenna on the vessel in order to increase distance from the vessel mast. However, this inadvertently led to more exposure of the primary antenna to wash from waves during rough seas, resulting in positioning spikes. These were addressed in final processing and final data is within speicifactions.

During this project, the POSMV Wavemaster II ran firmware version SW09.13-Mar03/17.

<table>
<tr><th colspan="3">POSMV Wavemaster II</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>0.03 degrees</td></tr>
<tr><td rowspan="2">Kinematic Surveying</td><td>Positioning Accuracy</td><td>Horizontal: +/- (8 mm + 1 ppm x baseline length)
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<tr><td>Roll, Pitch Accuracy</td><td>0.02 degrees (1 sigma)</td></tr>
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<tr><td colspan="2">Heading Accuracy</td><td>0.03 degrees (1 sigma, 2 m baseline)</td></tr>
</table>

Table 8 – 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.

Note that although RPM data was logged, final dynamic draft correctors were speed-based.

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

A.6. GPS Base Stations

One GPS base station was installed for this project. The station site was selected due to its centrally-located position relative to the survey area, little to no satellite masking, and ability to obtain permission from the land owner.

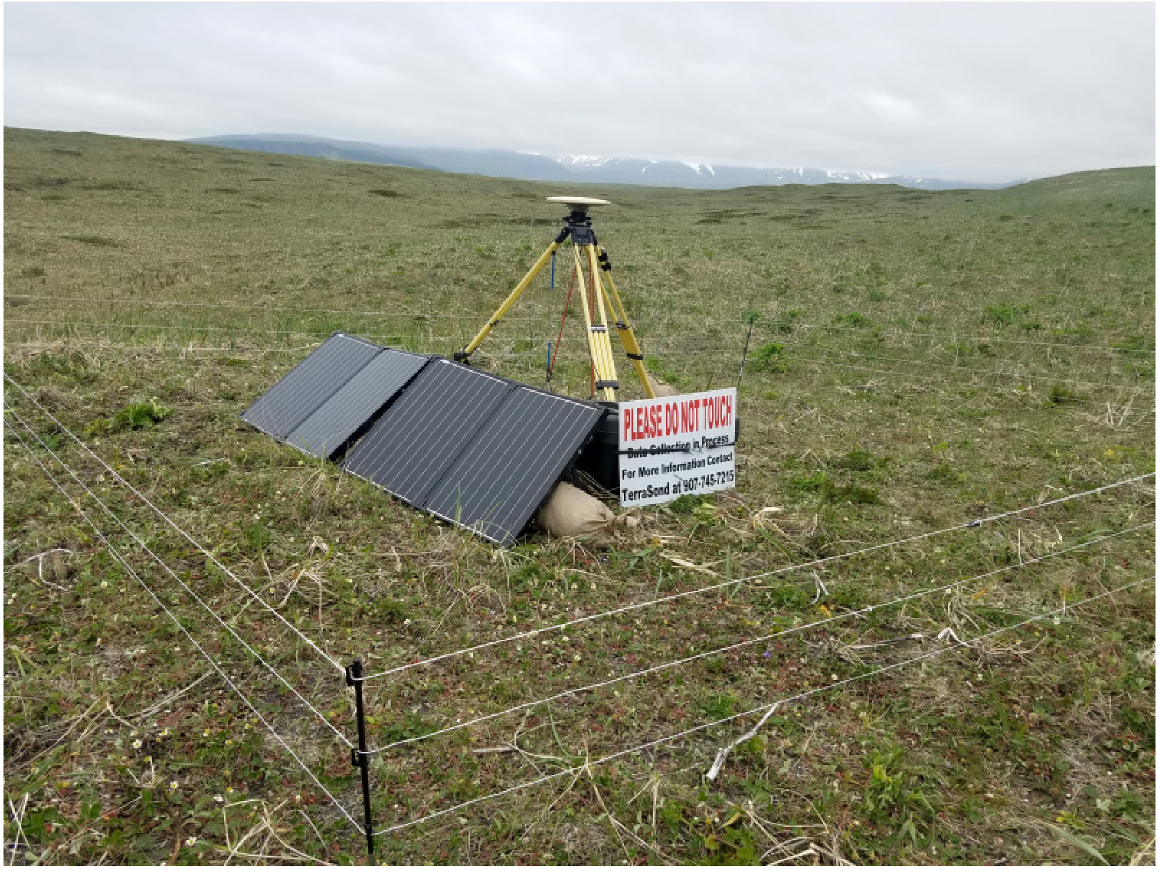


Figure 4 – Project GPS base station installed on the Ikatan Peninsula.

A Trimble 5700 (T5700) GPS receiver with a dual-frequency Trimble Zephyr Geodetic antenna was utilized at the site. The receiver was configured to log data continuously to a memory card at 1 Hz, breaking files every 24 hours at the Julian day rollover. The receiver was powered by two gel-cell 12V deep-cycle batteries recharged by two 100w solar panels. Data was retrieved manually by swapping data cards during site checks, approximately every two weeks during operations.

Project Base Station					
Station ID	**Site**	**GPS Receiver**	**Antenna**	**Type**	**Position (NAD83)**
5240	Ikatan Peninsula	Trimble 5700 SN# 220275240	Trimble Zephyr Geodetic (TRM41249) SN# 60078756	Logging (PPK) 1 Hz (no RTK)	54-45-02.73460 N 163-19-37.53937 W Height: 21.611 m

Table 9 – GPS base station position and configuration.

Confidence checks on the stability of the GPS base station, 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), which always returned results comparing to

0.017 m vertically and 0.011 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 10 – Trimble 5700 technical specifications.

The station was reliable and did not experience any shutdowns or physical disturbances to the station hardware. However, for unknown reasons, the base station did not log data for the last 26 minutes of each Julian day. The loss of the base data did not have an adverse effect on survey data because the station was only used for QC and comparison purposes.

Refer to Section B of this report for further discussion on PPK processing methodology, as well as the accompanying Horizontal and Vertical Control Report (HVCR).

A.7. Tide Gauges

A.7.1. NWLON Stations

The NWLON station at King Cove (station number 9459881) was used as the control station for this project. However, all final corrections to MLLW were completed with ERS methodology via a NSPMVD model provided by NOAA.

A.7.2. Subordinate Stations

Subordinate tide station installation was not required. However, zoning / QC stations were installed to provide data for comparison with the PMVD model provided by NOAA for final corrections.

Zoning stations used Sea-Bird SBE 26 plus Wave and Tide Recorder units.

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 moorings (with approximately 500 to 1200 lbs weight depending on location) 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 moorings to an auxiliary mooring.

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

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

Additionally, GPS buoys were installed at two of the sites. In each GPS buoy, a Trimble 5700 GPS receiver logged dual-frequency data at a rate of 1 Hz. The ARP height above the waterline was measured at deployment and recovery. The data was post-processed in Applanix POSGNSS software.

The BMPG and GPS buoy tide equipment performed well with no major equipment-related issues or outages encountered.

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 11 – 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 12 – 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 identical 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.
- Teledyne RESON Sonar UIserved as the interface with the Reson SeaBat T50 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.
- NoMachine 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, a proprietary software developed by ASV Global, was used 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	8.18.1 (Build 2018.03.27.1)	2018	Acquire MBES data and provide vessel navigation
Teledyne RESON Sonar UI	4.0.0.0 (7kCenter 6.3.0.7)	2017	Interface with Reson T50 MBES
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	5.03		Interface with POSMV 320 V4 (*Q105*)
	9.03		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 13 – 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
ESRI ArcGIS ArcMap	10.2.1	2013	Produce chartlets for reports and track survey progress
Applanix POSPac MMS	8.3	2018	Post-processing of POSMV data
Microsoft Office	365	2018	Logsheets, reports, and various processing tasks
TerraLog	2014	2014	Keeping notes, reporting, process SVP casts, and produce PDF logsheets
Ultimate Underway Converter	2016	2016	Auto-convert Valeport Rapid SV files to MVP format prior to processing
Pydro XML DR	n/a	2018	XML DRs
Agisoft Photoscan Professional	1.4	2018	SfM processing of aerial imagery.
HydrOffice QC Tools	2.1	2017	Conformance checks on deliverables
QPS FMGT	n/a	2018	Backscatter Mosaic processing

Table 14 – 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 visible in both the multibeam and ortho-photomosaics, with positions usually 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 15 – 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 identical.

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 Teledyne RESON Sonar UI 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 5 – ASV-CW5 working near the Q105.

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 usually sufficient to transfer data as fast as new data was being acquired. This made it possible to process data soon after acquisition without the need to wait to physically download it, which allowed potential issues to be detected relatively 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 this occurred, the survey crew prioritized transfer of file types to only those necessary for immediate processing (XTF), and queued DB and POSMV files for later transfer—either by radio or 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 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 6 – Q105 data acquisition station, with direct interfaces to survey hardware.

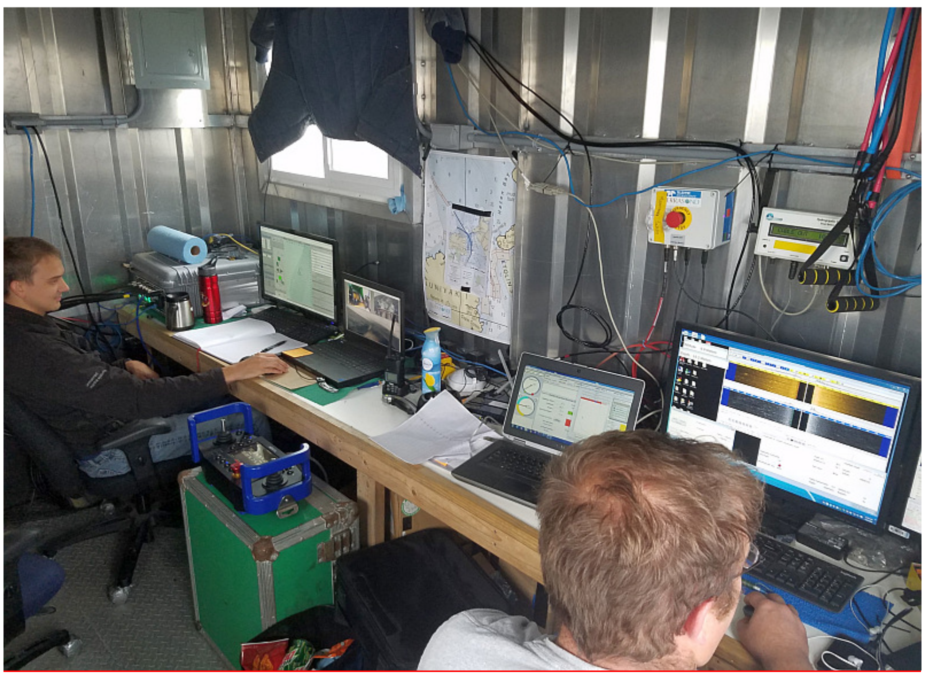


Figure 7 – Station aboard the Q105 for remotely controlling and monitoring the ASV-CW5. Displays are transmitted wirelessly from the unmanned vessel.

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.

Work was done to "Complete Coverage" ("Option A: Complete Coverage Multibeam") standards as described in the HSSD. 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 extreme 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.

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 sounder beams to improve across-track density, and providing substantial overlap between adjacent lines. 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 T50 sonar, generating 512 beams spaced equidistant across the swath for every ping, which was the maximum capability of the T50 MBES system. This combination of ping rate and beam mode caused the system to generate up to 5,120 soundings per second and—at the speeds used—meet density specifications. Substantial overlap between adjacent lines improved data density, especially in cases where erroneous data required rejection.

Most nearshore coverage in shallow areas was acquired using the beam-steering capability of the T50 sonar on the *ASV-CW5*. In this mode, the sonar operator would turn the sonar to equiangular beam mode (instead of equidistant) and steer the sonar beams to obtain additional coverage in the direction of the un-surveyed area – usually towards shore. This enabled up to 15 degrees of additional coverage to be obtained in the steered direction with the loss of up to 15 degrees of coverage on the opposite side of the vessel. This enabled shoaler areas to be surveyed more efficiently while maintaining coverage requirements. These lines usually have the name "nearshore" in the filename and typically did not receive outer beam filtering so as to not remove the shoalest beams facing shore.

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

B.2.5. MBES Backscatter

MBES backscatter was collected continuously during MBES operations. Presence of backscatter records in the raw MBES files was confirmed by periodic random checks through processing in Fledermaus Geocoder Toolbox (FMGT).

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

XTF files on this project do not contain backscatter records; these were intentionally configured to contain bathymetric sounding data only.

Following completion of field acquisition, backscatter was processed and mosaics were generated in FMGT at 1 meter resolution. The mosaics (GeoTIFF format) are provided with the processed survey deliverables.

Note that backscatter processing and mosaic generation was not a requirement of this survey and the georeferenced mosaics are provided for interest only. The mosaics may have flaws or holidays which could be addressed through further processing. However, they are of sufficient quality to show the relative changes in seafloor type.

B.2.6. 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 also taken whenever the potential to significantly change the draft was experienced, 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 obvious 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.2.1. Q105 Roll Alignment Issue

On examination of overlapping swath data, it was evident that a sporadic roll alignment bias was present in the data collected on the *Q105*. The initial roll correction determined by a patch test of -1.04° was found to periodically change, correlating approximately to when the multibeam arm was raised and lowered. This indicated that it was not always coming back into the same alignment relative to the POSMV IMU, which was mounted mid-ship on the keel and not on the retractable multibeam arm. The exact cause was unknown but small fluctuations in hydraulic pressure in the arm actuator was suspected. Effect on pitch or yaw alignment, if any, was not discernable.

Q105 data was systematically examined in CARIS subset mode to identify the extent of the issue. Although the multibeam arm alignment periodically changed relative to the initial alignment, it was determined that once the arm was deployed, the alignment remained stable. This made it possible to derive roll corrections based on the swath overlap with adjacent lines on this project.

Alignment corrections determined through this process were entered in to the Q105 HVF as a roll correction under the Transducer 1 sensor. Corrections spanned a range of -0.94° to -1.3°, as compared to the initial (and most common corrector) patch-test value of -1.04°. Data was re-merged with the new corrections to apply them to sounding data.

As a result, this error has largely been removed from the dataset. Some remnants may remain as slight across-track misalignments in Q105 data relative to adjacent swaths but are within specifications.

B.2.2. Sound Speed Measurements

Sound speed 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 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 to 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 UTC timestamps by the Valeport RapidSVLog software. Position was logged in TerraSond's TerraLog software, which was interfaced with a GGA position/time string from the POSMV.

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.

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

Additionally, line lengths were limited (generally 20 km or less) 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 equal to four hours. 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.2.3. 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-tag 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 seconds) is common between the TerraLog entry and the actual data file start and end. However, with 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

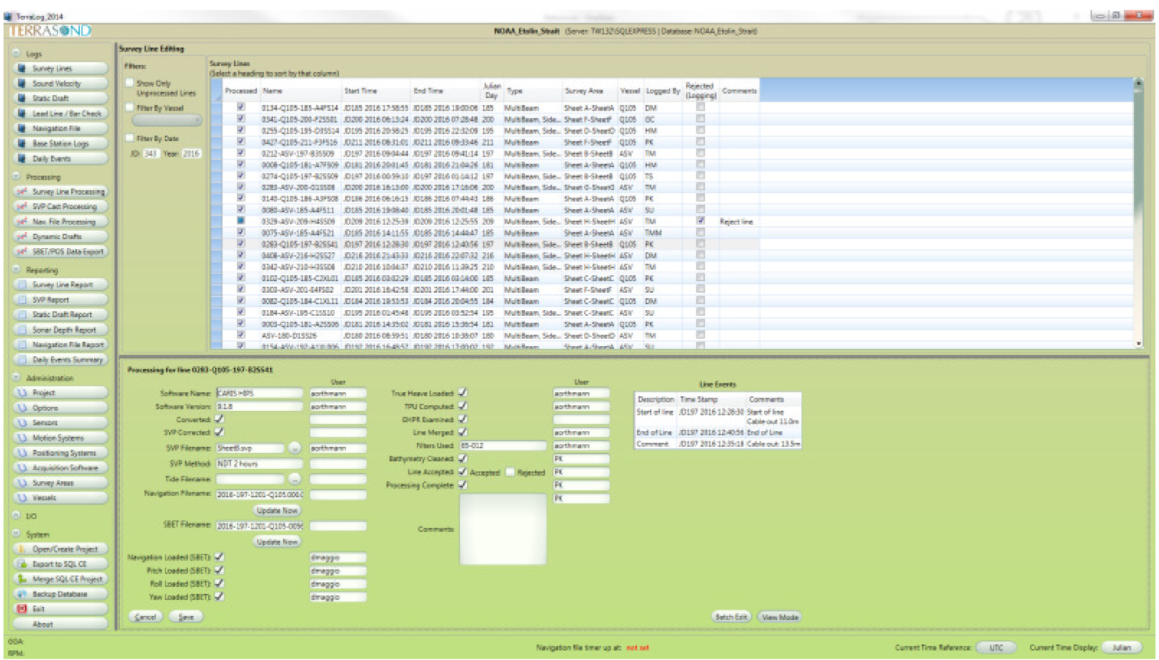


Figure 8 – TerraLog interface for line processing.

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.2.4. Base Station Deployment

As described in Section A of this report, a GPS base station was established on a centrally located isthmus of land in the survey area. The base station data was not used for vessel data processing because adequate results were obtained using commercially available station data, but the site was utilized for comparisons as well as post-processing GPS buoy data.

The base station's location was chosen for its clear view of the sky, accessibility from shore, and ability to secure permission from the land owner. A Trimble Zephyr Geodetic antenna was mounted on a tripod, which was secured to the ground from winds with stakes and sand bags. The Trimble 5700 GPS receiver, powered by two 100W solar panels and 12V batteries, was set to log dual-frequency GPS data (Trimble T01 format) at a rate of 1 Hz to a Compact Flash (CF) card. The CF card was swapped periodically during site check operations, usually every two weeks.

After the project, data was checked for continuity, and it was determined that for unknown reasons the site did not log the final 26 minutes of each Julian day. This did not have an adverse effect on data quality since the base was not used for final vessel data processing.

Confidence checks on the stability of the GPS base station 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), which always returned results comparing to 0.017 m vertically and 0.011 m horizontally (or better) of the original position. Base station confidence checks are available in *Separate I* of the project DRs and with the project HVCR.

B.2.5. Bottom Samples

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

To collect the samples, the *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 9 – Bottom sample collection with Van Veen sampler on the Q105 during this project.

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 most assigned locations, with exceptions 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 ("NATSUR") with field determinations for "NATQUA" as course, medium, or fine were encoded with "volcanic" for "NATQUA" to conform with allowable NATSUR/NATQUA combinations in the HydrOffice QC Tools manual, 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 10 -- Example bottom sample– 1st constituent broken brown shells, 2nd medium black sand, 3rd fine brown pebbles.

Bottom sample results are available in the S-57 FFF (Final Feature File) 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.2.6. 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, QPD	MBES Mainscheme and Crossline Data from QPS QINSy	**1165-ASV-224-A4MS01600 (.DB, .XTF, .QPD)** [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 16 – 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. "DH" HIPS Vessel Files

The CARIS HVFs (HIPS Vessel Files) for this project are amended with the text "-DH" to denote they were setup in a dual-head configuration. Per CARIS' technical bulletin "HIPS and SIPS Technical Note for Sound Velocity Correction for Teledyne Reson 7k Data", the CARIS HVFs were configured as dual-head configuration even though the systems were in fact single head. Per the bulletin, this was necessary because QINSy was configured to log "new" style (Reson 7027) bathymetric records.

Note that in this configuration vessel offsets (other than minor patch test corrections) appear only under the SVP1 and SVP2 sensors in the HVF, not under the Transducer 1 and Transducer 2 sensors as they might for other sonar configurations.

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 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.

B.3.6. Dynamic Draft Corrections

Dynamic draft corrections were determined for this project using squat-settlement tests.

Corrections were speed-based for both vessels. These corrections were applied using a speed-to-draft correction table entered into each HVF. The correction table was determined from squat-settlement tests completed on both vessels on JD203.

Note that as an Ellipsoid Referenced Survey (ERS) project, vertical changes in vessel displacement were captured in the GPS data for the vessel. Therefore dynamic draft correctors, which were applied to sounding data during sound speed correction, were also applied to GPS heights during the "Compute GPSTide" process (described later in this report), which had the end effect of not applying the correctors.

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 from the original file, and the processing personnel assigned the position that was logged during the cast.

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.

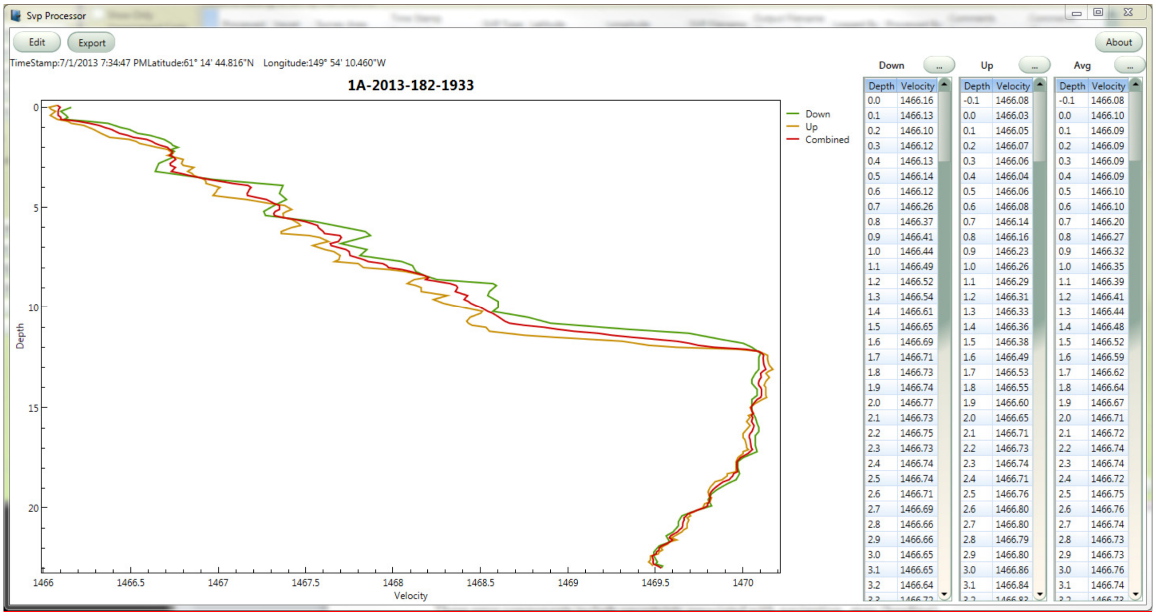


Figure 11 – Example SVP profile editing interface in TerraLog.

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.

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

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 T50P (400 kHz 512 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% for Heave % Amplitude, 0.05m for Heave (m)		CARIS TPU values for Applanix POSMV 320
Roll and Pitch*	0.01°		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	2 knots		Estimated average max current experienced in survey area
Loading	0.027 m	0.02 m	Standard deviation of the difference between subsequent static draft measurements
Draft	0.02 m		Estimated accuracy of static draft measurements
Delta Draft	0.02 m		Overall estimated uncertainty of squat-settlement test results
MRU Align StdDev Gyro	0.01°		Accuracy estimate of patch test value for yaw
MRU Align StdDev Gyro, Roll/Pitch	0.043°	0.01°	Q105: Standard deviation of difference between subsequent roll correctors ASV: Estimated accuracy of patch test value for roll

HVF TPU Entries			
HVF TPU Entry	***Q105***	***ASV-CW5***	**Source**
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 for most lines			

Table 17 – HVF TPU values used.

Other TPU computation parameters:

- **Tide error uncertainty**: During final TPU computation, a static tide error value of 0.098 m was used. This corresponds to the uncertainty value provided by NOAA for the NSPMVD separation grid applied to the soundings for tidal corrections.
- **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 in 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.

  Real-time errors were not available for the sonar or tide sensors.
- **Sound speed error**: For estimated sound speed error, a value of 2 m/s was entered. This corresponded to the surface change in sound speed which would require an additional sound speed profile to be collected.

Other TPU Settings			
TPU Setting	***Q105***	***ASV-CW5***	**Description**
Sound Speed - Measured	2 m/s		Approximate maximum variance in surface sound speed experienced before additional sound speed profiles would be acquired during acquisition
Sound Speed - Surface	0.025 m/s		Manufacturer-specified accuracy of the surface sound-speed probe

Other TPU Settings			
TPU Setting	***Q105***	***ASV-CW5***	**Description**
Tide (Measured)	0.098 m		NOAA provided uncertainty value for the NSPMVD grid applied for final tide corrections. A zero uncertainty value was entered for "Zoning".
Uncertainty Source	Position: Real-time Heading: Real-time Pitch: Real-time Roll: Real-time Tide: Real-time 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 18 – 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 produced SBET format .OUT files, which were loaded into all lines during processing. This superseded real-time navigation (position and GPS height) as well as real-time attitude data (gyro, pitch, and roll) 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 Trimble PP-RTX functionality was utilized for the majority of the POSPac processing. PP-RTX is a subscription-based service available within POSPac, based on Trimble CenterPoint RTX, that utilizes Precise Point Positioning (PPP) to post-process data without the use of base stations. Advertised accuracies are 0.1 m RMS Horizontal and 0.2 m RMS vertical. However, on this project, reported RMS errors were generally better than advertised – usually at the 0.05 to 0.1 m level vertically.

Applanix Smart Base (ASB) mode was also utilized on some lines that experienced issues processing or exhibited vertical busts while using PP-RTX. ASB utilizes nearby CORS (Continually Operating Reference Stations) stations to interpolate a virtual reference station for the boat location. ASB was also used to compare periodically against the PP-RTX results.

Following selection of PP-RTX (or ASB in select cases) and automatic download of applicable ephemeris and base station data, the POSPac Inertial processor function was run.

After completion of the inertial processor, QC plots of RMS error and vessel altitude were examined for spikes and other anomalies. QC reports in PDF format, that show performance metrics, were then created for each POSPac project and are available with the project HVCR.

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.

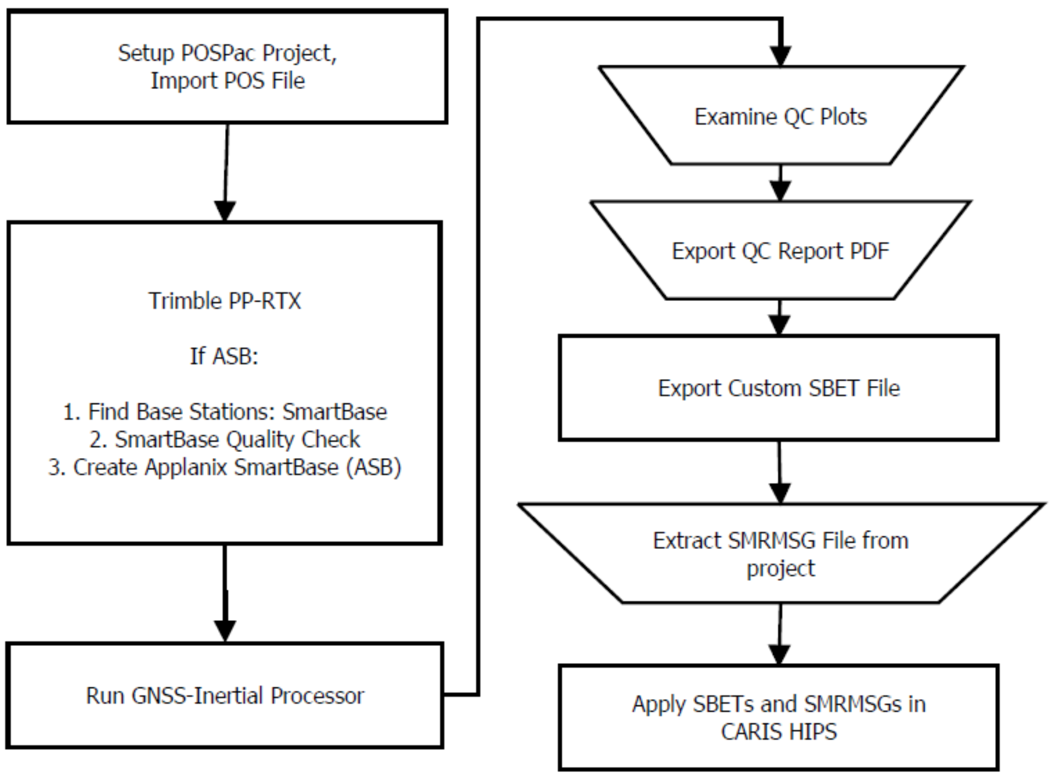


Figure 12 – Flow chart overview of POSPac workflow used on this project.

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 the POSPac QC Report PDFs.

Note that while SBETs were produced in NAD83 (2011), CARIS HIPS project geodetics were intentionally set to NAD83 without the 2011 epoch designation. This was done 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 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 in final processing, 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, vessel waterline, and the NOAA-provided NSPMVD (Not-So Poor Man's VDatum) separation model were used so that the GPSTide record reflects the elevation of the vessel waterline above MLLW.

Note that "Delayed Heave" was used as the heave source since the vast majority of lines were loaded with this record. Rare lines without "Delayed Heave" used real-time heave during this computation instead.

B.3.11. Load Tide

Conventional, ZDF (Zone Definition File) tide corrections were used for preliminary (vessel-based) field processing. This was because the NOAA NSPMVD separation model was not available until near the end of field operations, with the final model released after field ops had completed.

The ZDF provided with the survey planning package by NOAA was used for the preliminary tide corrections. Zones were based on the King Cove NWLON station (ID 9459881). Predicted or observed tides were used for the preliminary corrections, depending on availability and timing.

These were loaded using the CARIS "Load Tide" routine and applied during merge.

It is important to note that these preliminary corrections were superseded entirely by application of the NSPMVD grid during Compute GPSTide, with the final merge utilizing the GPS-based corrections.

B.3.1. Merge

The "Merge" process was run on all lines in CARIS HIPS. During this process, "GPS" was selected as the tide source to ensure the "GPSTide" record computed previously was used for tidal correction, and the Heave Source was set to "Delayed" to utilize the "Delayed Heave" records loaded previously.

B.3.2. 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 "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 to remove outer beam soundings in some configurations. For offshore lines, a standard beam filter of 65° was used, which rejected soundings greater than 65° from nadir. For inshore lines, which depended on the outermost beams to capture rocks and shallow hazards to navigation prior to the next survey line pass, outer beam filters were generally not used so as to keep the entire swath.

During office processing, data quality was reviewed and filtering revisited on an area-by-area basis. More aggressive filters were run as necessary to improve surface quality on groups of lines that exhibited higher error due to sound speed refraction or motion.

Crosslines were filtered at 50° to ensure good soundings for comparison to mainscheme surfaces. Filter settings used were recorded in the CARIS HIPS "Process" log.

On occasion outer beam filters opened gaps in coverage between adjacent survey lines. 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.

B.3.3. 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 obviously erroneous soundings (fliers) 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 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 (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.

The "Deep" and "Shoal" layers of the CUBE surfaces were also 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.

The "Node Standard Deviation" layer was also used to indicate areas with potentially high amounts of noisy soundings. Areas showing 1 m or greater standard deviation were examined and cleaned where necessary, although areas of rugged bottom naturally demonstrated higher standard deviations.

All 1 m surfaces (depths 20 m and less) were examined manually in subset mode, with special focus on areas around rocks or other hazards. Offshore areas (deeper than 20 m) were generally examined in subset mode only where the "Shoal", "Deep", and/or "Node Standard Deviation" layers of the CUBE surfaces indicated the potential for excessive noise.

B.3.4. 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).

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" (Option A, Section 5.2.2.3 in the HSSD). Resolutions ranged from 1 m to 16 m for final surfaces.

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.3.5. 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 V5.7" were used as NOAA extended attributes, which added custom NOAA attributes to the standard S-57 library. V5.7 was most recent version provided by NOAA (June 2018) at the time of field operations for this survey. During feature attribution, effort was taken to ensure required attributes described in the HSSD were applied.

B.3.6. 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 surface excluded crosslines to not bias the QC report results.

Differences in depth were grouped by beam number and statistics computed, which included the percentage of soundings with differences from the BASE surface falling within IHO Order 1. When at least 95% of the soundings exceed IHO Order 1, the crossline was considered to "pass," but when less than 95% of the soundings compare within IHO 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.3.7. Bathymetric Processing Flow Diagram

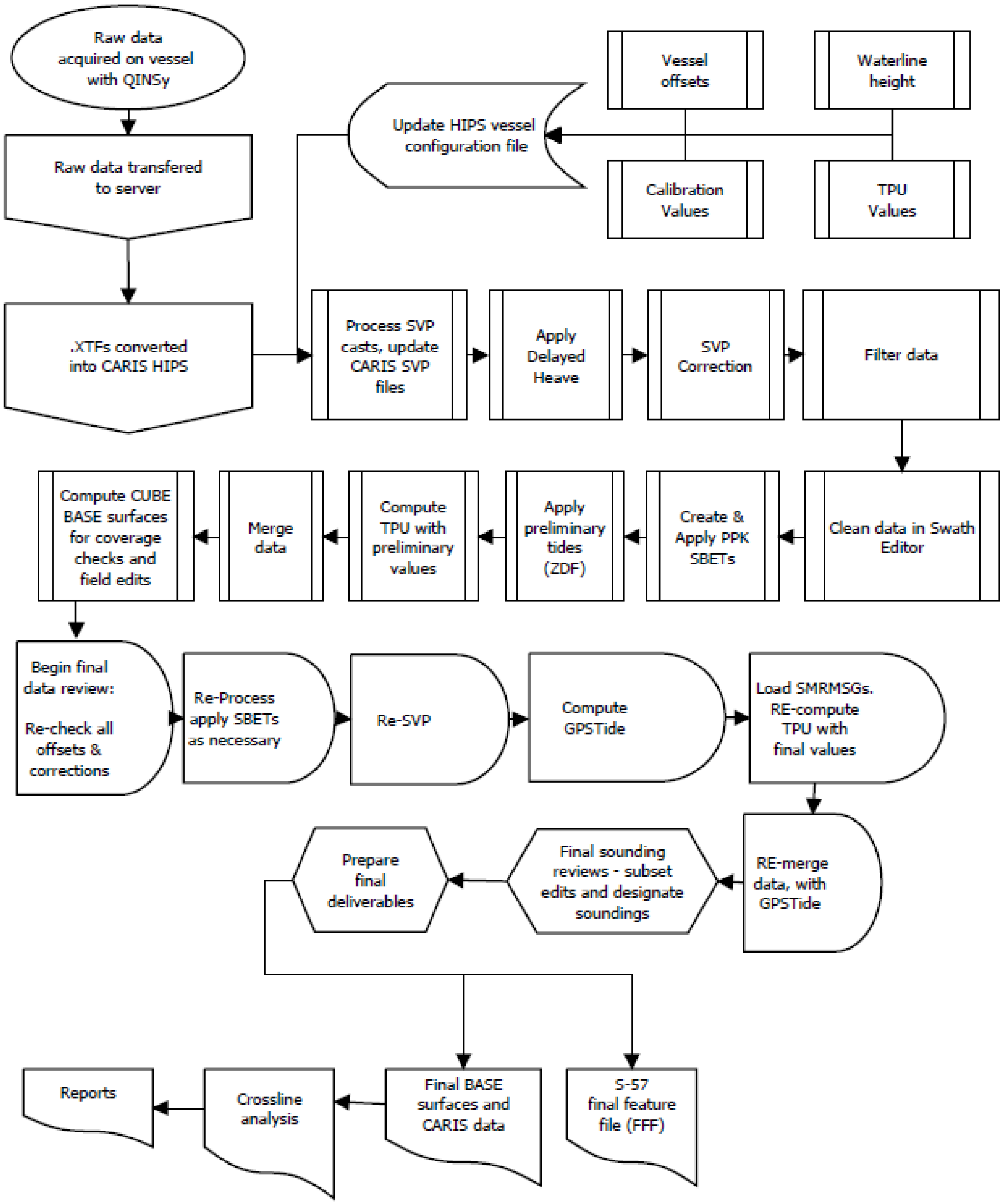


Figure 13 – Generalized flow chart of processing steps used on this project.

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 a 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 adjacent seafloor.

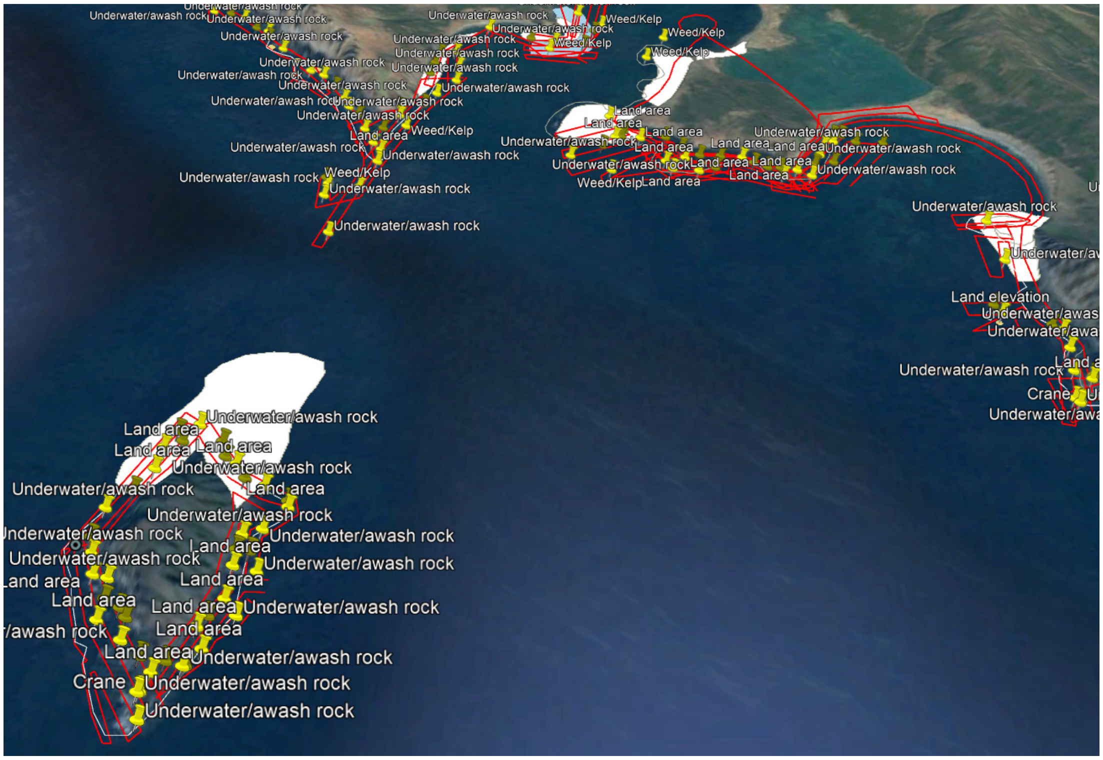


Figure 14 -- Pre-defined mission routes (red lines) over assigned features shown in Google Earth.

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 to 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 15 -- 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 16 -- 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 models them in 3D. On this project, care was taken to ensure at least three photos were acquired of each feature in order to provide 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 were computed, which was common with open water crossings.

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.

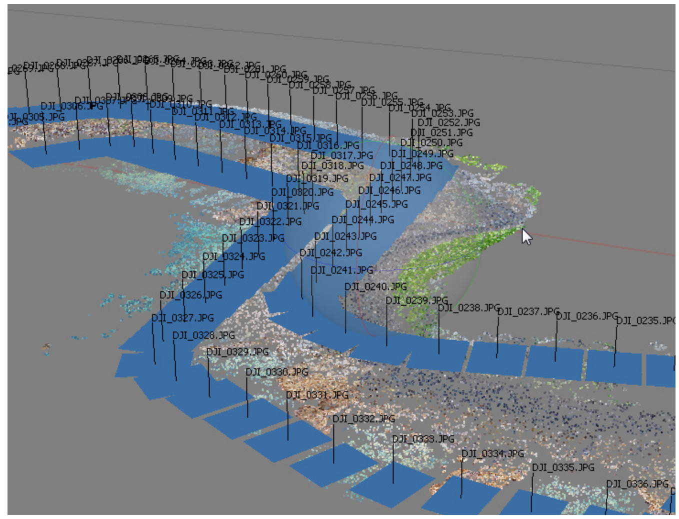


Figure 17 -- Aero-Triangulation Tie Points showing photo locations along the pre-defined mission route.

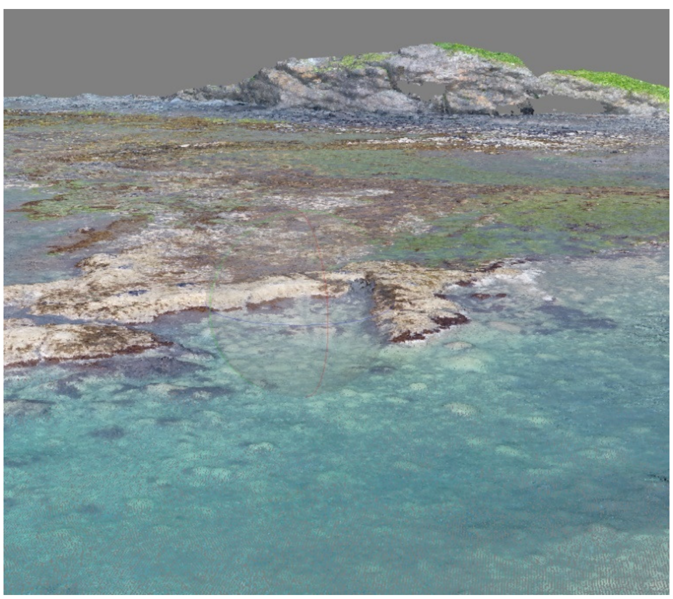


Figure 18 -- Dense Point Cloud generated through SfM

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 King Cove. 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.

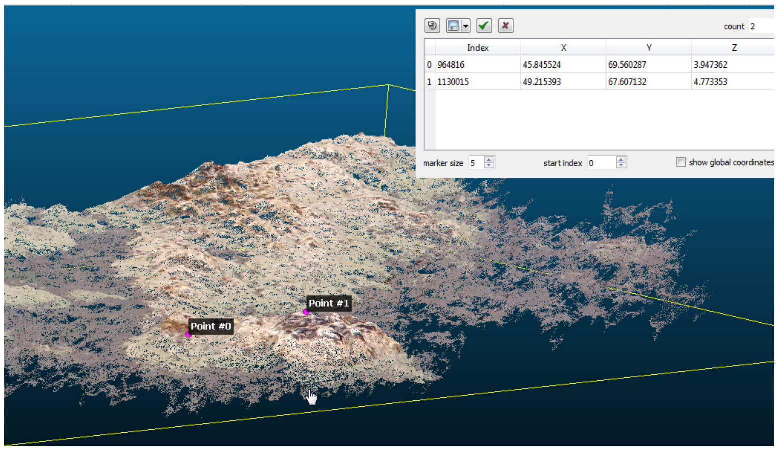


Figure 19 -- Manual height measurements in dense point cloud

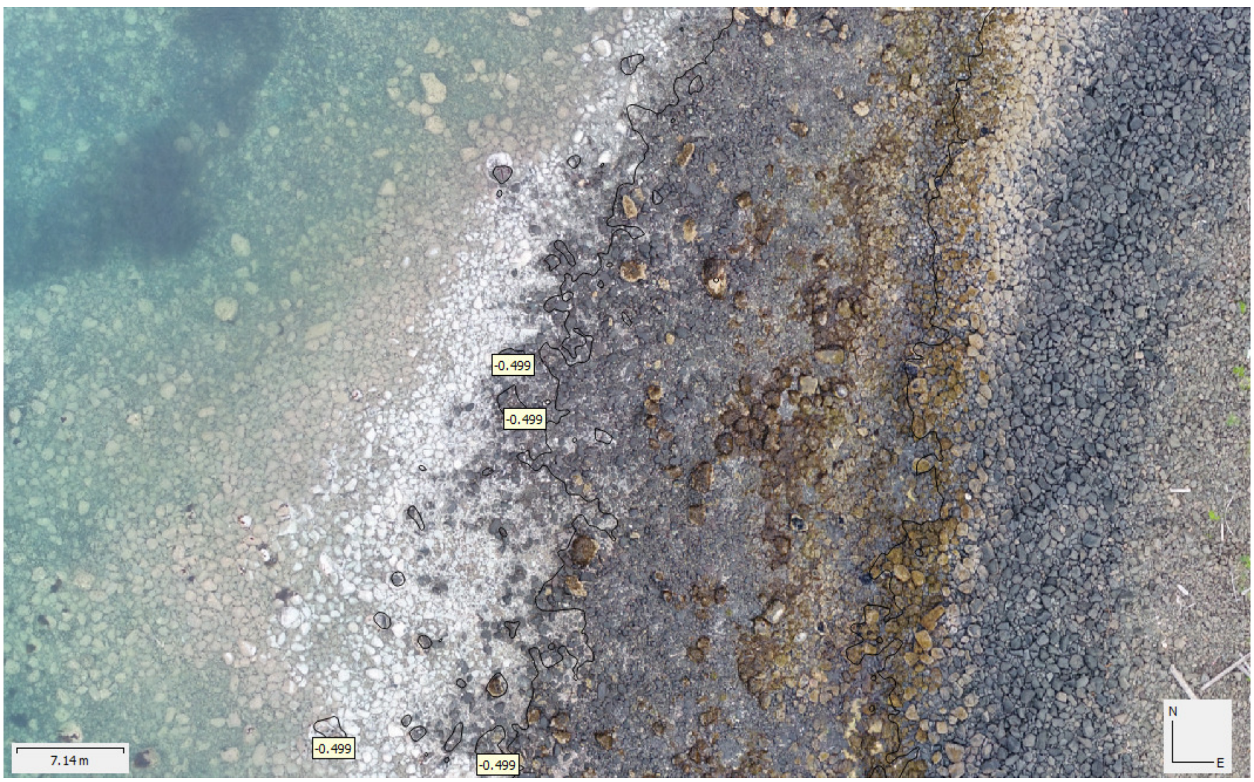


Figure 20 -- Waterline contour corrected for MLLW overlaid on DEM generated photo-mosaic in PhotoScan. A tide of -0.499 m at this mission time was assigned to the shoreline-water interface to adjust the final DEM to MLLW.

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 from one of these missions is shown below.

Figure 21 -- 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 3N.

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 V5.7 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.

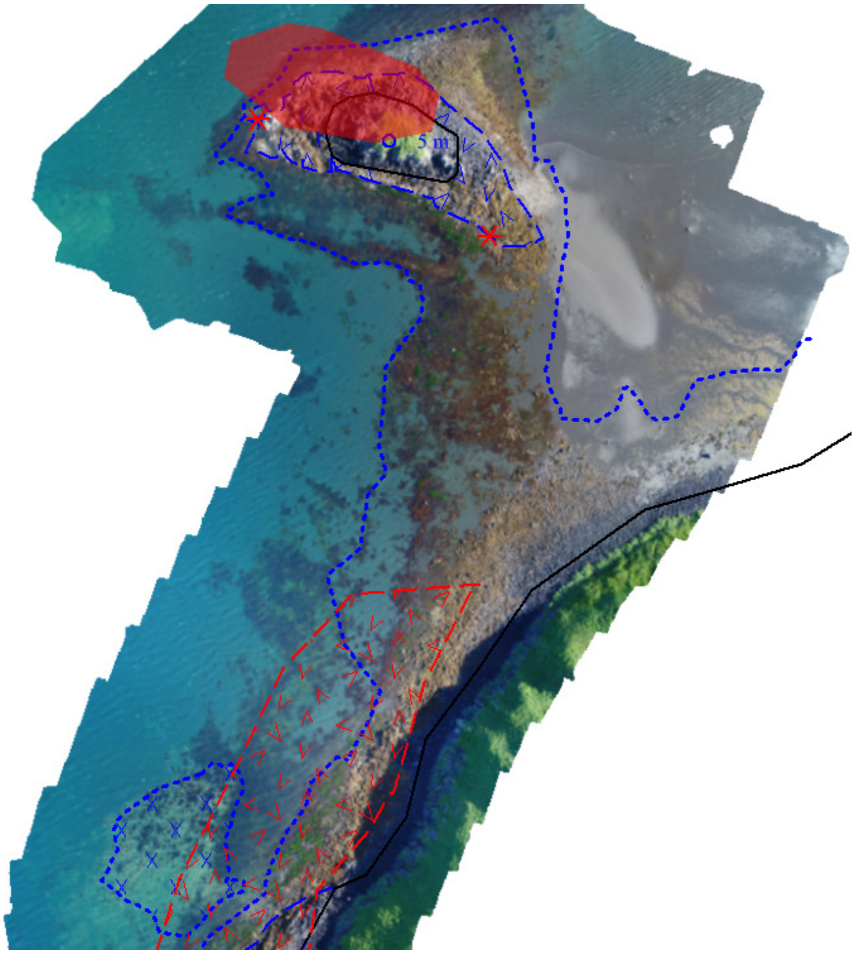


Figure 22 -- Example of shoreline feature processing -- assigned features (red) overlaid on ortho-photomosaic and correlated. New features, including a MHW height on the island derived from the SfM DEM, are shown in blue. MHW from the CSF is black.

Common scenarios 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.

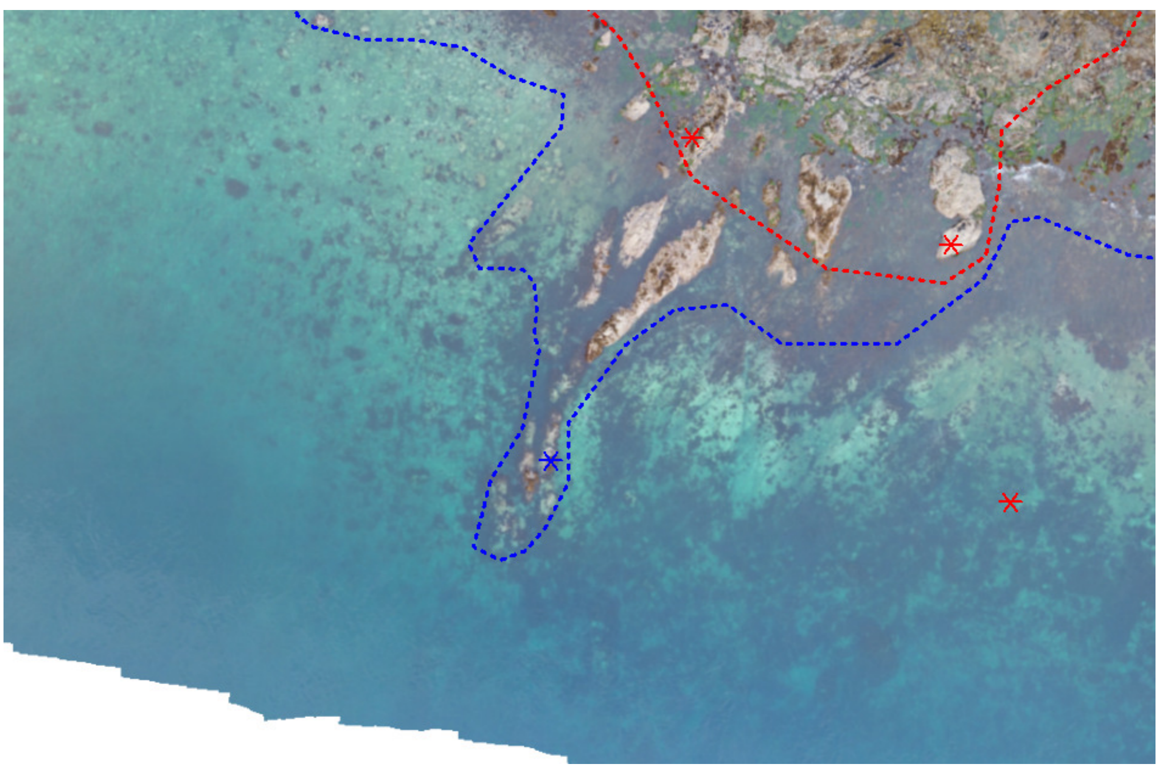
- Most foul lines/areas and ledges (both GC and chart-sourced) required re-digitizing based on the high-resolution ortho-photomosaics from this survey. The source data was rarely within 5 m of the observed locations. The assigned line or area feature was considered "verified but requiring extensive modifications 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 instances where the 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 (for example, offshore features). In these cases raw images were extracted at the feature location and examined to complete the correlation manually (with estimated heights). These are noted in the feature remarks when applicable.

- The published MHW value of 1.875 m for King Cove NWLON tide station was used for rock – islet determination. Therefore, feature heights determined to be greater than 2.485 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.



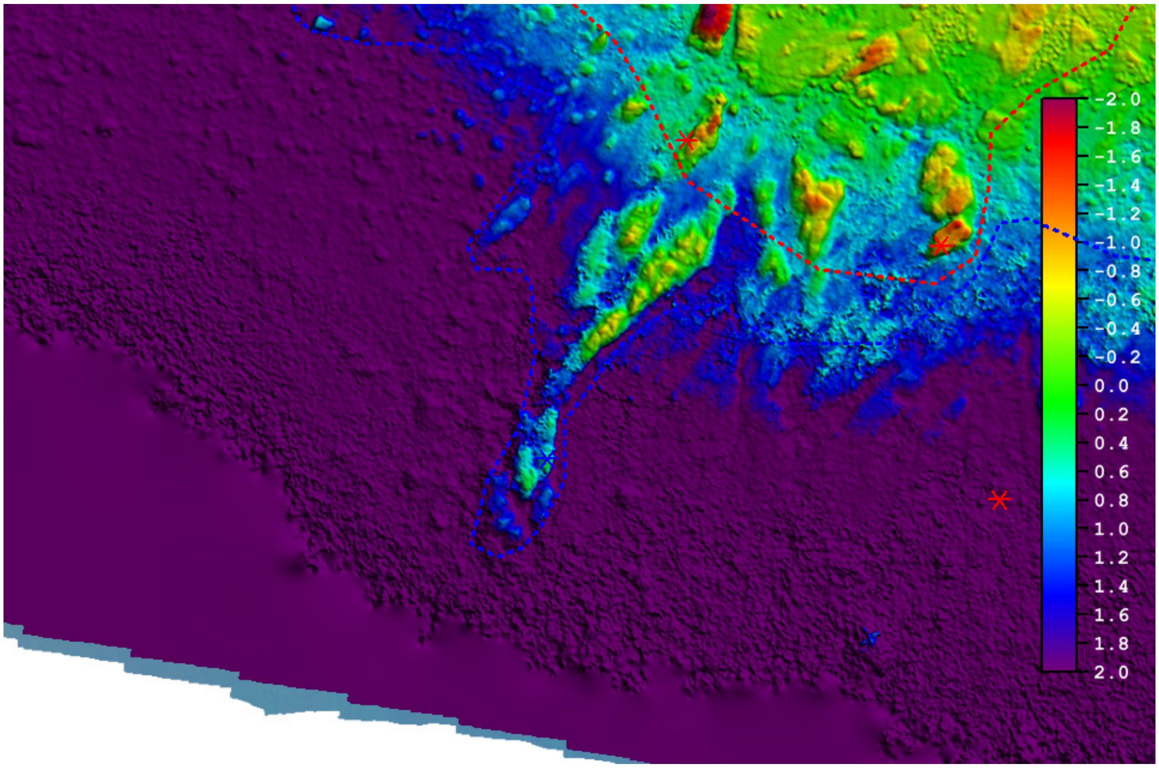


Figure 23 -- Example of DEM usage for height extraction – SfM ortho-photomosaic (top) clearly shows shoreline detail. DEM (bottom, scale in meters relative to MLLW) shows heights. Note smooth-appearing area in lower part of DEM is where heights could not be computed by the SfM algorithm due to water depth.

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

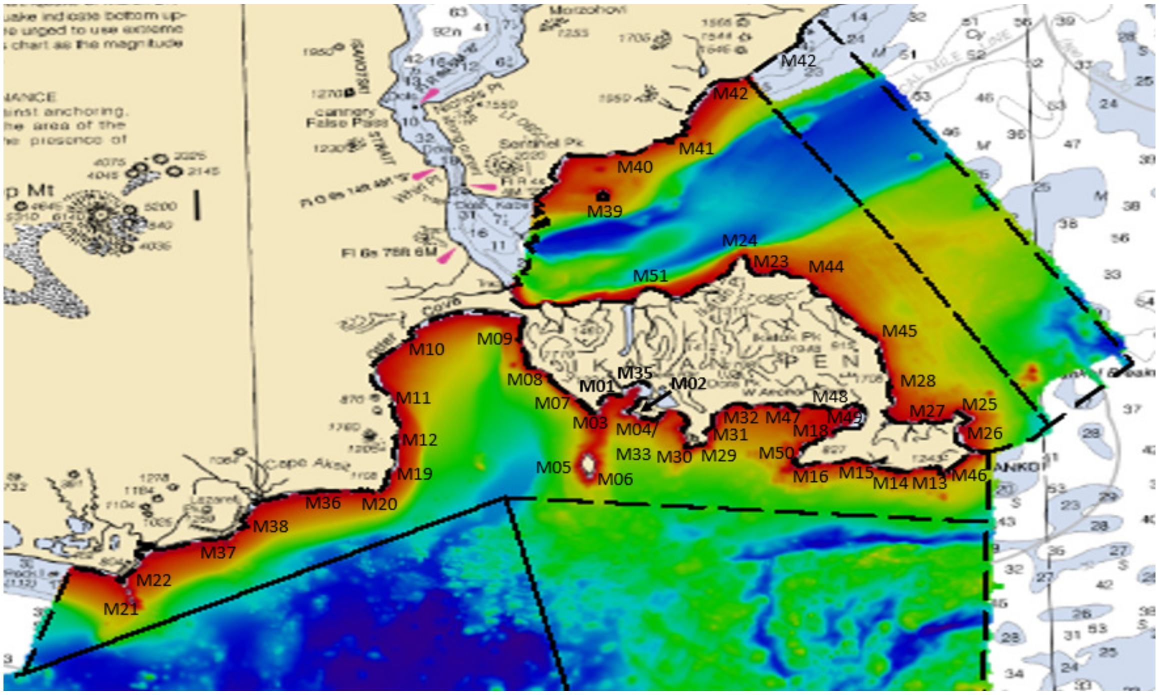


Figure 24 -- Mission number locations relative to the project area

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

Mission #	Orthomosaic Filename	DEM Filename	Notes
Mission 1	Mission 01-B-MLLW-ORTHO-NAD83UTM3N Mission 01-C-MLLW-ORTHO-NAD83UTM3N	Mission 01-B-MLLW-DEM-NAD83UTM3N Mission 01-C-MLLW-ORTHO-NAD83UTM3N	
Mission 2	Mission 02-MLLW-ORTHO-NAD83UTM3N	Mission 02-MLLW-DEM-NAD83UTM3N	
Mission 3	Mission 03-b-MLLW-ORTHO-NAD83UTM3N Mission 03-ROCKS-MLLW-ORTHO-NAD83UTM3N	Mission 03-b-MLLW-DEM-NAD83UTM3N Mission 03-ROCKS-MLLW-DEM-NAD83UTM3N	
Mission 4			Mission not used, re-flown with Mission 33
Mission 5	Mission 05-MLLW-ORTHO-NAD83UTM3N	Mission 05-MLLW-DEM-NAD83UTM3N	
Mission 6	Mission 06-MLLW-ORTHO-NAD83UTM3N	Mission 06-MLLW-DEM-NAD83UTM3N	
Mission 7	Mission 07-ORTHO-NAD83UTM3N	Mission 07-DEM-NAD83UTM3N	
Mission 8	Mission 08-ORTHO-NAD83UTM3N Mission 08-ROCK-ORTHO-NAD83UTM3N	Mission 08-DEM-NAD83UTM3N	Mission 08-Rock shows the two awash rocks, not WL corrected
Mission 9	Mission 09-MLLW-ORTHO-NAD83UTM3N	Mission 09-MLLW-DEM-NAD83UTM3N	
Mission 10	Mission 10-MLLW-ORTHO-NAD83UTM3N	Mission 10-MLLW-DEM-NAD83UTM3N	

Mission #	Orthomosaic Filename	DEM Filename	Notes
Mission 11	Mission 11-MLLW-ORTHO-NAD83UTM3N	Mission 11-MLLW-DEM-NAD83UTM3N	
Mission 12	Mission 12-MLLW-ORTHO-NAD83UTM3N	Mission 12-MLLW-DEM-NAD83UTM3N	
Mission 13	Mission 13_A-MLLW-ORTHO-NAD83UTM3N Mission 13_B-MLLW-ORTHO-NAD83UTM3N Mission 13_C-MLLW-ORTHO-NAD83UTM3N	Mission 13_A-MLLW-DEM-NAD83UTM3N Mission 13_B-MLLW-DEM-NAD83UTM3N Mission 13_C-MLLW-DEM-NAD83UTM3N	
Mission 14	Mission 14-MLLW-ORTHO-NAD83UTM3N Mission 14-Offshore Rocks	Mission 14-MLLW-DEM-NAD83UTM3N	
Mission 15	Mission 15-MLLW-ORTHO-NAD83UTM3N	Mission 15-MLLW-DEM-NAD83UTM3N	
Mission 16	Mission 16-MLLW-ORTHO-NAD83UTM3N Mission 16_Offshore Rocks Mission 16-50_Offshore Rocks	Mission 16-MLLW-DEM-NAD83UTM3N	
Mission 17	m17 rks ortho_ortho_part_1_1 Mission 17-Offshore Rocks_2 Mission 17_inshoreRks-MLLW-ORTHO-NAD83UTM3N	Mission 17_inshoreRks-MLLW-DEM-NAD83UTM3N	
Mission 18	Mission 18-MLLW-ORTHO-NAD83UTM3N	Mission 18-MLLW-DEM-NAD83UTM3N	
Mission 19	Mission 19-MLLW-ORTHO-NAD83UTM3N Mission 19-ROCK-MLLW-ORTHO-NAD83UTM3N	Mission 19-MLLW-DEM-NAD83UTM3N Mission 19-ROCK-MLLW-DEM-NAD83UTM3N	
Mission 20	Mission 20-MLLW-ORTHO-NAD83UTM3N	Mission 20-MLLW-DEM-NAD83UTM3N	
Mission 21	Mission 21-MLLW-ORTHO-NAD83UTM3N	Mission 21-MLLW-DEM-NAD83UTM3N	
Mission 22	Mission 22-A-MLLW-ORTHO-NAD83UTM3N Mission 22-B-MLLW-ORTHO-NAD83UTM3N Mission 22-C-MLLW-ORTHO-NAD83UTM3N	Mission 22-A-MLLW-DEM-NAD83UTM3N Mission 22-B-MLLW-DEM-NAD83UTM3N Mission 22-C-MLLW-DEM-NAD83UTM3N	
Mission 23	Mission 23-MLLW-ORTHO-NAD83UTM3N	Mission 23-MLLW-DEM-NAD83UTM3N	
Mission 24	Mission 24-MLLW-ORTHO-NAD83UTM3N	Mission 24-MLLW-DEM-NAD83UTM3N	
Mission 25	Mission 25-MLLW-ORTHO-NAD83UTM3N	Mission 25-MLLW-DEM-NAD83UTM3N	
Mission 26	Mission 26-MLLW-ORTHO-NAD83UTM3N	Mission 26-MLLW-DEM-NAD83UTM3N	
Mission 27	Mission 27-MLLW-ORTHO-NAD83UTM3N	Mission 27-MLLW-DEM-NAD83UTM3N	
Mission 28	Mission 28-MLLW-ORTHO-NAD83UTM3N M28-Rocks	Mission 28-MLLW-DEM-NAD83UTM3N	Ortho with rocks is not tide corrected, used for position only
Mission 29	Mission 29-MLLW-ORTHO-NAD83UTM3N	Mission 29-MLLW-DEM-NAD83UTM3N	
Mission 30	Mission 30-MLLW-ORTHO-NAD83UTM3N Mission 30--ISLET-MLLW-ORTHO-NAD83UTM3N Mission 30-Offshore Rocks	Mission 30-MLLW-DEM-NAD83UTM3N Mission 30--ISLET-MLLW-DEM-NAD83UTM3N	
Mission 31	Mission 31-MLLW-ORTHO-NAD83UTM3N	Mission 31-MLLW-DEM-NAD83UTM3N	

Mission #	Orthomosaic Filename	DEM Filename	Notes
Mission 32	Mission 32-MLLW-ORTHO-NAD83UTM3N	Mission 32-MLLW-DEM-NAD83UTM3N	
Mission 33	Mission 33-MLLW-ORTHO-NAD83UTM3N	Mission 33-MLLW-DEM-NAD83UTM3N	
Mission 34	Mission 34-MLLW-ORTHO-NAD83UTM3N	Mission 34-MLLW-DEM-NAD83UTM3N	
Mission 35	Mission 35-MLLW-ORTHO-NAD83UTM3N	Mission 35-MLLW-DEM-NAD83UTM3N	
Mission 36	Mission 36_B-MLLW-ORTHO-NAD83UTM3N	Mission 36_B-MLLW-DEM-NAD83UTM3N	
Mission 37A	Mission 37_A-MLLW-ORTHO-NAD83UTM3N Mission 37-B-2-MLLW-ORTHO-NAD83UTM3N Mission 37_C-MLLW-ORTHO-NAD83UTM3N M37_GM_Rubber_NAD83UTM3N	Mission 37_A-MLLW-DEM-NAD83UTM3N Mission 37-B-2-MLLW-DEM-NAD83UTM3N Mission 37C [poorWL]-MLLW-DEM-NAD83UTM3N	The last ortho (GM Rubber) was made in Global Mapper to obtain position
Mission 37B	Mission 37-B-MLLW-ORTHO-NAD83UTM3N	Mission 37-B-MLLW-DEM-NAD83UTM3N	
Mission 38	Mission 38-MLLW-ORTHO-NAD83UTM3N	Mission 38-MLLW-DEM-NAD83UTM3N	
Mission 39	Mission 39-MLLW-ORTHO-NAD83UTM3N	Mission 39-MLLW-DEM-NAD83UTM3N	
Mission 40	Mission 40_B-std-ORTHO-NAD83UTM3N Mission 40-MLLW-ORTHO-NAD83UTM3N	Mission 40-MLLW-DEM-NAD83UTM3N	
Mission 41	Mission 41-MLLW-ORTHO-NAD83UTM3N	Mission 41-MLLW-DEM-NAD83UTM3N	
Mission 42	Mission 42-MLLW-ORTHO-NAD83UTM3N	Mission 42-MLLW-DEM-NAD83UTM3N	
Mission 43			Oblique used to verify kelp
Mission 44	Mission 44-MLLW-ORTHO-NAD83UTM3N	Mission 44-MLLW-DEM-NAD83UTM3N	
Mission 45	Mission 45-MLLW-ORTHO-NAD83UTM3N	Mission 45-MLLW-DEM-NAD83UTM3N	
Mission 46	Mission 46_A-MLLW-ORTHO-NAD83UTM3N Mission 46_B-MLLW-ORTHO-NAD83UTM3N Mission 46_C-MLLW-ORTHO-NAD83UTM3N	Mission 46_A-MLLW-DEM-NAD83UTM3N Mission 46_B-MLLW-DEM-NAD83UTM3N Mission 46_C-MLLW-DEM-NAD83UTM3N	
Mission 47	Mission 47-MLLW-ORTHO-NAD83UTM3N	Mission 47-MLLW-DEM-NAD83UTM3N	
Mission 48	Mission 48-MLLW-ORTHO-NAD83UTM3N	Mission 48-MLLW-DEM-NAD83UTM3N	
Mission 49	Mission 49-MLLW-ORTHO-NAD83UTM3N	Mission 49-MLLW-DEM-NAD83UTM3N	
Mission 50	Mission 50_A-MLLW-ORTHO-NAD83UTM3N Mission 50_B_inshore-MLLW-ORTHO-NAD83UTM3N Mission 50_C-MLLW-ORTHO-NAD83UTM3N	Mission 50_A-MLLW-DEM-NAD83UTM3N Mission 50_B_inshore-MLLW-DEM-NAD83UTM3N Mission 50C-MLLW-DEM-NAD83UTM3N	
Mission 51	Mission 51 [obl] -MLLW-ORTHO-NAD83UTM3N	Mission 51 [obl] -MLLW-DEM-NAD83UTM3N	Mission was flown oblique
Mission 52			52 was flown manually to verify kelp and fish traps
Mission 53			Mission 53 was flown manually

Mission #	Orthomosaic Filename	DEM Filename	Notes
			to verify Pankof Breaker

Table 19 – Ortho-photomosaic filenames and tide corrections.

The following table lists the average time of each mission and tide correction used:

Mission #	Time (ADT)	UTC	Tidal Correction (m) for Mission
Mission1	2018/06/17 14:00	2018/06/17 22:00	**0.02**
Mission2	2018/06/17 14:30	2018/06/17 22:30	**0.21**
Mission3	2018/06/17 14:48	2018/06/17 22:48	**0.35**
Mission4	2018/06/17 15:24	2018/06/17 23:24	**0.64**
Mission5	2018/06/18 11:12	2018/06/18 19:12	**0.27**
Mission6	2018/06/18 11:48	2018/06/18 19:48	**0.10**
Mission7	2018/06/18 12:36	2018/06/18 20:36	**-0.04**
Mission8	2018/06/18 13:24	2018/06/18 21:24	**-0.07**
Mission9	2018/06/18 13:48	2018/06/18 21:48	**-0.01**
Mission10	2018/06/18 14:24	2018/06/18 22:24	**0.11**
Mission11	2018/06/18 15:30	2018/06/18 23:30	**0.44**
Mission12	2018/06/18 15:06	2018/06/18 23:06	**0.28**
Mission13	2018/06/20 12:12	2018/06/20 20:12	**0.71**
Mission14	2018/06/20 12:54	2018/06/20 20:54	**0.48**
Mission15	2018/06/20 14:48	2018/06/20 22:48	**0.22**
Mission16	2018/06/20 15:12	2018/06/20 23:12	**0.23**
Mission17	2018/06/20 15:46	2018/06/20 23:46	**0.31**
Mission18	2018/06/20 17:30	2018/06/21 01:30	**0.68**
Mission19	2018/06/21 15:30	2018/06/21 23:30	**0.37**
Mission20	2018/06/21 15:54	2018/06/21 23:54	**0.36**
Mission21	2018/06/22 18:06	2018/06/23 02:06	**0.56**
Mission22	2018/06/22 18:24	2018/06/23 02:24	**0.62**
Mission23	2018/06/26 09:42	2018/06/26 17:42	**-0.28**
Mission24	2018/06/26 09:54	2018/06/26 17:54	**-0.23**
Mission25	2018/06/28 10:24	2018/06/28 18:24	**-0.14**
Mission26	2018/06/28 13:42	2018/06/28 21:42	**0.97**
Mission27	2018/06/28 12:54	2018/06/28 20:54	**0.62**
Mission28	2018/06/29 13:36	2018/06/29 21:36	**0.66**
Mission29	2018/06/30 10:06	2018/06/30 18:06	**-0.21**
Mission30	2018/06/30 10:54	2018/06/30 18:54	**-0.25**
Mission31	2018/06/30 12:12	2018/06/30 20:12	**-0.09**
Mission32	2018/06/30 12:36	2018/06/30 20:36	**0.02**
Mission33	2018/07/01 13:06	2018/07/01 21:06	**-0.02**
Mission34	2018/07/01 13:36	2018/07/01 21:36	**0.13**

Mission #	Time (ADT)	UTC	Tidal Correction (m) for Mission
Mission35	2018/07/04 14:18	2018/07/04 22:18	**0.08**
Mission36	2018/07/05 13:12	2018/07/05 21:12	**0.13**
Mission37A	2018/07/05 14:36	2018/07/05 22:36	**0.16**
Mission37B	2018/07/05 14:48	2018/07/05 22:48	**0.19**
Mission38	2018/07/05 15:06	2018/07/05 23:06	**0.23**
Mission39	2018/07/09 08:54	2018/07/09 16:54	**0.31**
Mission39_OBL	2018/07/09 08:54	2018/07/09 16:54	**0.31**
Mission40	2018/07/09 09:24	2018/07/09 17:24	**0.47**
Mission40b	2018/07/09 09:36	2018/07/09 17:36	**0.56**
Mission41	2018/07/10 08:12	2018/07/10 16:12	**-0.35**
Mission42	2018/07/10 08:54	2018/07/10 16:54	**-0.24**
Mission43	2018/07/10 09:12	2018/07/10 17:12	**-0.13**
Mission43_OBL	2018/07/10 09:12	2018/07/10 17:12	**-0.13**
Mission44	2018/07/13 10:30	2018/07/13 18:30	**-0.53**
Mission45	2018/07/13 11:06	2018/07/13 19:06	**-0.38**
Mission46	2018/07/14 09:18	2018/07/14 17:18	**-0.47**
Mission47	2018/07/14 10:54	2018/07/14 18:54	**-0.53**
Mission48	2018/07/14 11:18	2018/07/14 19:18	**-0.48**
Mission49	2018/07/14 11:48	2018/07/14 19:48	**-0.37**
Mission50	2018/07/14 13:48	2018/07/14 21:48	**0.62**
Mission51	2018/07/22 13:42	2018/07/22 21:42	**0.73**
Mission52	2018/07/22 16:00	2018/07/23 00:00	**0.56**
Mission53_Pankof1	2018/07/22 19:06	2018/07/23 03:06	**0.94**

Table 20 – Aerial mission times and tide corrector values.

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 depth (at time of observation) 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 3 North. GeoTIF images are named for the associated mission, and split when necessary to address issues with processing individual sections. GeoTIF DEMs are referenced to MLLW and open as BASE surfaces with associated elevation data in CARIS HIPS.

Note that the accuracy of ortho-photomosaics and DEMs degrades toward the outside edges. For some offshore features where it was obvious that a better position existed at a “hole” in multibeam data where the top of the feature could not be surveyed by sonar, the multibeam position of the hole was used instead of the orthomosaic aerial position. These are noted in the feature remarks when applicable.

Raw aerial images are included with the survey deliverables as well, organized by mission in the raw data (preprocess) directory.

B.4.4. SfM Quality Control

Ground control for positioning aerial imagery was not used for this project. However, one formal check was completed using the project base station in addition to regular reality checks. These are summarized below.

A formal check was accomplished by overflight of the project base station on the Ikatan Peninsula. This position was the only fixed “known” position on the project. Missions 9 and 51 were planned so as to include the base station in the flight path as if the GPS base station tripod were an assigned shoreline feature. The position for the center of the GPS antenna could be easily identified in the orthomosaics, and was subsequently compared to the known location of the GPS antenna for the two missions. Agreement was 1.8 to 3.9 meters horizontally.

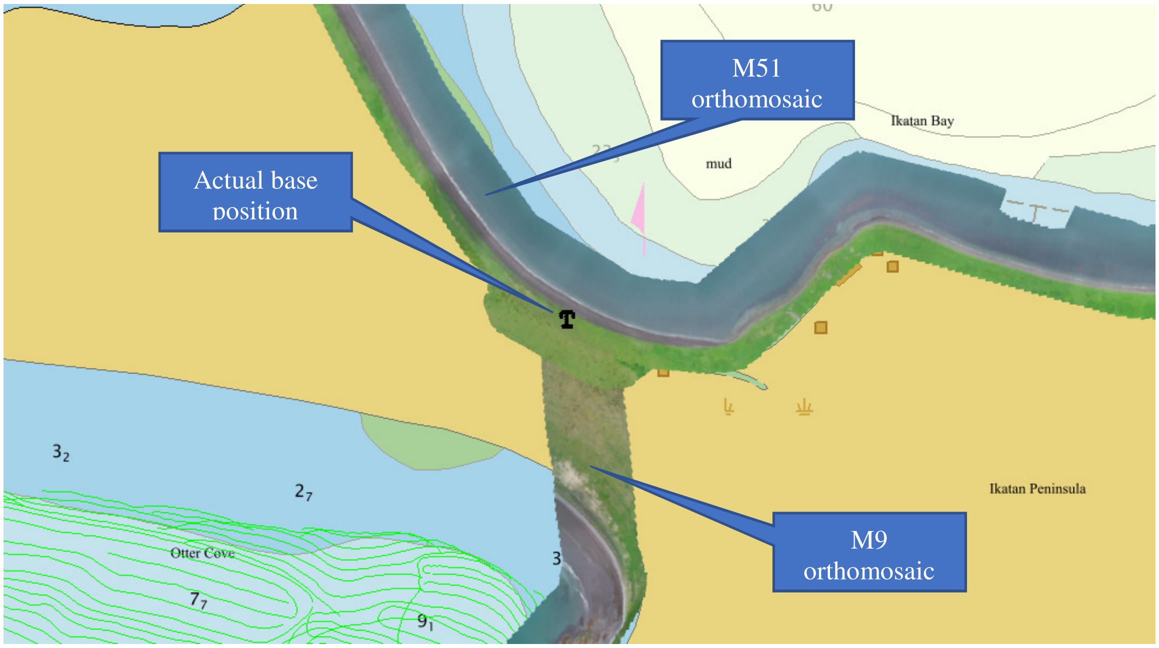
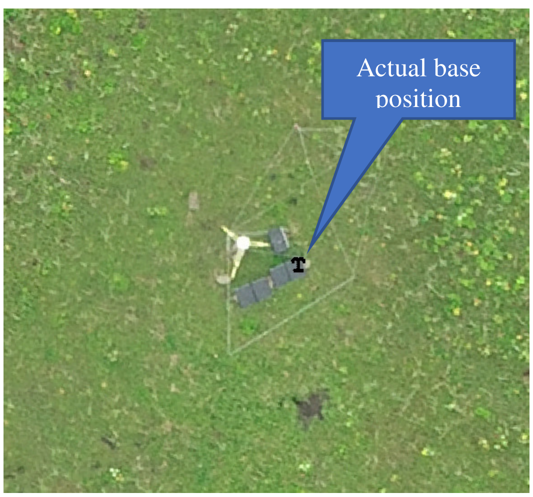
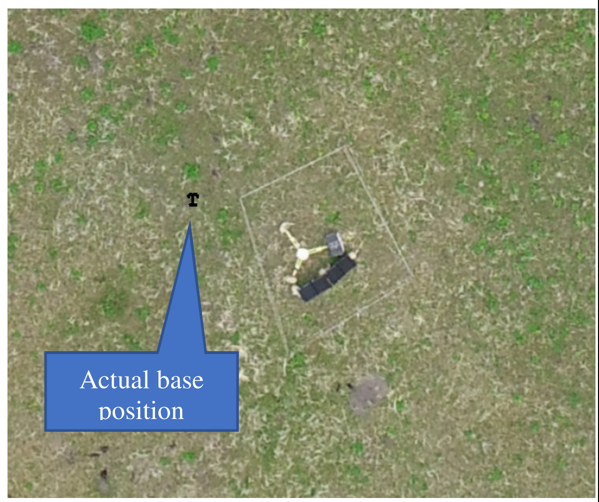


Figure 25 Base station comparison with aerial orthomosaics. GPS tripod with white Trimble antenna is visible in the orthomosaics.

Mission 51 (July 22nd, 2018)	Mission 9 (June 18th, 2018)
	
Difference: 1.8 meters	Difference: 3.9 meters

A vertical check was also accomplished using the base station. The known height of the antenna above MHW was compared to the SfM point cloud data result for the antenna. Results compared to within 0.06 m vertically, as shown in the following table:

Base Station	Known Height (MHW)	Point Cloud Height (MHW)	Difference
Antenna (Top)	3.96	4.03	-0.06

Additionally, the relative height difference between the antenna and the benchmark on the ground directly under the antenna was compared to the height difference between the antenna and the ground underneath in the SfM point cloud. The measured antenna height by the field crew of 1.171 m (top of antenna) compared well to the SfM computed relative height difference, which was 1.20 m – a difference of 0.03 m.

The charted position for the Ikatan Point Light ATON was also compared to the SfM results from Mission 24.

Figure 26 Ikatan Point Light. Charted position for the light was compared to the SfM results as well.

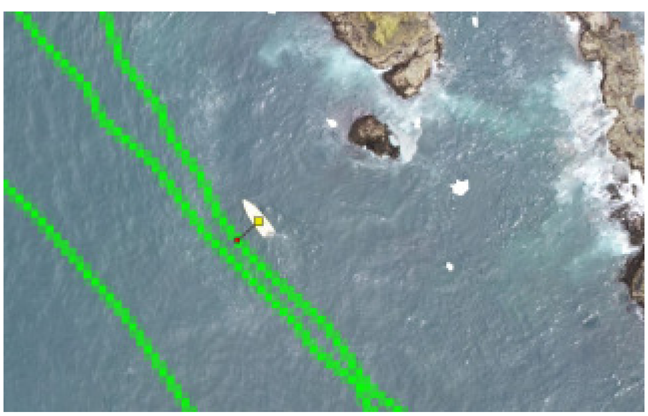
Horizontally, the orthomosaic position of the light differed from the charted position by 5 meters. However, it is unknown if the charted position is the actual light on the structure or center of the structure itself. This comparison assumed the charted position is for the light – the results would be approximately 1 m better if the charted position is actually for the center of the structure.

Figure 27 Mission 24 orthomosaic compared to charted Ikatan Point Light position, showing a 5 m horizontal difference.

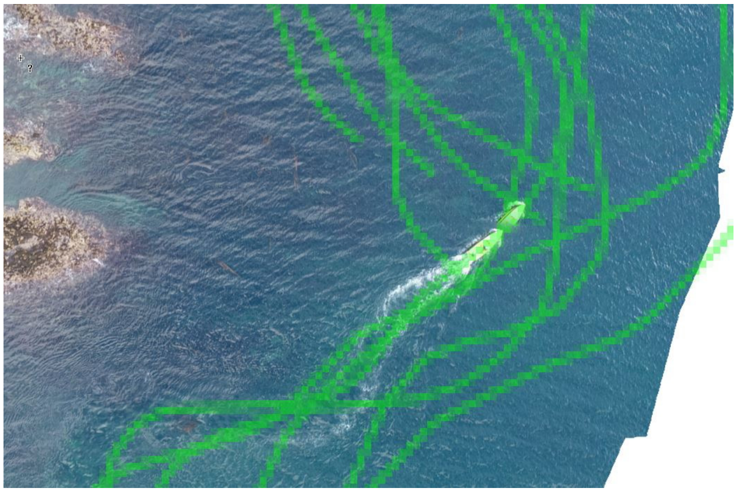
Vertically the MHW height of the light compared very well to the point cloud MHW height, as shown below.

	Known Height (MHW)	Point Cloud Height (MHW)	Difference
Ikatan Point Light	24.69	24.75	-0.06

Horizontal positioning results were also received reality checks by comparison with the post-processed vessel tracklines for the ASV-CW5, which was incidentally captured in the orthomosaic imagery during some missions. Results are summarized below.

ASV-CW5	Cross-track Difference
 Mission 13	3.7 meters

 Mission 18	7.6 meters
 Mission 19	2.2 meters
 Mission 35	0.7 meters

 Mission 41	0.1 meters

Agreement is generally good between the *ASV-CW5* and its orthomosaic position. The outlier of 7.6 m may be the result of the fact that the *ASV-CW5* was in the outer edge of the imagery and the orthomosaic accuracy degrades as the outer edges are approached.

There is significant overlap between the orthomosaics and the multibeam data for this project. This served as a readily available check on orthomosaic positions along the entire survey area. This position agreement was examined frequently during compilation of the FFF and was found to almost always agree to 5 m or better, but usually within 1-2 m. 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.

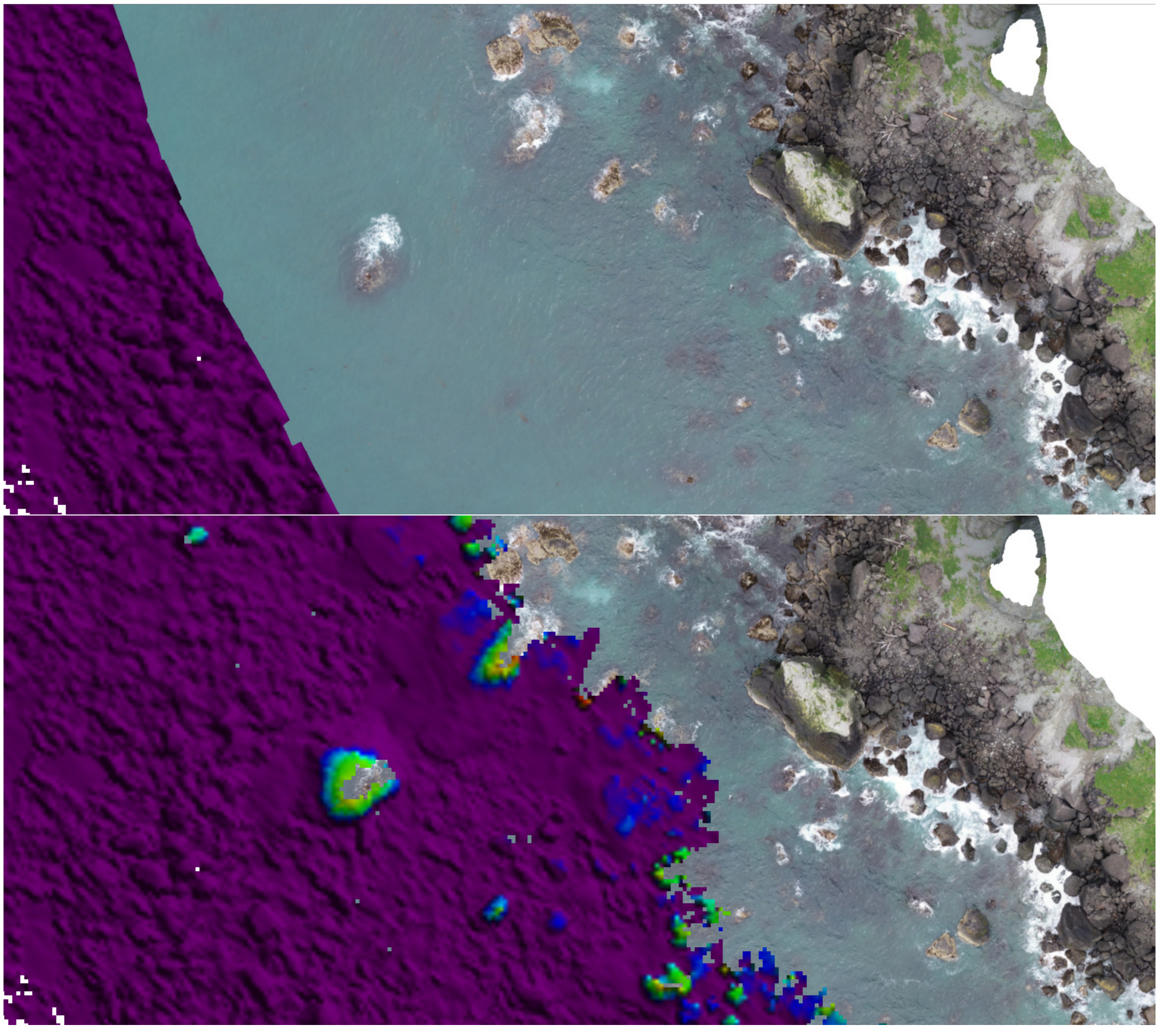


Figure 28 Example of typical multibeam-orthomosaic agreement (Mission 8). Top image shows the orthomosaic on top of the 1m resolution multibeam. Lower image is the multibeam on top of the orthomosaic. Horizontal agreement of the rocks is about 1-2 meters.

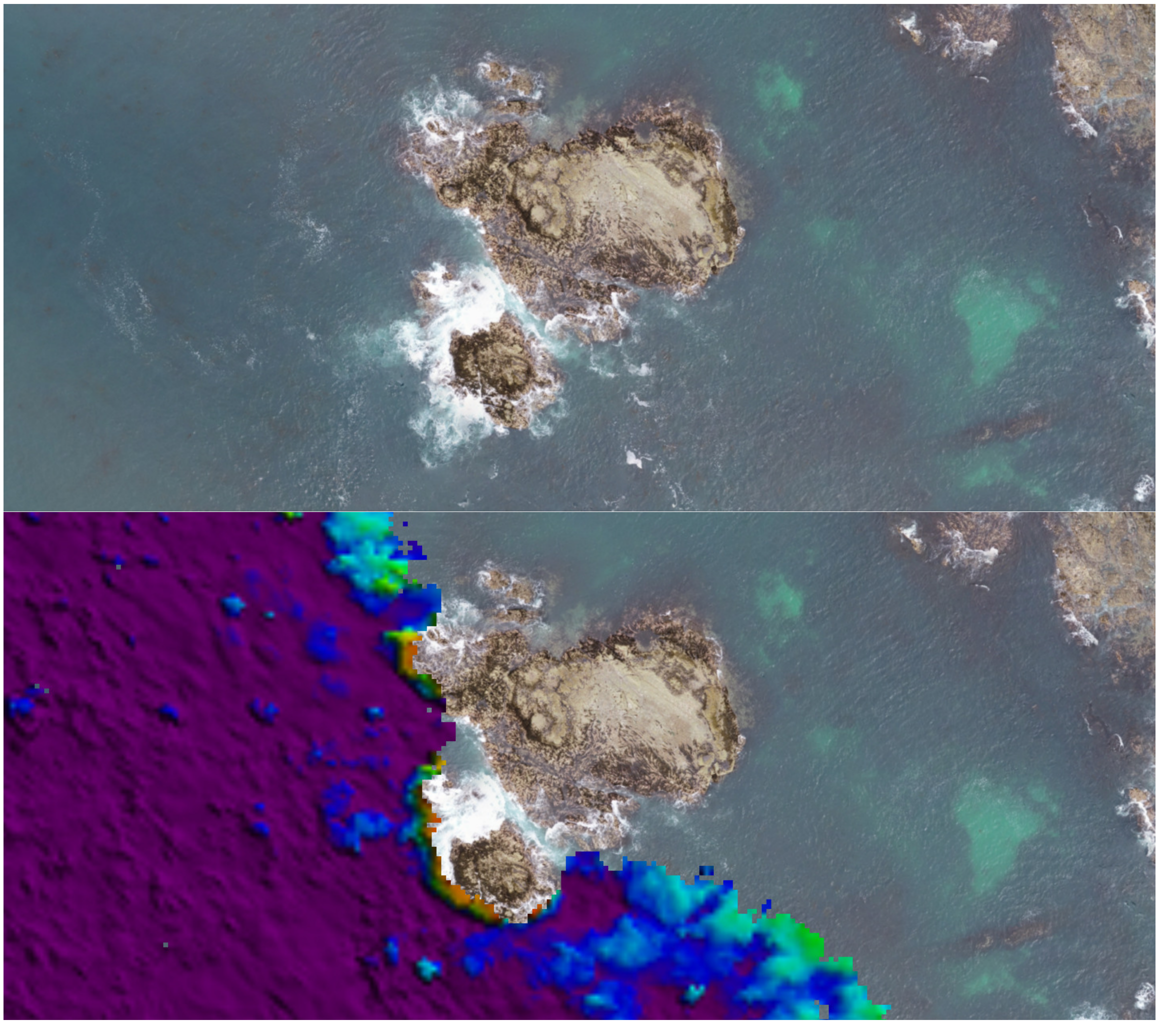


Figure 29 Example of typical multibeam-orthomosaic agreement (Mission 7). Top image shows the orthomosaic on top of the 1m resolution multibeam. Lower image is the multibeam on top of the orthomosaic. Multibeam agrees well with the edges of the rock in the orthomosaic, within 1-2 meters.

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.

PhotoScan software processing report with individual Mission statistics is available in Separate I for the DR of survey H13113.

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	Planned Frequency
Depth Check: Bar Check	Check depth accuracy Determine and refine Z offsets	Once per project
Depth Check: Lead Line	Check depth accuracy	When dockside
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 (PPRTX vs ASB vs Local 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, when possible
Tide Float	Independent GPS over vessel waterline during tide floats, compared to POSMV-computed waterline	During tide floats at project tide gauges

Table 21 – Summary of formal confidence checks.

B.5.1. Bar Checks

One formal bar check was completed during this project. The bar check results were 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 due to the difficulty involved with this check on the unmanned vessel – MBES data was compared directly to *Q105* data instead (see multi-vessel echosounder comparisons below).

The bar check was completed while dockside in the Sand Point Harbor on JD158. Weather conditions were calm.

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 2.5-6.5 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.

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 (static draft) applied. Depth of the bar relative to the waterline was extracted from HIPS in swath editor and compared to the actual bar depth at that time.

Processed bar depths (CARIS results) compared to actual bar depths to 0.061 m on average with a standard deviation of 0.018 m. Computed bar depths (correction with known offsets using observed depth from the sounder) compared to 0.042 m on average with a standard deviation of 0.02 m. The computed acoustic center Z value compared to within 0.005 m with a standard deviation of 0.020.

The reason for the slight bias of 0.061 m between processed (CARIS) results and actual bar depth (with processed results shoaler) is unknown, especially since the acoustic center offset check was excellent at 0.005 m. However, this amount of deviation was considered acceptable given that it is well within error specifications and the vessel showed excellent agreement during comparisons with the other survey vessel on the project (the *ASV-CW5*), and lead line checks (discussed in next section) showed excellent agreement.

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 completed periodically on the *Q105* to check for gross error in the absolute accuracy for the echosounder and processing systems. This check was done on four separate occasions over the course of the project, normally whenever dockside in the Sand Point harbor: On JD158 concurrent with the bar check described previously, and again on JD171, JD183, and JD198. All were done in calm conditions.

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 little to no slope was apparent on the seafloor at the dockside test position in the harbor.

The real-time or raw sonar depth was noted and compared to the lead line depth, with corrections for static draft and vessel offsets applied.

XTF files were also logged so that the processed results from CARIS could be compared to the lead line depth. Sound speed casts were not taken during the JD171 and JD183 tests however, making a comparison of processed results unavailable for these two checks.

Results are summarized in the following table.

Julian Day	Actual (Lead Line) Depth	Real-time: LL versus Corrected Raw Sonar Depth		Processed: LL versus CARIS Processed Depth	
		Depth	Difference	Result	Difference
JD158	6.935 m	6.864 m	0.071 m	6.908 m	0.027 m
JD171	7.130 m	7.114 m	0.016 m	n/a	n/a
JD183	6.950 m	6.969 m	-0.019 m	n/a	n/a
JD198	8.200 m	8.204 m	-0.004 m	8.207 m	-0.007 m

Table 22 – Q105 Lead Line check results summary

Results were excellent, with processed results comparing to 0.027 m or better, and real-time results comparing to 0.071 m or better.

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.

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 4 m resolution were created for each vessel and differenced from each other. The difference surfaces were exported to text and analyzed in Excel.

Nine separate comparisons were conducted. Echosounder data from the separate vessels compared well, with average differences falling in the range of 0.076 m (*Q105* shoaler) to -0.147 m (*ASV-CW5* shoaler), with several comparing to 0.02 m or better.

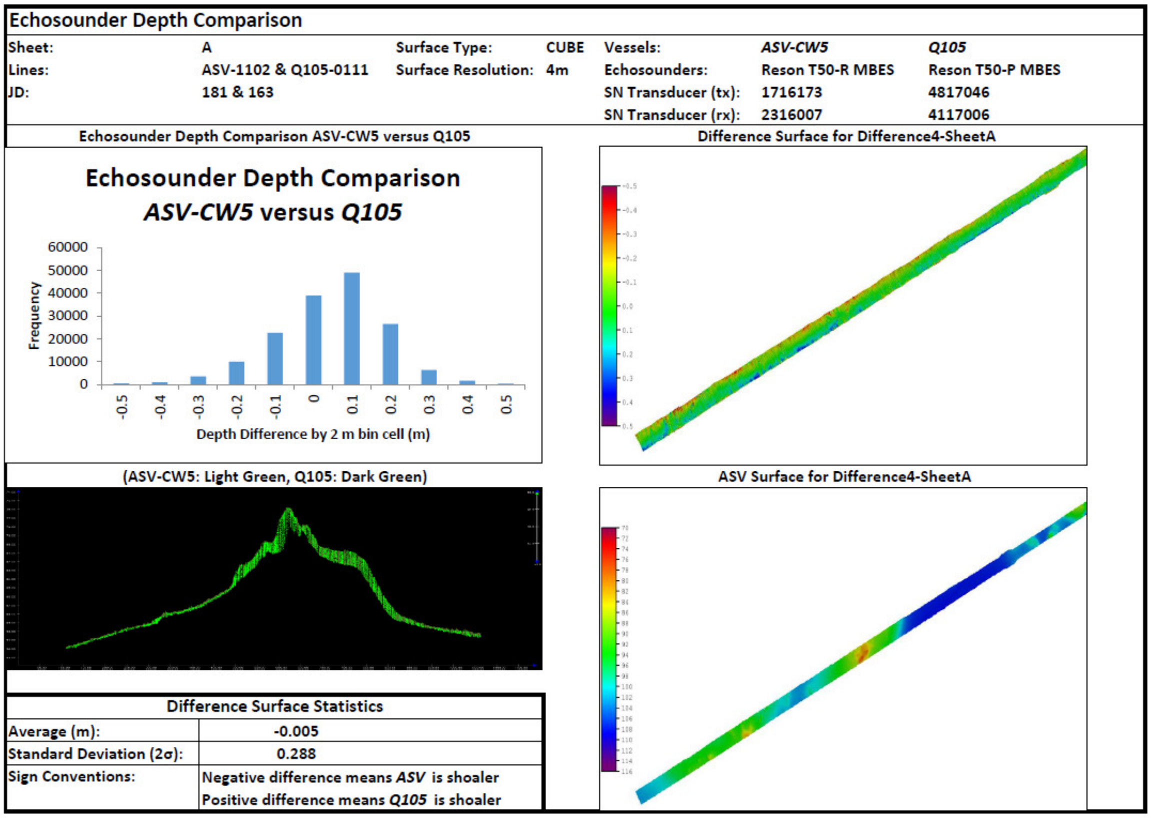


Figure 30 – Example Echosounder Depth Comparison report from this project.

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.

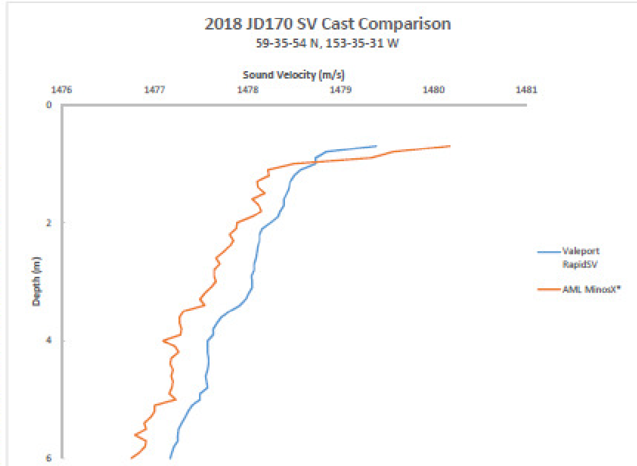
B.5.4. SVP Comparison

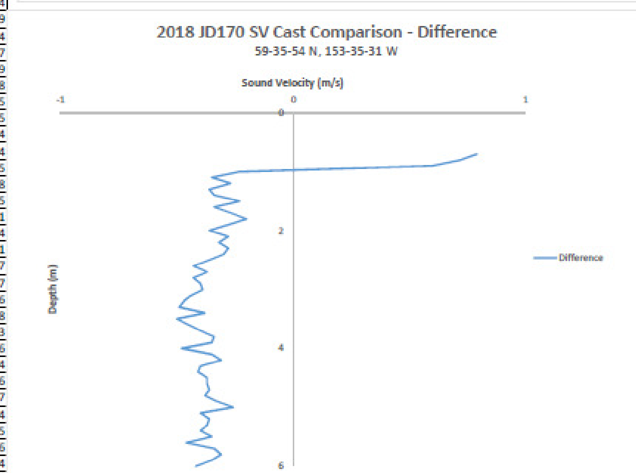
An SVP comparison was used to check the accuracy and consistency of the sound velocity profiler data. In the test, data from the primary sound speed profiler was compared to one other independent, recently calibrated sound speed profiler. Both profilers were lowered simultaneously to the seafloor, with 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 a AML MinosX (with SV-Xchange and P-Xchange sensors). This check was accomplished on JD170 and extended to a depth of approximately 6 m. Comparison results were good, with the probes comparing to each other within 0.3 m/s on average.

SVP confidence checks/comparison results are available with the project DRs.

SV Probe Results			
Sensor:	Valeport RapidSV	AML MinosX*	
SN:	49911	30421	
Date of Cal.	4/20/2018	4/10/2018	
Date/Time:	2018-170 23:30	2018-170 23:43	
Depth	Sound Speed (m/s)		Difference
0.7	1480.17	1479.38	0.79
0.8	1479.57	1478.85	0.72
0.9	1479.33	1478.73	0.6
1	1478.5	1478.73	-0.23
1.1	1478.22	1478.57	-0.35
1.2	1478.23	1478.5	-0.27
1.3	1478.1	1478.46	-0.36
1.4	1478.11	1478.45	-0.34
1.5	1478.19	1478.42	-0.23
1.6	1478.05	1478.39	-0.34
1.7	1478.12	1478.39	-0.27
1.8	1478.15	1478.35	-0.2
1.9	1478.05	1478.33	-0.28
2	1477.89	1478.25	-0.36
2.1	1477.88	1478.16	-0.28
2.2	1477.81	1478.13	-0.32
2.3	1477.85	1478.13	-0.28
2.4	1477.81	1478.11	-0.3
2.5	1477.74	1478.1	-0.36
2.6	1477.66	1478.09	-0.43
2.7	1477.7	1478.07	-0.37
2.8	1477.64	1478.07	-0.43
2.9	1477.64	1478.04	-0.4
3	1477.66	1478.05	-0.39
3.1	1477.61	1478.05	-0.44
3.2	1477.54	1478.01	-0.47
3.3	1477.49	1477.98	-0.49
3.4	1477.54	1477.92	-0.38
3.5	1477.31	1477.81	-0.5
3.6	1477.27	1477.72	-0.45
3.7	1477.27	1477.67	-0.4
3.8	1477.29	1477.63	-0.34
3.9	1477.28	1477.63	-0.35
4	1477.09	1477.57	-0.48
4.1	1477.22	1477.57	-0.35
4.2	1477.26	1477.57	-0.31
4.3	1477.18	1477.58	-0.4
4.4	1477.17	1477.58	-0.41
4.5	1477.2	1477.57	-0.37
4.6	1477.18	1477.55	-0.37
4.7	1477.2	1477.56	-0.36
4.8	1477.19	1477.57	-0.38
4.9	1477.16	1477.49	-0.33
5	1477.23	1477.49	-0.26
5.1	1477	1477.4	-0.4
5.2	1477	1477.36	-0.36
5.3	1476.96	1477.33	-0.37
5.4	1476.89	1477.29	-0.4
5.5	1476.91	1477.26	-0.35
5.6	1476.79	1477.25	-0.46
5.7	1476.91	1477.25	-0.34
5.8	1476.9	1477.21	-0.31
5.9	1476.84	1477.19	-0.35
6	1476.75	1477.17	-0.42





*Minos X includes SV-Xchange sensor SN204167 and P-Xchange sensor SN305722

Average difference: -0.30148 (Valeport reads faster)
Std Dev: 0.255398

Figure 31 – Example of SVP confidence check (comparison results).

B.5.5. Base Station Position Checks

For the project base station, 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 site. This position became the accepted, surveyed position that subsequent measurements were compared against.

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 at the base. An ARP of 1.118 m, determined and checked during site visits in the field, was entered as the antenna height.

Results returned by OPUS compared to 0.017 m vertically and 0.011 m horizontally (or better) of the original position, which demonstrates excellent stability of the initial ARP position for the base station. 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.

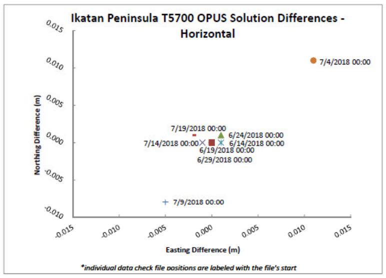
TerraSond Limited | Base Station Position Checks | NOAA SW AK Peninsula, 2018

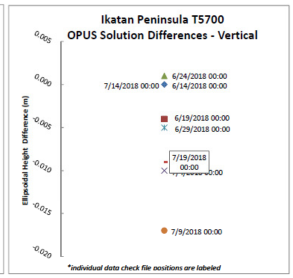
Base Station Position Checks

Base Name:	TerraSond Ikatan Peninsula Base	ID: 5240	Receiver Serial:	220275240
Site Description:	Located over TBM on Ikatan Peninsula		Antenna Serial:	60078756
Receiver Type:	Trimble 5700			
Antenna Type:	Trimble Zephyr Geodetic (TRM41249.00)			
Project number:	OPR-P377-KR-18			
Horizontal Datum:	NAD83 (2011)			
Projection:	UTM Zone 3N			
Ellipsoid:	GRS80			

Notes:
* Surveyed position is from 24-hour OPUS solution filename "52401650.18o", logged JD165 (6/14/18), with ARP height of 1.118 m

PPK Site Coordinate:		Latitude(dms)	Longitude(dms)	Northing(m)	Easting (m)	Ellipsoidal Height(m)
Surveyed*	24-hr OPUS (6/14/18)	54 45 2.73460	163 19 37.53937	6068340.588	607670.553	21.611





Ikatan Peninsula T5700 Location

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 OPUS	Latitude(dms)	Longitude(dms)	Northing(m)	Easting(m)	Ellipsoidal Height (m)	Northing (m)	Easting (m)	Ellipsoidal Height (m)
1	6/14/2018 00:00	6/14/2018 23:34	24.0	52401650.18o	ARP	1.1180	54 45 2.73460	163 19 37.53937	6068340.588	607670.553	21.611	0.000	0.000	0.000
1	6/19/2018 00:00	6/19/2018 23:34	24.0	52401700.18o	ARP	1.1180	54 45 2.73460	163 19 37.53934	6068340.588	607670.553	21.607	0.000	0.000	-0.004
1	6/24/2018 00:00	6/24/2018 23:34	24.0	52401750.18o	ARP	1.1180	54 45 2.73463	163 19 37.53930	6068340.589	607670.554	21.612	0.001	0.001	0.001
1	6/29/2018 00:00	6/29/2018 23:34	24.0	52401800.18o	ARP	1.1180	54 45 2.73460	163 19 37.53930	6068340.588	607670.554	21.606	0.000	0.001	-0.005
1	7/4/2018 00:00	7/4/2018 23:34	24.0	52401850.18o	ARP	1.1180	54 45 2.73496	163 19 37.53872	6068340.599	607670.564	21.601	0.011	0.011	-0.010
1	7/9/2018 00:00	7/9/2018 23:34	24.0	52401900.18o	ARP	1.1180	54 45 2.73434	163 19 37.53966	6068340.580	607670.548	21.594	-0.008	-0.005	-0.017
1	7/14/2018 00:00	7/14/2018 23:34	24.0	52401950.18o	ARP	1.1180	54 45 2.73460	163 19 37.53941	6068340.588	607670.552	21.611	0.000	-0.001	0.000
1	7/19/2018 00:00	7/19/2018 00:00	24.0	52402000.18o	ARP	1.1180	54 45 2.73463	163 19 37.53944	6068340.589	607670.551	21.602	0.001	-0.002	-0.009

Comments: Good agreement between all subsequent data points

	Northing (m)	Easting (m)	Ellipsoidal Height (m)
Max Delta:	0.011	0.011	0.001
Min Delta:	-0.008	-0.005	-0.017
Std Dev:	0.005	0.005	0.006

Figure 32 – Example Base Station Position Check logsheet.

B.5.6. Vessel Positioning Confidence Checks – Alternate Processing Method

To ensure vessel positioning was consistent regardless of the base station or PPK processing method used, and as an accuracy check of vessel positioning, vessel position confidence checks were accomplished by processing with an alternative POSPac processing methods and comparing the primary method. These checks were accomplished on a weekly basis.

To complete the check for each vessel, a random POS file was selected from each week and re-processed with Applanix SmartBase (ASB). This was compared to the same POS file processed with PP-RTX. 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 processing method used.

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

TerraSond Limited Vessel Positioning Confidence Check NOAA SW AK Peninsula

Vessel Positioning Confidence Check

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

POS file:2018-167-0010-Q105.000 **Date:** June 16, 2018 (JD167) **Vessel:** Q105

Base Stations Used

Base Station Name	Operating Agency	Function	Data Rate	Min. Baseline Distance (m)	Max. Baseline Distance (m)
PPRTX	PPP / Trimble	Project Primary	n/a	n/a	n/a
ASB	Various CORS	Project Secondary	varies	n/a	n/a

Table 1- Base stations used for comparison

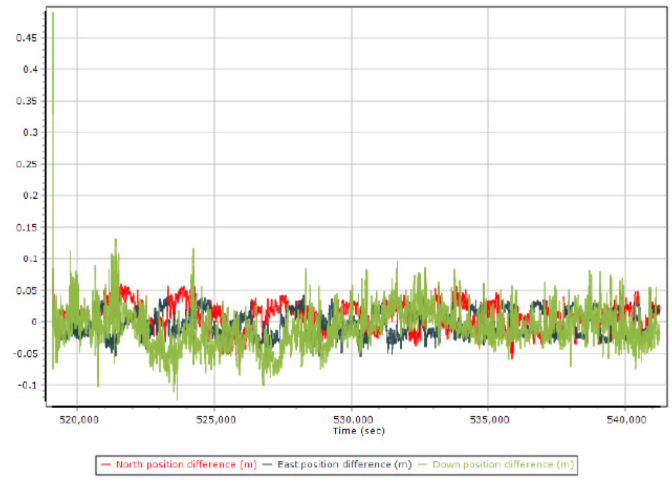


Figure 1 - Results of position difference between use of the two different processing methods

Comments: *Agreement generally 0.05 m or better horizontally and vertically*

Figure 33 – Example of Vessel Positioning Confidence Check (alternate base station), from JD167.

B.5.7. Tide Station Staff Shots and Operation

No tertiary tide stations were required or installed for this project. However, three zoning gauges (including two GPS buoys) were deployed per the TerraSond tides proposal to provide data checks on the final tide correction model.

Refer to the project HVCR for more information on the project zoning sites and quality control measures undertaken.

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 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 and SV2 sensors in the HVF. This was done per CARIS's technical bulletin "HIPS and SIPS Technical Note for Sound Velocity Correction for Teledyne Reson 7k Data".

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

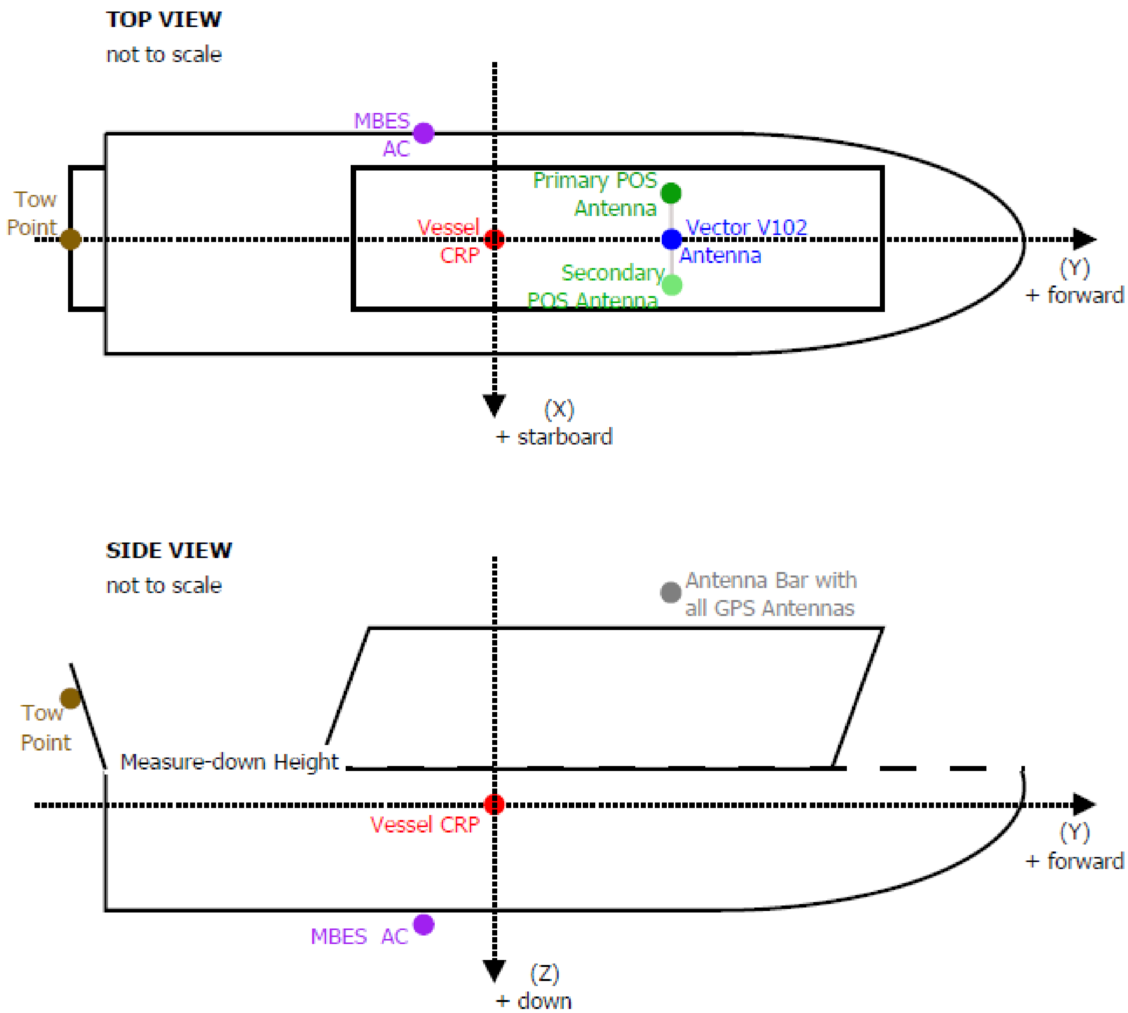


Figure 34 – Q105 vessel survey showing relative positions of installed survey equipment.

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 (Tx)	-3.993	-3.127	1.000	AC of MBES Projector – vessel survey
MBES Acoustic Center (Rx)	-3.993	-2.935	1.047	AC of MBES Receiver – vessel survey
Primary POS Antenna	-0.989	5.095	-14.021	POSPac lever arm calibration
Secondary POS Antenna	1.029	5.106	-14.019	Calculated through GAMS calibration results
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	

Table 6 – Q105 offset measurements relative to CRP.

C.1.2. ASV-CW5 Offsets

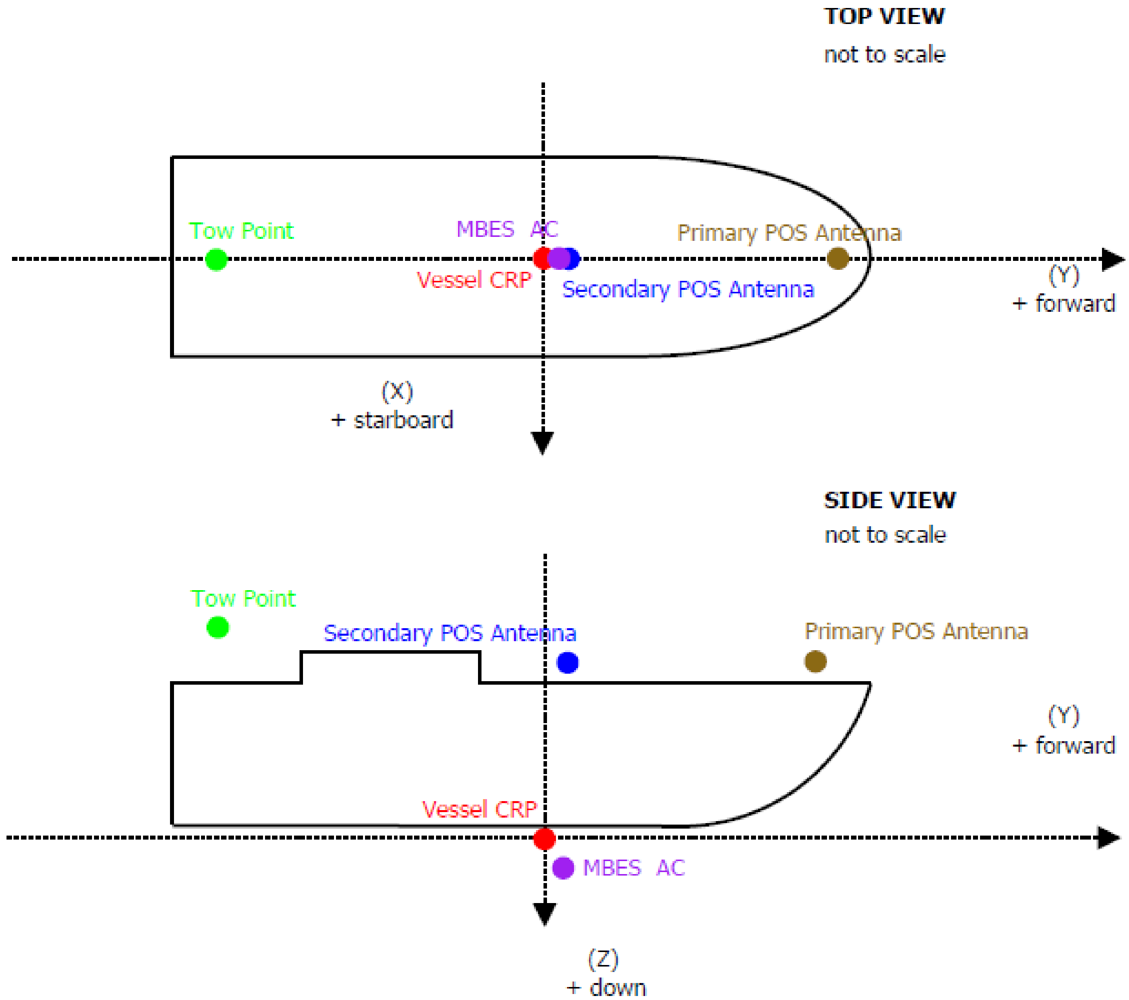


Figure 35 – ASV-CW5 vessel survey showing relative positions of installed survey equipment.

<table>
<tr><th rowspan="2">Equipment</th><th>X (m)</th><th>Y (m)</th><th>Z (m)</th><th rowspan="2">Comments</th></tr>
<tr><th>(+ stbd)</th><th>(+ fwd)</th><th>(+ down)</th></tr>
<tr><td>CRP</td><td>0.000</td><td>0.000</td><td>0.000</td><td>Top-center of POSMV IMU</td></tr>
<tr><td>MBES Acoustic Center (Tx)</td><td>0.000</td><td>0.093</td><td>0.166</td><td>AC of MBES Projector – vessel survey</td></tr>
<tr><td>MBES Acoustic Center (Rx)</td><td>0.000</td><td>0.284</td><td>0.213</td><td>AC of MBES Receiver – vessel survey</td></tr>
<tr><td>Primary POS Antenna</td><td>0.000</td><td>1.660</td><td>-1.556</td><td>Vessel survey</td></tr>
<tr><td>Secondary POS Antenna</td><td>-0.200</td><td>0.157</td><td>-1.539</td><td>Calculated through GAMS calibration results</td></tr>
<tr><td>Stern Tow Point</td><td>0.000</td><td>-3.17</td><td>-0.91</td><td>A-frame block in tow position (not used this project)</td></tr>
<tr><td>Draft Measure-down Point (port side)</td><td>-</td><td>0.000</td><td rowspan="2">-1.300</td><td rowspan="2">ASV deck above CRP</td></tr>
<tr><td>Draft Measure-down Point (stbd side)</td><td>-</td><td>0.000</td></tr>
</table>

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

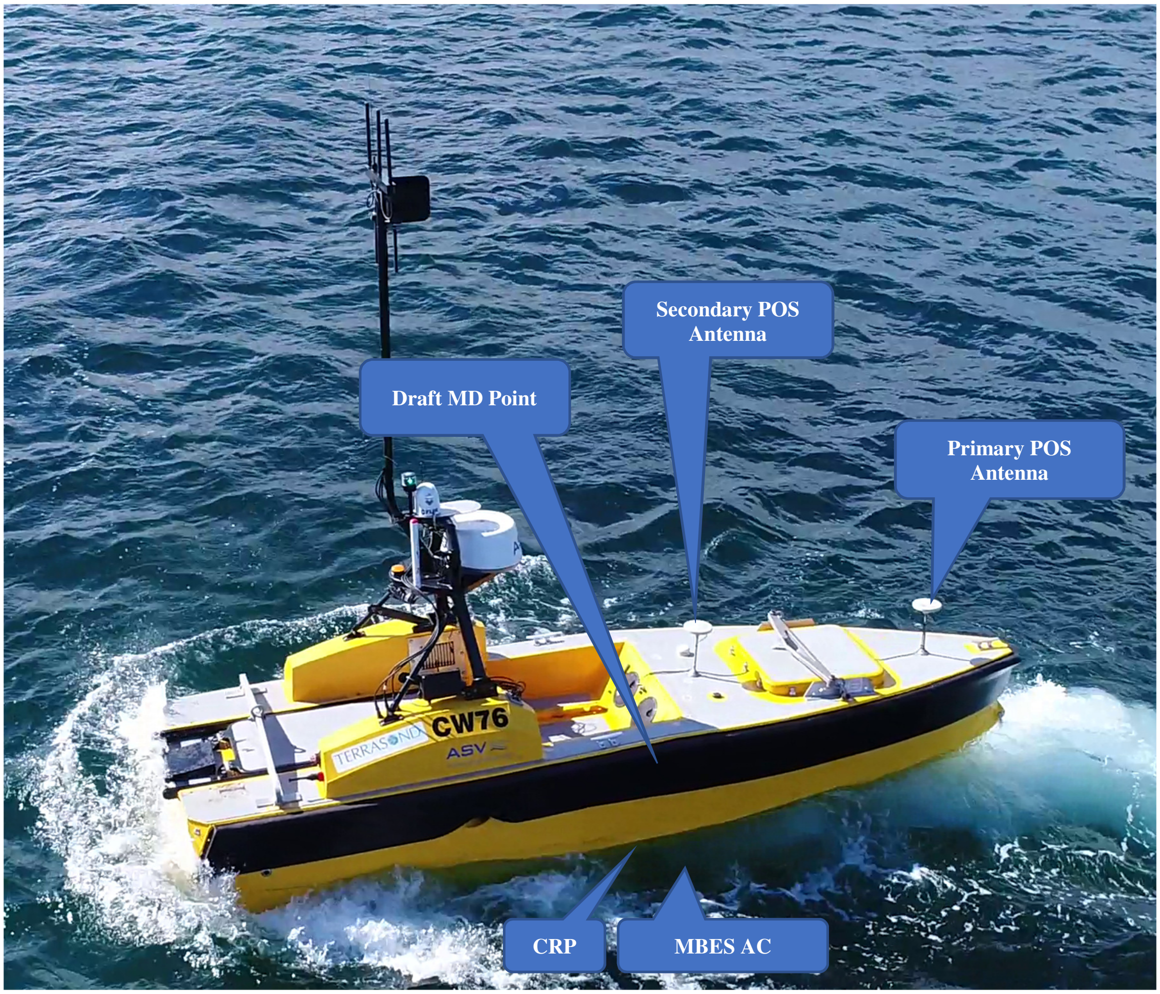


Figure 36 – ASV-CW5 primary sensors and offset measurement points.

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	2018-155	2.018	2.018	0.010	0.002
ASV-CW5		1.516	-0.200	-1.503	0.017

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.

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.

An initial patch test was completed during sea trials shortly after mobilization in Homer, Alaska on JD155. Values were checked with a close-out patch test in the survey area near the end of operations on JD204.

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 into the HVF.

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

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

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

As described in Section B of this report, it was necessary to determine and apply roll corrections for the *Q105* to compensate for periodic changes in alignment between the multibeam arm and the POSMV IMU. These roll corrections are available for review in the CARIS HVF for the *Q105*.

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

Vessel	Patch Test	Latency (seconds)	Pitch	Yaw	Roll	Comments
Q105	2018-155	0.000	-1.300	1.150	-1.040	Homer, Alaska
	2018-204	0.000	-1.300	1.150	-0.960	Project area
ASV-CW5	2018-155	0.000	0.000	7.200	-0.150	Homer, Alaska
	2018-204	0.000	0.000	7.200	-0.150	Project area

Table 7 – Patch Test calibration results.

Note that no pitch offset was discernable for the *ASV-CW5* data and only a small roll offset, likely due to the mount configuration on that vessel whereby the POSMV IMU was directly secured on the sonar head mount using the manufacturer's mount hardware. However, an abnormally large yaw correction of 7.2° was derived from the patch test results and reconfirmed. The suspected reason was a skew in the primary antenna mount to starboard, relative to the vessel's fore-aft axis and the secondary antenna. The IMU itself was confirmed to be well aligned with the vessel fore-aft axis. No adverse effect on the data was apparent from the large yaw offset.

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.

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. Over the course of the project, multiple measurements were taken on the *Q105* while only one measurement was necessary on the *ASV-CW5*.

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 were speed-based. Engine RPM data was logged but not used for dynamic draft corrections.

Corrections were determined for each vessel by means of a squat settlement test. PPK GPS methods were used to produce and extract the GPS altitudes from the test. Corrections were determined for a range that covered normal vessel speeds experienced while surveying. The values were checked against results obtained on the same vessels in prior years, with results comparing well.

Note that as an Ellipsoid Referenced Survey (ERS) project, vertical changes in vessel displacement were captured in the GPS data for the vessel. Therefore dynamic draft correctors, which were applied to sounding data during sound speed correction, were also applied to GPS heights during the "Compute GPSTide" process (described later in this report), which had the end effect of not applying the correctors.

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. 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.

Refer to Section B of this report for more information on the acquisition and processing of the RPM data. 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 JD203. Speed values between 2.2 and 4.1 m/s were tested (RPM values between 650 and 1050). This range encompassed the speed and RPM settings used during survey operations. Values were smoothed using a 2nd order polynomial equation to create a correction at every 0.1 m/s change in speed and entered into the HVF.

Squat settlement results obtained on this vessel from 2013 through 2017 were compared to this test, with results showing good consistency between years, comparing on average to 0.02 m or better at each speed/RPM point.

Q105 Squat-Settlement Results (2018)	
Speed (m/s)	Dynamic Draft (+ down)
2.2	0.009
2.3	0.007
2.4	0.005
2.5	0.003

Q105 Squat-Settlement Results (2018)	
Speed (m/s)	Dynamic Draft (+ down)
2.6	0.002
2.7	0.002
2.8	0.001
2.9	0.001
3.0	0.002
3.1	0.003
3.2	0.004
3.3	0.006
3.4	0.008
3.5	0.011
3.6	0.014
3.7	0.018
3.8	0.021
3.9	0.026
4.0	0.030
4.1	0.035

Table 8 – Q105 squat settlement results.

Note that entries of 0 m at 0 m/s speed and 0.035 m at 10.3 m/s speed were also entered into the HVF to cover any possibility of speeds outside the tested range.

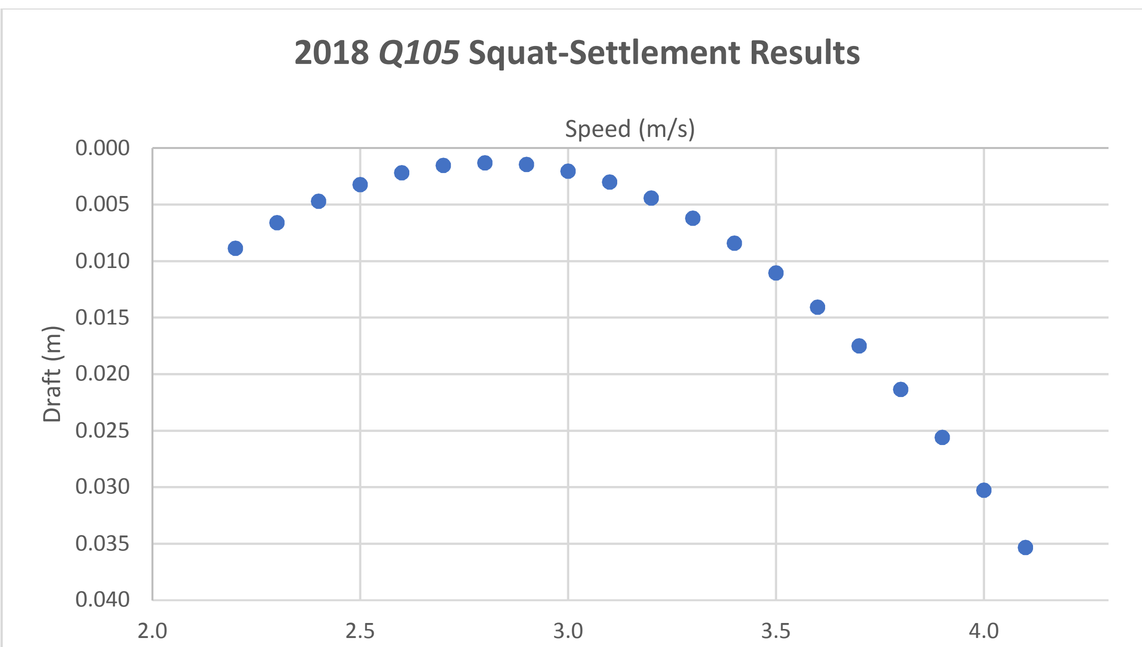


Figure 37 - Q105 squat settlement results.

C.6.3. ASV-CW5 Dynamic Draft Corrections

To determine the dynamic draft corrections, a squat settlement test was completed on JD203. Speed values between 1.8 and 3.6 m/s were tested (RPM values between 1200 and 2600). This range encompassed the speed and RPM settings used during survey operations. Values were smoothed using a 2nd order polynomial equation to create a correction at every 0.1 m/s change in speed and entered into the HVF.

Squat settlement results obtained on this vessel from 2016 through 2017 were compared to this test, with results showing good consistency between years, comparing on average to 0.03 m or better at each speed/RPM point.

***ASV-CW5* Squat-Settlement Results (2018)**	
Speed m/s	Dynamic Draft (+ down)
1.8	0.023
1.9	0.023
2.0	0.024
2.1	0.024
2.2	0.025
2.3	0.025
2.4	0.025
2.5	0.026
2.6	0.026
2.7	0.026
2.8	0.026
2.9	0.026
3.0	0.026
3.1	0.026
3.2	0.026
3.3	0.026
3.4	0.025
3.5	0.025
3.6	0.025

Table 9 – ASV-CW5 squat settlement results.

Note that entries of 0 m at 0 m/s speed and 0.025 m at 10.3 m/s speed were also entered into the HVF to cover any possibility of speeds outside the tested range.

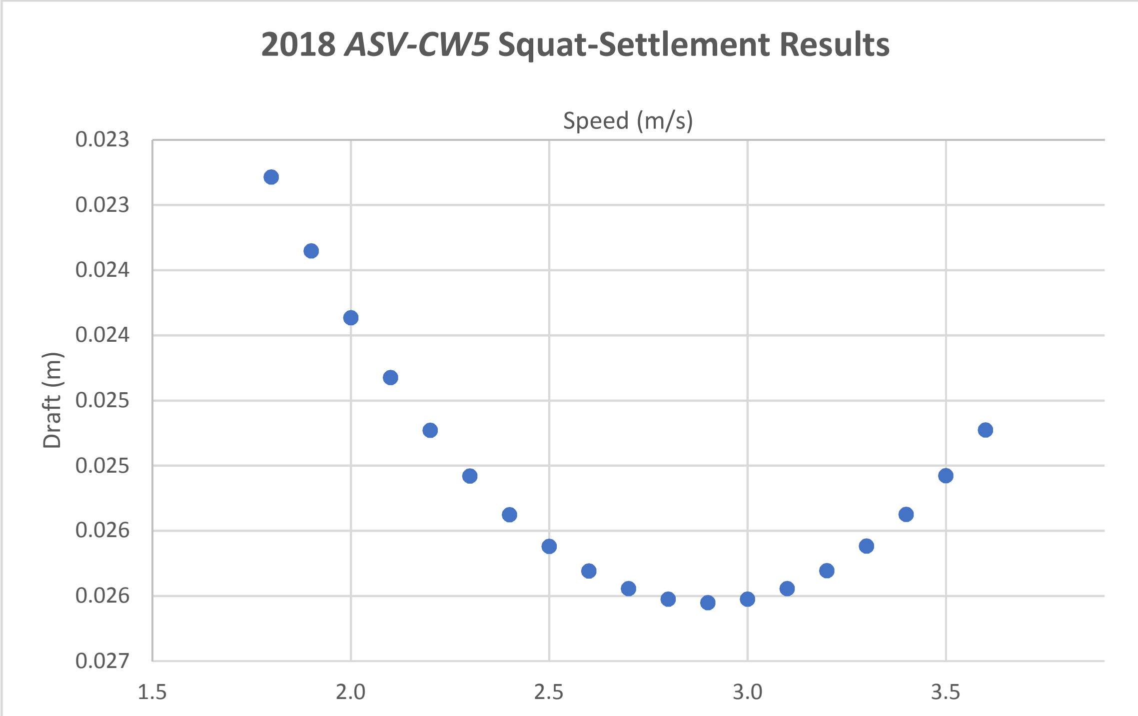


Figure 38 – ASV-CW5 squat settlement results.

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

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

Ellipsoidally Referenced Zoned Tides (ERZT) were also computed for this project but were used for comparison purposes only. Results of using ERZT (as well as tide zones) were compared to the NSPMVD results and compared well within vertical specifications.

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

APPROVAL SHEET

For

Data Acquisition and Processing Report: H13112 through H13116

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: 2019.01.11 13:22:27 -09'00'

Andrew Orthmann

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

Charting Program Manager

TerraSond Limited