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-R315-KR-14

Time Frame May – September 2014

LOCALITY

State ALASKA

General Locality Bechevin Bay

Sub Locality Bechevin Bay and Approaches; Isanotski Strait

2014

CHIEF OF PARTY

ANDREW ORTHMANN

LIBRARY & ARCHIVES

DATE

☆U.S. GOV. PRINTING OFFICE: 1985—566-054

NOAA FORM 77-28 (11-72) U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION	REGISTER NO.
HYDROGRAPHIC TITLE SHEET	**H12630, H12631, H12632**
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 Bechevin Bay

Locality Bechevin Bay and Approaches; Isanotski Strait

Scale 1:40,000 Date of Survey June 2 to August 15, 2014

Instructions Dated January 8, 2014 Project No. OPR-R315-KR-14

Vessel *Qualifier 105, Cutwater, Spare RHIB*

Chief of party Andrew Orthmann

Surveyed by TerraSond Personnel (A. Orthmann, G. Byrd, J. Theis, L. Scheurer, M. Krynytzky, S. Shaw, S. Udy, T. Morino, 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. DG133C-08-CQ-0005

All times are recorded in UTC

Hydrographic Survey:

TerraSond Limited
1617 South Industrial Way, Suite 3
Palmer, AK 99645

Tide Support:

JOA Surveys, LLC
2000 E. Dowling Rd., Suite 10
Anchorage, AK 99503

Data Acquisition and Processing Report

OPR-R315-KR-14

December 22nd, 2014

Research Vessels Cutwater and Qualifier 105 in Bechevin Bay, Alaska

Vessels: ***Qualifier 105, Cutwater, and Spare RHIB***

General Locality: ***Bechevin Bay, Alaska***

Sub Locality: ***H12630 – Approaches to Bechevin Bay***
H12631 – Bechevin Bay
H12632 – Isanotski Strait

Lead Hydrographer: ***Andrew Orthmann***

TABLE OF CONTENTS

A. Equipment 1
A.1. Echosounder Systems 1
A.1.1. Side Scan Sonar 1
A.1.2. Multibeam Echosounder 1
A.1.3. Single Beam Echosounder 2
A.2. Vessels 3
A.2.1. R/V Qualifier 105 4
A.2.2. R/V Cutwater 6
A.2.3. Spare RHIB 8
A.3. Speed of Sound 9
A.3.1. Sound Speed Sensors 10
A.3.2. Sound Speed Sensor Technical Specifications 10
A.4. Positioning and Attitude Systems 11
A.4.1. Q105 and Cutwater 11
A.4.2. Spare RHIB 12
A.4.3. Position and Attitude System Technical Specifications 13
A.5. Dynamic Draft Corrections 14
A.6. GPS Base Stations 14
A.6.1. Base Station Equipment Technical Specifications 17
A.7. Tide Gauges 18
A.7.1. Subordinate Stations 18
A.7.2. Bottom Mounted Pressure Gauges 18
A.7.3. Tide Gauge Technical Specifications 19
A.8. Software Used 20
A.8.1. Acquisition Software 20
A.8.2. Processing and Reporting Software 21
A.9. Bottom Samples 22
A.10. Shoreline Verification 22
B. Quality Control 23
B.1. Overview 23
B.2. Data Collection 23
B.2.1. QPS QINSy 23
B.2.2. HYPACK 24
B.2.3. Draft Measurements 24
B.2.4. Sound Speed Measurements 25
B.2.5. Logsheets 26
B.2.6. Base Station Deployment 28

B.2.7. File Naming and Initial File Handling 29
B.3. Bathymetric (MBES & SBES) Data Processing 31
B.3.1. Conversion into CARIS HIPS and Waterline Offset 31
B.3.2. Load Delayed Heave 32
B.3.3. Spare RHIB Heave Corrections 32
B.3.4. Sound Speed Corrections 33
B.3.5. Total Propagated Uncertainty 34
B.3.6. Post-Processed Kinematic GPS 37
B.3.7. Load Attitude / Navigation Data 39
B.3.8. Load Tide, Compute GPS Tide, and Merge 39
B.3.9. Navigation and Attitude Sensor Checks & Smoothing 39
B.3.10. Multibeam Swath Filtering 40
B.3.11. Multibeam Editing 40
B.3.12. Single Beam Editing 41
B.3.13. Dynamic Draft Corrections 42
B.3.14. Final BASE Surfaces and Feature Files 43
B.3.15. Crossline Analysis 43
B.3.16. Bathymetric Processing Flow Diagram 45
B.4. Confidence Checks 46
B.4.1. Bar Checks 46
B.4.2. Lead Lines 47
B.4.3. Echosounder Comparison (Multi-Vessel) 48
B.4.4. SVP Comparison 48
B.4.5. Base Station Position Checks 49
B.4.6. Vessel Positioning Confidence Checks – Alternate Base Station 50
B.4.7. Vessel Positioning Confidence Checks – Independent GPS 51
B.4.8. Tide Station Staff Shots and Operation 52
C. Corrections to Echo Soundings 52
C.1. Vessel Offsets 52
C.1.1. Q105 Vessel Offsets 54
C.1.2. Cutwater Vessel Offsets 56
C.1.3. Spare RHIB Vessel Offsets 58
C.2. Attitude and Positioning 59
C.2.1. Q105 Pitch Error Adjustment 60
C.3. Calibration / Patch Tests 60
C.3.1. Latency, Pitch, and Roll 61
C.4. Speed of Sound Corrections 62
C.5. Static Draft 62

C.6. Dynamic Draft Corrections 63
C.6.1. Squat Settlement Test Procedure 63
C.6.2. R/V Q105 Dynamic Draft Results 65
C.6.3. Cutwater Dynamic Draft Results 66
C.6.4. Spare RHIB Dynamic Draft Results 67
C.7. Tide Correctors and Project Wide Tide Correction Methodology 68
APPROVAL SHEET 69

A. *Equipment*

A.1. Echosounder Systems

To collect sounding data, this project utilized a Reson Seabat 7101 Multibeam Echosounder (MBES) and Odom Echotrac CV100 Single Beam Echosounders (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 multibeam system was used on this survey. The system was installed on the *R/V Qualifier 105*.

The Reson SeaBat 7101 is a digital 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 QPS QINSy acquisition software, which logged .DB (database format) files. The system was also configured to output backscatter (multibeam "snippet") data, which was logged, but not processed. Prior to processing, .DB files were exported to .XTF (extended Triton format).

Echosounder accuracy was checked by bar check methods on two separate occasions (JD197 and JD214), with processed results comparing on average to 0.03 m (or better) of the actual bar depth. Four comparison lead lines were also taken (JD197, JD202, two on JD214), with agreement varying from 0.01 m to 0.12 m, results that were deemed acceptable given the conditions and variables surrounding lead line collection.

Additionally, the 7101 multibeam data was examined where it overlapped with single beam data collected by the single beam vessels. The two data sets demonstrate good agreement, with the single beam data on average 0.058 m shoaler, with a standard deviation of 0.252 m. However, discrepancies of up to 2 m exist where multibeam data overlaps single beam in areas undergoing bottom change, which were common in this survey.

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 Wet End 8101.1.08.C215
Sonar Operating Frequency	240 kHz
Along Track Transmit Beamwidth	1.6° ± 0.3°
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

Two Odom Echotrac CV100 systems were used on this survey. One was installed aboard the *R/V Cutwater*, while the other was installed aboard the skiff *Spare RHIB*.

The Odom Echotrac CV100 is a digital imaging single beam echosounder (SBES), which utilizes Odom eChart software to serve as the user interface. The CV100 used on the *R/V Cutwater* was interfaced with an Odom/Airmar SMB200-3 transducer, which generates a 3 degree beam at 200 kHz. The CV100 used on the skiff *Spare RHIB* was interfaced to an Odom/Airmar SMSW200-4A transducer, which generates a 4 degree beam at 200 kHz.

Power, gain, depth filters and other user-selectable settings were adjusted, as necessary, through eChart to monitor data quality. Each vessel's system was configured to output the bathymetric data via Ethernet network connection to acquisition software (HYPACK on the *R/V Cutwater*, QPS QINSy on the skiff *Spare RHIB*) running on a Windows 7 PC, which logged the data to file.

Odom CV100s are all-digital units that do not create a paper record of bottom track quality information. Instead, this information was logged to file, consisting of .BIN files from the HYPACK system on the *R/V Cutwater*, and .DSO files logged in eChart on the skiff *Spare RHIB*.

Echosounder accuracy was checked by bar check methods on three occasions on the *R/V Cutwater* (JD121, JD153, and JD227), with processed echosounder results comparing on average to 0.024 m (or better) of the actual bar depth. One bar check was completed on the skiff *Spare RHIB* (JD223), with processed echosounder results comparing on average to 0.006 m of the actual bar depth.

Lead line checks were also undertaken. These were accomplished on the *R/V Cutwater* on JD153 and JD160, and compared to 0.16 m (or better) of the actual depth. One lead line check was accomplished on the skiff Spare RHIB on JD223, comparing to 0.060 m of the actual depth. Other lead line checks were completed, but results were discarded as outliers due to poor check conditions usually involving the high amount of current experienced in this area.

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 the single beam data on average 0.058 m shoaler, with a standard deviation of 0.252 m. However, discrepancies of up to 2 m exist where multibeam data overlaps single beam in areas undergoing bottom change, which were common in this survey.

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*), *R/V Cutwater (Cutwater),* and a skiff *(Spare RHIB).* The *Q105* acquired all multibeam data, while the *Cutwater* acquired the majority of the single beam data. The *Spare RHIB* acquired a small amount of single beam data and performed shoreline verification.

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 provided fuel and support for the *Cutwater*, collected bottom samples, deployed Seabird tide gauges, and deployed/recovered the *Spare RHIB* as necessary.

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) at Red Dog Mine, 2013.

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 top of 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 Underway SV system was installed on the port stern to collect sound speed profiles. A Trimble 5700 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. Detailed vessel drawings showing the location of all primary survey equipment are included in Section C of this report.

The survey equipment on the *Q105* performed within normal parameters with no major issues encountered.

***Q105* Survey Equipment**

Description	Manufacturer	Model / Part	Serial Number(s)
Multibeam Echosounder	Teledyne Reson	7101 7-P-1 Sonar Processor PC Unit	3507006 18290413019
Surface Sound Speed	AML Oceanographic	MICRO-X with SV-XChange Sensor	203266 10276
Position, Motion, Heading	Applanix	POSMV 320 V5 IMU-200 AeroAntenna GNSS Antennas (x2)	PCS: 5849 IMU: 783 GNSS Ant1: 8521 GNSS Ant2: 8526
Check GPS	Trimble	5700 Zephyr Antenna	Receiver: 220320056 GPS Ant: 60124992
Sound Speed (Profiler)	Teledyne Oceanscience	Underway SV 400	n/a
Sound Speed (Probe)	Valeport	Rapid SVT 200Bar	44474
Check Sound Speed	AML Oceanographic	SV Plus v2	3279
Check Sound Speed	Teledyne Odom	Digibar Pro	98427
RTK Signal Receiver	Pacific Crest	ADLP-2	12503778

Table 3 – Major survey equipment used aboard the R/V Q105.

A.2.2. R/V Cutwater

The *Cutwater,* also owned and operated by Support Vessels of Alaska (SVA), was chartered as the primary single beam collection platform. The *Cutwater* was operated on a 12-hour/day schedule and collected the majority of the project single beam data. It was also utilized for bottom sampling and Seabird tide gauge deployments.

The *Cutwater* is a 12.2 m aluminum hull vessel with a 4.3 m beam and a 1.1 m draft. The vessel is propelled by dual outdrives powered by two Cummins diesel engines. AC electrical power was provided alternatively by a 2500 watt AC inverter and a Honda EU2000 generator.

Figure 2 – R/V Cutwater in False Pass Boat Harbor, 2014.

For this survey, the *Cutwater* was outfit with a pole-mounted single beam transducer on its starboard side, just aft of the main cabin. An Applanix POSMV 320 V5 provided attitude and positioning, with the IMU co-located with the transducer on the transducer pole. The POSMV GNSS antennas were mounted on the port side of the antenna bar above the main cabin. A Trimble 5700 GPS system was also installed for independent positioning checks. Sound speed casts were collected with a hand-deployed AML SV+ or Odom Digibar Pro. Calibrations and quality control checks were performed on all installed systems as described in Section B of this report. Detailed vessel drawings showing the location of all primary survey equipment are included in Section C of this report.

The survey equipment on the *Cutwater* performed within normal parameters with no major issues encountered.

Cutwater Survey Equipment

Description	Manufacturer	Model / Part	Serial Number
Single Beam Echosounder	Teledyne Odom	Echotrac CV100	3505
Single Beam Transducer	Airmar/Odom	SMB200-3	TR8416
Position, Motion, Heading	Applanix	POSMV 320 V5 IMU-200 AeroAntenna GNSS Antennas (x2)	PCS: 5849 IMU: 783 GNSS Ant1: 8521 GNSS Ant2: 8526
Check GPS	Trimble	5700 Zephyr Antenna	Receiver: 220320002 GPS Ant: 12368889
Sound Speed Probe	AML Oceanographic	SV Plus v2	3279
Check / Backup Sound Speed Probe	Teledyne Odom	Digibar Pro	98427
RTK Signal Receiver	Pacific Crest	ADLP-2	12503778

Table 1 – Major survey equipment used aboard the R/V Cutwater.

A.2.3. Spare RHIB

The skiff *Spare RHIB*, which is owned and operated by TerraSond, was utilized primarily for shoreline verification, but also collected single beam data in extremely shallow areas that were inaccessible to the other survey vessels. The vessel was deployed from the *Q105* when environmental conditions were favorable.

The *Spare RHIB* is a fiberglass Rigid Haul Inflatable Vessel (RHIB) manufactured by Zodiac. It is 6.4 m in length with a 2.4 m beam and a 0.5 m draft. The vessel is propelled by dual 60-HP Yamaha engines. To power survey equipment, 12V DC was tapped from vessel charging system.

Figure 3 – Spare RHIB in Bechevin Bay, 2014.

For this survey, the *Spare RHIB* 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. Antennas for both GPS systems were mounted mid-ship on an antenna bar above the control console. Sound speed casts were collected with a hand-deployed AML SV+ or Odom Digibar Pro. An Odom Echotrac CV100 was used for single beam data collection, with the transducer haul-mounted in a fluid-filled compartment above an acoustically transparent ABS-plastic plate starboard of the keel under the control console. Calibrations and quality control checks were performed on all installed systems as described in Section B of this report. Detailed vessel drawings showing the location of all primary survey equipment are included in Section C of this report.

The survey equipment on the *Spare RHIB* performed within normal parameters with no major issues encountered.

***Spare RHIB* Survey Equipment**

Description	Manufacturer	Model / Part	Serial Number
Single Beam Echosounder	Teledyne Odom	Echotrac CV100	3504
Single Beam Transducer	Airmar	SMSW200-4A	TR8537
Heading, Pitch, Roll, Backup Position & Heading	Hemisphere	Vector V113	A1218-V113H-0002
Primary GPS & Heave (PPK)	Trimble	5700 Zephyr Antenna	Receiver: 220320056 GPS Ant: 60124992
Sound Speed Probe	Teledyne Odom	Digibar Pro	98427
Check / Backup Sound Speed Probe	AML Oceanographic	SV Plus v2	3279

Table 2 – Major survey equipment used aboard the Spare RHIB.

A.3. Speed of Sound

For speed of sound corrections for multibeam data, an Oceanscience Underway SV system – equipped with a Valeport RapidSVT sensor – was utilized aboard the *Q105*. Profiles were collected as deep as possible while underway, generally reaching 95% of the water depth.

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.

For single beam data collection on the *Cutwater* and *Spare RHIB*, hand-deployed Odom Digibar Pro and AML SV+ sensors were used. Profiles were acquired as deep as possible, normally extending to the seafloor.

Sound speed casts were collected on an interval of 3 hours during MBES operations and 6-12 hours during SBES operations. The intervals were determined in the field by examining sound speed variance and deemed sufficient to minimize error due to sound speed while also limiting the required volume of profiles. New profiles were also collected when transiting significant distance to change survey areas.

Sound speed profiles were applied by nearest in distance within 3 hours for multibeam and nearest in distance within 12 hours for single beam. Any exceptions are described in the applicable Descriptive Report (DR).

Confidence checks on sound speed profilers were accomplished by comparing the results obtained by the probes to each other, normally on a weekly basis during survey operations. A total of nine sound speed confidence checks were accomplished on this project (JD160, JD168, JD177, JD182, JD189, JD197, JD202, JD212 and JD227). Results (available in the DRs *Separate II*) were typically very good (comparing to 0.5 m/s or better), especially when it was possible to collect the profiles simultaneously.

The AML Micro-XChange sensor used on the Reson 7101 MBES head was also compared for accuracy against the recently calibrated Odom Digibar Pro on JD197. Results were good, with both instruments reading within 0.1 m/s of each other.

Sound speed profiles were found to vary widely on this survey, ranging from highly stratified on the Bering Sea side to well-mixed in Bechevin Bay and Isanotski Strait.

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 3 – 7 were used to collect sound speed data on this project.

A.3.1. Sound Speed Sensors

Sound Speed Device	Manufacturer	Serial Numbers	Calibration Date
AML MICRO-X with SV-XChange Sensor	AML Oceanographic	203266 (Sensor) 10276 (Probe)	4/21/2013
Valeport Rapid SVT	Valeport Limited	44474	11/19/2013*
AML SV Plus (+) v2	AML Oceanographic	3279	4/4/2014
Odom Digibar Pro	Teledyne Odom Hydrographic Inc.	98427 (Display) 032114 (Probe)	3/21/2014
* Valeport calibration date is outside of the 6-month requirement for SV calibrations required in the HSSD. The probe was new at the time of calibration and permission was obtained from the NOAA COR to use the probe despite the outdated calibration. The probe was also compared regularly to the recently calibrated probes and returned good results. Correspondence is included with the project DRs.			

Table 3 – 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 4 – AML Oceanographic SV-XChange specifications.

Valeport Rapid SVT (200Bar)	
SV Range	1375 – 1900m/s
SV Accuracy	±0.02m/s
SV Resolution	0.001m/s
Pressure Range	10, 50, 100, 200
Pressure Accuracy	±0.05% range
Pressure Resolution	0.001% range

Table 5 – Valeport Rapid SVT specifications.

Applied Microsystems SV Plus v2	
SV Precision	0.03 m/s
SV Accuracy	0.05 m/s
SV Resolution	0.015 m/s
Pressure Precision	0.03 % of full scale
Pressure Accuracy	0.05 % of full scale
Pressure Resolution	0.005 % of full scale

Table 6 – AML SV Plus v2 specifications.

Odom Digibar Pro	
SV Accuracy	0.3 m/s
SV Resolution	0.1 m/s
Depth Sensor Accuracy	0.31 m

Table 7 – Odom Digibar Pro specifications.

A.4. Positioning and Attitude Systems

A.4.1. Q105 and Cutwater

An Applanix POSMV 320 V5 system served as the primary source of vessel positioning, motion, and heading aboard both the *Q105* and *Cutwater*. Note that the same POSMV 320 V5 system was interchanged between the *Cutwater* and *Q105* since both vessels did not acquire data at the same time.

The POSMV system consists of two dual-frequency GNSS antennas and an inertial measurement unit (IMU) coupled to a topside processor. For real-time GPS position corrections, the POSMV was interfaced with a Pacific Crest ADL radio, which received Real-Time Kinematic (RTK) corrections transmitted from the project base stations established by the survey crew. The POSMV was also configured to automatically utilize its internal WAAS (wide-area augmentation system) receiver when RTK corrections were unavailable. It is important to note however that all real-time corrections, whether RTK or WAAS, were replaced in processing by application of post-processed kinematic (PPK) corrections to the dataset.

Additionally, the POSMV was configured to record all raw data to .POS files over Ethernet, which were logged continuously during survey operations. As a backup, the unit also logged all raw data to .000 files directly to USB drives. These raw files enabled post-processing of the GPS and inertial data in Applanix POSPac MMS software in conjunction with simultaneous raw base station GPS to produce higher quality post-processed kinematic (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 on the *Q105* to the Underway SV acquisition software (for sound speed profile time-tagging and positioning).

For positioning confidence checks a Trimble 5700 (T5700) with a Trimble Zephyr antenna was used. During survey operations, the T5700 was set to continuously log dual-frequency GPS data to a compact flash card at 10 Hz. The T5700 and POSMV positions were simultaneously displayed in the acquisition software to continuously ensure the independent systems were producing results free of gross error. Daily screenshots of the comparison were taken, and are available in each DR *Separate I*.

A.4.2. Spare RHIB

The *Spare RHIB* 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.

Positioning confidence checks are available in *Separate I* of the DRs.

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) Vertical: +/- (15 mm + 1 ppm x baseline length)
	Roll, Pitch Accuracy	0.01 degrees (1 sigma)
Heave Accuracy		Realtime Heave: 5 cm or 5% TrueHeave: 2 cm or 2% (whichever is greater) for periods of 20 seconds or less
Heading Accuracy		0.02 degrees (1 sigma, 2 m baseline)
Velocity Accuracy		0.03 m/s horizontal

Table 8 – 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 9 – 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 10 – 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 all 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.

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 precise 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.

On the *Cutwater,* RPM was monitored by the survey crew from the vessel tachometer. Values were manually entered into TerraLog at start of line and for any significant (generally >200 RPM) change for later processing

Due to the high variability of engine throttle settings during skiff operations, RPM data was not logged on the *Spare RHIB.* Speed-based corrections were used instead.

See Section B for processing methodology.

A.6. GPS Base Stations

Two base stations (with three separate, independent GPS receivers) were installed to support survey operations. The stations were located strategically at False Pass and Cape Chunak so that baseline distances to all survey tracklines were within 20 kilometers of a base station.

Both stations utilized Trimble NetRS GPS receivers with Zephyr Geodetic antennas, and Pacific ADL radios for RTK correction transmissions. The receivers were configured to log dual-frequency GPS data to internal flash memory at a rate of 1 Hz and additionally set to broadcast CMR+ (Trimble format) corrections over the ADL radios. Satellite internet connections at both sites enabled access to the station over the internet for QC and data retrieval. A T5700 receiver was also installed at the Cape Chunak site, as a backup to the NetRS receiver, and also configured to log at 1 Hz.

The base station at False Pass was installed in an 8’ covered trailer, which provided weather protection for electronics and a firm mounting structure for exterior components which included the GPS and RTK antennas. Two 12V gel cell batteries interfaced to an AC float charger provided power for the base, a configuration that allowed base station operation to continue in the event of AC power failures. The GPS antenna was firmly mounted above the trailer where it had an unobscured view of the sky.

Figure 4 – False Pass base station trailer.

The base station at Cape Chunak was located in a remote area, necessitating the use of alternative energy systems. At this site a 400 watt wind plant and four 100 watt solar panels provided cumulative 800 watt charging ability. Eight 12V gel cell batteries provided reserve capacity when necessary to power the site for multiple days without solar or wind input. The NetRS and T5700 GPS antennas were tripod-mounted with an unobscured view of the sky.

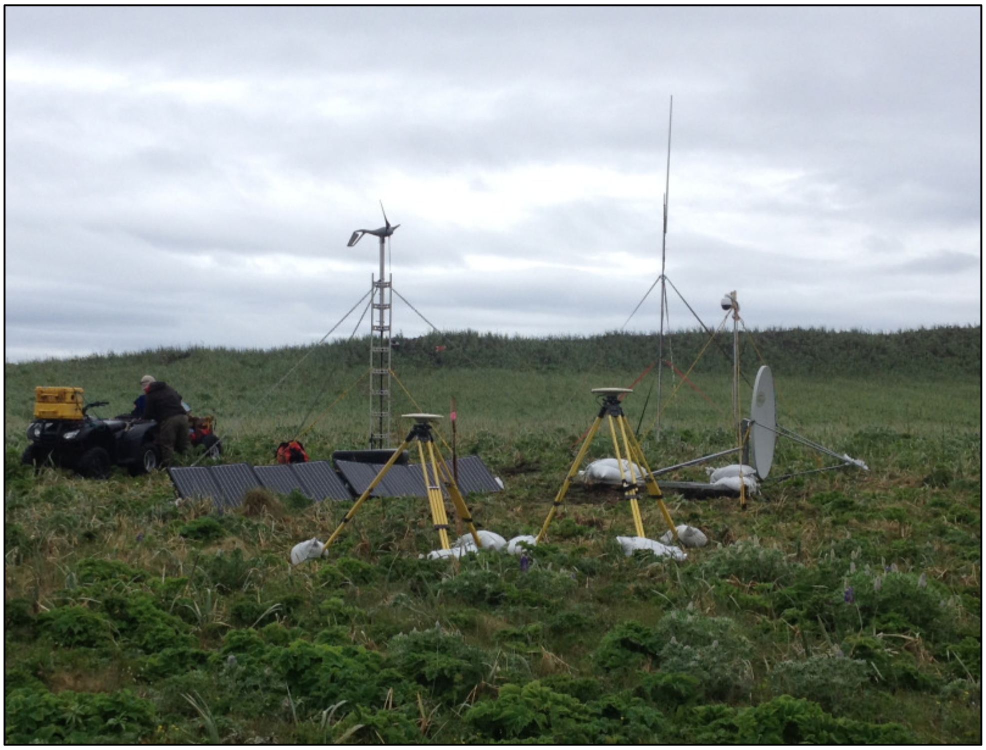


Figure 5 – Cape Chunak base station. NetRS (left) and T5700 (right) GPS antennas in foreground.

Station ID	Site	GPS Receiver	Antenna	Type	Position (NAD83)
FALS	False Pass	Trimble NetRS SN# 444924148	Trimble Zephyr Geodetic (TRM41249) SN# 12469585	Transmit (RTK) Logging (PPK)	54-51-46.11908 N 163-24-46.21984 W
OUTE	Cape Chunak	Trimble NetRS SN# 4412232926	Trimble Zephyr Geodetic (TRM41249) SN# 12682207	Transmit (RTK) Logging (PPK)	55-02-57.27853 N 163-32-14.21492 W
5240	Cape Chunak	Trimble 5700 SN# 0220275240	Trimble Zephyr Geodetic (TRM41249) SN# 60078756	Logging (PPK)	55-02-57.27113 N 163-32-14.12462 W

Table 11 – GPS Base Station Positions and Configurations.

The *Q105* and *Cutwater* received the RTK CMR+ signal via Pacific Crest ADL radios, which provided the correction message to the vessel POSMV, allowing it to compute an RTK solution. Signal reception was highly variable throughout the project area, and signal loss was common. When signal loss occurred, the POSMV automatically defaulted to WAAS corrections.

The *Spare RHIB* was not configured to receive RTK corrections. The Hemisphere V113 on board the *Spare RHIB* utilized WAAS corrections for real-time positioning instead.

However, real-time positions (whether RTK or WAAS) were replaced with PPK positioning following post-processing. Any exceptions are noted in the appropriate DR.

The base station data was downloaded from the NetRS receivers at both base stations via satellite internet link daily in order to post-process the previous day's data. Checks of proper operation of the GPS receivers (including satellite tracking, power levels, and logging status) were also made at this time. A webcam at the Cape Chunak base station enabled a remote visual inspection of the site possible.

The T5700 backup receiver at Cape Chunak was not internet accessible. Therefore, it was downloaded whenever the site was physically visited, normally every 3 weeks.

Confidence checks on the stability of the base station mounts and repeatability of the position solutions were accomplished at least weekly by upload of 24-hour data series to NGS OPUS (Online Positioning User Service), which always returned results comparing to 0.031 m vertically and 0.010 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 Net RS	
Accuracy (Static)	Horizontal 5 mm + 1 ppm RMS Vertical 10 mm + 1 ppm RMS
Output Standard Used	CMR+
Update Rate (both RTK and logging)	1 Hz

Table 12 – Trimble NetRS specifications.

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

Table 13 – Trimble 5700 technical specifications.

A.7. Tide Gauges

A.7.1. Subordinate Stations

Four subordinate tide stations were installed for this project. The stations were installed at Cape Chunak (946-2941), Neumans Cove (946-2948), False Pass (946-2955), and Isanotski Strait (946-2961). JOA Surveys, LLC (JOA) of Anchorage, AK was subcontracted to install, uninstall, and monitor the stations as well as to compute tide datums and tide zones.

A total of eight gauges (six WaterLOG series DAA H350XL bubbler gauges and two Sea-Bird SBE 26plus submerged gauges) were installed at the tide stations. The Neuman's Cove, False Pass, and Isanotski tide stations each used two H350XL bubblers outfit with NOAA GOES radios, enabling daily remote data quality checks. The two Sea-Bird submerged gauges were utilized at Cape Chunak, where the environmental conditions were not conducive to bubbler-style gauges.

All gauges were calibrated prior to the start of survey operations and checked for accuracy following demobilization. In the field, they were installed in pairs for redundancy and as checks on each other. Staff shots were collected regularly at each site to confirm gauge stability.

All tide gauges performed well with no major issues or outages encountered. The tide house at Isanotski Strait tide station was repaired following demolition by bears, but the gauges within were not disconnected or damaged during the attack. The submerged gauges at Cape Chunak experienced minor settling, which was corrected for in tide data processing.

Refer to the Horizontal and Vertical Control Report (HVCR) and accompanying records provided by JOA for more information.

A.7.2. Bottom Mounted Pressure Gauges

Bottom mounted pressure gauges (BMPGs) were deployed offshore in the survey area for tide zoning purposes. For this survey, Sea-Bird SBE 26plus Wave and Tide Recorder submersible tide gauges ("Seabirds") were utilized.

Seven separate deployments were accomplished over the course of the project. Two separate Seabird units were deployed, pulled, and redeployed as necessary. Deployment durations ranged from 3 to 40 days, averaging about 18 days at each site. The deployment locations were strategically chosen to bracket the survey area to provide the data required for computing time and range corrections between the zoning site and the subordinate gauges, and therefore, derivation of final tide zones.

Each Seabird was synced to UTC and set to log at a 6-minute interval using a 180 second averaging period. The Seabird was mounted in a specially fabricated mooring (with approximately 300 lbs. of weight) and gently lowered to the bottom at the deployment location by the *Q105* or *Cutwater*. Following the deployment period, the Seabird was pulled and the logged data was downloaded. Barometric pressure was downloaded from a barometer installed at the Cape Chunak tide station, which provided atmospheric pressure corrections.

Following each deployment and just prior to pulling, a "PPK float" was accomplished. In this process the survey vessel would anchor or wait within 500 m of the deployment location and log GPS data for PPK processing for one hour. The ellipsoid elevation of the waterline in the area of the Seabird derived from this process was later directly compared to the simultaneous data recorded by the Seabird as an additional stability check.

All Seabird tide gauges were factory calibrated prior to the start of the survey season.

Refer to the HVCR for more information regarding the calibration, installation and data processing procedures used for these stations.

A.7.3. Tide Gauge Technical Specifications

WaterLOG H-350XL	
Pressure Sensor Accuracy	0.02% of full scale
Temperature Accuracy	1° C
Pressure Resolution	0.002%
Temperature Resolution	0.002%
Pressure Accuracy 0-15 PSI	0.007 ft
Pressure Accuracy 0-30 PSI	0.014 ft

Table 14 – WaterLOG H-350XL tide gauge specifications.

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

Table 15 – Sea-Bird SBE 26plus specifications.

A.8. Software Used

A.8.1. Acquisition Software

All vessels were outfit with quad-core PCs running Windows 7 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 *Spare RHIB* 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 *Cutwater* 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 *Cutwater* and *Spare RHIB* 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 SV+ sound speed probe.
- 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.*

Program Name	Version	Date	Primary Function
QPS QINSy	8.10 (Build 2014.03.06.1)	2014	Acquisition and navigation software used on the *Q105 and Spare RHIB*.
HYPACK	2014	2014	Acquisition and navigation software used on the *Cutwater*.
Reson 7k Control Center	4.5.10.5	2013	Multibeam interface
Oceanscience RapidSVLog	n/a	n/a	Underway SV interface
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 SV Plus v2
Sea-Bird Seasoft	2.0	2011	Configuration and data download for Sea-Bird SBE26 Plus tide gauges
Applanix POSView	7.41	2013	POSMV configuration, monitoring and logging
TerraLog	2014	2014	Log 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 16 – Software used for data acquisition.

A.8.2. Processing and Reporting Software

Processing and reporting was done on quad-core PCs running 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 post-processed kinematic (PPK) data. Both the MMS and POSGNSS modules were utilized. MMS was used to post-process POSMV data from the *Q105* and *Cutwater*, while POSGNSS was used to post-process T5700 data from the *Spare RHIB*.
- 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	8.1.10	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	2013	2013	Extract heave from PPK data for *Spare RHIB*
Microsoft Infopath	2013	2013	Populate DR XML schemas
Altova XMLSpy	2014	2014	Edit DR XMLs

Table 17 – Software used during processing and reporting.

A.9. Bottom Samples

The *Q105* and *Cutwater* collected bottom samples for this survey.

At planned locations, a Van Veen style 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 spreadsheet logsheet.

The logsheet was later imported by processing into CARIS Notebook software for producing the S-57 deliverable. A table with bottom sample locations is available in each DR, *Appendix V: Supplemental Survey Records and Correspondence*.

A.10. Shoreline Verification

Limited shoreline verification was conducted aboard the *Spare RHIB*. The *Spare RHIB* utilized a Hemisphere V113 GPS Compass for positioning shoreline features, and the V113 heading for projecting the position of features that could not be approached directly. The vessel's Odom CV100 single beam was used for scouting depths and searching for submerged features. QPS QINSy was used for navigation and plotting assigned items from the NOAA-provided composite source file (CSF).

Fixes were imported into ArcGIS and projected to final positions as necessary before import into CARIS Notebook. In Notebook, features were edited, attributed, and saved to the project S57 FFF (final feature file), provided with the survey deliverables.

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* and *Spare RHIB*. 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 Trimble T5700 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 *Cutwater*. 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 *Cutwater* 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 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 was measured daily on the *Cutwater* and *Spare RHIB*. On the *Q105* static draft was measured every 2-3 days, as weather conditions were not always conducive to an accurate measurement. On all vessels, an additional measurement was undertaken whenever any situation was experienced with the potential to significantly change the draft, such as after fueling or adjustments in ballast.

With the vessel at rest, a calibrated "measure-down" pole or tape was used to measure the distance from the waterline to the measure-down point on the vessel gunwale. The measurement was taken on both sides of the vessel. On the *Cutwater*, only the starboard-side measurement was used for corrections because the measure-down point was nearly coincident with both the reference point and the single beam transducer.

The *Q105* also utilized an ultrasonic measure-down system, TerraSonic. This featured sensors which continually ranged from a known point to the waterline. However, use of the ultrasonic measure downs were generally not required on this survey since it was possible to conduct a reasonable quantity of manual measure-downs. To calibrate the system, a correction factor was periodically entered after manual measure downs to bring the TerraSonic value in agreement with the manual measurement.

Draft values were checked to ensure they fell within the normal range for the survey vessel, and time-tagged and logged in the TerraLog software comments for later inclusion in the CARIS HIPS Vessel File (HVF) by processing (included with the survey deliverables).

B.2.4. Sound Speed Measurements

Sound speed profiles or "casts" were collected on an interval of 3 hours during MBES operations (*Q105)* and 6-12 hours during SBES operations (*Cutwater* and *Spare RHIB)*. The intervals were determined in the field by examining sound speed variance and deemed sufficient to minimize error due to sound speed while also limiting the required volume of profiles. New profiles were also collected when transiting significant distance to change survey areas.

Sound speed profiles were applied by nearest in distance within 3 hours for multibeam and nearest in distance within 12 hours for single beam. Any exceptions are described in the applicable Descriptive Report (DR).

Casts were taken from the *Q105* using an Oceanscience UnderwaySV system, which utilized a Valeport SV sensor. When deployed, the sensor freefalls through the water column and the fall is arrested when a manual break is applied by the operator at the UnderwaySV winch, before the sensor hits the bottom. The sensor is then winched back aboard the vessel, and the stored profile data downloaded wirelessly by UnderwaySV software.

Prior to survey operations commencing, the system was sea-trialed to determine the rate of descent at various survey speeds and depths. A drop table was formulated from multiple data points, allowing computation of a 2^{nd} order polynomial prediction formula which assisted greatly with determining the appropriate amount of drop time to achieve the desired depth. The time – depth relationship was non-linear, with the probe slowing significantly with depth. At 10 m depth for example, the probe dropped at a rate of 2.7 m/s but at 150 m depth the descent rate was 1.5 m/s. Effort was made to ensure 95% of the water column was profiled, though the variable seafloor topography in this area occasionally made full-depth profiles impractical.

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.

For single beam operations as well as during weekly SVP comparisons, Odom Digibar and AML SV+ sensors were deployed by hand with the vessel at a stop. During these deployments, the AML SV+ (or Digibar) was held at the surface for approximately one minute to achieve temperature equilibrium before being lowered slowly to the bottom (approximately 1 meter/second) and raised by hand in the same fashion. When back aboard, the sensor was downloaded and the profile examined to ensure a good profile was acquired. If a profile was not acquired, or contained obvious problems, another profile was collected. The sound speed file was entered into TerraLog, which automatically co-referenced the filename with a position and a timestamp.

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 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) 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) – occasionally 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

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.

On the *Cutwater* and *Spare RHIB,* a new TerraLOG SQL file was created and updated each day and later merged into the master database.

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.

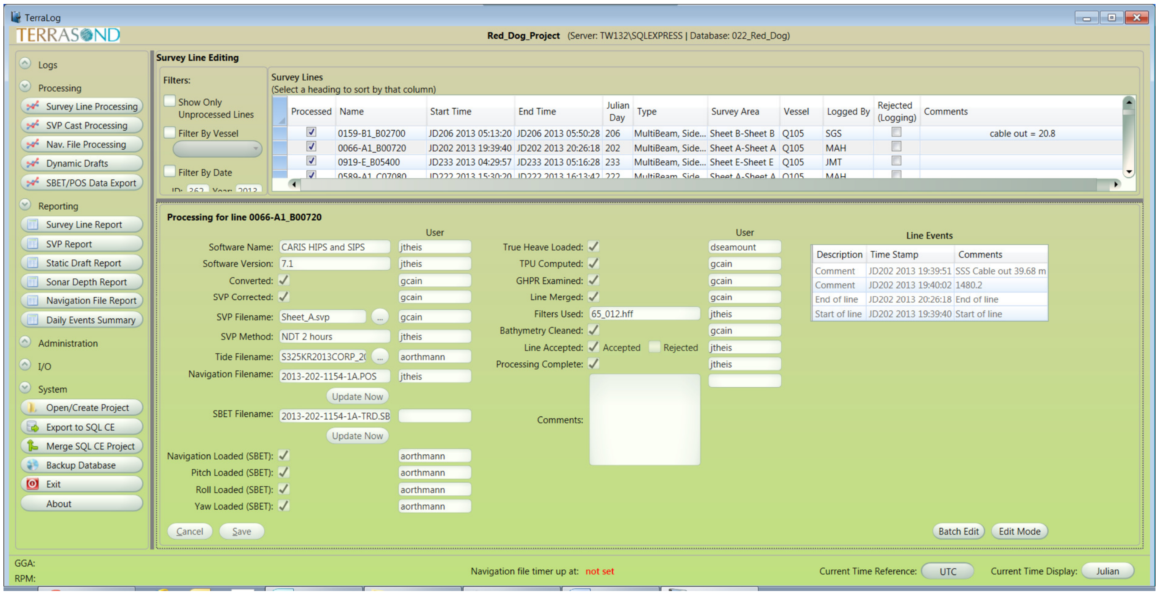


Figure 6 – TerraLog interface for line processing.

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*.

B.2.6. Base Station Deployment

Due to the lack of DGPS coverage in the area, and to enable PPK processing, two base stations (with three separate, independent GPS receivers) were installed for the project. The specific equipment utilized and photos of the sites are available in Section A of this report.

The stations were located strategically at False Pass and Cape Chunak so that baseline distances to all survey tracklines were within 20 kilometers of a base station. Cape Chunak had little to no GPS masking, while False Pass had minor masking due to nearby mountains. Both sites had clear line of site to satellite Galaxy 18 at 123° W, which enabled installation of satellite internet dishes for remote download and quality control of the station data. Additionally, both sites had fair line of site to the survey area for RTK transmission.

During deployment, GPS antennas were leveled and secured. Antennas were tripod-mounted at Cape Chunak. At False Pass the GPS antenna was mounted to a length of threaded rod above a purpose-modified covered trailer. Battery voltage, logging status, antenna height, and other important parameters were logged during installation and regularly throughout the project.

The GPS tripods at Cape Chunak were firmly secured to the ground with sandbags. However, it proved insufficient when an extreme wind event on June 25th (JD176) tipped the NetRS tripod on its side. It was re-centered and re-secured during a site visit on June 28th (JD179). During the same event, the RTK antenna mast was bent and a site-monitoring camera were damaged. Cape Chunak NetRS data logged during this period (JD176-JD179) was rejected with none utilized for post-processing, using instead the adjacent T5700 base station or the station at False Pass (both of which were unaffected).

During the survey, proper operation of the base stations was checked remotely via each station's satellite internet link. The JD176 issue with the Cape Chunak NetRS described above was detected in this manner. Real-time checks included battery voltage, logging status, and confirmation of satellite tracking. Data was also downloaded at least twice daily, converted to Rinex format, and used to process the prior day's vessel GPS data – a process which also served as a check on data integrity, as any issues with base station data quality or coverage would manifest itself as positioning problems during processing.

Antenna levelness and height were checked at Cape Chunak during physical site visits there, which averaged every 3 weeks. Antenna levelness and height checks were not applicable to the False Pass base station.

As a confidence check on antenna and monument stability, an OPUS solution was derived at least once weekly from a 24-hour data set and compared to the initial 24-hour OPUS solution at each station. Results were excellent with all subsequent position results comparing to within 0.031 m vertically and 0.010 m horizontally (or better) of the initial positions.

The base station confidence checks are available with the project HVCR. Vessel position confidence checks are available in *Separate I* of the DRs.

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

<table>
<tr><th>Type</th><th colspan="2">Description</th><th>Example / Format</th></tr>
<tr><td rowspan="2">Raw MBES DB and XTF (QINSy)</td><td colspan="2">MBES Mainscheme</td><td>1002-210-2B2_8000-0001 (.DB and .XTF)
[Index]-[JD]-[Vessel#][AreaID]_[Line#][Sequence#]</td></tr>
<tr><td colspan="2">MBES Test / Check / Lead Line / Bar Check</td><td>1292-214-2Bar-0001 (.DB and .XTF)
[Index]-[JD]-[Vessel#][CalItem]-[Sequence#]</td></tr>
<tr><td rowspan="2">RAW and BIN (HYPACK)</td><td colspan="2">SBES Mainscheme</td><td>1B-2014CU1610019 (.RAW and .BIN)
[Vessel#][AreaID]-[Year][Vessel][JD][SOL HHMM]</td></tr>
<tr><td colspan="2">SBES Test / Check / Lead Line / Bar Check</td><td>1Y-2014CU1771528 (.RAW and .BIN)
Same with ‘Y’ for area ID</td></tr>
<tr><td rowspan="2">SVP</td><td colspan="2">Text File from Digibar or AML</td><td>1A-2014-158-1945 (.AML or .DIGI)
[Vessel#][AreaID]-[Year]-[JD]-[Time HHMM]</td></tr>
<tr><td colspan="2">Text file from UnderwaySV</td><td>2014-07-19-05-03-20 (.TXT)
[Year]-[Month]-[Day]-[Hour]-[Minute]-[Second]</td></tr>
<tr><td>HEX</td><td colspan="2">Raw File from Seabird Tide Gauge</td><td>2014-161-198-Deploy3-SN1158 (.HEX)
[Year]-[StartJD]-[EndJD]-[Name]-SN[DeviceSN]</td></tr>
<tr><td rowspan="5">T01</td><td colspan="2">Trimble 5700 Binary File (navigation / base)</td><td rowspan="5">00562070 (.T01)
[ReceiverSN][StartJD][FileSequence#]</td></tr>
<tr><td>Platform</td><td>Receiver SN</td></tr>
<tr><td>Q105 & Spare RHIB</td><td>0056</td></tr>
<tr><td>Cutwater</td><td>0002</td></tr>
<tr><td>Cape Chunak Base</td><td>5240</td></tr>
<tr><td rowspan="4">T00</td><td colspan="2">Trimble NetRS Binary File (base)</td><td rowspan="4">FalsePass201406020000a (.T00)
[Station][Year][Month][Day][Start time HHMM][FileSequenceLetter]</td></tr>
<tr><td>Station</td><td>ID</td></tr>
<tr><td>False Pass</td><td>FALS</td></tr>
<tr><td>Cape Chunak Base</td><td>OUTE</td></tr>
<tr><td rowspan="2">POS</td><td colspan="2">Raw Positioning Data (.000 file) from POSMV, network logged</td><td>2014-198-0007-2A (.POS)
[Year]-[JD]-[Start time HHMM]-[Vessel#][Sheet Letter]</td></tr>
<tr><td colspan="2">Raw Positioning Data (.000 file) from POSMV, auto-logged to USB</td><td>2014_198_0007_2A.132 (.POS)
[Year]_[JD]_[Start time HHMM]_[Vessel#][Sheet Letter].[file sequence #]</td></tr>
<tr><td>DSO</td><td colspan="2">Bottom track record from Odom eChart (Spare RHIB only)</td><td>MK3_2014_08_08_19_07_22 (.DSO)
[SonarType]_[Year]_[Month]_[Day]_[Hour]_[Minute]_[Second]</td></tr>
</table>

Table 18 – Common raw data files and their naming convention from this project.

Files that were logged over Julian day rollovers were named (and filed) for the day in which logging began. This was adhered to even if the majority of the file was logged in the "new" day. This was a common occurrence since Julian day midnight (00:00) occurred at 16:00 local time during prime daylight hours.

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 (or after a full shift for the *Cutwater* and *Spare RHIB*) the data was copied to 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 where processing and reporting continued.

Note that during the initial 6 weeks of the project the *Cutwater* was shore-based without the *Q105* on-site. During this phase *Cutwater* data was transmitted via satellite internet to TerraSond's Palmer, Alaska office where it was processed and reviewed the next day. Following mobilization of the *Q105* all data and processing transitioned offshore.

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

Initial data processing was carried out in TerraSond's Palmer office, or 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 the next day.

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 were recorded to database file using the TerraLog interface. Log files were then output to PDF. These are available in each DR, *Separate I: Acquisition and Processing Logs.*

B.3.1. Conversion into CARIS HIPS and Waterline Offset

CARIS HIPS was the primary software used for bathymetric processing for this project. The XTFs exported from QINSy (*Q105* and *Spare RHIB*) and the SBES RAW files written by HYPACK (*Cutwater*) 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 *Cutwater* data only), containing the digital trace data, were also carried over to the line directories at this time.

The CARIS HIPS vessel definition file (HVF) for each vessel was updated with a new waterline value prior to sound speed correction. 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 static draft. 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.

Note that port and starboard measure-downs were recorded on the *Cutwater*, but only the starboard measurement was used (with no averaging of the two values). This was done because the *Cutwater* reference point was located on the starboard side nearly coincident with the starboard measure-down point, making averaging to obtain draft at a centrally located reference point undesirable.

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* and *Cutwater* (which were equipped with a POSMV) delayed heave (also known as "TrueHeave") was logged continually during survey operations to POS file with few exceptions. In processing, CARIS HIPS' "Load Delayed Heave" utility was utilized to load the lines with the TrueHeave record. The TrueHeave records, whenever present, were utilized by CARIS HIPS by default for heave correction.

Delayed heave was applied during sound speed correction.

B.3.3. Spare RHIB Heave Corrections

On the *Spare RHIB* 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 post-processed kinematic (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 RP 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 *Spare RHIB* 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 was also successfully used on the 2012 Nushagak River surveys and 2013 Red Dog surveys with identical equipment. On this survey, simultaneous PPK heave and TrueHeave from the POSMV were compared for a sampling of *Cutwater* data, with results comparing very well, within 0.10 m or better.

Note: On the *Spare RHIB*, a loss of the raw T01 files from the T5700 receiver caused PPK data, including PPK heave, to be unavailable for 15 lines (JD220, lines 0030 – 0044). This outage necessitated the use of Hemisphere V113 heave instead, which is of lower rated accuracy. To ensure the acceptability of Hemisphere V113 heave, a comparison was undertaken from a random sampling of *Spare RHIB* lines in which both PPK heave and V113 heave were available. It was found that the two compare very closely, normally within 0.05 m. Given that conditions were very calm during the time of acquisition of the affected lines, and the good comparison with PPK heave, the heave corrections used on these lines is well within specifications.

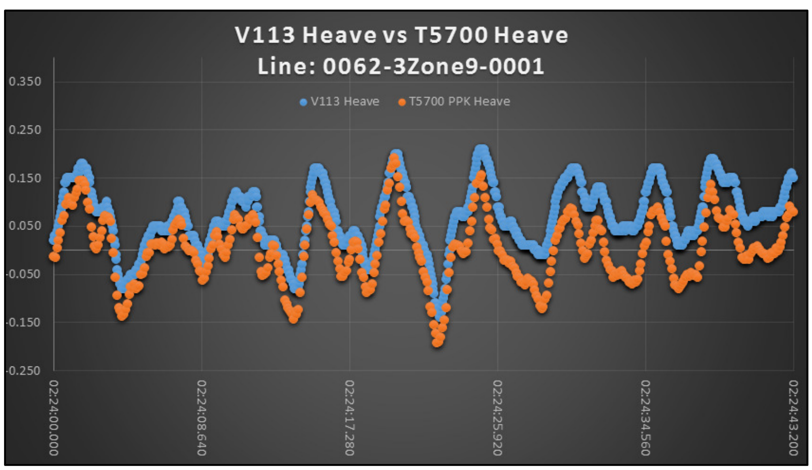


Figure 7 Example comparison of V113 heave vs T5700 (PPK) heave.

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 UnderwaySV 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 vessel and survey sheet.

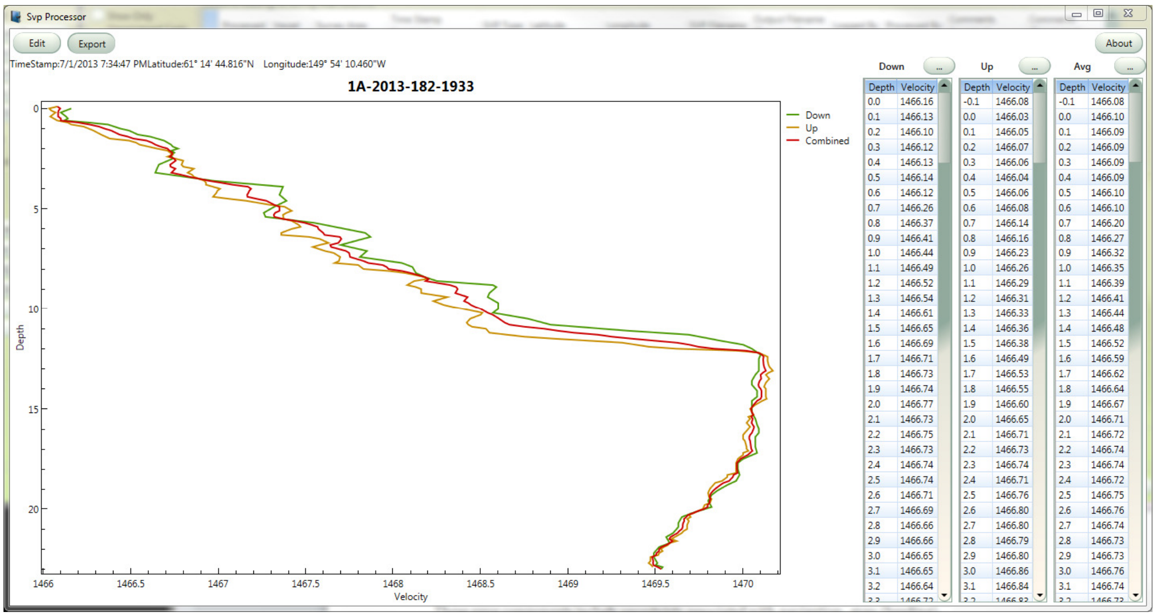


Figure 8 – Example SVP profile editing interface in TerraLog.

As TerraLog did not natively support the raw UnderwaySV files, the UnderwaySV files were reformatted to a file type readable by TerraLog. An in-house utility, UnderwaySV Converter converted the UnderwaySV files to "MVP" type, modeled on the MVP-200 system. In addition to being compatible with TerraLog, MVP-type had the advantage of including the geographic position and timestamps originally written to the raw file by the UnderwaySV software.

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, 3 hours was used for multibeam and 12 hours was used for single beam. The value was chosen to match the cast 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 3" or "NDT 12" (for nearest-in-distance within 3 or 12 hours).

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 19 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	*Cutwater* Error Entry	*Spare RHIB* Error Entry	Source
Sonar Type	Reson Seabat 7101 (239 beams)	Odom Echotrac CV	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°	0.02°	0.3°	*Q105 / Cutwater*: CARIS TPU values for Applanix POSMV 320 (2 m baseline) *Spare RHIB*: Manufacturer specs for Hemisphere V113
Heave	5% or 0.05m	5% or 0.05m	5% or 0.124 / 0.170 m	*Q105 / Cutwater*: CARIS TPU values for Applanix POSMV 320 *Spare RHIB*: Higher of 5% or 0.124 (PPK Heave) and 0.170 m (Hemisphere V113 Heave)
Roll and Pitch	0.010°	0.010°	1°	*Q105 / Cutwater*: CARIS TPU values for Applanix POSMV 320 (RTK) *Spare RHIB*: Manufacturer specs for Hemisphere V113
Navigation	0.1 m	0.1 m	0.1 m or 2 m	PPK processing results reports indicate RMS positioning errors better than 0.10 m on average. A small number of *Spare RHIB* lines that were DGPS-only have an estimated 2 m positional accuracy
Timing – (all systems)	0.01 sec.	0.1 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	0.02 m	Accuracy estimate of the X offset measurement of the transducer acoustic center relative to the vessel RP

HVF TPU Entry	*Q105* Error Entry	*Cutwater* Error Entry	*Spare RHIB* Error Entry	Source
Offset Y	0.05 m	0.02 m	0.02 m	Same as above
Offset Z	0.03 m	0.05 m	0.026 m	Uncertainty of bar check results
Vessel Speed	3 knots	3 knots	3 knots	Estimated average current experienced in survey area
Loading	0.02 m	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	0.02 m	Estimated accuracy of static draft measurements
Delta Draft	0.02 m	0.02 m	0.02 m	Uncertainty of squat-settlement test results
MRU Align StdDev Gyro, Roll/Pitch	0.1°	1°	1°	Estimate of accuracy of patch test results for the applicable sensors

Table 19 – TPU values used.

Other parameters affecting TPU computation:

- For "MRU to Trans" offsets under "TPU values", the offset from the POSMV IMU for the *Q105* and *Cutwater* (GPS antenna on *Spare RHIB*) to the sonar was entered.
- For "Nav to Trans" offsets, once again, the offset from the POSMV IMU for the *Q105* and *Cutwater* (GPS antenna on *Spare RHIB*) to the sonar was entered.
- The tide zone ZDF (zone definition file) 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 0.044 m to 0.163 m. The error estimate for water level measurements at the gauges ranged from 0.032 to 0.060 m. The ZDF and gauge files are included with the CARIS survey deliverables. Note that values for tide error were left at zero during the "Compute TPU" process, as CARIS HIPS ignores these values and uses the tide error computed for each line instead.
- All *Q105* and the majority of *Cutwater* lines utilized real-time error estimates for heave, pitch, roll, gyro, and position. SMRMSG (smoothed RMS) error estimate files, produced as part of the PPK process in Applanix POSPac, were loaded into all applicable lines at 1 Hz. Additionally, during the load Delayed Heave process, CARIS HIPS loaded estimated error values for heave from the POSMV files. During Compute TPU, "Realtime" was selected as the error source so that CARIS

HIPS would default to use these dynamic error estimates wherever they exist instead of the fixed values from the HVF.

- *Spare RHIB* did not have a source of real-time error estimates for pitch, roll, gyro, position, and heave. Therefore, this vessel uses the fixed error estimates from the vessel file for these sensors.
- *Spare RHIB* uncertainty estimates in the HVF are altered on JD220 for approximately 3 hours, reflecting the temporary shift to the Hemisphere V113 instead of the T5700 as the vessel's primary navigation and heave source. This was required because the raw data (T00) file necessary for PPK processing from the T5700 was not recovered from the unit for this period. The Hemisphere V113 provided positioning and heave data within specifications, though not to the same degree of accuracy as PPK T5700 data, necessitating modification to the error estimates to provide a better final TPU estimate.
- For estimated sound speed error, a value which varied by survey sheet and vessel was entered. Values ranged from 1.04 to 2.62 m/s. The estimates were derived by comparing subsequent casts 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 *Spare RHIB* of 0.124 m (PPK heave from the T5700) is based on 0.10 m of potential vertical error from post-processed GPS with 0.024 m of additional error to account for vessel roll misinterpreted as heave. A heave error value of 0.170 m was used briefly on JD220 when Hemisphere V113 heave was used; this value was based on a comparison to T5700 PPK heave.
- For surface sound speed error, 0.025 was entered for multibeam data (*Q105* only) as the manufacturer specified accuracy of the surface sound speed probe. A value of '0' was entered for SBES data since no surface probe was used (or necessary) on the *Spare RHIB* and *Cutwater.*

B.3.6. Post-Processed Kinematic GPS

All final positions for this project were post-processed.

The project was not located within USCG DGPS coverage. Real-time kinematic (RTK) GPS base stations (described previously in this report) were established to transmit corrections to the survey vessels, enabling accurate 3D positioning in real-time via radio broadcast. However, the RTK radio reception was still susceptible to frequent interruption and interference. Therefore, post-processed kinematic (PPK) GPS methods were utilized for final positions.

PPK processing for this project utilized Applanix POSPac software (both MMS and POSGNSS modules). POSPac MMS made use of the dual-frequency 1 Hz GPS data logged at the project base station (Rinex format, converted from T00 or T01), 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* and *Cutwater*, text format for the *Spare RHIB*) were loaded into all lines in processing, which replaced navigation logged in real-time. For *Q105* and *Cutwater* 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 applied 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 or T01 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 all final positions were NAD83. The custom SBETs were then applied in CARIS HIPS. The flow chart in the Figure 9 is a generalized overview of the POSPac workflow used on this project.

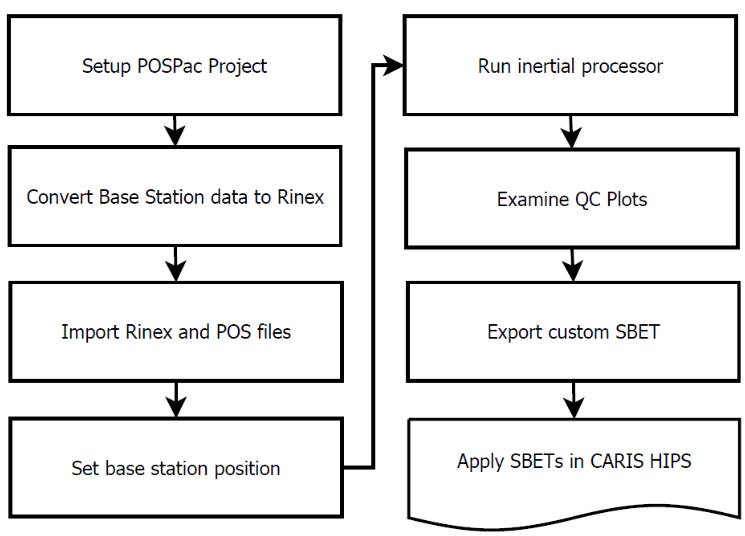


Figure 9 – Flow chart overview of POSPac workflow used on this project.

Spare RHIB 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* and *Cutwater,* 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 *Spare RHIB* SBES data, the PPK text files were loaded using CARIS HIPS Generic Data Parser utility. This step was done concurrent with the loading of PPK Heave, which was described earlier 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* and *Cutwater* 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 and attitude originally converted from QINSy XTF file or HYPACK RAW file with PPK navigation. Exceptions are rare and are noted in the applicable DR.

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

CARIS HIPS "Load Tide" function was used to load all lines with discrete tide zone data. The zone definition file (ZDF) "OPR-R315-KR-14_20141121.zdf" was selected. This file referenced five tide gauge files (one NWLON station at Unalaska and the four project tide stations) that contained 6-minute tide data on MLLW. 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).

"GPS Tide" was also computed to provide all lines with an ellipsoid elevation for reference and troubleshooting. It is important to note the computation of GPS Tide had no effect on the data since it was not applied during merge, but exists within each line for reference only.

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.

Spare RHIB pitch and roll data, derived from the Hemisphere V113, was somewhat jagged. For this reason, it was smoothed in CARIS HIPS Attitude Editor with a 5-point moving average and applied during sound speed correction. *Q105* and *Cutwater* attitude data, derived from a POSMV, did not require smoothing.

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.

In this process, all beams greater than 65° or 70° from nadir (port and starboard) were automatically rejected. Additionally, all soundings with a quality flag of 0, 1, or 2, were also rejected regardless of their angle from nadir. This left only high quality soundings within 65° or 70° of nadir, and removed the majority of erroneous soundings, which assisted with manual cleaning. This also removed the data most susceptible to sound speed and motion artifact errors.

In rare cases, especially when sound speed refraction error caused the edges of multibeam swathes to curve outside of allowable error specifications, beams were rejected at values less than 65°, including 55° filters that were occasionally necessary to reject soundings particularly affected by sound speed refraction error.

Filter settings were initially saved to a HIPS filter file (HFF). The HFF was selected for subsequent filtering. The HFFs are included with the CARIS deliverables (session directory), and the file 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. An additional examination of data was done in the field in CARIS HIPS Subset Editor.

Final cleaning was done in CARIS HIPS Subset Editor, following 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 2013 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 – which frequently occurred on the slopes of this project area.

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 10-12 lines, width was constrained to 20-30 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 *Cutwater* and *Spare RHIB*, 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 (stored in the BIN file recorded by HYPACK for *Cutwater* data) was used as background data in Single Beam Editor to ensure the soundings accurately portrayed the bottom. The digital bottom greatly assisted in determination of noise from real bottom.

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.

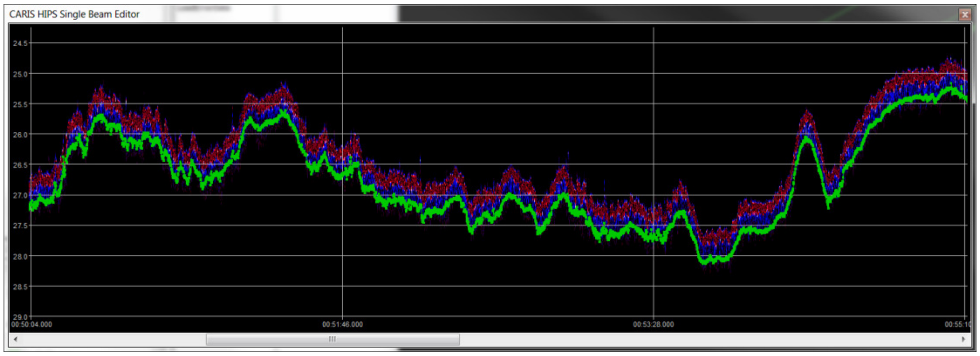


Figure 10 – Example of soundings (green) and digital bottom trace data (magenta and blue) in CARIS HIPS Single Beam Editor.

Note that BIN files containing bottom trace information are not available for lines logged on the *Spare RHIB,* and therefore, bottom trace information is not available in CARIS Single Beam Editor on these lines. *Spare RHIB* utilized QINSy, which does not log bottom trace information to a CARIS-compatible format; only digitized soundings are logged. In lieu of this and given the relatively minor total mileage acquired by the *Spare RHIB*, Odom eChart was used to log DSO files which contain the bottom trace information. During editing, DSO files were displayed in eChart side-by-side with the soundings in CARIS Single Beam Editor.

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 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 1 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 squat settlement test. Rare instances of missing RPM data from the TerraTach files were manually interpolated. A draft correction file consisting of time and settlement value was then loaded into all lines using CARIS HIPS "Load Delta Draft" function.

Dynamic draft corrections on the *Cutwater* were also engine RPM-based. Speed-based corrections were not used. TerraSond's TerraLog software was used to produce a correction file containing time and settlement values. To do this, TerraLog utilized the time-tagged RPM values entered by the acquisition crew in conjunction with a text file containing the *Cutwater* squat-settlement results. Rare instances of missing RPM data from the TerraLog records were manually interpolated. The draft correction file was loaded into all lines using CARIS HIPS "Load Delta Draft" function.

On the *Spare RHIB*, dynamic draft corrections were speed-based. A speed-settlement curve was entered into the *Spare RHIB* HVF. Unlike the other vessels, "Load Delta Draft" was not applicable to *Spare RHIB* 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.

Final surfaces were created at various resolutions depending on sonar and depth. For multibeam, resolutions of 1 m, 2 m, and 4 m (depending on depth) were created per the HSSD requirements for complete coverage surveys. For single beam, only 4 m resolution surfaces were made per HSSD requirements for single beam set-line spacing.

CUBE was selected as the gridding algorithm for all 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.

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.

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.

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".

Failures were typically attributable to bottom change frequently observed in this dynamic area, especially when collection periods were separated by many days or weeks. An additional source of failures were steep slopes and very rugged terrain, wherein sounding to surface comparisons often fail even though the underlying soundings and surface are within specifications.

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

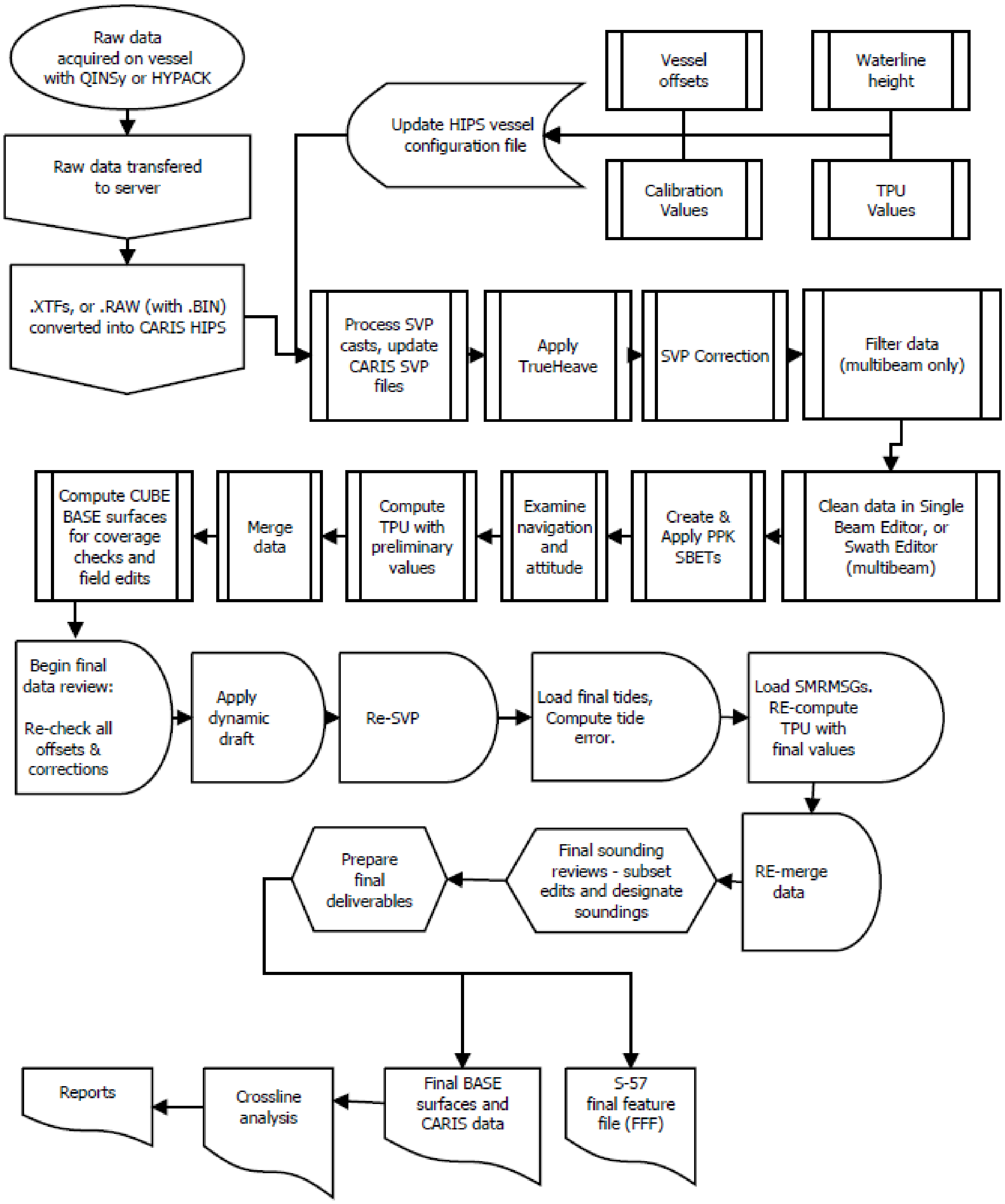


Figure 11 – Generalized flow chart of processing steps used on this project.

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.

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

Confidence Check	Purpose	Planned Frequency
Depth Checks (Bar and/or Lead Line)	Check depth accuracy Determine and refine Z offsets	Minimal one bar check, lead lines when possible
Echosounder Comparison (Multiple Vessels)	Overall check of consistency of survey systems.	No planned frequency; examine intersections of all three vessels
SVP Comparison	Check SVP sensors for consistency	Weekly
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	Check for accurate and consistent vessel positioning with independent GPS source	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 20 – 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 three completed on the *Cutwater.* All were performed alongside the dock in either Homer or False Pass, 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. 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 and *Spare RHIB* SBES) or HYPACK (for *Cutwater* 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 to 7 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. Results obtained from CARIS HIPS always compared to better than 0.05 m on average of the actual bar depth for all systems.

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 checks also served to identify and quantify a pitch error adjustment of 3.3° that was applied to *Q105* multibeam data. See Section C for more information.

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 planned to occur on a weekly basis, though it was not always possible to complete these on schedule. These were often undertaken when alongside a dock, concurrent with a bar check. Some were taken offshore when the right combination of slack current and weather presented itself, which was rare on this survey.

Lead lines were accomplished by lowering a calibrated measuring tape outfit with a 7 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 recorded depth in a depth check log.

On the *Q105*, four successful lead lines were acquired, with depth differences ranging from -0.01 m to 0.12 m. On the *Cutwater*, three successful lead lines were acquired, with depth differences ranging from -0.23 m to 0.16 m. On the *Spare* RHIB, four lead lines were acquired, with depth differences ranging from -0.03 m to 0.06 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 Comparison (Multi-Vessel)

During acquisition, care was taken to ensure significant overlap was achieved between the three survey vessels for comparison purposes.

To compare the echosounder data, CARIS BASE surfaces at 2 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 0.06 m on average, with a standard deviation of 0.25 m. Overall, the single beam is slightly shoaler, which is not atypical given the larger beam footprint of the single beam systems versus the multibeam system (3° on the *Cutwater*, 4° on the *Spare RHIB*, versus 1.5° on the *Q105*). The relatively large standard deviation is likely due to bottom change in the weeks and sometimes months between single beam and multibeam acquisition, with widespread shifting sand waves and scouring from the extreme currents throughout the area.

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

B.4.4. SVP Comparison

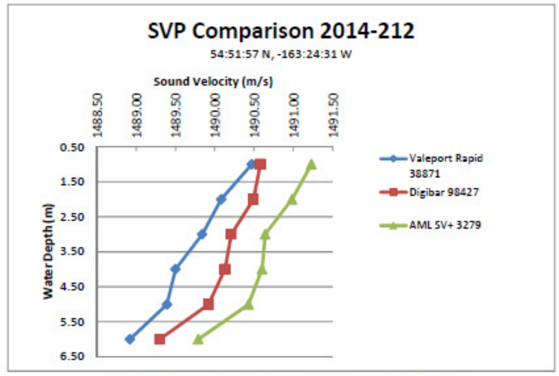
SVP comparisons were undertaken to check the accuracy and consistency of the sound velocity probe data. In the test, data from the primary sound speed profiler was compared to at least one other independent, calibrated sound speed profiler. These comparisons were planned to occur on a weekly basis though operational issues frequently caused their postponement.

To perform the test, a spare profiler probe was used to collect a cast coincident with the primary probe. Usually, all probes were lowered at the same time, though occasionally it was necessary to collect the profiles separately (though 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 m/s, though some show greater variance that is attributable to change over the slight differences in times of acquisition of the profiles.

The AML Micro-XChange sensor used on the Reson 7101 MBES head was also compared for accuracy against the recently calibrated Odom Digibar Pro on JD197. Results were good, with both instruments reading within 0.1 m/s of each other.

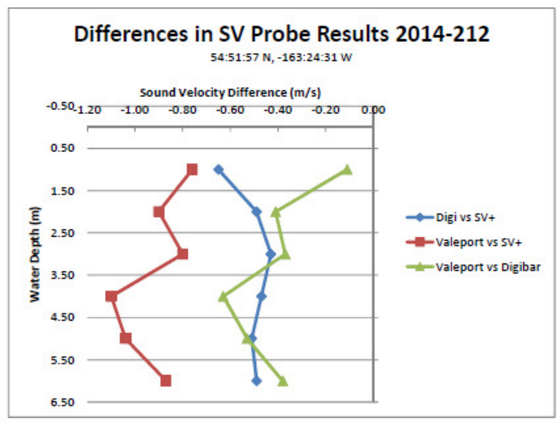
SVP confidence checks / comparison results are available in *Separate II* of the DRs.

SV Probe Results			
S/N	Valeport Rapid 38871	AML SV+ 3279	Digibar 98427
Date/time:	2014-212 00:34:15	2014-212 00:34:15	2014-212 00:33:38
Depth	Sound Velocity (m/s)		
0.00			
1.00	1490.47	1491.23	1490.58
2.00	1490.08	1490.98	1490.49
3.00	1489.84	1490.64	1490.21
4.00	1489.50	1490.60	1490.13
5.00	1489.39	1490.43	1489.92
6.00	1488.92	1489.79	1489.30
7.00			
8.00			
9.00			
10.00			
11.00			
12.00			
13.00			
14.00			
15.00			
16.00			
17.00			
18.00			
19.00			
20.00			



(Figure 1- Sound velocity from each Sound velocity Probe)

Statistics on the SV Probe results			
	Difference in Sound Velocity (m/s)		
Depth	Digi vs SV+	Valeport vs SV+	Valeport vs Digibar
0.00			
1.00	-0.65	-0.76	-0.11
2.00	-0.49	-0.90	-0.41
3.00	-0.43	-0.80	-0.37
4.00	-0.47	-1.10	-0.63
5.00	-0.51	-1.04	-0.53
6.00	-0.49	-0.87	-0.38
7.00			
8.00			
9.00			
10.00			
11.00			
12.00			
13.00			
14.00			
15.00			
16.00			
17.00			
18.00			
19.00			
20.00			



(Figure 2- Differences between the Maximum and Minimum Sound Velocity of the two casts)

Figure 12 – Example of typical SVP confidence check (comparison results): JD212 SVP comparison using three separate sound speed profilers.

B.4.5. Base Station Position Checks

For each project base station, the precise geographic position was established using NOAA NGS OPUS (Online Positioning User Service) 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 0.031 m vertically and 0.010 m horizontally (or better) of the initial (surveyed) positions. Base station confidence check logsheets (see Figure 13) are available with the project HVCR.

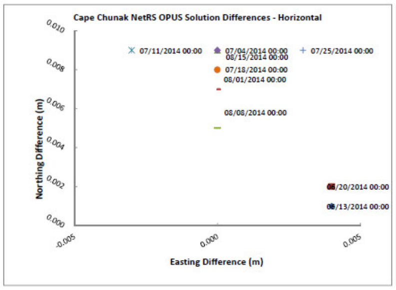
TerraSond Limited — Base Station Position Checks — NOAA Bechevin Bay 2014

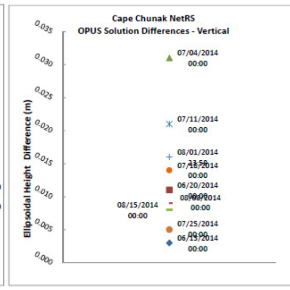
Base Station Position Checks

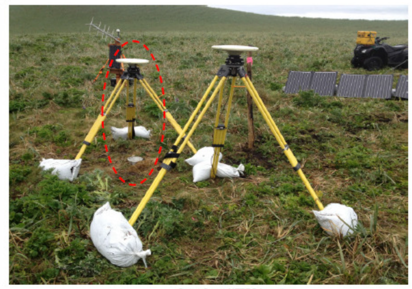
Base Name: TerraSond Cape Chunak NETRS — ID: OUTE
Site Description: Located at Cape Chunak tide station, over tidal benchmark 9462941A
Receiver Type: Trimble NetRS — **Receiver Serial:** 4412232926
Antenna Type: Trimble Zephyr Geodetic (TRM41249.00) — **Antenna Serial:** 12682207
Project number: OPR-R315-KR-14
Horizontal Datum: NAD 83 (2011)(EPOCH:2010)
Projection: UTM Zone 3N
Ellipsoid: GRS 80

Notes: ** Surveyed position is from 24-hour OPUS solution 6/6 filename "oute157e.14o"*

RTK Site Coordinate:		Latitude(dms)	Longitude(dms)	Northing(m)	Easting (m)	Ellipsoidal Height(m)
Surveyed*	24-hr OPUS 6/6/14	55 2 57.27853	163 32 14.21492	6101249.073	593449.815	23.493







Outer Coast NETRS Location

Base Station Position Uncertainty Check:

Times of OPUS solution				File Information	Antenna Height		OPUS Solution Results (NAD83)					RESULTS (DIFFERENCE) Delta (m) = OPUS solution check - Surveyed Coord.		
Deployment #	Start	End	Hours	OPUS Rinex File name	Measure Point	ARP(m)-Enter in OPUS	Latitude(dms)	Longitude(dms)	Northing(m)	Easting(m)	Ellipsoidal Height (m)	Northing (m)	Easting (m)	Ellipsoidal Height (m)
1	06/13/2014 00:00	06/13/2014 23:59	24.0	comb1640.14o	9462941A	1.231	55 2 57.27855	163 32 14.21471	6101249.074	593449.819	23.496	0.001	0.004	0.003
1	06/20/2014 00:00	06/20/2014 23:59	24.0	comb1710.14o	9462941A	1.231	55 2 57.27860	163 32 14.21470	6101249.075	593449.819	23.504	0.002	0.004	0.011
2	07/04/2014 00:00	07/04/2014 23:59	24.0	comb1850.14o	9462941A	1.223	55 2 57.27880	163 32 14.21492	6101249.082	593449.815	23.524	0.009	0.000	0.031
2	07/11/2014 00:00	07/11/2014 23:59	24.0	comb1920.14o	9462941A	1.223	55 2 57.27881	163 32 14.21506	6101249.082	593449.812	23.514	0.009	-0.003	0.021
3	07/18/2014 00:00	07/18/2014 23:59	24.0	comb1990.14o	9462941A	1.232	55 2 57.27879	163 32 14.21489	6101249.081	593449.815	23.507	0.008	0.000	0.014
4	07/25/2014 00:00	07/25/2014 23:59	24.0	comb2060.14o	9462941A	1.232	55 2 57.27880	163 32 14.21474	6101249.082	593449.818	23.498	0.009	0.003	0.005
4	08/01/2014 00:00	08/01/2014 23:59	24.0	comb2130.14o	9462941A	1.232	55 2 57.27876	163 32 14.21492	6101249.080	593449.815	23.509	0.007	0.000	0.016
4	08/08/2014 00:00	08/08/2014 23:59	24.0	comb2200.14o	9462941A	1.232	55 2 57.27868	163 32 14.21489	6101249.078	593449.815	23.502	0.005	0.000	0.009
4	08/15/2014 00:00	08/15/2014 23:59	24.0	comb2270.14o	9462941A	1.232	55 2 57.26687	163 32 14.28834	6101249.082	593449.815	23.501	0.009	0.000	0.008
											Max Delta:	0.009	0.004	0.031
											Min Delta:	0.001	-0.003	0.003
											Std Dev:	0.003	0.002	0.009

Comments: JD178 results N/A because tripod was tipped over for this check -- data from JD176-JD179 for this station has been rejected
Overall good results, max delta was 0.031 (for Z) m on 7/4 check. Horizontally all are better then 0.01 m.

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* and *Cutwater*. These were accomplished on a weekly basis.

To complete the check for each vessel, a random POS file was selected from each week and re-processed with an alternate (and usually more distant) base station. Results were differenced from the original post-processed solution with 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.

For this project, the project base stations were separated by about 23 kilometers. This resulted in a maximum baseline for comparisons of about 30 kilometers.

Results were excellent, with average differences agreeing to 0.1 m (or better). Results deviated up to 0.3 m on occasion, which is still well within positioning specifications The vessel positioning confidence check logs are available in *Separate I* of the DRs.

TerraSond Limited | Vessel Positioning Confidence Check | NOAA Bechevin Bay 2014

Vessel Positioning Confidence Check

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

POS file: 2014-226-1514-1ABC.POS **Date:** August 14th, 2014 (JD226) **Vessel:** Cutwater

Base Stations Used

Base Station Name	Operating Agency	Function	Data Rate	Min. Baseline Distance (m)	Max. Baseline Distance (m)
FALS	TerraSond	Project Primary	1 Second	11,500	21,250
OUTE	TerraSond	Project Primary	1 Second	6,500	21,300

Table 1- Base stations used for comparison

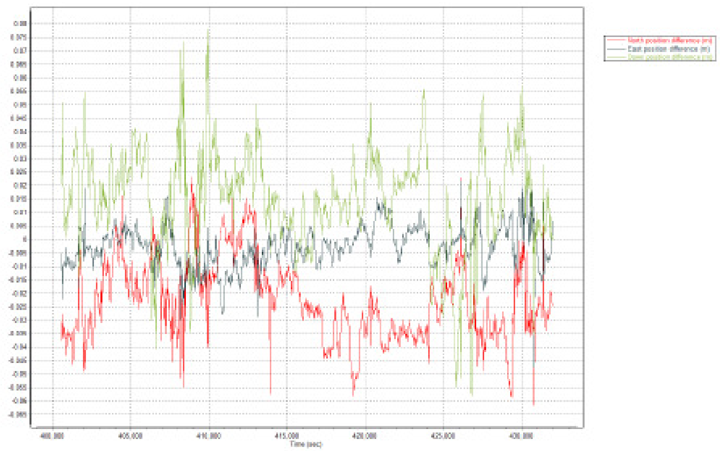


Figure 1 - Results of position difference between 2014-226-1514-1ABC.POS processed with FALS and OUTE

Result Statistics

Position	Min. Difference (m)	Max. Difference (m)	Mean Difference (m)
North	-0.062	0.023	-0.025
East	-0.045	0.022	-0.005
Down	-0.057	0.077	0.01

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 JD226.

B.4.7. Vessel Positioning Confidence Checks – Independent GPS

Checks of the primary position (from the Applanix POSMV) and an independent GPS source (a Trimble 5700, or T5700) were accomplished in real-time on the *Q105* and *Cutwater.*

QPS QINSy (on the *Q105)* or HYPACK (on the *Cutwater)* were configured to draw a scatterplot comparison of the two position sources. The scatterplot was examined and a screenshot taken of the plot once daily. No abnormalities were observed during this project, with the positions usually comparing within 2 m horizontally. Screenshots of the scatterplots were saved daily, and are available in *Separate I* of the DRs.

B.4.8. Tide Station Staff Shots and Operation

Standard leveling procedures were utilized to perform "staff shots" at the project seabird stations to confirm tide gauge stability. During staff shots, leveling was undertaken 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 to 3 hours during each visit, which were accomplished normally every 2 weeks. Hydrometer readings were collected so salinity adjustments could later be made.

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 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, as well as daily QC on the data transmitted from the bubbler tide stations via NOAA GOES satellite. JOA's daily QC included checks for data continuity, proper gauge functions such as charging status and operating voltage, and analysis for anomalies such as data spikes or gauge settling.

Note that three of the four project tide stations (Newman's Cove, False Pass, and Isanotski) had bubbler-style tide gauges that could be downloaded immediately after staff shots. Cape Chunak, however, had submerged gauges which could only be accessed and downloaded after being pulled by the survey vessel, sometimes weeks or months after the staff shots.

No major issues with the gauges occurred on this project. Minor settling at the submerged Cape Chunak 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 center reference point (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 *Cutwater*, the CRP was located starboard side mid-ship on the same mounting structure and nearly coincident with the

SBES transducer. On the *Spare RHIB*, the top-center of the SBES transducer was utilized, which was mounted just starboard of the keel mid-ship.

On the *Q105* and *Cutwater*, 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 CARIS HIPS Vessel File (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. This specialized HVF configuration does not apply to XTFs produced by the *Spare RHIB* or RAW files produced by the *Cutwater*, since these vessels did not use Reson 71xx 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. Vessel outlines and offset descriptions are provided in the following figures and tables.

C.1.1. Q105 Vessel Offsets

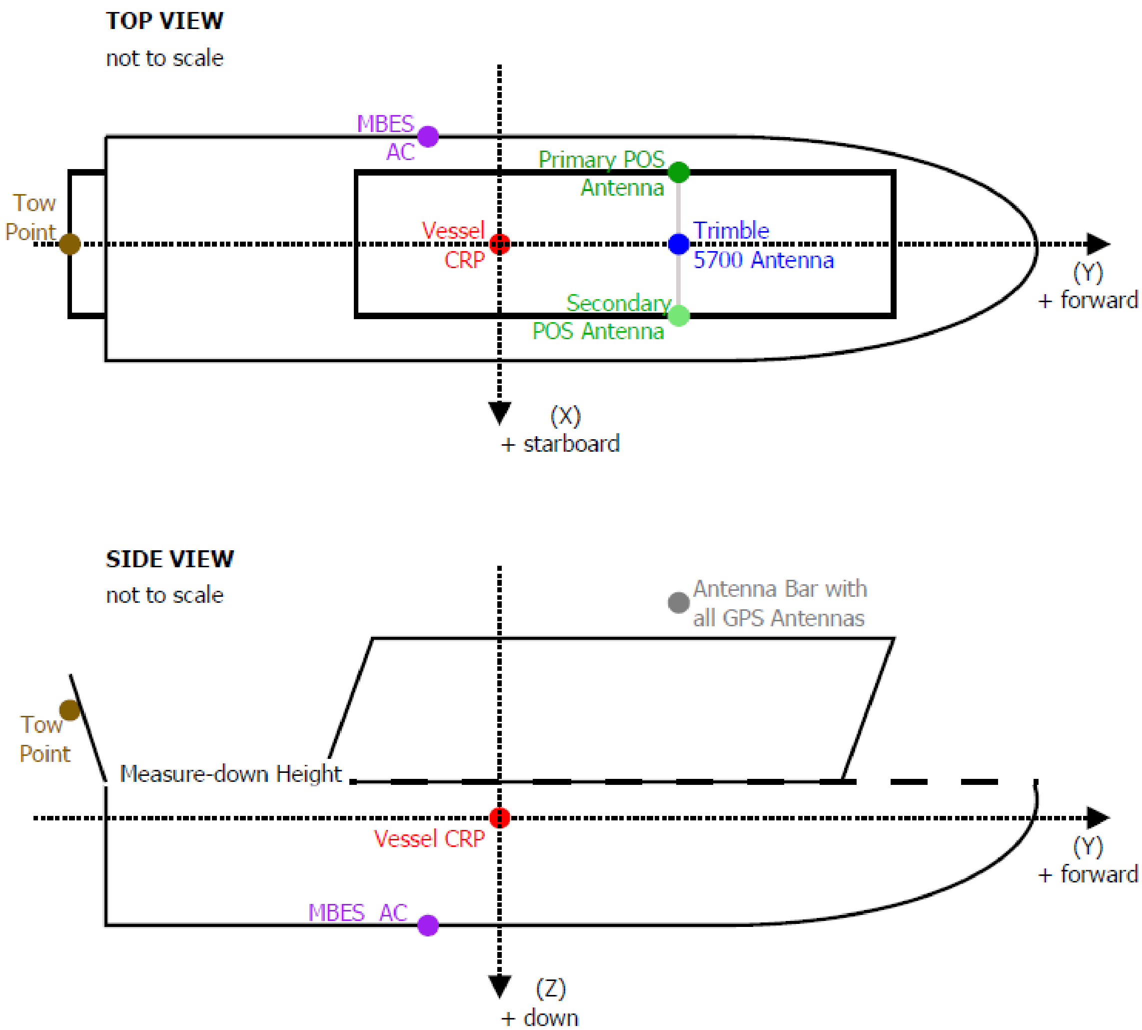


Figure 15 – Q105 vessel survey showing relative positions of installed survey equipment.

Equipment	X (m) (+ stbd)	Y (m) (+ fwd)	Z (m) (+ down)	Comments
MBES Acoustic Center	-4.178	-3.380	+1.120	Z value determined by bar check
POS MV Primary GPS Antenna	-0.998	+5.093	-13.903	Z value determined from POSPac calibration
POS MV Secondary GPS Antenna	+1.009	+5.115	-13.954	Primary position corrected by GAMS A-B vector
POS MV IMU Reference Point	0.000	0.000	0.000	
Trimble 5700 (Zephyr) Antenna	+0.002	+5.088	-13.904	
Stern Tow Point	0.000	-14.94	4.00	A frame in tow position. N/A for this project.
Draft Measure-down Point (port side)	-	-	-2.551	
Draft Measure-down Point (stbd side)	-	-	-2.551	

Table 21 – R/V Q105 offset measurements.

C.1.2. Cutwater Vessel Offsets

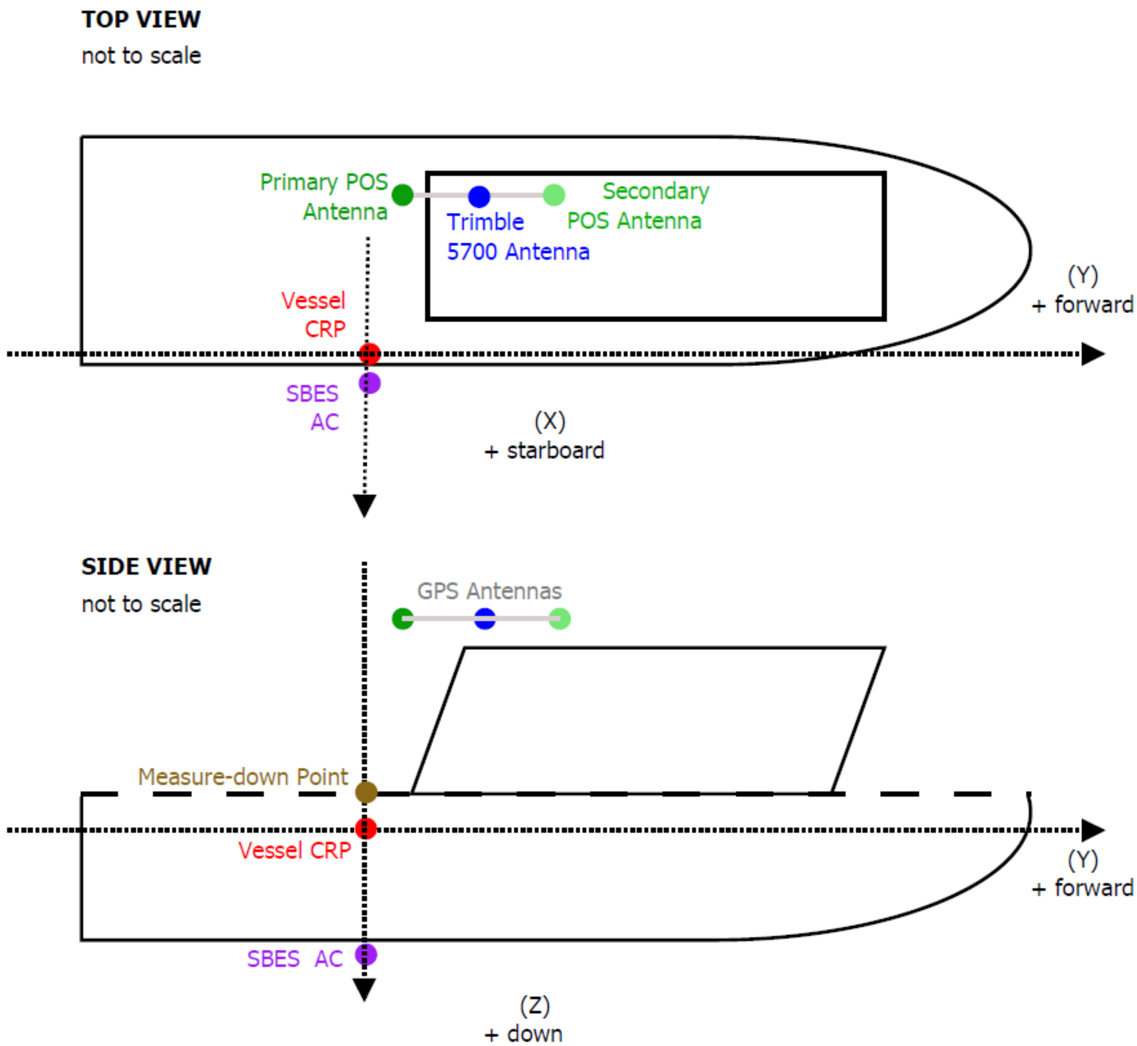


Figure 16 – Cutwater vessel survey showing relative positions of installed survey equipment.

Equipment	X (m) (+ stbd)	Y (m) (+ fwd)	Z (m) (+ down)	Comments
SBES Acoustic Center	0.560	0.000	+2.125	Z value determined by bar check
POS MV Primary GPS Antenna	-2.435	+0.510	-2.585	Determined from POSPac calibration
POS MV Secondary GPS Antenna	-2.400	+2.513	-2.558	Primary position corrected by GAMS A-B vector
POS MV IMU Reference Point	0.000	0.000	0.000	
Trimble 5700 (Zephyr) Antenna	-2.418	+1.512	-2.572	
Rotation Center	-1.625	0.000	+1.664	
Draft Measure-down Point (port side)	-	-	-	N/A
Draft Measure-down Point (stbd side)	-	-	-0.251	

Table 22 – Cutwater offset measurements from CRP.

C.1.3. Spare RHIB Vessel Offsets

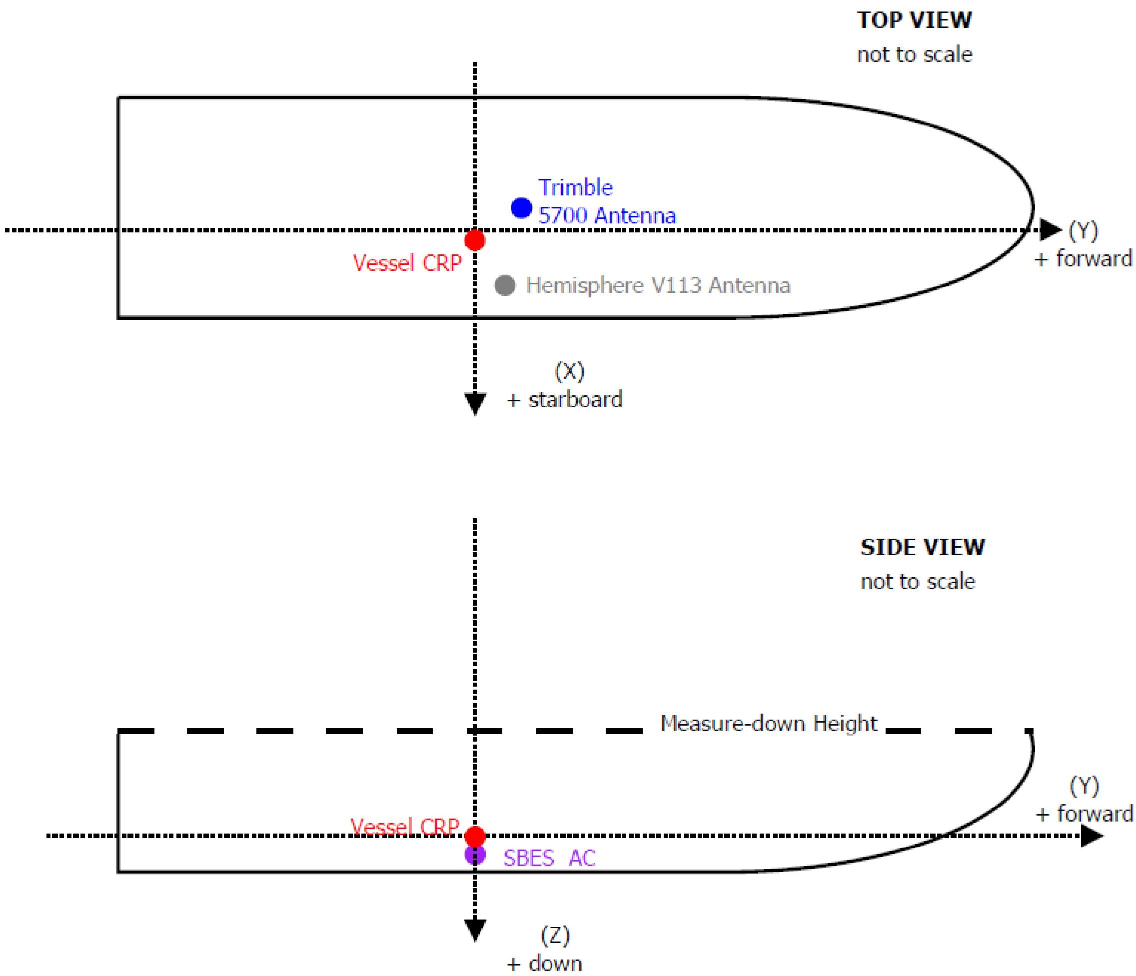


Figure 17 – Spare RHIB vessel survey showing relative positions of installed survey equipment.

Equipment	X (m) (+ stbd)	Y (m) (+ fwd)	Z (m) (+ down)	Comments
SBES Acoustic Center	0.000	0.000	+0.073	Z value determined by bar check
Hemisphere V113 Primary Antenna	+0.415	+0.175	-2.650	
Trimble 5700 (Zephyr) Antenna	-0.150	+0.425	-2.560	
Draft Measure-down Point (port side)	-	-	-1.050	
Draft Measure-down Point (stbd side)	-	-	-1.050	

Table 23 – Spare RHIB offset measurements from CRP.

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* and *Cutwater* 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. On the *Cutwater*, the POSMV output to HYPACK using standard NMEA strings via RS-232 serial cable. 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 *Cutwater* a reference to center of rotation offset was entered into the POSMV. This was done to allow the POSMV to correct for remote heave due to roll at the IMU's position near the starboard gunwale. This correctly resulted in slightly non-zero average heave records, depending on the vessel roll state. The center of rotation was estimated to be mid-ship, 1.625 m to port and 1.664 m below the IMU.

On the *Q105* and *Cutwater,* a GAMS (GPS azimuth measurement subsystem) calibration was done to maximize the heading accuracy of the system. Two GAMS calibrations were necessary on the *Cutwater* because the POSMV in-use was mobilized on that vessel twice during the project. The results are shown in Table 24.

Vessel	Date (JD)	A-B Antenna Separation (m)	Baseline Vector (m)		
			X (+ stbd)	Y (+ fwd)	Z (+ down)
Cutwater	2014-152	2.003	0.035	2.003	0.027
	2014-214	2.000	0.027	1.999	0.028
Q105	2014-192	2.008	2.007	0.022	-0.045

Table 24 – POSMV GAMS calibration results.

On the *Spare RHIB*, 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 QPS QINSy. A Trimble 5700 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, Trimble 5700 PPK navigation and heave data replaced Hemisphere V113 real-time navigation and heave data with few exceptions as described earlier in this report.

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 0.03 m on average. Agreement with the single beam data acquired on the smaller vessels also improved, to better than 0.06 m on average.

C.3. Calibration / Patch Tests

A patch test was 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 on a distinct bottom feature soon after beginning operations on-site, and the resulting values were entered into the HVF for application to all multibeam data. The values were confirmed by a second patch test on another distinct bottom feature near the end of multibeam correction. Values were consistent between the two patch tests.

On the single beam vessels *Cutwater* and *Spare RHIB*, 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 *Cutwater* and *Spare RHIB*, which were outfit with single beam systems, 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 systems.

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 *Cutwater* and *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.

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: Roll was also examined on the single beam vessels, but was more difficult to determine than multibeam due to the low data density. Roll values were adjusted until irregularities in bottom beam tracking were improved, if possible, to determine the roll often.

Refer to Section B of this report for uncertainties associated with patch test results. Table 25 summarizes the results.

Vessel	Patch Test Date	Latency Results (seconds)	Pitch Results (degrees)	Yaw Results (degrees)	Roll Results (degrees)
Q105	2014-192 2014-211	0.000	-2.250	1.380	-0.120
Cutwater	2014-153 2014-214	0.000	0.000	n/a	0.000
Spare RHIB	2014-217	0.000	-2.300	n/a	-2.000

Table 25 – Calibration test results.

C.4. Speed of Sound Corrections

A Valeport sensor on an Underway SV system was used to acquire sound speed profiles for multibeam data corrections. An Odom Digibar and an AML SV Plus sensor were used for acquiring sound speed profiles for single beam data corrections. All profilers were factory calibrated prior to commencement of survey operations.

Profiles were collected by acquisition normally on a 3-hour interval for multibeam and a 6-12 hour interval for single beam. 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.

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 3 hours for multibeam, and 12 hours for single beam.

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 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 was measured daily on the *Cutwater* and *Spare RHIB*. On the *Q105* static draft was measured every 2-3 days, as weather conditions were not always conducive to an accurate measurement. On all vessels, an additional measurement was undertaken whenever any situation was experienced with the potential to significantly change the draft, such as after fueling or adjustments in ballast.

With the vessel at rest, a calibrated pole or tape was used to measure the distance from the waterline to the measure-down point on the vessel gunwale. The measure-down point relationship to the vessel center reference point had previously been determined by vessel survey. The measurement was taken on both sides of the vessel and recorded in TerraLog.

The *Q105* also utilized an ultrasonic measure-down system, TerraSonic. This featured sensors which continually ranged from a known point to the waterline. However, use of the ultrasonic measure downs were generally not required on this survey since it was possible to conduct a reasonable quantity of manual measure-downs (TerraSonic data was used only to insert a data point during a 1-week gap between manual measure downs, on JD211). To calibrate the system, a correction factor was periodically entered after manual measure downs to bring the TerraSonic value in agreement with the manual measurement.

The CARIS HIPS vessel definition file (HVF) for each vessel was updated with a new waterline value prior to sound speed correction. 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 static draft. 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.

Note that port and starboard measure-downs were recorded on the *Cutwater*, but only the starboard measurement was used (with no averaging of the two values). This was done because the *Cutwater* reference point was located on the starboard side nearly coincident with the starboard measure-down point, making averaging to obtain draft at a centrally located reference point undesirable.

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, in *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 the POS file (*Q105* and *Cutwater*), or raw positioning data from the T5700 (*Spare RHIB*), while the nearby shore base station (False Pass) logged dual-frequency GPS data at 1 Hz. A survey line was run in each direction, at incrementing engine RPM/speed. Between each line set, as well as at the start and end of the test, a "static" was collected whereby the vessel would sit with engines in idle and log for a minimum of 2-minutes. The survey crew would note the time and speed of each event.

The POS (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 1 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 squat settlement test. Rare instances of missing RPM data from the TerraTach files were manually interpolated. A draft correction file consisting of time and settlement value was then loaded into all lines using CARIS HIPS "Load Delta Draft" function. Note: In rare cases when RPM records were not logged, values from adjacent lines run under similar conditions were interpolated to the affected lines, which are itemized in the appropriate DR.

Dynamic draft corrections on the *Cutwater* were also engine RPM-based. Speed-based corrections were not used. TerraSond's TerraLog software was used to produce a correction file containing time and settlement values. To do this, TerraLog utilized the time-tagged RPM values entered by the acquisition crew in conjunction with a text file containing the *Cutwater* squat-settlement results. Rare instances of missing RPM data from the TerraLog records were manually interpolated. The draft correction file was loaded into all lines using CARIS HIPS "Load Delta Draft" function. Note: In rare cases when RPM records were not entered in TerraLog, values from adjacent lines run under similar conditions were interpolated to the affected lines, which are itemized in the appropriate DR.

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

C.6.2. R/V Q105 Dynamic Draft Results

A squat settlement test was completed on the *Q105* on JD213. RPM values between 600 and 1200 were tested, at 100-RPM increments. A squat-settlement test was also completed on this vessel in 2013, which yielded very similar results. However, results were slightly noisier for this 2014 test. This range encompassed the RPM settings used during survey operations. Therefore, a few data points were carried forward or modified based on the 2013 results, as noted in Figure 18.

RPM	Dynamic Draft (m) (positive down)	Comments
600	0.011	
700	0.014	Interpolated between 600-800
800	0.017	From 2013 squat-settlement
900	0.034	
1000	0.059	
1100	0.067	
1200	0.063	
1300	0.053	From 2013 squat-settlement

Table 26 – R/V Q105 settlement results.

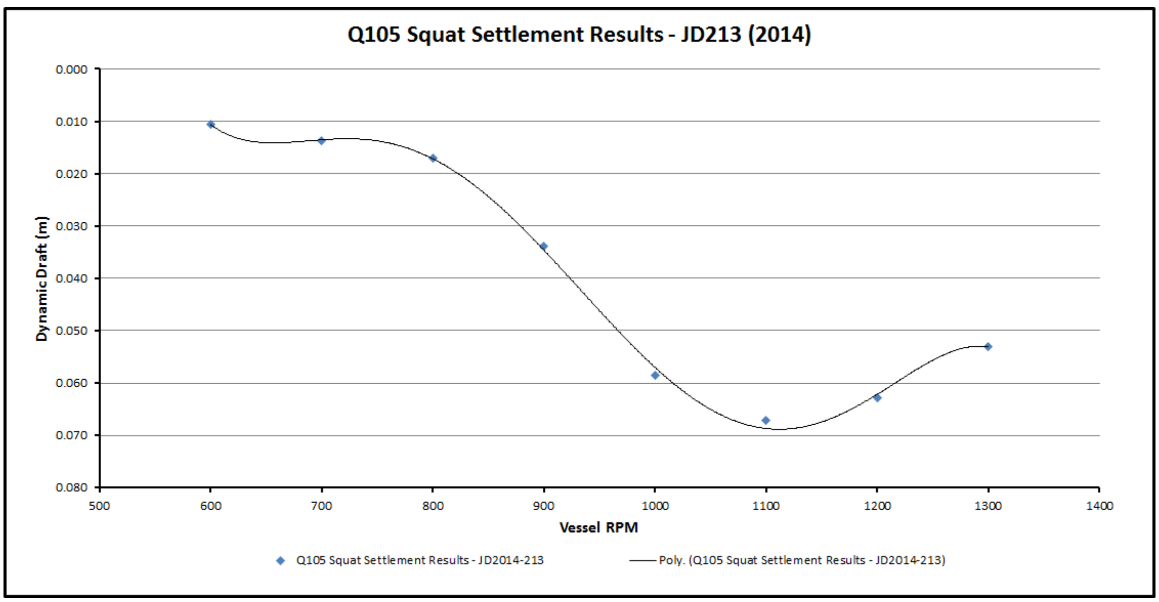


Figure 18 – Q105 settlement results. Vertical units are meters, positive down.

C.6.3. *Cutwater Dynamic Draft Results*

A squat settlement test was completed on the *Cutwater* on JD185. RPM values between 800 and 1800 were tested, at 200 RPM increments. This range encompassed the RPM settings used during survey operations.

RPM	Dynamic Draft (m) (positive down)
800	0.023
1000	0.034
1200	0.041
1400	0.052
1600	0.061
1800	0.056

Table 27 – Cutwater settlement results.

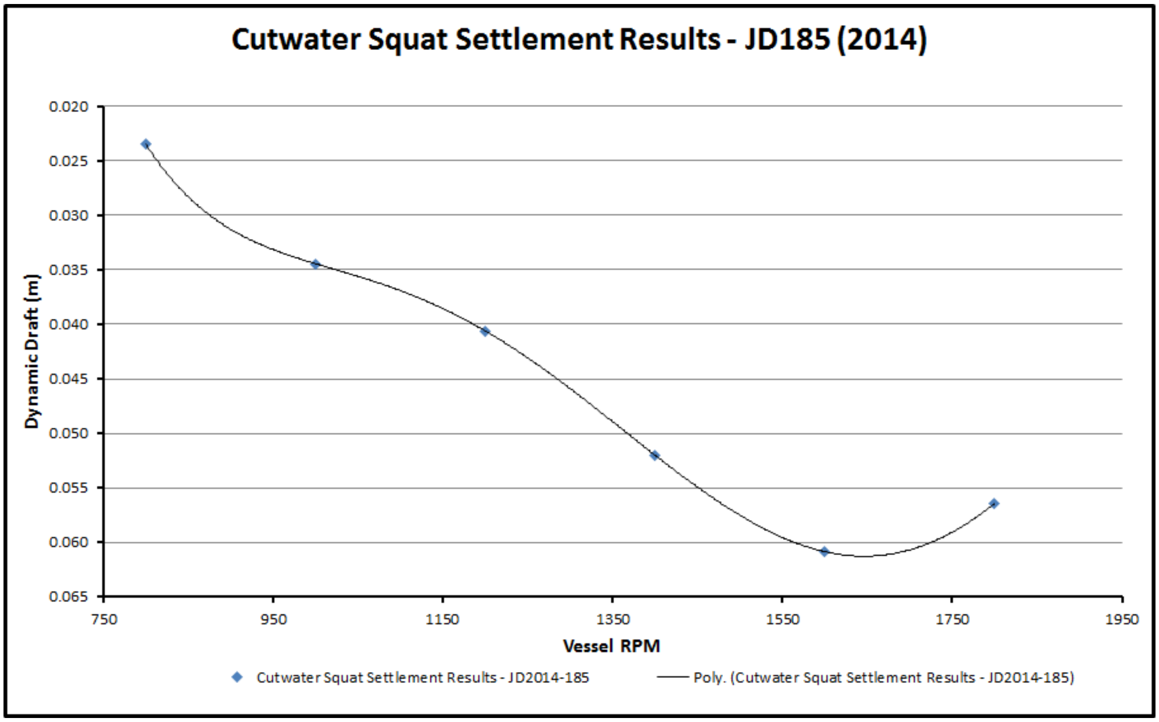


Figure 19 – Cutwater settlement results. Vertical units are meters, positive down.

C.6.4. Spare RHIB Dynamic Draft Results

A squat settlement test was completed on the *Spare RHIB* on JD225 (finished on JD227). Speed values from 2.3 knots to 11.5 knots were tested. This range encompassed the speeds used during survey operations. Note a best-fit polynomial curve (shown in the graph of Figure 20 along with the original data points) was used to interpolate and smooth data at a 0.1 knot interval. The speed-draft table in the HVF used for final corrections is the interpolated data.

Speed (knots)	Dynamic Draft (m) (positive down)
0.000	0.000
2.300	-0.014
2.875	0.012
3.400	0.015
4.025	0.014
4.775	0.013
5.225	0.028
5.763	0.025
6.113	0.005
6.600	-0.002
7.250	-0.039
8.325	-0.036
11.450	-0.106

Table 28 – Spare RHIB settlement results.

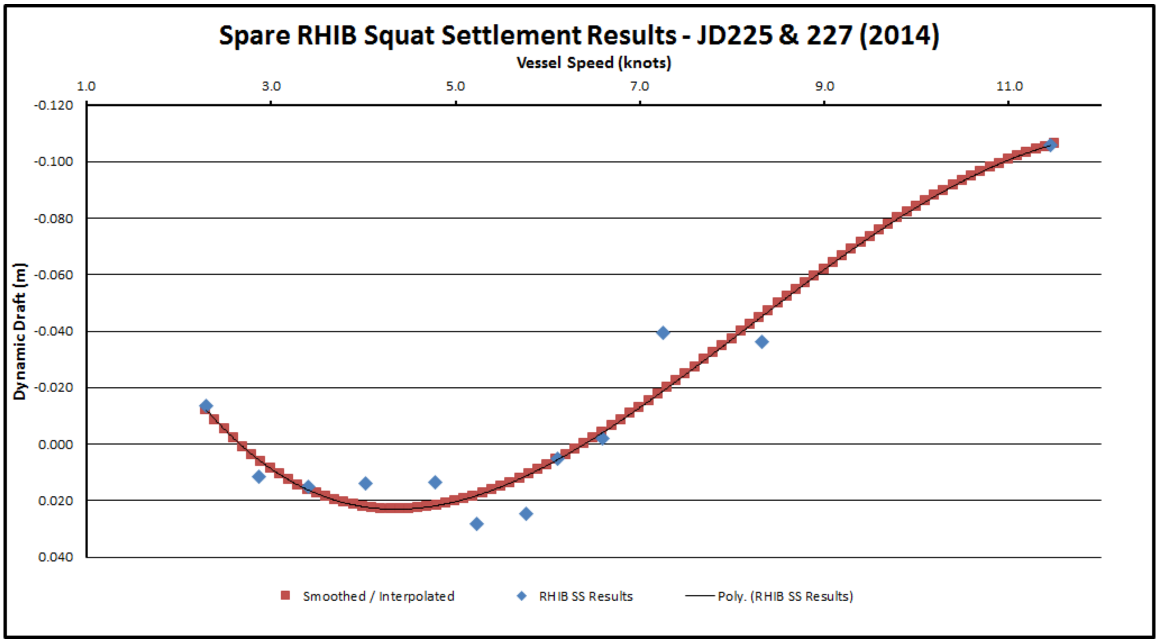


Figure 20 – Spare RHIB settlement results. Vertical units are meters, positive down.

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. Four subordinate tide stations were installed to provide tide corrections. Seven separate, temporary BMPG submersible gauges were deployed across the survey area to provide zoning data. The NWLON tide station at Unalaska was also used for tide corrections. Data from all gauges were used to derive a zone definition file (ZDF) which contained time and range correctors by area across the survey area, as well as estimated gauge and zoning errors. The ZDF is available with the CARIS deliverables. Refer to the project HVCR for more detail regarding tidal corrections.

APPROVAL SHEET

For

H12630 through H12632

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.

2014.12.23
18:15:39
-09'00'
Palmer, AK

Andrew Orthmann
NSPS-ACSM Certified Hydrographer (2005), Certificate No. 225
Charting Program Manager
TerraSond Limited