NOAA FORM 76-35A

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

# DATA ACQUISITION AND PROCESSING REPORT

*Type of Survey* Hydrographic

*Project No.* OPR-S313-KR-15

*Time Frame* June – July 2015

## LOCALITY

*State* ALASKA

*General Locality* Bering Strait

*Sub Locality* Cape Prince of Wales Shoal

**2015**

**CHIEF OF PARTY**

ANDREW ORTHMANN

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**DATE**

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| NOAA FORM 77-28 (11-72) U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION | REGISTER NO. |
|---|---|
| HYDROGRAPHIC TITLE SHEET | **H12751, H12752, H12753, H12754** |
| **INSTRUCTIONS** – The Hydrographic Sheet should be accompanied by this form, filled in as completely as possible, when the sheet is forwarded to the Office | FIELD NO. **N / A** |

State Alaska

General Locality Bering Strait

Locality Cape Prince of Wales Shoal

Scale 1:40,000 Date of Survey June 27 to July 30, 2015

Instructions Dated May 5, 2015 Project No. OPR-S313-KR-15

Vessel *Qualifier 105, ASV-CT3*

Chief of party Andrew Orthmann

Surveyed by TerraSond Personnel (A. Orthmann, S. Glaves, J. Theis, G. Cain, S. Udy, T. Morino, D. Frank, and others)

Soundings taken by echosounder, hand lead, pole Echosounder – (Pole-Mounted)

Graphic record scaled by N/A

Graphic record checked by N/A

Protracted by N/A Automated plot by N/A

Verification by

Soundings in METERS at MLLW

REMARKS:

Contract No. EA-133C-14-CQ-0036

All times are recorded in UTC

Hydrographic Survey:

TerraSond Limited
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Tide Support:

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Anchorage, AK 99503

# Data Acquisition and Processing Report

## OPR-S313-KR-15

## November 20th, 2015

***Research Vessel Qualifier 105 and ASV CT3 in Bering Strait, Alaska***

Vessels: ***R/V Qualifier 105 & ASV-CT3***

General Locality: ***Bering Strait, Alaska***

Sub Locality: ***H12751 – 9 NM North of Cape Prince of Wales***
***H12752 – 19 NM North of Cape Prince of Wales***
***H12753 – 30 NM North of Cape Prince of Wales***
***H12754 – 43 NM North of Cape Prince of Wales***

Lead Hydrographer: ***Andrew Orthmann***

# TABLE OF CONTENTS

# A. *Equipment*

## *A.1. Echosounder Systems*

To collect sounding data, this project utilized a Reson Seabat 7101 Multibeam Echosounder (MBES) and an Odom Echotrac CV100 Single Beam Echosounder (SBES).

### *A.1.1. Side Scan Sonar*

Side scan sonar was not required or utilized on this survey.

### *A.1.2. Multibeam Echosounder*

One Reson SeaBat 7101-ER (Extended Range) multibeam system was used on this survey. The system was installed on the *R/V Qualifier 105*.

The Reson SeaBat 7101 is a multibeam echosounder (MBES), which utilizes Reson 7k Control Center software (running on a Windows 7 PC) to serve as the user interface. The 7101 is an upgraded 8101 unit, with improvements that include the ability to form additional beams.

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

Echosounder accuracy was checked by bar check and lead line methods on two separate occasions (JD191 and JD204). Processed multibeam data compared to the actual bar depth within 0.033 m (or better), and within 0.051 m (or better) of actual bottom depth measured by lead line. Results were considered satisfactory given the variables involved in bar check and lead line collection.

Additionally, the multibeam data was examined where it overlapped with single beam data collected by the single beam vessel. The two data sets demonstrate good agreement, with an average difference of 0.012 m (multibeam data is shoaler) with a standard deviation of 0.051 m.

Echosounder accuracy test results are available in *Appendix II* of this report.

See Table 1 for echosounder specifications.

| Reson SeaBat 7101 | |
|---|---|
| Firmware Version | 7K UI 4.5.10.5<br>7KI/O 3.4.1.11<br>Wet End 8101.1.08.C215 |
| Sonar Operating Frequency | 240 kHz |
| Along Track Transmit Beamwidth | 1.6° ± 0.3º |
| Across Track Receive Beamwidth | 1.5° |
| Max Ping Rate | 40 pings / s |
| Pulse Length | 21 μsec to 225 μsec |
| Number of Beams | 101 - 511 (332 used) |
| Max Swath Angle | 150° |
| Depth Range | 1 – 500 m |
| Depth Resolution | 1.25 cm |

***Table 1 – Reson SeaBat 7101 multibeam echosounder technical specifications.***

### *A.1.3. Single Beam Echosounder*

One Odom Echotrac CV100 system was used on this survey, installed aboard the *ASV-CT3*.

The Odom Echotrac CV100 is a digital single beam echosounder (SBES), which utilizes Odom eChart software to serve as the user interface. The CV100 was interfaced with an Airmar SMB200-3 transducer, which generates a 3 degree beam at 200 kHz.

Power, gain, depth filters and other user-selectable settings were adjusted, as necessary, through eChart. eChart was configured to output the bathymetric data via Ethernet network connection to acquisition software (HYPACK) running on a Windows 7 PC, which logged the raw data.

CV100s are all-digital units that do not create a paper record of bottom track quality information. Instead, this information was logged to BIN format files, which were later viewable in CARIS HIPS' single beam editor software during data processing.

Echosounder accuracy was checked by bar check and lead line methods on JD204. Processed echosounder data compared to actual bar depth to 0.015 m on average, and to within 0.046 m of actual bottom depth measured by lead line. Results were considered satisfactory given the variables involved in bar check and lead line collection.

Additionally, the Odom CV100 single beam data was examined where it overlapped with the Reson 7101 multibeam data. The two data sets demonstrate good agreement, with an average difference of 0.012 m (multibeam data is shoaler) with a standard deviation of 0.051 m.

Echosounder accuracy test (depth check) results are available in *Appendix II* of this report. See Table 2 for echosounder specifications.

| **Odom Echotrac CV100** | |
|---|---|
| Firmware Version | 4.09 |
| Sonar Operating Frequency | 100 – 750 kHz (200 kHz used) |
| Output Power | 300 W RMS Max |
| Ping Rate | Up to 20 Hz |
| Resolution | 0.01 m |
| Depth Range | 0.3 – 600 m, depending on frequency and transducer |

***Table 2 – Odom Echotrac CV100 single beam echosounder 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, the *ASV-CT3*. The *Q105* acquired all multibeam data, while the *ASV-CT3* acquired all single beam data.

### *A.2.1. R/V Qualifier 105*

The *Q105*, owned and operated by Support Vessels of Alaska (SVA), was chartered as the multibeam survey platform for this survey. The *Q105* was operated on a 24/7 schedule for data acquisition, data processing, and personnel housing. The *Q105* also launched and recovered the *ASV-CT3*, collected bottom samples, and tended the project tide gauges.

The *Q105* is a 32 m aluminum hull vessel with 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 R/V Qualifier 105 (Q105) during survey operations, 2015.***

For this survey, the *Q105* was outfit with an Applanix POSMV 320 V5 to provide attitude and positioning, with IMU mounted at the best estimate of vessel center of gravity (COG), and GNSS antennas on the vessels crow's nest. A Reson Seabat 7101 MBES transducer was pole-mounted on the port side, just aft of the main cabin. An Oceanscience RapidCAST SV system was installed on the port stern to collect sound speed profiles. A Hemisphere Vector V102 GPS system was also installed for independent positioning checks. 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.

The survey equipment on the *Q105* performed within normal parameters with no major issues encountered, with one exception: A sound speed sensor (Valeport RapidSV SN45471) failed on JD182 (see Section A.3, Speed of Sound for more details).

***Q105* Survey Equipment**

| Description | Manufacturer | Model / Part | Serial Number(s) |
|---|---|---|---|
| Echosounder, Multibeam | Teledyne Reson | 7101-ER Head | 3507006 |
| | | 7-P-1 Sonar Processor | 18293412004 |
| Sound Speed, Surface | AML Oceanographic | Micro-X | 203266 |
| | | SV-Xchange | 10276 |
| Position, Motion, Heading | Applanix | POSMV 320 V5 | 5849 |
| | | IMU-200 | 783 |

| Description | Manufacturer | Model / Part | Serial Number(s) |
|---|---|---|---|
| | AeroAntenna | GNSS Ant1 | 8521 |
| | | GNSS Ant2 | 8526 |
| Positioning, Check | Hemisphere | Vector V102 | 0616-24479-0001 |
| Sound Speed, Deployment System | Teledyne Oceanscience | RapidCAST | 8000660D |
| Sound Speed, Profiler | Valeport | Rapid SVT 200Bar | 45471 |
| | | | 49911 |
| Sound Speed, Profiler | AML Oceanographic | MinosX | 30341 |
| | | SV-Xchange | 204167 |
| | | P-Xchange | 304457 |
| | | SV-Xchange | 204677 |
| | | P-Xchange | 304614 |

***Table 3 – Major survey equipment used aboard the Q105.***

### *A.2.2. ASV-CT3*

The vessel *ASV-CT3*, owned and operated by ASV Global, was used to collect single beam data on the project. The vessel was deployed when conditions were favorable, and monitored/remotely operated from the *Q105* via radio links.

The *ASV-CT3* is an aluminum vessel manufactured by ASV Global. It is 3.5 m in length with a 1.4 m beam and 0.3 m draft. The vessel is propelled by a 20 HP Mercury engine. To power survey equipment, 12V DC was tapped from vessel charging system.

The *ASV-CT3* experienced the following major issue(s) during this survey:

1. The *ASV-CT3* had a difficult time maintaining straight survey lines, resulting in an S-shaped line pattern on many of its survey lines. Probable causes identified included a vessel design not well suited to holding lines in sea swell, drag caused by the transducer, and line tracking algorithms in need of further refinement. Over-correction of vessel steering occasionally resulted in pulling the SBES transducer through water agitated by prop-wash and caused a loss of bottom lock. Areas of bottom lock loss were identified and rerun. Line-tracking was improved (though never perfected) through adjustments to line tracking parameters and mitigation of drag by removal of the SBES transducer fairing.


***Figure 2 – ASV-CT3 surveying in the Bering Strait, 2015.***

For this survey, the *ASV-CT3* was outfit with a Hemisphere V113 GPS Compass to provide attitude and heading data. Primary positioning and heave was provided by a Trimble 5700 GPS (post-processed). The Hemisphere and Trimble 5700 antennas were mounted on the vessel aft antenna bridge where they had unobstructed view of the sky. The Trimble 5700 GPS, from which final positions and heave data was derived, was nearly co-located horizontally with the single beam transducer. An Odom Echotrac CV100 was used for single beam data collection, with the transducer pole-mounted and secured to a bracket from the port-side transom. 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 primary survey equipment are included in Section C of this report.

The survey equipment on the *ASV-CT3* performed within normal parameters with no major issues encountered. Major issues with the vessel itself are described previously in this report.

***ASV-CT3 Survey Equipment***

| Description | Manufacturer | Model / Part | Serial Number |
|---|---|---|---|
| Echosounder, Single Beam | Teledyne Odom | Echotrac CV100 Topside | 3505 |
| | Airmar | SMBB-200-3 Transducer | 2944718 |
| Heading, Motion, and Positioning (Real-time) | Hemisphere | Vector V113 | A1218-V113H-0002 |
| Positioning & Heave (Post-processed/final) | Trimble | 5700 Receiver | 220321784 |
| | | Zephyr Antenna | 12572668 |

***Table 4 – Major survey equipment used aboard the ASV-CT3.***

## *A.3. Speed of Sound*

An Oceanscience RapidCAST system – equipped with a Valeport RapidSV sensor – was utilized aboard the *Q105* for the majority of sound speed profiles. Profiles 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.

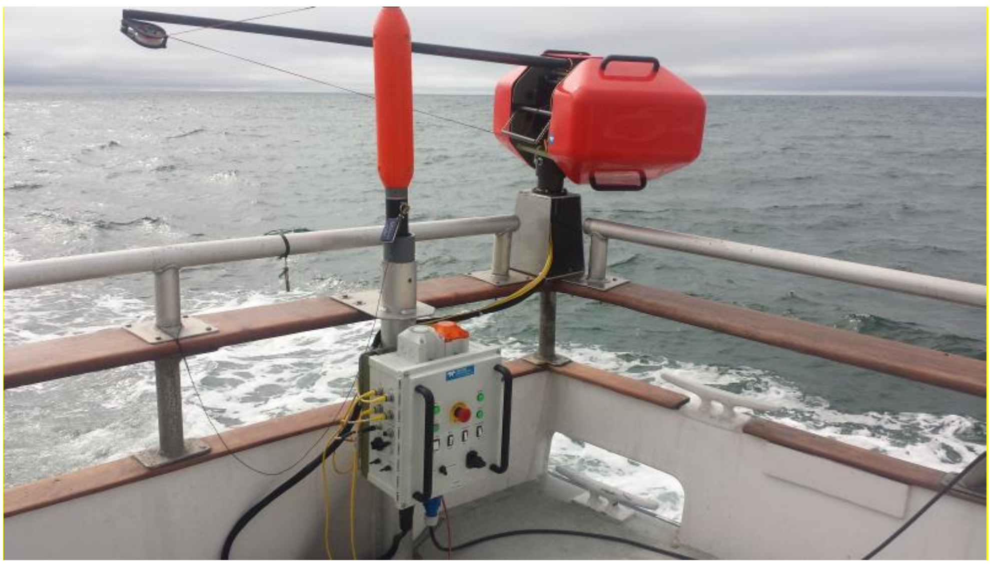


***Figure 3 – Oceanscience RapidCAST with Valeport SV sensor on the Q105.***

Note that sound speed profiles were not collected by the *ASV-CT3*. Instead, profiles collected by the *Q105* were used to correct the ASV's data. This was possible because when operating, the ASV was always kept in visual range, usually 200 m, but never exceeding 1 km, and profiles were obtained simultaneous with ASV operations.

The Reson 7101 multibeam head was outfit with an AML Micro-X SV-XChange sensor to continually monitor sound speed at the multibeam head for beam-forming purposes.

When using the RapidCAST system, sound speed casts were collected normally by collecting a “set” of 2-3 casts spatially distributed along a survey line, on an interval of approximately two hours between sets. This led to a collection of casts distributed so as to minimize both the distance and time between bathymetric data and sound speed profiles. Allowance for profile depth versus bottom depth was also given so as to ensure sound speed measurements were available for the deeper portions of the survey lines. Interval and spacing were adjusted in the field by examining sound speed variance and deemed sufficient to correct for changes in sound speed while also limiting the required volume of profiles.

Valeport RapidSV SN#45471, used as the primary source of sound speed measurements, failed early in the project, on JD182. During a SV cast, the unit began outputting obvious erroneous values in the range of 1440 m/s when normal sound speeds for the area fell within the range of 1470 to 1500 m/s. No obvious event led to the failure. The unit had recent factory calibration dated 2/18/15. The unit was immediately removed from service and no erroneous data was used to correct echo soundings.

From JD182 through JD189, a backup sound speed sensor (AML MinosX SN#30341) was used in place of the failed Valeport. The AML MinosX is not compatible with the RapidCAST system, requiring manual lowering to the seafloor. This necessitated the vessel come to a full stop, which reduced the cast interval to one profile every 2-4 hours while the backup was in use.

Note that the backup sensors pair (SV- and P- Xchange) used from JD182 through JD189 had calibrations that were out of date. The last factory calibrations were completed in September 2014, which pre-dates survey operations by greater than the six months permitted by the HSSD. To ensure the sensors were still providing accurate data they were compared against a recently calibrated Valeport as well as recently calibrated identical AML sensors. Results compared to 1.5 m/s or better against the Valeport, and 0.5 m/s or better against the AML sensors, and were deemed acceptable for survey use.

From JD190 onwards, a replacement Valeport RapidSV (SN#49911) was used as the primary source of sound speed profiles. No further issues occurred with the sound speed profiler.

Confidence checks on sound speed profilers were accomplished by comparing the results obtained by the probes to each other, normally every two weeks during survey operations. These checks were accomplished on JD 190, 204, and 211. Comparison results (available in the Descriptive Reports (DRs), *Separate II*) were acceptable, with probes comparing to each other within 1.5 m/s or better on average.

The AML Micro-XChange sensor used on the Reson 7101 MBES head was also compared for accuracy against the AML MinosX. The formal comparison was undertaken once, on JD191. Results were excellent, with both instruments comparing within 0.1 m/s.

Refer to the CARIS HIPS SVP file submitted with the deliverables for positions, collection times, and processed profile data. Raw SVP data is also available with the raw data deliverables. Copies of the manufacturer’s calibration reports are included in *Appendix IV* of this report. The instruments listed in Tables 5-9 were used to collect sound speed data on this project.

### *A.3.1. Sound Speed Sensors*

| Sound Speed Device | Manufacturer | Serial Numbers | Cal Date | In Use Days (2015) |
|---|---|---|---|---|
| AML Micro-X with SV-XChange Sensor | AML Oceanographic | 203266 (Probe)<br>10276 (Sensor) | N/A – installed on MBES head | JD179 – JD211 |
| Valeport Rapid SV | Valeport Limited | 45471 | 2/18/2015 | JD179 – JD182 |
| | | 49911 | 6/9/2015 | JD190 – JD211 |
| AML Minos-X | AML Oceanographic | 30341 | n/a | JD179 – JD211 |
| AML SV-XChange | | 204167 | 9/23/2014 | JD182 – JD189 |
| | | 204677 | 6/5/2015 | JD190 – JD211 |
| AML P-XChange | | 304457 | 9/19/2014 | JD182 – JD189 |
| | | 304614 | 7/6/2015 | JD190 – JD211 |

***Table 5 – Sound speed probes and calibration dates.***

### *A.3.2. Sound Speed Sensor Technical Specifications*

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

***Table 6 – AML Oceanographic SV-XChange specifications.***

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

***Table 7 – Valeport Rapid SVT specifications.***

| AML Oceanographic SV-Xchange Sensor* | |
|---|---|
| SV Precision | 0.006 m/s |
| SV Accuracy | 0.025 m/s |
| SV Resolution | 0.001 m/s |
| *Utilized on a AML MinosX instrument concurrent with P-Xchange sensor | |

***Table 8 – AML SV-Xchange specifications.***

| AML Oceanographic P-Xchange Sensor* | |
|---|---|
| Pressure Precision | 0.03 % of full scale |
| Pressure Accuracy | 0.05 % of full scale |
| Pressure Resolution | 0.02 % of full scale |
| *Utilized on a AML MinosX instrument concurrent with SV-Xchange sensor | |

***Table 9 – AML P-Xchange specifications.***

## *A.4. Positioning and Attitude Systems*

### *A.4.1. Q105*

An Applanix POSMV 320 V5 system served as the primary source of vessel positioning, motion, and heading aboard the *Q105*.

The POSMV system consists of two dual-frequency GNSS antennas and an inertial measurement unit (IMU) interfaced with a topside processor. For real-time GPS position corrections, the POSMV was configured to receive Wide Area Augmentation System (WAAS) correctors. However, all real-time corrections were replaced in processing by application of post-processed kinematic (PPK) corrections to the dataset.

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

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

Additionally, the POSMV was configured to output a GGA string to provide positions to TerraLOG software (general note keeping), and to the Valeport SV acquisition software (for sound speed profile time-tagging and positioning).

For real-time positioning confidence checks, the position generated by a Hemisphere Vector V102 antenna was compared to the position generated by the POSMV. The position of both systems were displayed side-by-side in QPS QINSy to serve as a continuous gross-error and reality check on vessel position. No discrepancies between the systems were observed during operations.

### *A.4.2. ASV-CT3*

The *ASV-CT3* utilized a Hemisphere V113 GPS Compass for real-time positioning. The V113 provided WAAS-based real-time DGPS positioning, as well has heading and motion data.

The vessel was also outfit with a T5700 dual-frequency GPS system. The T5700 was configured to continuously log dual-frequency GPS data to compact flash card at 10 Hz, which was later post-processed to provide final positioning and heave data.

Note that all real-time WAAS-based corrections from the Hemisphere V113 were replaced in processing by application of PPK corrections to the dataset.

### *A.4.3. Position and Attitude System Technical Specifications*

| POSMV 320 V5 | | |
|---|---|---|
| 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)<br>Vertical: +/- (15 mm + 1 ppm x baseline length) |
| | Roll, Pitch Accuracy | 0.01 degrees (1 sigma) |
| Heave Accuracy | | Realtime Heave: 5 cm or 5%<br>TrueHeave: 2 cm or 2%<br>(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 10 – Applanix POSMV 320 V5 technical specifications.***

| Trimble 5700 | | |
|---|---|---|
| Code Differential GPS Positioning | Horizontal Positioning Accuracy | ± 0.25 m + 1 ppm RMS |
| | Vertical Positioning Accuracy | ± 0.50 m + 1 ppm RMS |
| Kinematic Surveying | Horizontal Positioning Accuracy | ± 10 mm + 1 ppm RMS |
| | Vertical Positioning Accuracy | ± 20 mm + 1 ppm RMS |

***Table 11 – Trimble 5700 technical specifications.***

| Hemisphere Vector V113 | | |
|---|---|---|
| SBAS (WAAS) Positioning | Horizontal Positioning Accuracy | 0.3 m |
| | Vertical Positioning Accuracy | 0.6 m |
| Motion and Heading | Heading | 0.3° |
| | Pitch / Roll | 1 ° |
| | Heave | 0.3 m |

***Table 12 – Hemisphere Vector V113 technical specifications.***

### *A.5. Dynamic Draft Corrections*

Dynamic draft corrections for speed and engine RPM were determined using PPK GPS methods for both vessels by way of squat settlement tests. Corrections were determined for a range that covered normal survey speeds and engine RPMs. Results of the squat settlement tests are available in Section C of this report.

On the *Q105*, a purpose-built TerraSond TerraTach system was utilized. The TerraTach system, which was designed in-house, 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 timing synchronization. TerraTach also logged the data to file for later processing. Note 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 settings.

Due to the high variability of engine throttle settings during *ASV-CT3* operations, RPM data was not utilized to correct *ASV-CT3* data for dynamic draft. Speed-based corrections were used instead.

See Section B of this report for processing methodology.

### *A.6. GPS Base Stations*

One GPS base station was installed to support survey operations. To minimize baseline distance, the station was located at the closest point of land relative to the survey area, co-incident with the project tide station outside of Lopp Lagoon.

The station was configured as a logging-only (non-transmitting) site. At the site a T5700 receiver continuously logged raw GPS data at a rate of 1 Hz for later post-processing.

A Trimble Zephyr Geodetic antenna was mounted on a tripod, which was centered and secured over a tidal benchmark. Four 50w solar panels provided 12V DC to charge the station batteries, providing sufficient power to allow the T5700 receiver to log continuously. In the flat terrain of the region satellite masking was not an issue.

During visits to the site, approximately every two weeks, data was downloaded by swapping out compact flash memory cards. Station checks were also performed at this time, including confirmation of antenna stability.

No issues were encountered with the GPS base station.

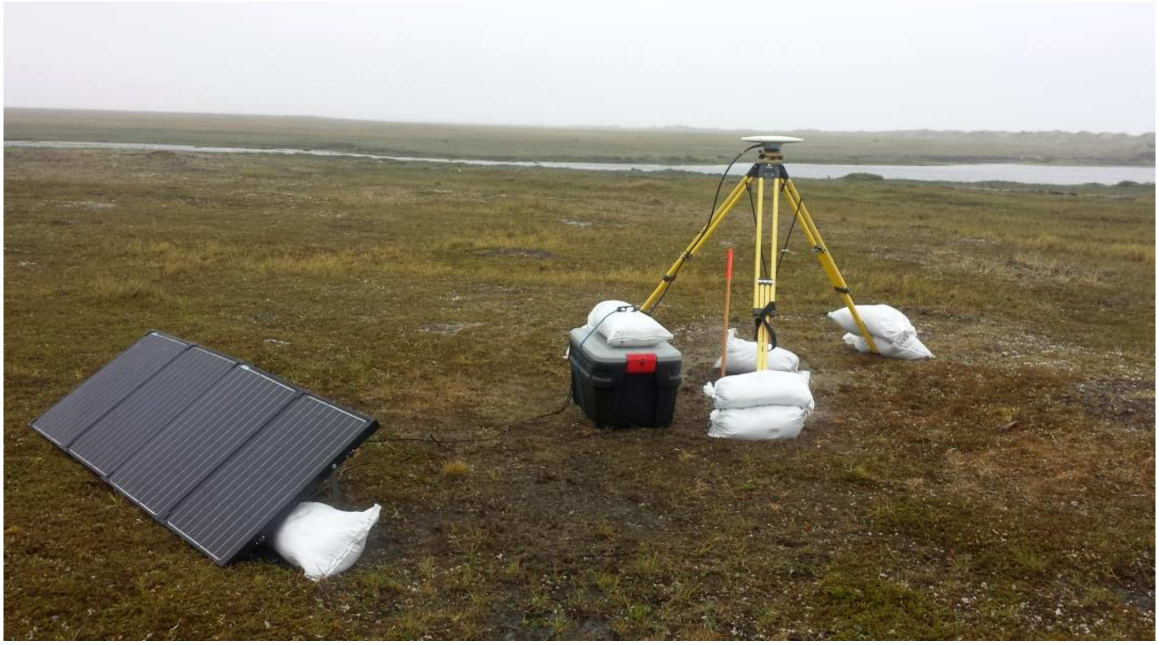


***Figure 4 – Project GPS base station outside Lopp Lagoon.***

A Continually Operating Reference Station (CORS) site was utilized for preliminary GPS post-processing. CORS site AB09, located in Wales, Alaska, was downloaded daily during operations and used to post-process positioning data. However, no AB09 data was used for final positions – the Lopp Lagoon project base station was used to derive all final positions because of its closer proximity to the survey area and better logging interval (one measurement per second for Lopp Lagoon station versus one measurement per 15 seconds for AB09).

| Station ID | Site | GPS Receiver | Antenna | Type | Position (NAD83) |
|---|---|---|---|---|---|
| 0056 | Outside Lopp Lagoon | Trimble 5700<br>SN# 220320056 | Trimble Zephyr Geodetic (TRM41249)<br>SN# 60001964 | Logging (PPK) 1 Hz | 65 42 49.80351N<br>168 0 32.26588W |

***Table 13 – GPS base station positions and configurations.***

Confidence checks on the stability of the GPS base station mount and repeatability of the position solutions were accomplished weekly by upload of 24-hour data series to NGS OPUS (Online Positioning User Service), which always returned results comparing to 0.018 m vertically and 0.016 m horizontally (or better) of the original position. See Section B of this report for more information regarding base station position confidence checks, which are available in *Separate I* of the project DRs.

### *A.6.1. Base Station Equipment Technical Specifications*

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

***Table 14 – Trimble 5700 technical specifications.***

## *A.7. Tide Gauges*

### *A.7.1. Subordinate and Zoning Stations*

One subordinate tide station was installed for this project. The "Outside Lopp Lagoon" station (946-9515) was established consisting of benchmarks and a barometer installed on-shore, and two bottom-mounted pressure gauges (BMPG) deployed approximately one mile offshore on 500-600 lb. moorings.

Sea-Bird SBE 26plus gauges were utilized as the BMPGs. All gauge moorings were also outfit with AML MinosX data loggers incorporating C-Xchange and T-Xchange sensors to log conductivity and temperature concurrent with the Sea-Bird pressure readings for derivation of water salinity. LinkQuest acoustic modems were also installed on the mooring as a data-recovery backup method, but were never utilized.

All sensors were calibrated prior to the start of survey operations and checked for accuracy following demobilization. At the subordinate tide station, two were deployed for redundancy and as a check on each other.

In addition to the two BMPG systems deployed at the subordinate tide station, additional BMPG deployments were accomplished to establish tide zoning parameters to model the movement of the tide across the survey area. Three such deployments occurred utilizing two separate BMPGs, which were deployed, pulled, and redeployed as necessary. Deployment durations ranged from 10-29 days at each site. The deployment locations were strategically chosen to bracket the survey area. This provided the data required for computing time and range corrections between the zoning site and the subordinate gauge, and therefore, derivation of final tide zones.

Staff shots were collected regularly to confirm gauge stability.

All tide gauges performed well with no major issues or outages encountered.

Refer to the Horizontal and Vertical Control Report (HVCR) and accompanying records for additional information regarding the tide stations.

### *A.7.2. Tide Gauge Equipment Technical Specifications*

| **AML Oceanographic C-Xchange Sensor*** | |
|---|---|
| Conductivity Precision | 0.003 mS/cm |
| Conductivity Accuracy | 0.01 mS/cm |
| Conductivity Stability | 0.003 mS/cm/month |
| Conductivity Resolution | 0.001 mS/cm |
| *Utilized on a AML MinosX instrument concurrent with T-Xchange sensor | |

***Table 15 – AML C-Xchange conductivity sensor specifications.***

| **AML Oceanographic T-Xchange Sensor*** | |
|---|---|
| Temperature Precision | 0.003° C |
| Temperature Accuracy | 0.005° C |
| Temperature Resolution | 0.001° C |
| *Utilized on a AML MinosX instrument concurrent with C-Xchange sensor | |

***Table 16 – AML T-Xchange temperature sensor specifications.***

## *A.8. Software Used*

### *A.8.1. Acquisition Software*

Survey vessels were outfit with quad-core PCs running Microsoft Windows 7 Professional for data acquisition and log keeping. A summary of the principal software installed and used on these systems during data collection follows:

- QPS QINSy hydrographic data acquisition software was used on the *Q105* and for navigation, and to log the bathymetric, positioning, and attitude data to DB (and XTF) format files.
- HYPACK hydrographic data acquisition software was used on the *ASV-CT3* for navigation, and to log the bathymetric, positioning, and attitude data to RAW and BIN format files.

- Reson 7k Control Center served as the interface with the Reson Seabat 7101 multibeam system on the *Q105*, allowing the system to be tuned and operated.
- Odom eChart served as the interface with the Odom Echotrac CV100 echosounder on the *ASV-CT3* during SBES operations. It also displayed the digital bottom track trace and waveform to assist the operator with ensuring proper bottom tracking.
- Trimble Configuration Toolbox was used, as necessary, to configure common options in the T5700 receivers prior to data acquisition.
- AML SeaCast was used to configure and download the AML MinosX instruments.
- 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 for initial configuration, calibrations, and on a daily basis for real-time QC of the POSMV navigation and attitude solutions. The software was also used to continuously log POS files during survey operations containing raw POSMV data for post-processing purposes.
- 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*.
- TerraSonic, an in-house software package, was used to configure, monitor, and log data from the custom-designed ultrasonic waterline measurement 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.

| Program Name | Version | Date | Primary Function |
|---|---|---|---|
| QPS QINSy | 8.10 (Build 2014.03.06.1) | 2014 | Acquisition and navigation software used on the *Q105* |
| HYPACK 2014 | 14.0.0.23 | 2014 | Acquisition and navigation software used on the *ASV-CT3* |
| Reson 7k Control Center | 4.5.10.5 | 2013 | Multibeam interface on Reson 7101 |
| Oceanscience RapidCAST Interface | 0.4.1 | 2015 | RapidCAST winch interface |
| Valeport RapidSVLog | 0400/7158/B1 27/03/2013 | 2013 | Communication with Valeport RapidSV probe |
| Odom eChart | 1.4.0 | 2010 | Single beam echosounder interface |
| Trimble Configuration Toolbox | 6.9.0.2 | 2010 | Trimble 5700 interface |
| AML SeaCast | 2.2.3 | 2011 | Configuration and download of AML MinosX instruments |
| Sea-Bird Seasoft | 2.0 | 2011 | Configuration and data download for Sea-Bird SBE26 Plus tide gauges |
| Applanix POSView | 7.92 | 2014 | POSMV configuration, monitoring and logging |
| TerraLog | 2014 | 2014 | Record keeping |
| TerraTach | 3.1.0 | 2014 | Configure, monitor, log data from engine RPM sensors |
| TerraSonic | 3.1.6 | 2014 | Configure, monitor, log data from ultrasonic water sensors |

***Table 17 – Software used for data acquisition.***

### *A.8.2. Processing and Reporting Software*

Processing and reporting was done on quad-core PCs running Microsoft Windows 7 Professional. A summary of the primary software installed and used on these systems to complete planning, processing, and reporting tasks follows:

- CARIS HIPS and SIPS was used extensively as the primary data 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.
- CARIS Notebook was used to create the S-57 deliverables. Shoreline features, bottom samples, and survey outlines were imported, edited, assigned attributes and exported to S-57 (and CARIS HOB) format.

- 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 was used extensively to produce PPK data. Both the MMS and POSGNSS modules were utilized. MMS was used to post-process POSMV data from the *Q105*, while POSGNSS was used to post-process T5700 data from the *ASV-CT3*.
- 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.

| Program Name | Version | Date | Primary Function |
|---|---|---|---|
| CARIS HIPS and SIPS | 8.1.13 | 2014 | Multibeam and Single Beam data processing |
| CARIS Notebook | 3.1.1 | 2011 | Feature attribution and creation of S-57 deliverables |
| ESRI ArcGIS ArcMap | 10.2.1 | 2013 | Desktop mapping software |
| Applanix POSPac MMS | 6.2 (SP2) | 2014 | Post-processing kinematic data from POSMV |
| Applanix POSPac POSGNSS | 5.3 | 2013 | Post-processing kinematic data from T5700 |
| Microsoft Office | 2013 | 2013 | Logsheets, reports, and various processing tasks |
| TerraLog | 2014 | 2014 | Keeping notes, reporting, process SVP casts, produce PDF logsheets |
| HeaveXtractor | 2015 | 2015 | Extract heave from PPK data for *ASV-CT3* |
| Microsoft Infopath | 2013 | 2013 | Populate DR XML schemas |
| Altova XMLSpy | 2015 | 2015 | Edit DR XMLs |

***Table 18 – Software used during processing and reporting.***

### *A.9. Bottom Samples*

The *Q105* collected bottom samples for this survey.

At planned locations, a Van Veen grab sampler was lowered and a bottom sample collected. Aboard the vessel, 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, which are included with the S-57 deliverable.

The logsheet was later imported by processing into CARIS Notebook to produce the Final Feature File (FFF) S-57 deliverable.

# 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 8.1 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. QPS QINSy*

QPS QINSy data acquisition software was used to log all bathymetric data and to provide general navigation for survey line tracking on the *Q105*. The software features a number of 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:

- Simultaneous display of independent Hemisphere Vector V102 position on the navigation window as real-time position reality checks
- Alarm for loss of ZDA timing sync or positioning data from POSMV
- Alarm for loss of attitude or positioning data from POSMV
- Alarm for loss of sonar input

### *B.2.2. HYPACK*

HYPACK data acquisition software was used to log all single beam data and to provide general navigation for survey line tracking on the *ASV-CT3*. The software features a number of quality assurance tools, which were utilized during this survey.

Using the raw echosounder depth data, HYPACK generated a real-time digital terrain model (DTM) during data logging. The DTM was displayed as a layer in the HYPACK "Navigation" view. The *ASV-CT3* vessel position was plotted on top of the DTM along with other background data, which included shape files containing the pre-planned survey lines and survey boundaries, as well as the nautical chart. GeoTIFs created from the *Q105* multibeam data were also displayed to ensure overlap between the two datasets for QC purposes.

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 by HYPACK 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, HYPACK 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 an alarm for loss of ZDA time synchronization and sonar input status.

It should be noted that HYPACK automatically breaks and restarts RAW file logging at the Julian day rollover. This process takes 2-3 seconds during which no bathymetric data is recorded. Therefore, lines run over the Julian day change (which occurred at 4:00 pm local time) may have a small along-track gap. These small gaps are rare, deemed insignificant, and re-ran only when necessary to better delineate a feature.

### *B.2.3. Draft Measurements*

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

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

The *Q105* also utilized an ultrasonic measure-down system, TerraSonic. This featured sensors which continually ranged from a known point to the waterline. However, TerraSonic data was used only for QC and was not used to derive waterline correctors.

On the *ASV-CT3*, draft measurements were made by reading draft markings that related the vessel CRP to the water level, as shown in Figure 5.

***Figure 5 – Draft marks on the ASV-CT3.***

Draft values were checked to ensure they fell within the normal range for the survey vessel, logged with current time, and entered into the CARIS HIPS Vessel File (HVF) by processing (included with the survey deliverables) for application to soundings.

### *B.2.4. Sound Speed Measurements*

Casts were taken from the *Q105* using an Oceanscience RapidCAST system, which utilized a Valeport SV sensor. 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 break is automatically applied by the winch software. The sensor is then winched back aboard the vessel, and the stored profile data downloaded wirelessly by Valeport RapidSV software.

During the cast, sensor depth is estimated by the RapidCAST software based on the manufacturer’s proprietary algorithm utilizing line tension continuously measured at the winch, free-fall time, and other factors. Survey personnel would 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 normally entered into the system to avoid striking bottom and potentially damaging the sensor. This resulted in profiles that were at least 80% of the water depth, but not extending completely to the seafloor. However, effort was made to ensure at least one cast per 24 hours (or more) extended to 95% of the water depth.

Downloaded sound speed profiles were automatically assigned position and UTC timestamps by the UnderwaySV software, which was interfaced with a GGA position/time string from the POSMV. These fields were then carried through to the CARIS SVP files during processing in TerraSond’s TerraLog software. Automatic time and position stamps helped to greatly reduce the possibility of assigning incorrect time or positions to profiles.

Note that TerraLog did not natively support the UnderwaySV format; therefore, an in-house software program (UnderwaySV Converter) was utilized to convert the UnderwaySV files to a TerraLog supported format ("MVP"), which maintained position and timestamps.

When using the RapidCAST system, sound speed casts were collected normally by collecting a "set" of 2-3 casts spatially distributed along a survey line, on an interval of approximately two hours between sets. This led to a collection of casts distributed so as to minimize both the distance and time between bathymetric data and sound speed profiles. Allowance for profile depth versus bottom depth was also given so as to ensure sound speed measurements were available for the deeper portions of the survey lines. Interval and spacing were adjusted in the field by examining sound speed variance and deemed sufficient to correct for changes in sound speed while also limiting the required volume of profiles.

On JD182 the Valeport RapidSV failed. From JD182 through JD189, a backup sound speed sensor (AML MinosX SN#30341) was used in place of the failed Valeport. The AML MinosX is not compatible with the RapidCAST system, requiring manual lowering to the seafloor. This necessitated the vessel come to a full stop, which reduced the cast interval to one profile every 2-4 hours while the backup was in use. During these manual casts the sensor was lowered slowly to the bottom and back, at about 1 m/s, following a ½ to 1-minute temperature equilibrium period at the surface. On JD190 a replacement Valeport RapidSV was acquired and normal operations with the RapidCAST system re-commenced.

Sound speed profiles were applied by nearest in distance within two hours for multibeam and nearest in distance within four hours for single beam. Exceptions were rare and are described in the applicable DR.

To ensure data quality, profiles from the separate sensors were compared directly to each other at least twice monthly. Comparison results are available in the DRs, *Separate II*).

### *B.2.5. 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 both acquisition and processing logsheet entries, provide a more seamless and consistent flow of user-entered log data from acquisition to processing, and output standardized logsheets in PDF format. Since TerraLog automatically records time- and position- tags (with GGA input) events, it largely eliminates errors associated with manually entered time and position. On this survey, TerraLog was configured to receive a GGA data string from the POSMV, enabling the software to position-tag all 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; therefore, it relied on operator entry which means a small time difference (usually on the order of seconds), which is common between the TerraLog entry and the actual data file start and end. However, for the purpose of log keeping, the time difference was deemed to be of no importance. Additionally, the acquisition software (both HYPACK and QINSy) would automatically split files when they became too large (or at Julian day rollovers) – often 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
- Generic POS file information including approximate start and stop times
- RTK 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
- Start and end of line cable out for side scan operations (n/a for this project)

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 6 is an example of the TerraLog line processing interface.

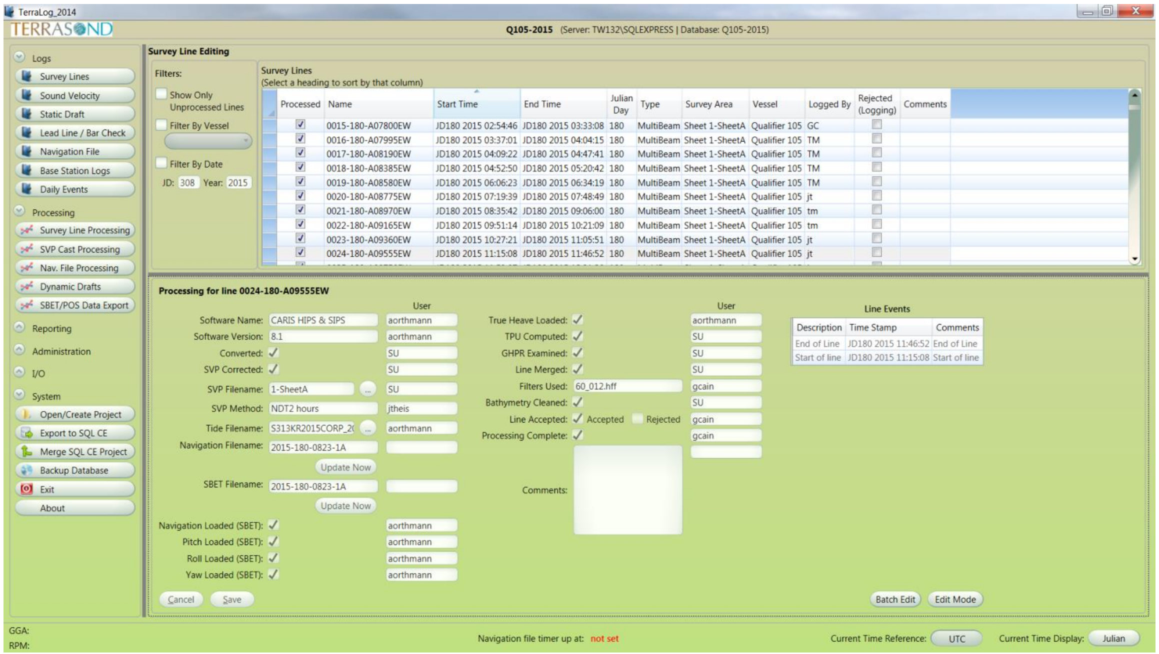



***Figure 6 – TerraLog interface for line processing.***

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*.

Note that TerraLog was only used for *Q105* data. It was not utilized for *ASV-CT3* data.

### *B.2.6. Base Station Deployment*

Due to the lack of DGPS coverage in the area, and to enable PPK processing, one GPS base station was installed for the project. The specific equipment utilized and photos of the sites are available in Section A of this report.

The base station was co-located with the project tide station and set over a tidal monument. Co-location allowed use of the same land access permit as well as allowed base station maintenance tasks to be completed simultaneous with tide station tasks by the field crew. The deployment site was as ideal as possible, with no satellite masking due to the flat nature of the region. The site was also on the closest land relative to the survey area, minimizing the processing baseline from 1.5 km on the south end of the survey area to 75 km on the north end. Despite the relatively large distance to the north end of the survey area, post-processing results were still very good, typically returning RMS error on the order of 0.10 m or better.

During deployment, the GPS antenna was leveled and secured on a survey tripod. The antenna was centered over a tidal benchmark and the antenna height measured. The tripod was secured to the ground by sandbags to prevent movement during the frequent high-wind events of the area. Battery voltage, logging status, antenna height, and other important parameters were logged during installation and regularly (approximately every two weeks) throughout the project. Antenna height was found to not vary by more than 0.003 m over the project and re-centering of the antenna over the survey monument was not required.

Data cards were swapped during site visits. In processing, the GPS data was converted from proprietary Trimble T01 format to Rinex and checked for continuity and quality.

Confidence checks on the stability of the GPS base station mount and repeatability of the position solutions were accomplished weekly by upload of 24-hour data series to NGS OPUS, which always returned results comparing to 0.018 m vertically and 0.016 m horizontally (or better) of the original position. See Section B of this report for more information regarding base station position confidence checks, which are available in *Separate I* of the project DRs as well as the project HVCR.

A CORS site was utilized for preliminary GPS post-processing. CORS site AB09, located in Wales, Alaska was downloaded daily during operations and used to post-process positioning data. However, no AB09 data was used for final positions – the Lopp Lagoon project base station was used to derive all final positions because of its closer proximity to the survey area and better logging interval (one measurement per second for Lopp Lagoon station versus one measurement per 15 seconds for AB09). AB09 was also considered to be a backup to the project GPS base station, but its use was not necessary for final data.

### *B.2.7. 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.

Table 19 lists raw data files commonly created in acquisition and transferred to data processing.

| Type | Description | Example / Format |
|---|---|---|
| **Raw MBES DB and XTF (QINSy)** | MBES Mainscheme | **0172-187-D15600NS-0001 (.DB and .XTF)**<br>[Index]-[JD]-[AreaID][Line#][LineSet]-[ FileSequence#] |
| | MBES Crossline | **XL-0365-199-D22890EW-0001 (.DB and .XTF)**<br>[XL]-[Index]-[JD]-[AreaID][Name][LineSet]-[FileSequence#] |
| | MBES Patch Test / Lead Line / Bar Check | **0239-191-BarCheck-0001 (.DB and .XTF)**<br>[Index]-[JD]-[CheckType]-[FileSequence#] |
| **RAW and BIN (HYPACK)** | SBES – all lines | **2015AS2040108_47 (.RAW and .BIN)**<br>[Year][Vessel "AS"][JD(204)][Start time HHMM]_ [Line#] |
| **SVP** | Text File from AML SV | **2015-185-0546_AML (.ASVP or .REL)**<br>[Year]-[JD]-[Time HHMM]_["AML"] |
| | Text File from Valeport SV | **2015-07-26-03-25-07 (.TXT)**<br>[Year]-[Month]-[Day]-[Hour]-[Minute]-[Second] |
| **Tide - Pressure** | Raw File from Sea-Bird Tide Gauge | **2015_178-207_SN1131_Zoning1-SE (.HEX)**<br>[Year]_[StartJD]-[EndJD]_[SN]_[Name] |
| **Tide – C/T** | Text file from AML C/T logger | **2015_178-207_AMLCT_Zoning1-SE (.TXT)**<br>[Year]_[StartJD]-[EndJD]_[Name] |
| **T01** | Trimble 5700 Binary File (navigation / base)<br>**Platform** – **Receiver SN**<br>*ASV-CT3* – 1784<br>*Lopp Lagoon Base* – 0056 | **17842031 (.T01)**<br>[ReceiverSN][StartJD][FileSequence#] |
| **POS** | Raw Positioning Data (.000 file) from POSMV, network logged | **2015-202-2331-1D (.000)**<br>[Year]-[JD]-[Start time HHMM]-[Vessel#][Area designator(s)] |
| | Raw Positioning Data (.000 file) from POSMV, auto-logged to USB | **2015_202_1236_1D.XXX**<br>[Year]_[JD]_[Start time HHMM]_[Vessel#][Initial area designator].[file sequence #] |

***Table 19 – 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 policy was adhered to even if the majority 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 on the acquisition PCs. At the end of each line the data was copied to a network share on the vessel server that was available to the processors. Data processors then moved the data files to their permanent storage location on the server, where the data was backed-up and processing began. At the end of the project, when the *Q105* was demobilized, the field server containing all data was physically transferred to the TerraSond office in Palmer, Alaska where processing and reporting continued.

### *B.3. Bathymetric (MBES & SBES) Data Processing*

Initial data processing was carried out in the field aboard the *Q105*. Final data processing and reporting was completed in the Palmer office.

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 normally accomplished in real-time for MBES data, directly after each line was acquired, providing rapid coverage and quality determination. For SBES this usually took place in batches instead of line-by-line.

Following the completion of field operations and prior to deliverable creation, final data processing was completed in the Palmer office. This consisted of a review of all collected data, final cleaning and designating soundings, and application of final correctors.

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.* Note SBES line edits were not tracked in TerraLog; however, edits and corrections are viewable for each line in the CARIS "Process Log" within CARIS HIPS.

#### *B.3.1. Conversion into CARIS HIPS and Waterline Offset*

CARIS HIPS was the primary software used for bathymetric processing for this project. The XTFs exported from QINSy (*Q105*) and the SBES RAW files written by HYPACK (*ASV-CT3*) were imported into CARIS HIPS using the conversion wizard module. During conversion, CARIS HIPS created a directory structure organized by project, vessel, and Julian day.

During conversion of SBES files, 1500 m/s was entered as the sound speed to match the value set in the Odom CV100s by acquisition, which allowed CARIS HIPS to convert depths in the RAW or XTF files to travel time for later sound speed correction. The BIN files (HYPACK-logged *ASV-CT3* data only), containing the digital trace data, were also carried over to the line directories at this time.

The HVF for each vessel was updated with a new waterline value prior to sound speed correction. For the *Q105*, port and starboard measure-downs recorded in TerraLog were averaged and reduced to the vessel's CRP using the surveyed vessel offsets to determine the static draft. For the *ASV-CT3*, a measurement was obtained directly from the CRP to the waterline. This value was entered as a new waterline value in each vessel's HVF and checked to confirm the values fell within the normal range for the vessel.

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

### *B.3.2. Load Delayed Heave*

On the *Q105* (which was equipped with a POSMV) delayed heave (also known as "TrueHeave") was logged continually during survey operations to a POS file. In processing, CARIS HIPS' "Load Delayed Heave" utility was utilized to load the lines with the TrueHeave record. The TrueHeave records were then utilized by CARIS HIPS by over real-time heave for final heave correction.

Delayed heave was applied during sound speed correction.

### *B.3.3. ASV-CT3 Heave Corrections*

On the *ASV-CT3* only, which was outfit with a dual-frequency GPS system instead of a heave sensor, heave corrections were accomplished by extracting the heave component from PPK GPS altitudes.

During survey operations, GPS data was continually logged on the vessel at a rate of 10 Hz to ensure enough altitude data points existed to capture the full heave period from waves or swells. The data was post-processed in POSPac POSGNSS with concurrent base station data from the nearby TerraSond base station to produce PPK navigation files in text format.

HeaveXtractor was used to extract heave data at 10 Hz from the navigation files. HeaveXtractor is an in-house software utility that uses a high-pass filter (20-second moving average) cycled over each altitude, centered on the time of the data point for the averaging period. The filter result was subtracted from the data point, resulting in a residual value which consisted of the heave component of the altitude. Longer term effects of dynamic draft and tide were removed through this process. The final result is heave experienced at the vessel's Trimble antenna (which was nearly co-located with the vessel CRP and transducer), centered on zero.

HeaveXtractor included a number of quality control tools. These included a check for overlapping navigation files, a check to ensure the output files overlapped the CARIS line files completely, internal data integrity (spikes or noise or non-zero average heave), and data consistency.

The utility wrote text files that contained the original PPK data, plus the moving average value and residual heave. These files were loaded into *ASV-CT3* survey lines using CARIS' HIPS Generic Data Parser (GDP). The lines were subsequently re-SVP'd and re-merged to apply the correctors.

This method of extracting heave from PPK data has been successfully used on similar projects in the past including the 2012 Nushagak River, 2013 Red Dog, and 2014 Bechevin Bay surveys with identical equipment.

### *B.3.4. Sound Speed Corrections*

Sound speed profiles (casts) were processed using TerraLog, an in-house software package. During entry of the cast in acquisition, the software assigned the cast a timestamp according to the average time recording in the SVP file, as well as a geographic position. If the raw SVP file contained a position and time-tag (as Valeport SV files logged on the *Q105* on this project did), TerraLog utilized it instead.

During processing, TerraLog separated the profile into its up and down components and graphed the data points, allowing obvious 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.

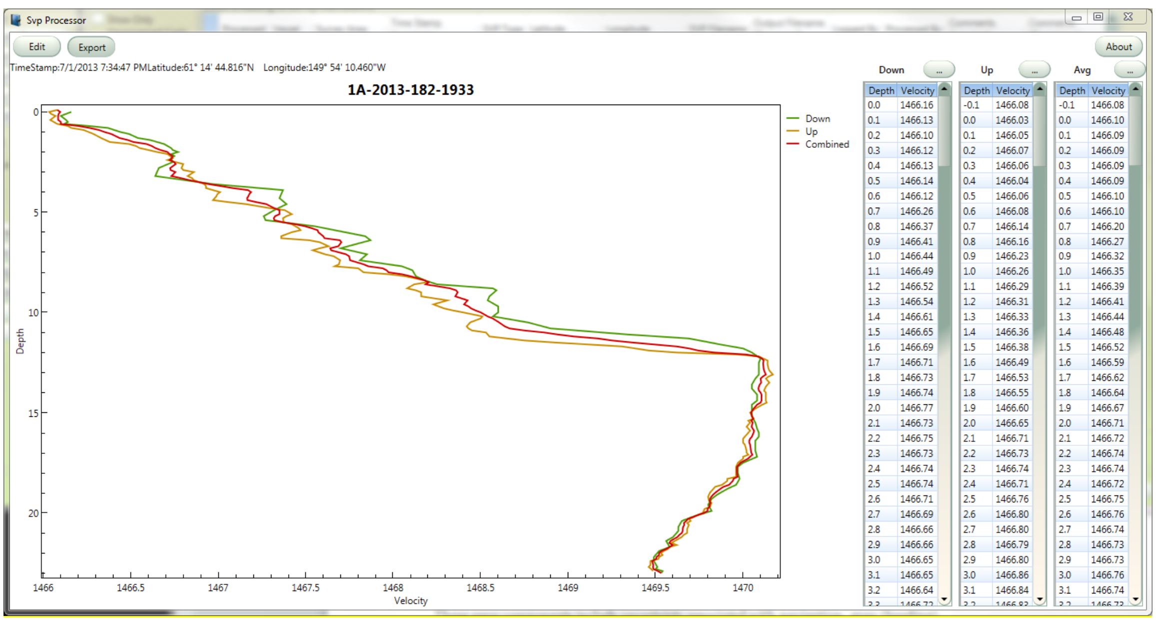



***Figure 7 – Example SVP profile editing interface in TerraLog.***

As TerraLog did not natively support the raw Valeport SV or AML files, the files were reformatted to types readable by TerraLog. An in-house utility, UltimateUnderwaySV Converter, converted Valeport files to “MVP” type and AML files to “Digi” type. The conversion automatically rejected extreme outliers (sound speeds less than 1400 m/s or greater than 1520 m/s) as well as sound speeds in less than 0.5 m water depth.

Each line was corrected for sound speed using CARIS HIPS “Sound Velocity Correction” utility. “Nearest in distance within time” was selected for the profile selection method. For the time constraint, two hours was used for multibeam and four hours was used for single beam. The value was chosen to match the cast set interval done in acquisition. Deviations to the intervals, when they occurred, are described in the corresponding DR. Each line logsheet is also marked with the correction method, typically coded as "NDT 2" (for nearest-in-distance within two hours).

Note that the same profiles used to correct *Q105* MBES data were used to correct *ASV-CT3* single beam data, which was possible because the *ASV-CT3* always worked in close proximity to the *Q105*.

### *B.3.5. Total Propagated Uncertainty*

After sound speed correction, 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 component measurements.

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). Table 20 describes the TPU values entered in the HVF. Note all values entered are at 1-sigma, per CARIS guidance, while CARIS reports TPU at 2-sigma.

| **HVF TPU Entry** | ***Q105* Error Entry** | ***ASV-CT3* Error Entry** | **Source** |
|---|---|---|---|
| Sonar Type | Reson Seabat 7101 (239 beams) | Odom Echotrac CV | 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 |
| Gyro | 0.02° | 0.3° | *Q105*: CARIS TPU values for Applanix POSMV 320 (2 m baseline)<br>*ASV-CT3* Manufacturer specs for Hemisphere V113 |
| Heave | 5% or 0.05m | 5% or 0.124 | *Q105*: CARIS TPU values for Applanix POSMV 320<br>*ASV-CT3*: Higher of 5% or 0.124 (PPK Heave) |
| Roll and Pitch | 0.010° | 1° | *Q105*: CARIS TPU values for Applanix POSMV 320 (RTK)<br>*ASV-CT3*: Manufacturer specs for Hemisphere V113 |
| Navigation | 0.1 m | 0.1 m | PPK processing results reports indicate RMS positioning errors better than 0.10 m on average |

| HVF TPU Entry | *Q105* Error Entry | *ASV-CT3* Error Entry | Source |
|---|---|---|---|
| Timing – (all systems) | 0.01 sec. | 0.1 sec | Estimated overall synchronization error. CV100s are less precisely synced than the MBES system |
| 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 | 0.03 m | 0.025 m | Uncertainty of bar check results |
| Vessel Speed | 2 knots | 3 knots | Estimated average current experienced in survey area |
| Loading | 0.02 m | 0.01 m | Estimated change in vessel draft due to loading changes experienced between draft measurements |
| Draft | 0.03 m | 0.02 m | Estimated accuracy of static draft measurements |
| Delta Draft | 0.02 m | 0.015 m | Uncertainty of squat-settlement test results |
| MRU Align StdDev Gyro, Roll/Pitch | 0.1° | 1° | Estimate of accuracy of patch test results for the applicable sensors |
| MRU to Trans and Nav to Trans Offsets | IMU to Transducer X, Y, Z offset | T5700 ARP to Transducer X, Y, Z offset | Offsets are from the POSMV IMU for the *Q105*, and from the T5700 ARP for the *ASV-CT3* |

***Table 20 – HVF TPU values used.***

Other parameters affecting TPU computation:

- **Tide error uncertainty**: The tide zone definition file (ZDF) for the project contains error estimates for each tide zone and gauge. This ZDF was loaded in CARIS HIPS with the "Compute Errors" option enabled, which computed error estimates for tide dynamically by zone and tidal stage along every line. Error estimates for the zones ranged from 0.053 to 0.065 m. The error estimate for water level measurements at the gauge was 0.041 m. The ZDF and gauge files are included with the CARIS survey deliverables. Note that values for tide error (gauge and zone) were set to 0.1 m during the "Compute TPU" process, but CARIS HIPS ignores these values and uses the tide error computed for each line instead. Refer to documentation supplied with the project HVCR for more information regarding derivation of tide error estimates.
- **MBES real-time error estimates**: *Q105* MBES lines were loaded with real-time error estimates for navigation and attitude using CARIS HIPS "Load Error Data"

function. SMRMSG files produced as part of the Applanix POSPac PPK process were loaded, which contained RMS error at a rate of 1 Hz. RMS error for delayed heave was loaded separately, as part of the CARIS HIPS "Load Delayed Heave" process.

*ASV-CT3* did not have a source of real-time error estimates and therefore used static values from the HVF instead (except for tide, which used real-time error).

- **Sound speed error**: For estimated sound speed error, a value which varied by survey sheet was entered. The estimates were derived by comparing subsequent profiles side-by-side according to the cast interval in use, differencing the change in sound speed at each depth, and calculating the standard deviation of the differences. Specific values used can be found in the DRs.
- **Heave error for *ASV-CT3***: This value was estimated at 0.124 m based on 0.10 m of potential vertical error from post-processed GPS with 0.024 m of additional error to account for vessel motion misinterpreted as heave.
- **TPU computation settings**: During TPU computation, customized settings were selected based on the vessel, area, and availability of real-time error estimates. Table 21 summarizes the settings used during TPU computation.

<table>
<tr><th>TPU Setting</th><th>Q105 Selection</th><th>ASV-CT3 Selection</th><th>Description</th></tr>
<tr><td>Sound Speed - Measured</td><td colspan="2">Varied by sheet, from 1.425 m/s to 2.111 m/s</td><td>Unique value entered by sheet based on analysis of sound speed variance. See each DR for values used</td></tr>
<tr><td>Sound Speed - Surface</td><td>0.025 m/s</td><td>0</td><td>Q105: Manufacturer-specified accuracy of the surface sound-speed probe<br>ASV-CT3: No surface probe utilized, or necessary</td></tr>
<tr><td>Uncertainty Source</td><td>Real-time*</td><td>Custom:<br><br>All Sensors "Vessel" except Tide "Realtime"</td><td>Q105: Used "Realtime" to use the loaded real-time error data for TPU<br>ASV-CT3: Used "Custom," selecting "Vessel" for all sensors but "Realtime" for tides. This resulted in the use of static values from the HVF while still using the tide zone error model from the ZDF</td></tr>
<tr><td colspan="4">*For the relatively few lines without real-time error loaded, CARIS defaulted to the static values from the HVF during TPU computation. Lines without real-time error loaded are listed in the applicable DR.</td></tr>
</table>

***Table 21 – TPU computation settings.***

### *B.3.6. Post-Processed Kinematic GPS*

All final positions for this project were post-processed.

The project was not located within a region of USCG DGPS coverage. WAAS corrections were used for real-time positioning but were replaced in final processing PPK GPS methods.

PPK processing for this project utilized Applanix POSPac software (both MMS and POSGNSS modules). POSPac made use of the dual-frequency 1 Hz GPS data logged at the project base station (Rinex format, converted from T00), the known position of the base stations established by NGS OPUS, and the raw positioning data logged on-board the vessels to produce post-processed positioning files. These PPK files (SBET format for *Q105*, text format for the *ASV-CT3*) were loaded into all lines in processing, which replaced navigation logged in real-time. For *Q105* data, the process also produced the SMRMSG file, which contained root mean square (RMS) error estimates for the post-processed solution, which was loaded and used for TPU estimates as 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. Base station data was converted from the native Trimble T00 format to Rinex using the POSPac “Convert to Rinex” utility and imported into the project, followed by the POS file.

Following successful importation of the base and POS data, the base station position was set to the known ITRF position established by OPUS using an initial 24-hour data set. Antenna height at the base station in use was set where applicable.

Next, the GNSS-Inertial Processor was run. “IN-Fusion Single Baseline” was selected as the GNSS processing mode. This performed the actual PPK processing step.

To ensure quality positioning, the QC plots produced by POSPac were reviewed for spikes and other anomalies following successful completion of processing. SBET altitude and smoothed performance metrics for north, east, and down position error RMS were reviewed.

Finally, SBETs were exported from POSPac. The option to produce “Custom Smoothed BET” was used to produce an SBET in the NAD83(2011) reference frame. This made it so that all final positions were NAD83. The NAD83 SBETs were then applied in CARIS HIPS.

The flow chart in Figure 8 is a generalized overview of the POSPac workflow used on this project.

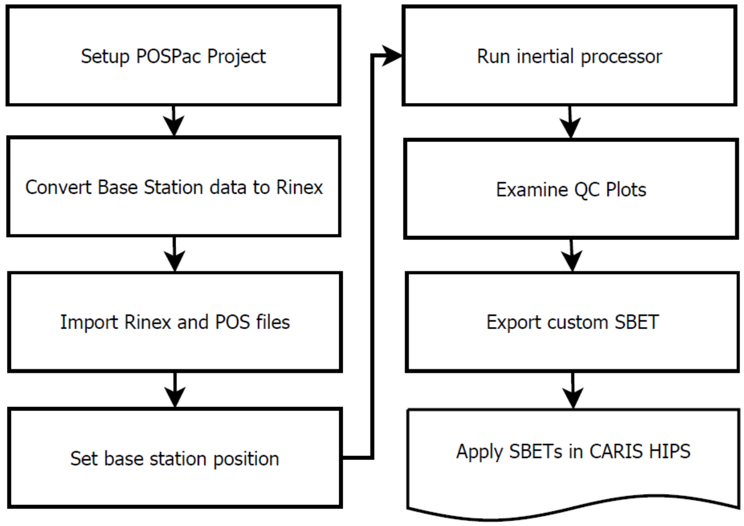



***Figure 8 – Flow chart overview of POSPac workflow used on this project.***

*ASV-CT3* T5700 data was post-processed in a nearly identical fashion, except POSPac's POSGNSS module was utilized instead, and a text file was produced in place of an SBET. All PPK navigation files (SBET and text) that were applied to the data are included with the survey deliverables, as well as RMS graphs.

### *B.3.7. Load Attitude / Navigation Data*

For *Q105*, SBETs were loaded into lines using CARIS HIPS "Load Navigation/Attitude Data" utility. During the loading process, the options to import post-processed navigation (at 0.1 second interval), gyro, pitch, roll, and GPS height (at 0.02 second interval) were selected. For a select few lines, SBET data had to be loaded via CARIS HIPS Generic Data Parser (GDP) utility, noted in the applicable DR.

For *ASV-CT3* SBES data, the PPK text files were loaded using GDP. Heave was also loaded at this time from the same files, derived from the PPK GPS height as described previously in this report.

In this process, each line's original (real-time) navigation and altitude (GPS height) records were overwritten with the information in the PPK files. For *Q105* lines, pitch, roll, and gyro from the SBET were also loaded, replacing the real-time values. The name of the PPK file applied to each survey line was noted by the data processors in the data processing logsheet.

It is important to note that this process replaced all real-time navigation for both vessels, all real-time attitude for the *Q105*, and all real-time heave data for the *ASV-CT3*.

Note: A GPS leap second was introduced on July 1$^{st}$, 2015, during survey operations. This caused loaded SBETs (and SMRMSG files) to behind UTC by 1-second for JD182 through JD185 (remainder of the GPS week in which the leap second was introduced). Per CARIS guidance, 1-second was added to the times on these files during the loading process, which fully addressed the issue.

### *B.3.8. Load Tide, Compute GPS Tide, and Merge*

CARIS HIPS "Load Tide" function was used to load all lines with final, verified discrete tide zone data. The ZDF "S313KR2015CORP_20151008.zdf" was selected. This ZDF was computed following the completion of field operations, when all tide data sets were fully available for review. Note preliminary tide correction was accomplished in the field using a ZDF provided by CO-OPS based on the NWLON station at Red Dog Dock (station ID 949-1094), but was replaced during final processing with the custom ZDF described above.

This ZDF file referenced one tide gauge file for the project tide station, "9469515.tid", which contained the 6-minute tide data on MLLW for the project tide station "Outside Lopp Lagoon" (station ID 946-9515). The option to "Compute Errors" was enabled, which allowed CARIS HIPS to compute estimates for tidal error for each line based on the error parameters defined in the ZDF (described previously in this report).

The CARIS HIPS "Merge" function was used to apply final corrections including discrete tide zones.

Refer to the project HVCR for more information regarding the derivation of the ZDF.

### *B.3.9. Navigation and Attitude Sensor Checks & Smoothing*

Navigation data was reviewed using CARIS HIPS Navigation Editor. The review consisted of a visual inspection of plotted fixes noting any gaps in the data or unusual jumps in vessel position.

Attitude data was reviewed in CARIS HIPS Attitude Editor. This involved checking for gaps or spikes in the gyro, pitch, roll, and heave sensor fields.

Significant gaps or spikes in records, which were extremely rare, were reviewed by the Lead Hydrographer and a determination was made whether interpolation was possible, or if rejection and rerun would be required.

*ASV-CT3* pitch and roll data, derived from the Hemisphere V113, was generally poor, with many spikes. Pitch and roll for this vessel was de-spiked, but not applied to the data because there was no obvious benefit after application.

Checks done on the sensors were tracked in TerraLog; processing results are recorded there. Exported logsheets are available in the DR, *Separate 1: Acquisition and Processing Logs*.

### *B.3.10. Multibeam Swath Filtering*

Prior to manual review and cleaning, all multibeam data was filtered using CARIS HIPS "Filter Select Lines" function.

All lines were initially filtered with a 65° filter, which removed beams greater than 65 from nadir. Soundings flagged by the multibeam system to be less then high quality (quality flag of 0, 1, and 2) were also rejected at this time.

This left only high quality soundings within 65° of nadir, and removed the majority of erroneous soundings, facilitating manual cleaning and removing the data most susceptible to sound speed and motion artifact errors.

After the initial filtering at 65°, lines were selected for additional filtering based on the presence of residual motion artifact (particularly roll) in outer beam data exceeding 0.20 m. Filters were more aggressively applied, from 60° down to 50° where necessary, to achieve acceptable artifact levels. Sea conditions were often marginal during the survey and roll artifact in the data is directly proportional to sea conditions. Note that full coverage was not a requirement of this survey, so no line spacing adjustments were necessary to compensate for filtered data.

Crosslines were filtered at 45° regardless, in order to provide the highest quality soundings for comparison against the mainscheme surfaces.

Filter settings were saved to HIPS filter files (HFF). The HFFs are included with the CARIS deliverables (session directory), and the HFF used for each survey line was noted in the line logsheet by processing.

### *B.3.11. Multibeam Editing*

Initial field cleaning of multibeam data was done using CARIS HIPS Swath Editor. Soundings were examined for spikes or other abnormalities, and obvious erroneous soundings were rejected. Cleaning status was tracked in the processing section of TerraLog, along with the processors' comments or notes, if any.

A second examination of data was done in the office following the completion of operations, also in Swath Editor.

A final examination was done in CARIS HIPS Subset Editor after application of final corrections (including tides).

In CARIS HIPS, CUBE surfaces were first generated based on the depth resolution standards and CUBE parameters conforming to the 2014 Hydrographic Surveys Specifications and Deliverables (HSSD). The CUBE surface, which was loaded as a reference layer, was then examined in subset mode simultaneous with the contributing soundings.

To prevent unnecessary and excess rejection of soundings, requirements in the HSSD were adhered to during the subset editing process. Specifically, only soundings which 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 many noisy 'accepted' soundings that can exceed the TVU allowance, however, the final deliverable is the surface (not the soundings), which meets TVU specifications.

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 one-half the maximum allowable TVU at that depth (for depths under 20 m), or greater than the TVU at that depth (for depths over 20 m). 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. Note that for this survey, designated soundings were rare.

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 10-15 lines, width was constrained to 50-100 m, and vertical exaggeration in the subset window was manually set so the vertical scale graticule displayed in increments of 0.20 m. Subset tiles were used to track editing progress, with care taken to ensure all data was examined.

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

### *B.3.12. Single Beam Editing*

Single beam data, which was collected by the *ASV-CT3*, was manually cleaned using CARIS HIPS Single Beam Editor. Erroneous soundings exceeding the error tolerances outlined in the HSSD (deviating by more than one-half of the TVU for the depth) were rejected.

The soundings were examined for spikes or other abnormalities. During this process, the bottom trace data was used as background data in Single Beam Editor to ensure the soundings accurately portrayed the bottom. The digital bottom assisted in determination of noise from real seafloor.

In the version of CARIS HIPS used on this project, the alignment of soundings to the digital trace frequently shows a vertical shift. This is due to the fact that CARIS HIPS does not correct the trace position for the effects of sound speed and offsets from the HVF, while the soundings have been corrected. However, the trace still served as a useful tool when editing soundings.

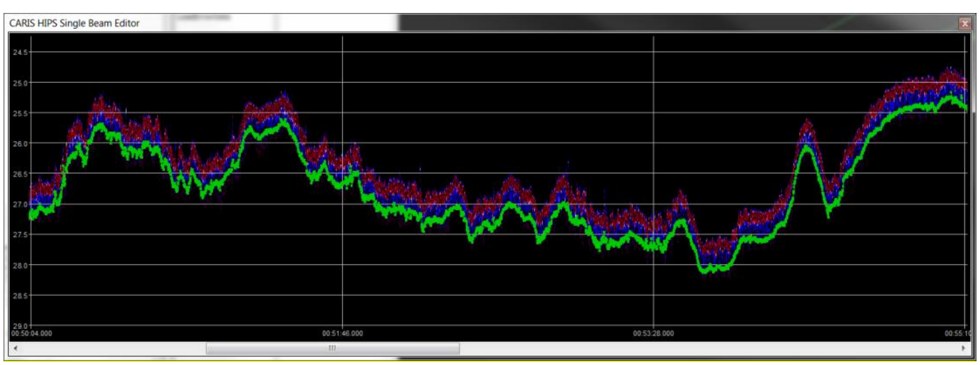



***Figure 9 – Example of soundings (green) and digital bottom trace data (magenta and blue) in CARIS HIPS Single Beam Editor.***

Note that incorrect sonar minimum depth gate settings removed some of the shoalest soundings from *ASV-CT3* data on JD203/204. However, the digital bottom trace data was unaffected. This allowed the digital bottom trace to be used as a guide for a hydrographer to manually digitize soundings where they had been originally gone un-digitized due to depth gates.

As a final check on the SBES data for gross fliers, all SBES data was loaded into CARIS HIPS Subset mode and reviewed with the 2D slice set parallel to each line. Auto-exaggeration was turned on, and any remaining gross fliers were rejected.

Subset mode was also used to examine the data for matchup with crosslines and overlapping multibeam lines.

### *B.3.13. Dynamic Draft Corrections*

Dynamic draft corrections were computed and applied for this survey. Processing varied by vessel.

Dynamic draft corrections on the *Q105* were based on engine RPM. Speed-based corrections were not used for this vessel. As described in Section A of this report, a TerraTach system was used to continuously compute, time tag, and log engine RPM data at 1 Hz with a resolution of 1 RPM on this vessel. In processing, the 100-RPM resolution dynamic draft results were interpolated at one RPM to match the resolution of the TerraTach system (1 RPM). A VB.NET utility was written that averaged port and starboard readings and then paired each RPM value logged with the corresponding settlement value determined by a squat settlement test. Rare instances of missing RPM data from the TerraTach files were filled using RPM data saved by TerraLog, which was also configured to record RPM values. A draft correction file consisting of time and settlement value was then loaded into all lines using CARIS HIPS "Load Delta Draft" function.

On the *ASV-CT3*, dynamic draft corrections were speed-based. A speed-settlement curve was entered into the *ASV-CT3* HVF. Unlike the *Q105*, "Load Delta Draft" was not applicable to this vessel data since corrections were speed-based.

Refer to Section C of this report for dynamic draft results.

### *B.3.14. Final BASE Surfaces and Feature Files*

The final depth information for this survey is submitted as a collection of BASE surfaces (CARIS HIPS 8.1 CSAR format), which best represent the seafloor at the time of survey.

Per the 2014 HSSD, final surfaces were created at 4 m resolution based on the requirements for set-line spacing. Separate surfaces were created for MBES and SBES data.

"CUBE" was selected as the gridding algorithm for MBES surfaces. "Density and Locale" was chosen as the dis-ambiguity 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.

"Uncertainty" was selected as the gridding algorithm for SBES surfaces.

For all surface types, "Order 1a" was selected as the IHO S-44 Order type.

Each surface was finalized 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. Designated soundings were applied, which forced the final surfaces to honor these soundings when applicable.

A final feature S-57 file (FFF) (in CARIS HIPS .HOB format) 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 version 5.3.2 extended attributes) that may be useful for chart compilation. The FFF was created in CARIS Notebook 3.1 by importing all applicable features and assigning mandatory attributes as necessary.

### *B.3.15. Crossline Analysis*

The crossline analysis was conducted using CARIS HIPS "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 (CUBE-type) surface created from the mainscheme data. QC BASE surfaces were created with the same CUBE parameters and resolutions as the final BASE surfaces, with the important distinction that the QC BASE surfaces did not include crosslines so as to not bias the QC report results. Note that crosslines were filtered to reject soundings greater than 45° from nadir, in order to leave the highest quality portion of the swath for comparison against the mainscheme surfaces.

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

### *B.3.16. Bathymetric Processing Flow Diagram*

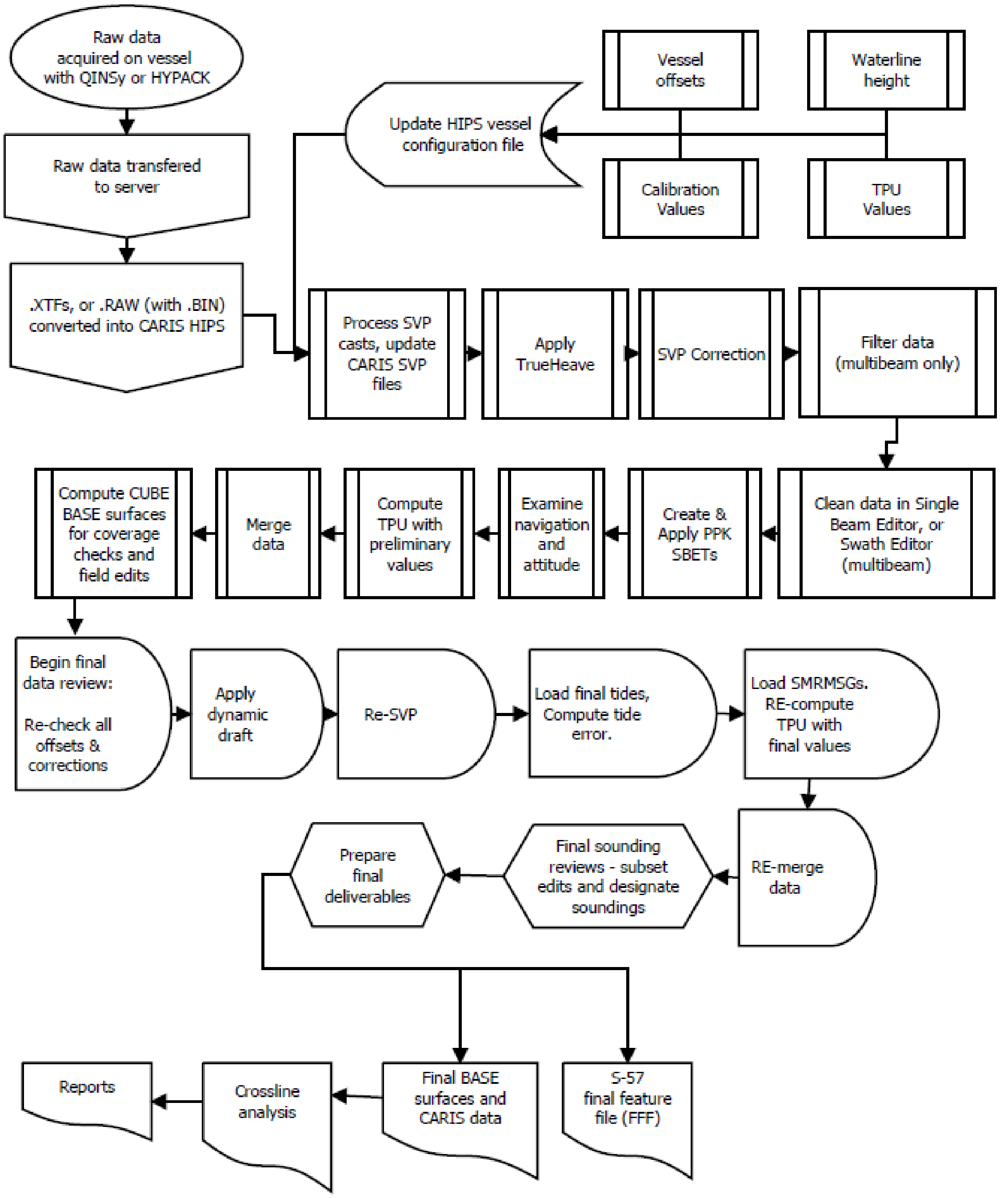



*Figure 10 – Generalized flow chart of processing steps used on this project.*

### *B.4. Confidence Checks*

In addition to daily QC steps undertaken as part of the acquisition and processing procedures outlined in the above sections, formal confidence checks were also completed throughout the survey.

Table 22 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, the planned confidence check was accomplished as soon as possible when conditions allowed.

| Confidence Check | Purpose | Frequency |
|---|---|---|
| Depth Checks<br>(Bar and/or Lead Line) | Check depth accuracy<br>Determine and refine Z offsets | Every two weeks |
| Echosounder Depth Comparison (Multiple Vessels) | Overall check of consistency of survey systems | No planned frequency; examine intersections of vessels |
| SVP Comparison | Check SVP sensors for consistency | Every two weeks |
| 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 (project base versus CORS) | Weekly |
| Vessel Position Confidence Check – Independent GPS | Continuous gross-error check in acquisition | Daily, real-time |
| Staff Shots | Check of tide gauge stability | Every two weeks |
| ERS – Discrete Tides Comparison | Compare ERS survey to discrete tide zone survey | N/A for this survey; ERS was not utilized |

***Table 22 – Summary of formal confidence checks.***

#### *B.4.1. Bar Checks*

For this survey, bar checks were utilized to determine and refine sonar Z offsets, and to check the relative accuracy of the echosounder and processing systems. Each vessel received at least one successful bar check, with two completed on the *Q105* and one completed on the *ASV-CT3*. All were performed alongside the dock in Nome, with calm seas and little or no current.

To perform the bar check, a rectangular aluminum grate was hung by steel cable from guide points on the vessel's gunwale (or from the vessel reference point on the *ASV-CT3*). The steel cable was marked at an interval of 1 m from the bar, measured by tape. A sound speed profile was collected and the average velocity entered into the echosounder for the CV100 units (not required for the Reson 7101 with its real-time SV sensor), and static draft was measured.

With QINSy (for *Q105* MBES) or HYPACK (for *ASV-CT3* SBES) logging and the sonar tuned to track the bar instead of the bottom, the bar was lowered by 1 m increments directly below the transducer while bar depth and time were noted in the log. Bar check maximum depth, which ranged from 2-4 m on this survey, was determined by ability to maintain a sonar lock on the bar as well as depth at the test location.

The bar depth was read relative to the waterline for later comparison to the CARIS HIPS results, as well as relative to the gunwale measure-down points for determining and re-confirming the acoustic center offset.

Bar checks were processed in CARIS HIPS. Depth of the bar relative to the waterline was extracted from HIPS and compared to the actual bar depth at that time. Actual bar depths compared to processed bar depths within 0.033 m on average for multibeam, and 0.015 m on average for single beam.

In addition to serving as depth confidence checks, bar checks were critical to establish acoustic center offsets on the Odom single beam system. Odom single beam systems have an acoustic center position that can vary from the transducer face due to electronic delays between the processor, transducer and interconnecting cable. Odom refers to this offset from the transducer face as the “index value.” Once determined for a particular equipment layout however, the value remains fixed.

Bar check logs are available in *Appendix II* of this report.

### *B.4.2. Lead Lines*

Lead line checks were utilized to check the absolute accuracy of the echosounder and processing systems. These were done when alongside the dock in Nome to ensure drift would not affect the results, concurrent with a bar check.

Lead lines were accomplished by lowering a calibrated 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.

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

On the *Q105*, two lead lines were acquired, with processed depth comparing to 0.051 m, or better. One lead line was acquired for the *ASV-CT3*, with processed depth comparing to 0.046 m. Results on all vessels were deemed reasonable given the variables associated with lead line checks.

Depth check (lead line) logs are available in *Appendix II* of this report.

### *B.4.3. Echosounder Depth Comparison (Multi-Vessel)*

During acquisition, care was taken to ensure significant overlap was achieved between the two survey vessels for comparison purposes. *Q105* crosslines regularly intersect *ASV-CT3* data, and in several instances the *Q105* ran completely over *ASV-CT3* lines, creating ample comparable data.

To compare the echosounder data, CARIS BASE 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.

Project wide, the multibeam data agrees to the single beam data to 0.012 m on average, with a standard deviation of 0.051 m, with the multibeam data slightly shoaler. The maximum difference was 0.426 m, and minimum difference was -0.238 m.

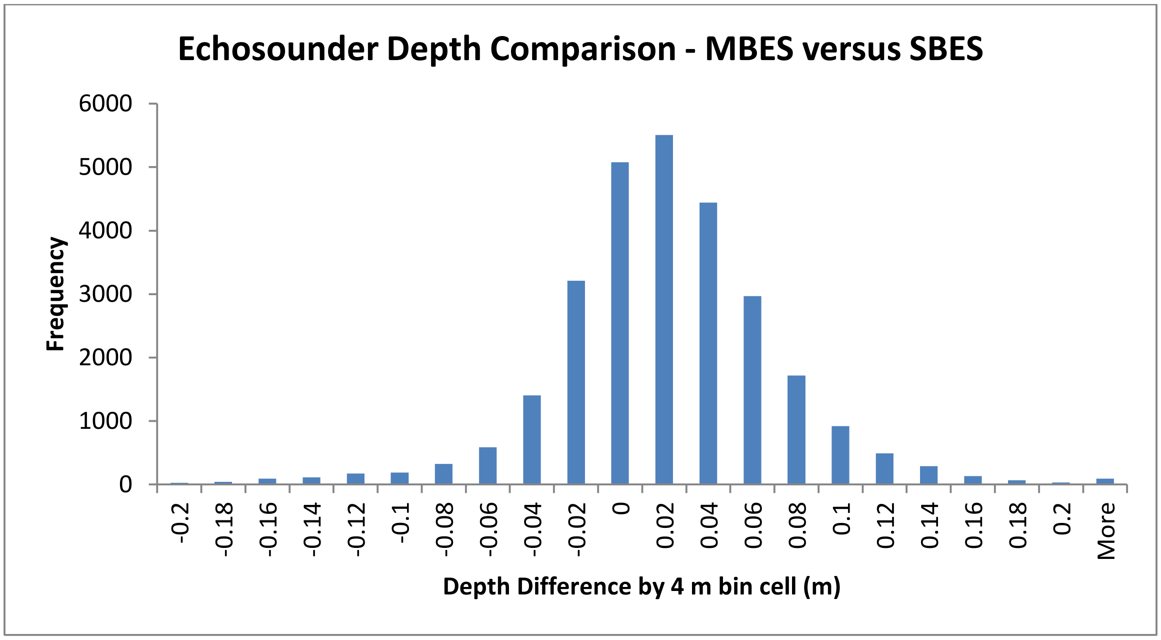



***Figure 11 – Histogram of vessel to vessel echosounder comparison.***

Overall agreement is excellent between the two vessels – each with completely independent sonar and positioning systems – which helps demonstrate the lack of significant systematic biases.

### *B.4.4. SVP Comparison*

SVP comparisons were undertaken to check the accuracy and consistency of the sound velocity probe data. In the test, data from the primary sound speed profiler was compared to at least one other independent, calibrated sound speed profiler. These comparisons took place every two weeks during survey operations.

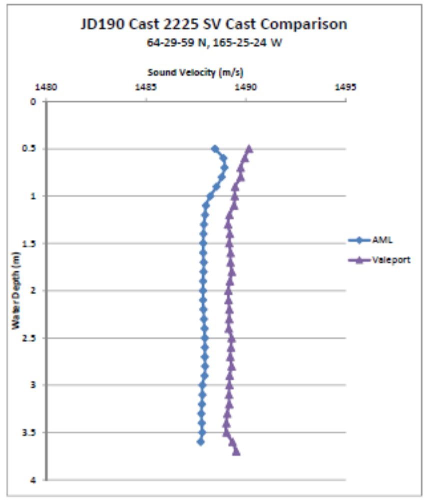
To perform the test, a spare profiler probe was used to collect a cast coincident with the primary probe. Probes were normally strapped together and lowered at the same time, though occasionally it was necessary to collect the profiles separately (though very close in time). The data from both probes underwent standard processing and were compared depth-by-depth in an SVP comparison logsheet (see Figure 12). Results of the comparisons were good, with sound speed at all depths usually comparing to better than 1.5 m/s, though some show greater variance that is attributable to change over the slight differences in times of acquisition of the profiles.

A slight shift was noted when comparing the project Valeport sensor to two separate AML sensors, with the Valeport generally reading 1-1.5 m/s faster. The difference was considered negligible enough to not have significant impact on data quality, assuming one was more accurate than the other.

The AML Micro SV-XChange sensor used on the Reson 7101 MBES head was also compared for accuracy against an AML MinosX SV-Xchange sensor on JD191. Results were excellent, with both instruments reading within 0.1 m/s of each other.

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

| SV Probe Results | | |
|---|---|---|
| Sensor: | AML MinosX | Valeport RapidSV |
| SN | MinosX 30341, SV-Xchange 204677, P-Xchange 304614 | 49911 |
| Date/Time | 2015-190 22:26:17 | 2015-190 22:25:58 |
| Depth | Sound speed (m/s) | |
| 0.5 | 1488.45 | 1490.15 |
| 0.6 | 1488.88 | 1489.94 |
| 0.7 | 1488.93 | 1489.73 |
| 0.8 | 1488.79 | 1489.74 |
| 0.9 | 1488.53 | 1489.46 |
| 1 | 1488.22 | 1489.44 |
| 1.1 | 1488 | 1489.4 |
| 1.2 | 1487.96 | 1489.18 |
| 1.3 | 1487.9 | 1489.11 |
| 1.4 | 1487.88 | 1489.2 |
| 1.5 | 1487.87 | 1489.16 |
| 1.6 | 1487.87 | 1489.23 |
| 1.7 | 1487.89 | 1489.23 |
| 1.8 | 1487.88 | 1489.29 |
| 1.9 | 1487.86 | 1489.2 |
| 2 | 1487.86 | 1489.12 |
| 2.1 | 1487.86 | 1489.13 |
| 2.2 | 1487.88 | 1489.17 |
| 2.3 | 1487.9 | 1489.16 |
| 2.4 | 1487.93 | 1489.14 |
| 2.5 | 1487.94 | 1489.28 |
| 2.6 | 1487.95 | 1489.25 |
| 2.7 | 1487.95 | 1489.22 |
| 2.8 | 1487.96 | 1489.28 |
| 2.9 | 1487.93 | 1489.19 |
| 3 | 1487.82 | 1489.17 |
| 3.1 | 1487.82 | 1489.15 |
| 3.2 | 1487.8 | 1489.16 |
| 3.3 | 1487.77 | 1489.07 |
| 3.4 | 1487.79 | 1489.02 |
| 3.5 | 1487.81 | 1489.03 |
| 3.6 | 1487.74 | 1489.33 |
| 3.7 | | 1489.51 |




| Statistics on the SV Probe Results | |
|---|---|
| Depth | AML vs Valeport |
| 0.5 | 1.7 |
| 0.6 | 1.06 |
| 0.7 | 0.8 |
| 0.8 | 0.95 |
| 0.9 | 0.93 |
| 1 | 1.22 |
| 1.1 | 1.4 |
| 1.2 | 1.22 |
| 1.3 | 1.21 |
| 1.4 | 1.32 |
| 1.5 | 1.29 |
| 1.6 | 1.36 |
| 1.7 | 1.34 |
| 1.8 | 1.41 |
| 1.9 | 1.34 |
| 2 | 1.26 |
| 2.1 | 1.27 |
| 2.2 | 1.29 |
| 2.3 | 1.26 |
| 2.4 | 1.21 |
| 2.5 | 1.34 |
| 2.6 | 1.3 |
| 2.7 | 1.27 |
| 2.8 | 1.32 |
| 2.9 | 1.26 |
| 3 | 1.35 |
| 3.1 | 1.33 |
| 3.2 | 1.36 |
| 3.3 | 1.3 |
| 3.4 | 1.23 |
| 3.5 | 1.22 |
| 3.6 | 1.59 |
| 3.7 | |

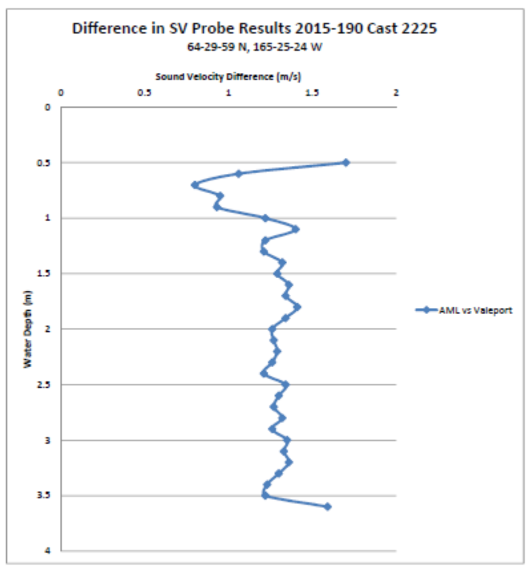
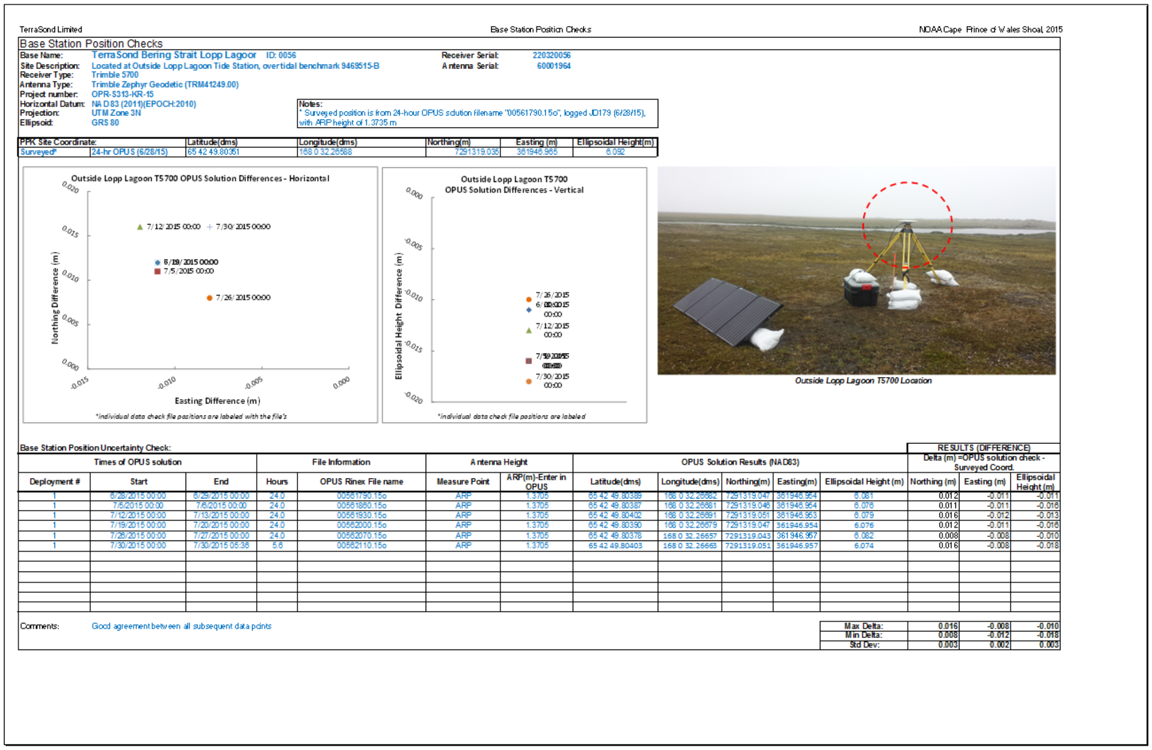



***Figure 12 – Example of SVP confidence check (comparison results): JD190 SVP comparison using Valeport and AML sensors.***

### *B.4.5. Base Station Position Checks*

For the project base station, the precise geographic position was established using NOAA NGS OPUS by upload of the first 24-hour GPS static session logged at the site. This position became the accepted, surveyed position that was used for data processing as well as the position against which subsequent measurements were compared.

As a confidence check on antenna and monument stability and to ensure repeatability, an OPUS solution was derived at least once weekly from a 24-hour data set and compared to the surveyed position. Results were excellent with all subsequent position results comparing to within 0.018 m vertically and 0.012 m horizontally (or better) of the initial (surveyed) position. Base station confidence check logsheets (see Figure 13) are available with the project HVCR.



TerraSond Limited — Base Station Position Checks — NOAA Cape Prince of Wales Shoal, 2015

Base Station Position Checks

Base Name: TerraSond Bering Strait Lopp Lagoon ID: 0056
Site Description: Located at Outside Lopp Lagoon Tide Station, over tidal benchmark 9469515-B
Receiver Type: Trimble 5700
Antenna Type: Trimble Zephyr Geodetic (TRM41249.00)
Project number: OPR-S313-KR-15
Horizontal Datum: NAD83 (2011)(EPOCH:2010)
Projection: UTM Zone 3N
Ellipsoid: GRS 80
Receiver Serial: 220320056
Antenna Serial: 60001964

Notes: * Surveyed position is from 24-hour OPUS solution filename "00561790.15o", logged JD179 (6/28/15), with ARP height of 1.3735 m

| PPK Site Coordinate: | | Latitude(dms) | Longitude(dms) | Northing(m) | Easting (m) | Ellipsoidal Height(m) |
|---|---|---|---|---|---|---|
| Surveyed* | 24-hr OPUS (6/28/15) | 65 42 49.80351 | 168 0 32.26588 | 7291319.035 | 361946.965 | 6.092 |



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 | 6/28/2015 00:00 | 6/29/2015 00:00 | 24.0 | 00561790.15o | ARP | 1.3705 | 65 42 49.80389 | 168 0 32.26682 | 7291319.047 | 361946.954 | 6.081 | 0.012 | -0.011 | -0.011 |
| 1 | 7/5/2015 00:00 | 7/6/2015 00:00 | 24.0 | 00561860.15o | ARP | 1.3705 | 65 42 49.80387 | 168 0 32.26681 | 7291319.046 | 361946.954 | 6.076 | 0.011 | -0.011 | -0.016 |
| 1 | 7/12/2015 00:00 | 7/13/2015 00:00 | 24.0 | 00561930.15o | ARP | 1.3705 | 65 42 49.80402 | 168 0 32.26691 | 7291319.051 | 361946.963 | 6.079 | 0.016 | -0.012 | -0.013 |
| 1 | 7/19/2015 00:00 | 7/20/2015 00:00 | 24.0 | 00562000.15o | ARP | 1.3705 | 65 42 49.80390 | 168 0 32.26679 | 7291319.047 | 361946.954 | 6.076 | 0.012 | -0.011 | -0.016 |
| 1 | 7/26/2015 00:00 | 7/27/2015 00:00 | 24.0 | 00562070.15o | ARP | 1.3705 | 65 42 49.80378 | 168 0 32.26657 | 7291319.043 | 361946.957 | 6.082 | 0.008 | -0.008 | -0.010 |
| 1 | 7/30/2015 00:00 | 7/30/2015 05:36 | 5.6 | 00562110.15o | ARP | 1.3705 | 65 42 49.80403 | 168 0 32.26663 | 7291319.051 | 361946.957 | 6.074 | 0.016 | -0.008 | -0.018 |

Comments: Good agreement between all subsequent data points

| | Northing (m) | Easting (m) | Ellipsoidal Height (m) |
|---|---|---|---|
| Max Delta: | 0.016 | -0.008 | -0.010 |
| Min Delta: | 0.008 | -0.012 | -0.018 |
| Std Dev: | 0.003 | 0.002 | 0.003 |

***Figure 13 – Example Base Station Position Check logsheet.***

### *B.4.6. Vessel Positioning Confidence Checks – Alternate Base Station*

To ensure that vessel positioning was accurate and consistent, regardless of the base station in use – and as independent check of vessel positioning – vessel position confidence checks were undertaken on the *Q105*. These were accomplished on a weekly basis. The checks were not performed on the *ASV-CT3* due to the relatively small amount of data for this vessel and the fact that positioning compared well with *Q105* data.

To complete the check for each vessel, a random POS file was selected from each week and re-processed with a CORS GPS site, AB09 at the relatively nearby village of Wales. AB09 was approximately 11.5 kilometers from the project base station. 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 Figure 14) along with the comparison parameters and observations.

Results were excellent, with average differences agreeing to 0.1 m, or better. The vessel positioning confidence check logs are available in *Separate I* of the DRs.

TerraSond Limited Vessel Positioning Confidence Check NOAA Cape Prince of Wales Shoal 2015

## Vessel Positioning Confidence Check

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

**POS file:** 2015-179-1655_Tide.POS **Date:** June 28, 2015 (JD179) **Vessel:** Qualifier 105

**Base Stations Used**

| Base Station Name | Operating Agency | Function | Data Rate | Min. Baseline Distance (m) | Max. Baseline Distance (m) |
|---|---|---|---|---|---|
| Lopp Lagoon | TerraSond | Project Primary | 1 second | 2295 | 2340 |
| AB09 | UNAVCO/PBO | Backup/Comparison | 15 seconds | 12740 | 12910 |

*Table 1- Base stations used for comparison*

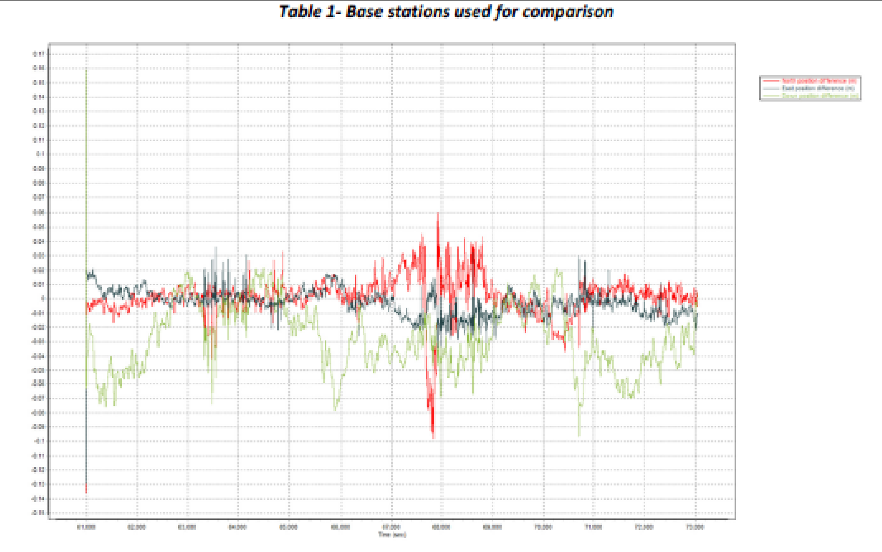


*Figure 1 - Results of position difference between 2015-179-1655_Tide.POS processed with Lopp Lagoon and AB09*

**Result Statistics**

| Position | Min. Difference (m) | Max. Difference (m) | Mean Difference (m) |
|---|---|---|---|
| North | -0.13 | 0.06 | -0.01 |
| East | -0.13 | 0.04 | 0.00 |
| Down | -0.1 | 0.16 | -0.02 |

*Table 2 - Approximate minimum, maximum and mean differences*

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

***Figure 14 – Example of Vessel Positioning Confidence Check (alternate base station) from JD179.***

### *B.4.7. Vessel Positioning Confidence Checks – Independent GPS*

Checks of the primary position and an independent GPS source were accomplished in real-time on both vessels.

QPS QINSy (on the *Q105)* or HYPACK (on the *ASV-CT3)* were configured to graphically plot the position of the primary navigation source (POSMV on the *Q105*, T5700 on the *ASV-CT3*) against the independent GPS source (Hemisphere V102 on the *Q105*, Hemisphere V113 on the *ASV-CT3*). Any major differences would alert the acquisition crew to a positioning error. However, no abnormalities were observed during this project, with the positions comparing within 2-5 m horizontally.

### *B.4.8. Tide Station Staff Shots and Operation*

Standard leveling procedures were utilized to perform "staff shots" at the project tide station to confirm tide gauge stability. During staff shots, leveling was undertaken to determine the difference in elevation between one, or more, tidal benchmarks and the water surface. Readings were timed to occur on a 6-minute interval synced with the simultaneous measurement taken by the gauges. Staff shots were collected for 1-4 hours during each visit, which normally was accomplished every two weeks. Hydrometer readings were collected periodically during staff shots for salinity checks.

Following staff shots, stage readings were downloaded from the gauges and differenced from the staff shot result in a staff shot form to compute the staff constant. The staff constant was compared to prior staff constants to confirm gauge stability.

Staff shot forms (and coincident gauge data, after download) were transmitted within 24-hours of collection to TerraSond's tide subcontractor, JOA Surveys (JOA). JOA performed additional QC on the acquired data and staff shot results. JOA also provided QC on data downloaded from the NWLON station at Red Dog Dock (station ID 949-1094), and provided corrector files on a daily basis for preliminary reduction of soundings in the field.

No major issues with the gauges occurred on this project. Minor settling at the submerged gauges were compensated for during tidal data processing by JOA. See the HVCR for more information concerning tide operations and JOA's tide station reports (included with HVCR), which include the staff shot forms.

## C. *Corrections to Echo Soundings*

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

### *C.1. Vessel Offsets*

Sensor locations were established with a pre-season survey of the vessels using conventional survey instruments. Acoustic center offsets were determined through bar check method for the MBES and SBES systems.

A CRP, or point from which all offsets were referenced, was selected for each vessel.

For the *Q105*, the top-center of the POSMV IMU, which was mounted at the vessels estimated center of gravity, was used as the CRP. For the *ASV-CT3*, the CRP was located on the port-side, aft end, on the transducer mount bracket.

On the *Q105*, the primary POSMV GPS antenna to POSMV IMU offset was applied automatically during data collection (and subsequent post-processing) so that all positions and motion data were computed for the vessel CRP, while the remaining offsets such as the CRP to sonar and CRP to waterline were applied by way of the HVF.

It is important to note that for the *Q105* multibeam data, X and Y offsets are entered only under the SV1 sensor in the HVF, while the Z offset is entered under both Swath1 and SV1. This configuration was intentionally done to prevent double application of the X and Y offsets (though this does not double-apply the Z offset), per consultation with CARIS. This configuration is specific to XTFs produced from Reson 71xx-series sonars.

All 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 (see Section B.3.5, Total Propagated Uncertainty). Vessel outlines and offset descriptions are provided in the following figures and tables.

### *C.1.1. Q105 Vessel Offsets*

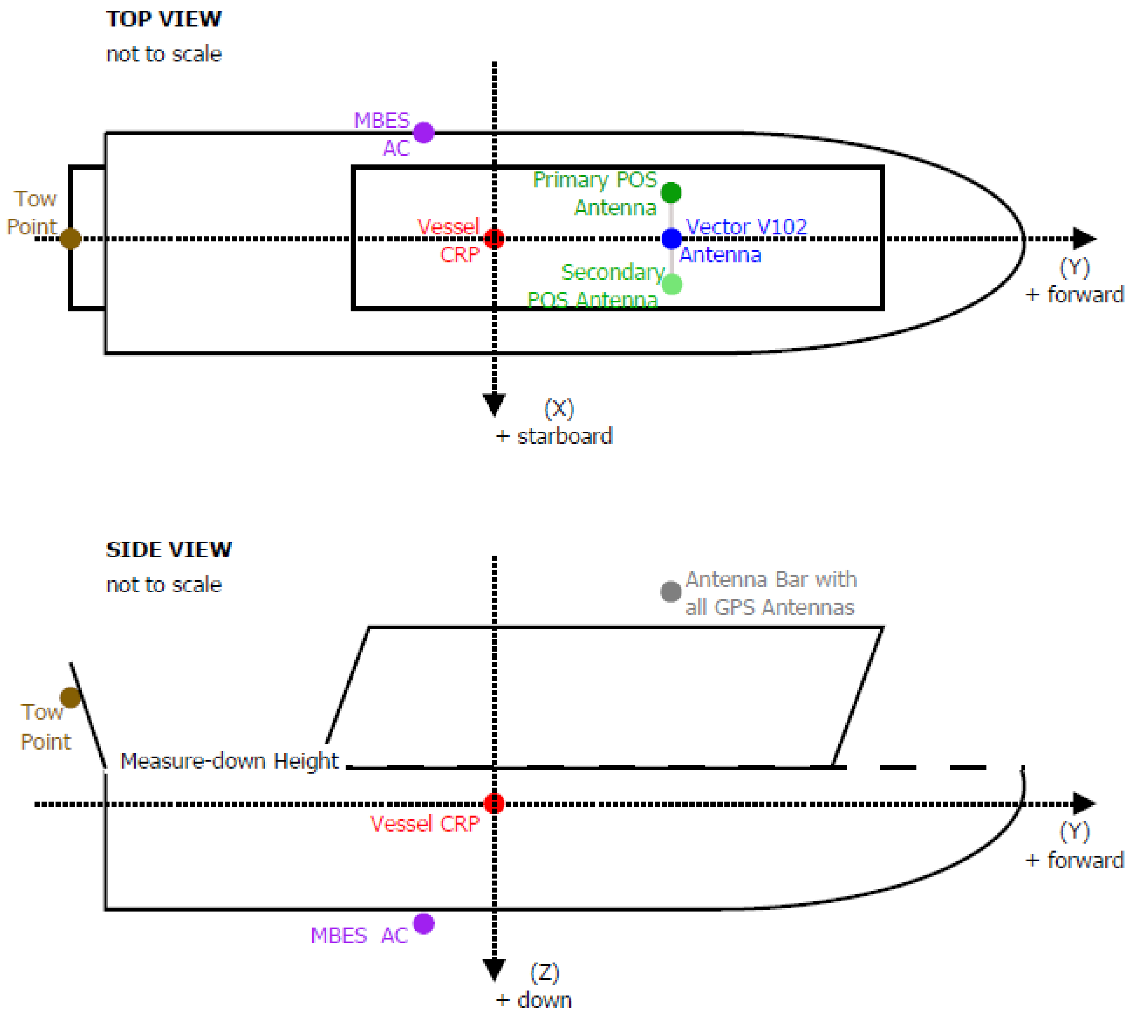



***Figure 15 – Q105 vessel survey showing relative positions of installed survey equipment.***

| Equipment | X (m) (+ stbd) | Y (m) (+ fwd) | Z (m) (+ down) | Comments |
|---|---|---|---|---|
| CRP | 0.000 | 0.000 | 0.000 | Top-center of POSMV IMU |
| MBES Acoustic Center (AC) | -4.178 | -3.380 | 1.120 | Z value determined by bar check |
| Primary POS Antenna | -0.998 | 5.093 | -13.903 | Z value determined from POSPac calibration |
| Secondary POS Antenna | 1.002 | 5.105 | -13.949 | Primary position corrected by GAMS A-B vector |
| Hemisphere Vector V102 | 0.002 | 5.099 | -13.926 | Real-time nav checks only |
| Stern Tow Point | 0.000 | -14.940 | 4.00 | A-frame block in tow position. (N/A this project) |
| Draft Measure-down Point (port side) | - | - | -2.551 | |
| Draft Measure-down Point (stbd side) | - | - | -2.551 | |

***Table 23 – Q105 offset measurements relative to CRP.***

### C.1.2. *ASV-CT3 Offsets*

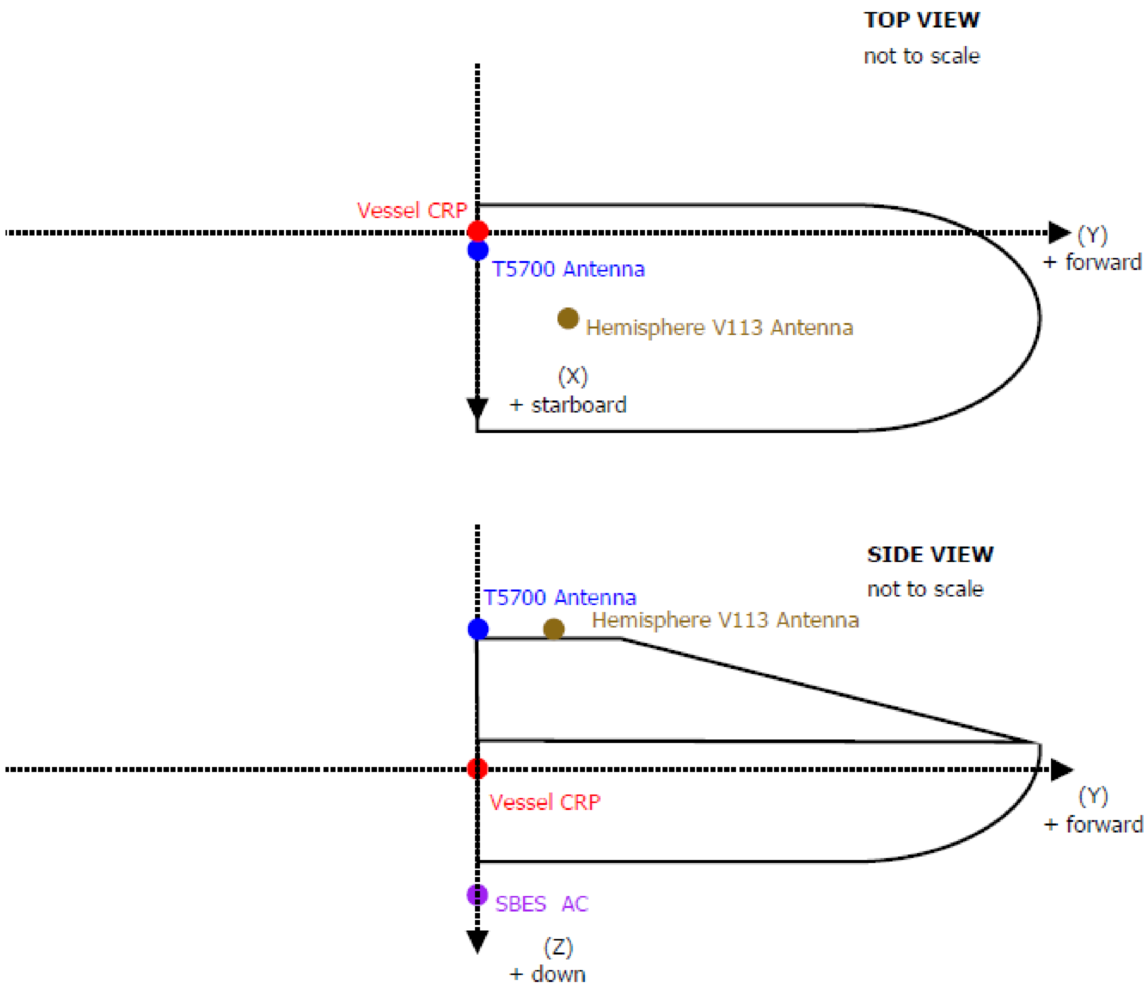



***Figure 16 – ASV-CT3 vessel survey showing relative positions of installed survey equipment.***

| Equipment | X (m) (+ stbd) | Y (m) (+ fwd) | Z (m) (+ down) | Comments |
|---|---|---|---|---|
| CRP | 0.000 | 0.000 | 0.000 | Starboard-top-aft-corner of SBES mount bracket |
| T5700 (Zephyr) ARP | 0.155 | 0.000 | -0.778 | Final position & heave |
| SBES Acoustic Center (AC) | -0.025 | 0.000 | 0.555 | Z determined by bar check |
| Hemisphere V113 | 0.420 | 0.125 | -0.778 | |
| Draft Measure-down Point | 0.000 | 0.000 | 0.000 | Draft measured directly from CRP |

***Table 24 – ASV-CT3 offset measurements relative to CRP.***


***Figure 17 – ASV-CT3 primary sensors.***

## *C.2. Attitude and Positioning*

As described in previous sections of this report, positioning, heave, roll, pitch, and heading (gyro) data were measured on the *Q105* with an Applanix POSMV 320 V5 system. The system was configured to output attitude and position for the top-center of the system's IMU. On the *Q105*, the POSMV output to QINSy as a UDP network stream. During survey operations, raw POSMV data was continually recorded to a POS file, which was post-processed to improve position and attitude accuracy, and used to apply TrueHeave data.

On the *Q105*, a GAMS (GPS azimuth measurement subsystem) calibration was done per POSMV manufacturer recommendations to ensure correct heading output. No additional GAMS calibrations were necessary. The results are shown in Table 25.

| Vessel | Date (JD) | A-B Antenna Separation (m) | Baseline Vector (m) | | |
|---|---|---|---|---|---|
| | | | X (+ stbd) | Y (+ fwd) | Z (+ down) |
| *Q105* | 2015-178 | 2.001 | 2.000 | 0.012 | -0.046 |

***Table 25 – POSMV GAMS calibration results.***

On the *ASV-CT3*, a Hemisphere V113 GPS Compass was used to provide heading, motion, and navigation for real-time positioning. The Hemisphere was configured to output GGA (GPS position), ZDA (time synchronization), HDT (heading), and TSS (motion) messages as standard NMEA strings via RS-232 serial cable to HYPACK. A Trimble 5700 (T5700) logged raw data to a compact flash data card at 10 Hz, enabling post-processing of the positions and extraction of heave records in processing. Note that in processing, T5700 PPK navigation and heave data replaced Hemisphere V113 real-time navigation and heave data with few exceptions as described earlier in this report.

On the *ASV-CT3*, pitch and roll data were logged but not applied to the final soundings. Pitch and roll corrections are not required for single beam by the HSSD, and application of the logged pitch and roll data was found to be of no benefit to the final soundings.

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 which aligns the vessel reference frame (vessel survey) and the motion sensor reference frame.

With the correction applied to the bar check data, agreement was improved to better than 0.033 m on average. Agreement with the single beam data acquired on the *ASV-CT3* was also excellent, with the two sets agreeing within 0.012 m on average.

## *C.3. Calibration / Patch Tests*

Patch tests were conducted on the *Q105* to establish latency, pitch, roll, and yaw alignment values between the POSMV and the multibeam system.

An initial patch test was completed over a bottom feature on JD180, soon after beginning operations on-site. Confidence in the values obtained from the initial patch test was low due to the subtle nature of the feature. Once a distinct feature was found, a second patch was performed on JD189, and the values obtained pre-dated to cover earlier survey data.

A third and final patch test was conducted near the end of the project on JD208 over the same distinct feature. The results differed slightly from the prior (JD189) patch test, which indicated a change in POSMV-MBES alignment at some point between the two patch tests. After a review of the data set it was determined that the alignment changed for unknown reasons on JD195. Therefore, results of the third patch test were pre-dated to JD195, which improved subsequent data agreement substantially.

On the single beam vessel *ASV-CT3*, a calibration was performed to determine latency between the navigation systems and the Odom echosounders. Pitch offset, if any, was also determined during this calibration, which took place over a steep slope at varying speeds.

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, and Roll*

The *ASV-CT3*, which was outfit with a single beam system, received latency and pitch checks only. The *Q105*, which was outfit with a multibeam system, received full patch tests for all sensors. This was done because it was not possible to discern roll or yaw corrections for the single beam system.

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 matchup was determined and entered into the HVF.

Note that for the *Q105* the timing correction (if any) was entered into the HVF for the Swath1 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, therefore, affects all output data. The sign of the value found also needed to be reversed since the correction was being added to the Swath1 sonar times instead of the navigation sensor.

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 which best compensated for the pitch misalignment was entered into the HVF. Note as described previously in this report, a pitch error of 3.3° was identified via bar checks in the *Q105* data, and was corrected for 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 matchup was determined and entered into the HVF.

Roll offset was also determined on the *Q105*. 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 improved matchup was determined and entered into the HVF.

Note as described previously, pitch and roll was logged but not applied for the *ASV-CT3*.

Refer to Section B of this report for uncertainties associated with patch test results. Table 26 summarizes the results.

| Vessel | Patch Test Date | Valid Start Date in HVF | Latency (seconds) | Pitch | Yaw | Roll |
|---|---|---|---|---|---|---|
| *Q105* | 2015-180 | N/A, results not used, low confidence in results due to subtle bottom feature | | | | |
| | 2015-189 | 2015-178 | 0.000 | -1.870° | 1.400° | -0.390° |
| | 2015-208 | 2015-195 | 0.000 | -1.570° | 1.120° | -0.480° |
| *ASV-CT3* | 2015-208 | 2015-197 | 0.000 | N/A | | |

***Table 26 – Calibration test results.***

### *C.4. Speed of Sound Corrections*

A Valeport sensor on a RapidCAST system was used to acquire the majority of sound speed profiles for data corrections. An AML MinosX with SV- and P-Xchange sensors was used briefly (JD182 through JD189) when the Valeport sensor in use failed. All profilers were factory calibrated prior to commencement of survey operations.

Profiles were collected by acquisition normally in sets of 2-3 casts along a line, with two hours between sets. They were processed in TerraSond's TerraLog software, which produced 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 by both time and distance.

Sound speed corrections were applied in processing to the raw sounding data through CARIS HIPS "Sound Velocity Correction" utility. The correction method selected was nearest in distance within two hours for multibeam, and four hours for single beam. Exceptions are rare and noted in the applicable DR.

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 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.

### *C.5. Static Draft*

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

On the *Q105*, with the vessel at rest, a calibrated "measure-down" pole was used to measure the distance from the waterline to a measure-down point on the vessel gunwale. The measurement was taken on both sides of the vessel and averaged. The relationship between the measure-down point and vessel CRP had been previously determined by a vessel survey, allowing computation of the CRP to waterline offset.

The *Q105* also utilized an ultrasonic measure-down system, TerraSonic. This featured sensors which continually ranged from a known point to the waterline. However, TerraSonic data was used only for QC and was not used to derive waterline correctors.

On the *ASV-CT3*, draft measurements were made by reading draft markings that related the vessel CRP to the water level.

Draft values were checked to ensure they fell within the normal range for the survey vessel, logged with current time, and entered into the HVF by processing (included with the survey deliverables) for application to soundings.

The HVF for each vessel was updated with a new waterline value prior to sound speed correction. On the *Q105*, port and starboard measure-downs recorded in TerraLog were averaged and reduced to the vessel's reference point using the surveyed vessel offsets to determine the CRP to waterline offset. On the *ASV-CT3*, the measurement was taken directly from the CRP to the waterline with no averaging necessary. This value was entered as a new waterline value in each vessel's HVF and checked to confirm the values fell within the normal range for the vessel. Values were pre-dated in the HVF on rare occasions when necessary to cover a known change that was not possible to measure at the time.

Refer to Section B for uncertainties associated with static draft measurements. 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 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 engine RPMs and vessel speeds experienced while surveying.

#### *C.6.1. Squat Settlement Test Procedure*

During the squat settlement test, the vessel logged raw POSMV attitude and positioning data to POS file (*Q105*), or raw positioning data from the T5700 (*ASV-CT3*), while the nearby shore base station (Lopp Lagoon) logged dual-frequency GPS data at 1 Hz. A survey line was run in each direction, at incrementing engine RPM/speed. Between each line set, as well as at the start and end of the test, a "static" was collected whereby the vessel would sit with engines in idle and log for a minimum of two minutes. The survey crew would note the time and speed of each event.

The POS (or T5700) file was post-processed concurrent with the nearby base station data in Applanix POSPac software to produce the PPK 3D positioning data, which was brought into Excel. Using the event notes, the positioning data was separated and grouped according to RPM/speed range, or static. Each range was averaged to remove heave and motion. A polynomial equation was computed which best fit the static periods, 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.

Dynamic draft corrections on the *Q105* were engine RPM-based. Speed-based corrections were not used. As described in Section A of this report, a TerraTach system was used to continuously compute, time tag, and log engine RPM data at 1 Hz with a resolution of 1 RPM on this vessel. In processing, the 100-RPM resolution dynamic draft results were interpolated at one RPM to match the resolution of the TerraTach system (1 RPM). An in-house VB.NET utility was written that averaged port and starboard readings and then paired each RPM value logged with the corresponding settlement value determined by squat settlement test. Rare instances of missing RPM data from the TerraTach files were interpolated by using RPM data logged concurrent with line events in TerraLog. A draft correction file consisting of time and settlement value was then loaded into all lines using CARIS HIPS “Load Delta Draft” function.

Note when delta draft is loaded in this fashion, CARIS ignores the speed-based values present in the HVF. Therefore, the speed-based values in the HVF, which were determined via squat-settlement tests in 2013, were utilized only for preliminary, field corrections and not applied to the final data.

On the *ASV-CT3*, dynamic draft corrections were speed-based. A speed-settlement curve was entered into the *ASV-CT3* HVF. Unlike the other vessels, “Load Delta Draft” was not applicable to *ASV-CT3* data since corrections were speed-based.

### *C.6.2. Q105 Dynamic Draft Results*

A squat settlement test was completed on the *Q105* on JD190. RPM values between 700 and 1200 were tested, at 100-RPM increments. This range encompassed the RPM settings used during survey operations. A squat settlement test was also completed on this vessel in 2013 and 2014, and yielded similar results. However, 2015 data points for 700 and 1200 RPMs appeared to be outliers compared to the prior years' tests and were rejected, using the prior values instead, as shown in Figure 18.

| RPM | Dynamic Draft (m) (positive down) | Comments |
|---|---|---|
| 700 | 0.014 | Rejected 2015 result of 0.038, used the average of 2014 and 2013 results |
| 800 | 0.016 | |
| 900 | 0.025 | |
| 1000 | 0.055 | |
| 1100 | 0.060 | |
| 1200 | 0.063 | Rejected 2015 result of 0.100 m, used 2014 result |

***Table 27 – Q105 settlement results.***

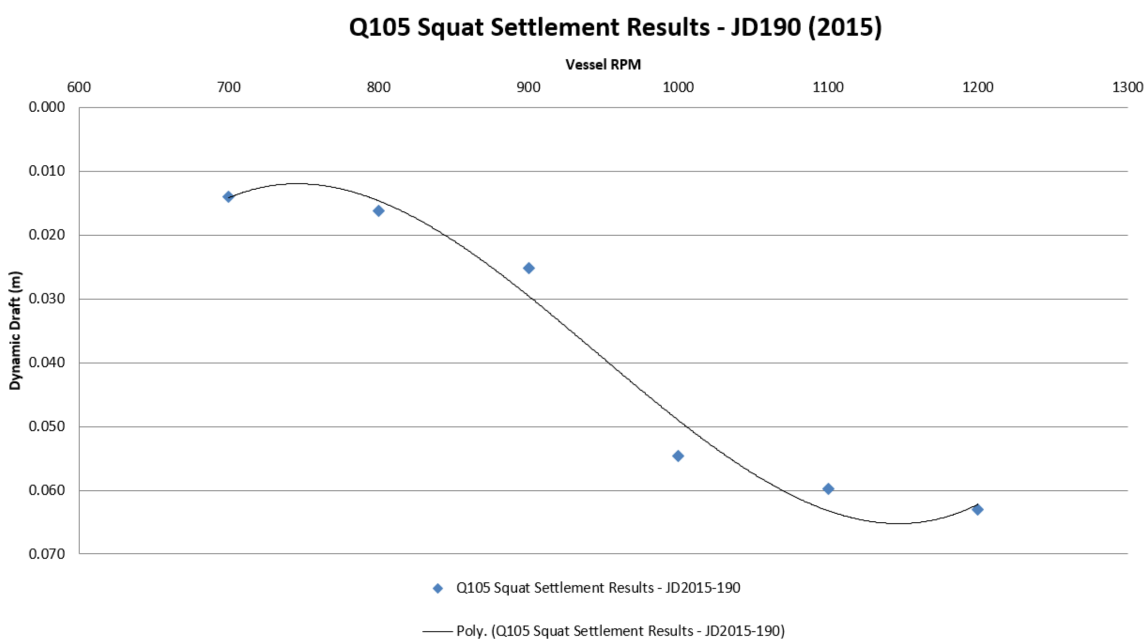



***Figure 18 – Q105 settlement results. Vertical units are meters, positive down.***

### *C.6.3. ASV-CT3 Dynamic Draft Results*

A squat settlement test was completed on the *ASV-CT3* on JD203. RPM values between 4100 and 4850 were tested, at 200-250 RPM increments. Speed was extracted from the RPM runs so that final values would be speed-based. Final values were smoothed using a 3rd order polynomial. This RPM and speed range encompassed the RPM and speed used during survey operations.

| Speed (knots) | Dynamic Draft (m) (positive down) |
|---|---|
| 4 | 0.050 |
| 5 | 0.127 |
| 6 | 0.162 |
| 7 | 0.153 |
| 8 | 0.100 |

***Table 28 – ASV-CT3 settlement results.***

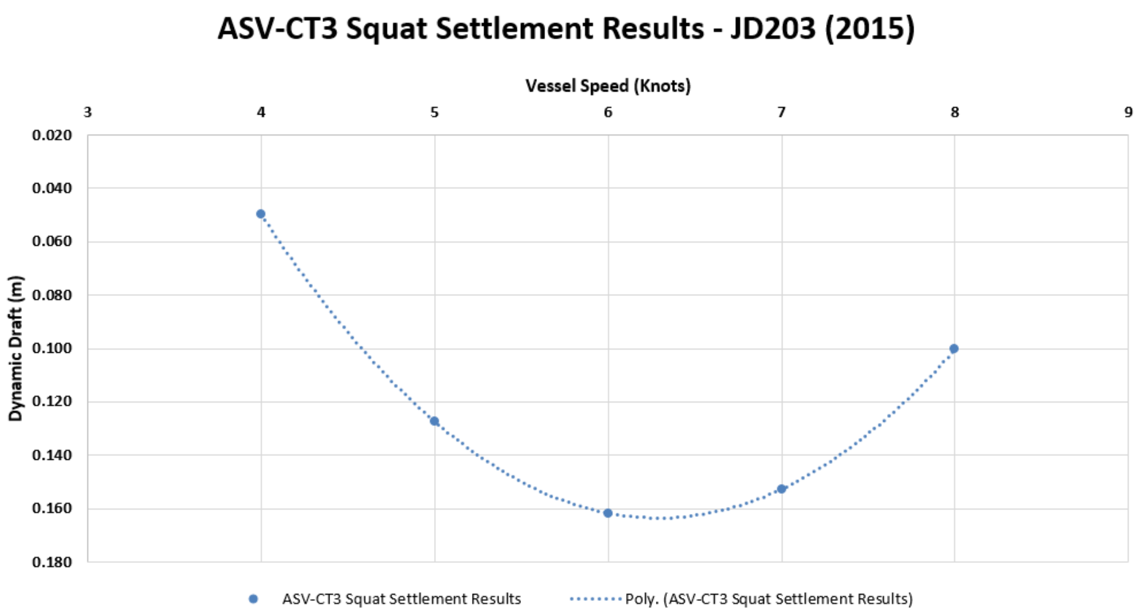



***Figure 19 – ASV-CT3 settlement results. Vertical units are meters, positive down.***

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

Traditional (discrete) tide zones were applied to the entire project to bring soundings to MLLW. One subordinate tide station (Outside Lopp Lagoon, station ID 946-9515) was installed to provide tide corrections. The NWLON station at Red Dog Dock (station ID 949-1094) served as long-term datum control. Three temporary BMPG submersible gauges were deployed across the survey area to provide phase and range offsets based on the subordinate tide station. Data from all gauges were used to derive a ZDF, which contained time and range correctors by area across the survey area, as well as estimated gauge and zoning errors. The ZDF and accompanying tide file from the subordinate station are available with the CARIS deliverables.

Refer to the project HVCR for more details regarding tidal corrections and derivation of tide zones.

# APPROVAL SHEET

# For

# H12751 through H12754

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 with 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.

Signature Not Verified

Andrew Orthmann

Digitally signed by Andrew Orthmann
DN: cn=Andrew Orthmann, o=TerraSond Limited, c=US
Date: 2015.11.20 13:14:44 -09'00'
Reason: I am approving this document
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