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-P385-KR-13

Time Frame June – July 2013

LOCALITY

State ALASKA

General Locality Cook Inlet

Sub Locality Knik Arm to Fire Island

2013

CHIEF OF PARTY

ANDREW ORTHMANN

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DATE

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NOAA FORM 77-28 (11-72) U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION HYDROGRAPHIC TITLE SHEET	REGISTER NO. **H12542**
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 Cook Inlet

Locality Knik Arm to Fire Island

Scale 1:10,000 Date of Survey June 15 to July 11, 2013

Instructions Dated April 30, 2013 Project No. OPR-P385-KR-13

Vessel M/V *Luna Sea*

Chief of party Andrew Orthmann

Surveyed by TERRASOND PERSONNEL (T. DePriest, E. Edwards, M. Krynytzky, C. Priest, S. Shaw, J. Theis, K. Wade, M. Hildebrandt ET. AL.)

Soundings taken by echosounder, hand lead, pole ECHOSOUNDER – (HULL 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-P385-KR-13

November 26th, 2013

Anchorage, Alaska Shoreline

Vessels: ***M/V Luna Sea***

General Locality: ***Cook Inlet, Alaska***

Sub Locality: ***H12542 – Knik Arm to Fire Island***

Lead Hydrographer: ***Andrew Orthmann***

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A. Equipment

A.1. Echosounder Systems

To collect sounding data, this project utilized an Odom Echotrac CV100 Single Beam Echosounder (SBES) system.

A.1.1. Single Beam Echosounders

One Odom Echotrac CV100 system was used on this survey.

The Odom Echotrac CV100 is a digital imaging echosounder, which utilizes Odom eChart software to serve as the user interface. The survey systems were coupled to single-frequency (200-kHz) transducer.

Power, gain, depth filters and other user-selectable settings were adjusted, as necessary, through eChart to maximize data quality. The system was configured to output bathymetric data via Ethernet network connection to an acquisition PC running HYPACK software, which logged .RAW and .BIN files.

Echotrac CV100s are all-digital units that do not create a paper record. In lieu of paper records, the .BIN files contain the bottom tracking information, which is converted and viewable in CARIS HIPS Single Beam Editor.

Echosounder accuracy was checked by bar check methods on three separate occasions (JD173, JD182, and JD189), with processed echosounder results comparing to better than 0.01 m of the expected result of the bar depth. Comparison lead lines were also taken on JD182 and JD189, with processed depths comparing to 0.20 m or better of the lead line depth, which was considered acceptable results given the difficulty of completing lead lines in this high current environment. Echosounder accuracy test results are available in Appendix II of this report.

See Table 1 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 1– Odom Echotrac CV100 single beam echosounder technical specifications.

A.2. Vessels

All hydrographic data for this survey was acquired using the survey vessel M/V *Luna Sea.* A landing craft vessel, the M/V *My Marie,* was also used to assist with tide gauge installation.

A.2.1. M/V *Luna Sea*

The M/V *Luna Sea*, owned and operated by TerraSond Limited, was used to collect all hydrographic data for this survey. It is a 12.8 meter (m) aluminum hulled vessel with a 3.6 m beam and a 1.4 m draft. The vessel is powered by twin 420 hp Caterpillar inboard engines. Depending on the equipment requirements, electrical power was provided by an AC inverter or directly from the vessel 12V DC system.

Figure 1 – M/V Luna Sea in the project area

For this survey, the M/V *Luna Sea* was outfit with an Applanix POSMV 320 V4 to provide attitude and positioning. An Odom SMBB200-3 transducer (200 kHz/3° beam width) was hull-mounted aft of the main cabin near the vessel centerline and interfaced with an Odom Echotrac CV100 single beam echosounder (SBES) system to provide sounding data. A Trimble 5700 GPS system as well as a Trimble DSM GPS system were also installed for independent positioning checks for both real-time operations and post-processed kinematics. 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.

During this survey the vessel experienced numerous mechanical breakdowns, usually resulting in the shutdown of one or both engines. However, these had no effect on survey data quality since the vessel stopped surveying and returned to dock each time until the issue was resolved.

The survey equipment on the M/V *Luna Sea* performed within normal parameters with no major issues encountered.

M/V *Luna Sea* Survey Equipment

Description	Manufacturer	Model / Part	Serial Number
Single Beam Sonar	Odom	Echotrac CV100	3505
Single Beam Transducer	Odom	SMBB200-3	TR7940
Positioning System	POSMV	320 V4	3167
Motion and Heading	POSMV	320 V4, IMU	778
Check GPS	Trimble	5700	440100987
SV Casting Probe	AML Oceanographic (formerly Applied Microsystems)	SV Plus v2	3279 and 3259
SV Casting Probe	Odom	Digibar	2992
RTK Signal Receiver	Sierra Wireless	LS300 Modem	CA80733048110

Table 2 – Major survey equipment used aboard the M/V Luna Sea.

A.2.2. M/V *My Marie*

The M/V *My Marie*, owned and operated by Hylite Fabrication LLC of Palmer, Alaska, was used for tide gauge installation and retrieval, as well as deployment and recovery of SeaBird submerged tide gauges. It is a 12.8 meter (m) aluminum hulled landing craft with a 3.2 m beam and a 0.5 m draft. The vessel is shown in Figure 2.

Figure 2 – M/V My Marie

The M/V *My Marie* was temporarily equipped with a Trimble 5700 GPS receiver coupled to a dual-frequency Trimble Zephyr Geodetic antenna to provide 3D positioning over

SeaBird deployment locations. Data logged with the Trimble 5700 was later post-processed using simultaneous data logged at the nearby Port of Anchorage base station (POA2) and used for ellipsoid-MLLW modeling purposes.

Figure 3 – Trimble 5700 logging data on the M/V My Marie.

M/V *My Marie* Survey Equipment

Description	Manufacturer	Model / Part	Serial Number
GPS Positioning	Trimble	5700	0220275240

Table 3 – Survey equipment used aboard the M/V My Marie.

A.3. Speed of Sound

Speed of sound data was collected by vertical casts on the M/V *Luna Sea* using Applied Microsystems (AML) SV Plus v2 (AML SV+) sensors and an Odom Digibar. The sensors were factory calibrated prior to the start of survey operations and then normally compared on a weekly basis to each other.

AML SV+ with serial number (SN#) 3259 was used for sound speed corrections until JD173, when for unknown reasons it began to give obviously erroneous values during a weekly comparison with an Odom Digibar. On that day, the instrument was removed from the project and replaced with a spare AML SV+ (SN# 3279), which was then used as the primary source of sound speed corrections through the end of the project. Although AML SV+ SN# 3259 was never directly compared to an alternate sound speed source during the project, it was factory calibrated prior to the season and produced reasonable corrections well within the normal range experienced in the area during its pre-JD173 operational period.

Sound speed profiles were taken as deep as possible in order to capture sound speed through the entire water column. Sound speed profilers were lowered by hand and extended to the sea floor in most instances. However, on occasion, swift currents prevented the profiler from reaching all the way to the sea floor.

Profiles were collected primarily in the center of the survey area and thus, are not well distributed geographically. Due to the extreme tidal currents and resulting lack of sound speed stratification in the water column (mixing), along with the relatively small size of the survey area, it was deemed more advantageous to data quality to obtain profiles near the center of the area.

Sound speed casts were taken daily, on an interval of 12-hours, or less, during SBES operations. Exceptions, if they occurred, were rare and are noted in the applicable Descriptive Report (DR).

In general, sound speed profiles were consistent with well-mixed conditions, showing only small variances (on the order of 2-3 m/s) through the water column and between casts.

As a confidence check, the SVP probe was compared to a second SVP probe on a weekly basis during survey operations. These checks occurred on JD176, JD184, and JD189. Results were good, with the probes always comparing to better then 1 m/s at all depths, but usually comparing to 0.5 m/s or better.

Refer to the CARIS HIPS .SVP file submitted with the deliverables for profile positions, collection times, and data. Refer to the DR, *Separate II: Sound Speed Data* for the sound speed comparison checks.

Copies of the manufacturer's calibration reports are included in the Appendix IV of this report. The instruments in Tables 4, 5 and 6 were used to collect data for sound speed.

A.3.1. Sound Speed Sensors

Sound Speed Profiler	Manufacturer	Serial Numbers	Calibration Date
SV Plus v2	Applied Microsystems, Ltd. Sydney, British Columbia, Canada	3279 and 3259	5/3/2013 by AML Oceanographic
Digibar Pro	Odom Hydrographic Systems, Inc. Baton Rouge, Louisiana	002992	3/28/2013 by Odom Hydrographic

Table 4 – Sound speed gauges and calibration dates.

A.3.2. Sound Speed Sensor Technical 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 5 – 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 6 – Odom Digibar Pro specifications.

A.4. Positioning and Attitude Systems

The M/V *Luna Sea* was configured with an Applanix POSMV 320 V4 system as the primary source of vessel positioning, motion, and heading. The POSMV system consists of two dual-frequency Trimble Zephyr antennas and an inertial measurement unit coupled to a topside processor.

For real-time GPS corrections, the POSMV was connected to a Sierra Wireless cellular modem, which received Real-Time Kinematic (RTK) corrections transmitted from the project base station established by the survey crew at the Port of Anchorage over cellular network.

Additionally, the POSMV recorded all raw data to .POS files, which were logged continuously during survey operations. This enabled post-processing of the GPS 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 (TrueHeave) to all sounding data.

For PPK 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. A subset of the T5700 data was later post-processed in Applanix POSPac POSGNSS software and compared to the POSMV data, with good results.

For real-time position confidence checks, a Trimble DSM 232 was utilized. The unit was set to utilize USCG DGPS corrections and output a position to HYPACK, which displayed the DSM position simultaneously with the POSMV position on the navigation display. This allowed the HYPACK operator to continuously ensure the POSMV was generating a reasonable position.

HYPACK provided time sync between systems (including the PC clock) using UTC time. For the UTC time source, HYPACK received a ZDA string output by the POSMV at a rate of 1 Hz.

Positioning confidence checks are available in Appendix III of this report.

A.4.1. Position and Attitude System Technical Specifications

POSMV 320 V4		
Code Differential GPS Positioning	Positioning Accuracy	0.5 – 2 m (1 sigma)
	Roll, Pitch Accuracy	0.02 degrees (1 sigma)
Kinematic Surveying	Positioning Accuracy	0.02 – 0.10 m (1 sigma)
	Roll, Pitch Accuracy	0.01 degrees (1 sigma)
Heave Accuracy		5 cm or 5% (whichever is greater) for periods of 20 s or less
Heading Accuracy		0.02 degrees (1 sigma)
Velocity Accuracy		0.03 m/s horizontal

Table 7 – Applanix POS MV V4 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 8 – Trimble 5700 technical specifications.

DSM 232		
Code Differential GPS Positioning	Horizontal Positioning Accuracy	Less than 1 m
Kinematic Surveying	Horizontal Positioning Accuracy	0.01 m + 1 ppm
	Vertical Positioning Accuracy	0.02 m + 1 ppm

Table 9 – Trimble DSM 232 technical specifications.

A.5. Dynamic Draft Corrections

Dynamic draft corrections based on engine RPM were determined using PPK GPS methods for the vessel with standard squat settlement calibration procedures. Corrections were determined for a range that covered normal survey speeds and engine RPMs.

To track engine RPM data, each engine was outfit with TerraSond TerraTach MKII units. The TerraTachs, which were designed in-house, were mounted near both engines and configured to directly count the revolutions-per-minute of the engine crankshafts and output the computed value at a rate of 1 Hz to TerraTach software, which time-tagged and logged the data to text files for later processing.

On this project, the port-side TerraTach functioned properly for only a short time and was not used for processing. However, the starboard-side TerraTach continued to function normally for the majority of the project. It was deemed sufficient to use starboard-only RPM data to represent average engine RPMs, since both engines were ordinarily operated at the same settings.

Further information is available in Sections B and C of this report.

A.6. GPS Base Stations

One GPS base station was installed on a building's rooftop in the secure area of the Port of Anchorage. Due to the relatively small size of the project area, one base was sufficient to adequately provide required positioning precision for the full area. The port was centrally located in the survey area and the base station installation there allowed for a maximum baseline of 20 kilometers, though typically much less.

The base station consisted of a Trimble NetRS GPS receiver with Zephyr Geodetic antenna interfaced with Sierra Wireless modem attached to a portable cellular antenna. Two 12V gel cell batteries interfaced to an AC float charger provided power for the base, a configuration that allowed operations to continue in the event of power failure.

The GPS antenna was firmly mounted above the building roofline with little or no masking. The receiver was 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 cellular network. The cellular data link also enabled the station to be accessible over the Internet for QC and data retrieval.

Station Name	GPS Receiver	Antenna	Rate	RTK Broadcast	Additional Equipment
POA2	Trimble NetRS SN#4412232926 Firmware V1.3.2	Trimble Zephyr Geodetic (TRM41249) SN#12682207	1 Hz	Continuously Broadcasting CMR+	Sierra Wireless Cell Modem

Table 10 – RTK base station equipment, power and download configurations.

The vessel was configured to receive the RTK CMR+ signal via a Sierra wireless cellular modem, which output the correction message to the vessel POSMV to compute an RTK solution. Signal reception was very good throughout the project area, although occasional brief signal loss did occur.

The base station data was downloaded from TerraSond's Palmer, Alaska office at least once per day, in order to post-process the prior day's POSMV data. Daily checks of proper operation of the NETRS (including satellite tracking, power levels, and logging status) were also made. The stability of the base station mount and accuracy of the position solution were checked at least weekly using position confidence checks, with excellent results. See Section B of this report for more information regarding base station position confidence checks.

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+

Table 11 – Trimble Net RS specifications.

A.7. Tide Gauges

A.7.1. Subordinate Stations

Two subordinate, shore-based tide stations were installed at historic U.S. Coast and Geodetic Survey locations at Goose Bay (946-5374) and Fire Island (945-5912), AK, to provide water levels and supplement data from the NWLON station in Anchorage (945-5920). To install, monitor, and uninstall the subordinate stations, TerraSond subcontracted JOA Surveys, LLC (JOA) of Anchorage, AK.

A total of five WaterLOG series DAA H350XL bubbler gauge with NOAA GOES radio systems were installed. Two were installed at the Goose Bay station, while three were installed at the Fire Island station. Data from the tide gauges were monitored remotely via the NOAA GOES satellite system and downloaded daily, corrected for meteorological influences, and checked against periodic staff observations.

The WaterLOG gauges were calibrated prior to the start of survey operations and checked for accuracy following demobilization. In the field, they were installed in multiples for redundancy and as checks on each other. Additionally, their installation stability was checked weekly to bi-weekly by way of staff shot observations.

Overall, the WaterLOG systems at the subordinate sites performed well. However, extreme current and sedimentation at the Goose Creek site led to outages and stability issues with one of the two systems there. The issues, which were addressed and corrected in the field, are described in more detail in JOA's supplementary records included with the Horizontal and Vertical Control Report (HVCR).

A.7.2. Bottom Mounted Pressure Gauges

In addition to the shore-based subordinate tide stations, bottom mounted pressure gauges (BMPGs) were also deployed offshore in the survey area. For this survey, Sea-Bird SBE 26plus Wave and Tide Recorder submersible tide gauges ("Seabirds") were utilized. Two Seabirds were used to log data at four separate deployment locations during survey operations. Due to past experience with non-recovery of bottom-mounted instruments in Cook Inlet due to the extreme currents and high sedimentation rates, deployments were limited to approximately 10 days. Deployment locations were strategically chosen to provide additional data points between the subordinate shore stations for tide modeling purposes.

The Seabirds were synced to UTC and set to log at a 6-minute interval using a 180 second averaging period and logged to internal memory. The gauges were downloaded upon retrieval. Barometric pressure was downloaded from Anchorage and Palmer Airport barometers to provide atmospheric pressure corrections, depending on proximity of the Sea-Bird to each airport during the comparison period.

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

Refer to the HVCR for detailed 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 12 – 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 13 – Sea-Bird SBE26plus specifications.

A.8. Software Used

A.8.1. Acquisition Software

The vessel was outfitted with a dual-core PC running Windows XP for data echosounder acquisition and log keeping. Additionally, a quad-core laptop running Windows 7 Professional was utilized for POSMV and RPM data logging. A summary of the primary software installed and used on these systems during data collection follows:

- HYPACK hydrographic data acquisition software was used on the acquisition vessel for navigation and to log all bathymetric, position and sensor data to .RAW, and electronic single beam "paper" trace to .BIN format.
- Odom eChart served as the interface with the Odom Echotrac echosounder and 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 Trimble 5700 receiver prior to data acquisition by the vessel.
- Hyperterminal and/or Putty were used to communicate with the AML SV+ sound profilers. This software allowed the technician to change settings on the profiler as well as download the data to a text file to be used by processing.
- Sea-Bird Seasoft was used to configure the Sea-Bird tide gauges prior to deployment and to download the data after retrieval.
- POSMV POSView was used as the interface with the POSMV. The software was used for initial configuration and GAMS calibration, and on a daily basis for real-time QC of the POSMV navigation and attitude solutions. The software was also used to continuously log a ".POS" file during survey operations. The POS file contained the raw accelerometer and GPS data necessary for post-processing, which was done later in Applanix POSPac MMS software in conjunction with base station data. The POS file also contained TrueHeave records, which were loaded into each survey line in processing.
- TerraTach, an in-house software package, was used to log RPM data generated by the TerraTach tachometer to file.
- TerraLog, an in-house software package, was used to keep digital logsheets for all echosounder, POS MV, and sound velocity files.

Program Name	Version	Date	Primary Function
HYPACK	13.0.0.6	2013	Single beam acquisition suite and navigation
Odom eChart	1.4.0	2010	Single beam echosounder interface
Trimble Configuration Toolbox	6.9.0.2	2010	Trimble 5700 interface
HyperTerminal / Putty	0.60	2007	Configuration and download of AML SV Plus v2 and Odom Digibar sound speed sensors
Sea-Bird Seasoft	2.0	2011	Configuration and data download for Sea-Bird SBE26 Plus tide gauges
Applanix POSView	3.4.0.0	2007	POSMV set up, monitoring and logging
TerraTach	3.0	2013	Log RPM data
TerraLog	1.1.0.6	2013	Log keeping

Table 14 – 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, configured for NOAA Extended Attributes version 5.3.2, was used to create the S-57 deliverable. Survey extents were imported, edited, and assigned attributes and exported to S-57 format.
- ESRI ArcGIS was used for pre-survey line planning preplots, 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 6.2 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, while POSGNSS was used to post-process Trimble 5700 data.
- TerraLog, an in-house multi-purpose software package, was used to process sound speed profiles and keep track of processing work completed on lines, drafts, depth checks, PPK files, and others.

Program Name	Version	Date	Primary Function
CARIS HIPS and SIPS	7.1.2 8.0.2	2012	Hydrographic data processing. Note: 8.0.2 was used only briefly at the start of the project and abandoned to use the more stable 7.1.2
CARIS Notebook	3.1.1	2011	Feature attribution and creation of S-57 deliverables
ESRI ArcGIS	9.3.1	2009	Desktop mapping software
Applanix POSPac MMS	6.2	2013	Post-processing kinematic GPS data from POSMV
Applanix POSPac POSGNSS	5.3	2013	Post-processing kinematic GPS data from Trimble 5700
Microsoft Office	2010	2010	Logsheets, reports and various processing tasks
TerraLog	1.1.0.6	2013	Keeping notes, reporting, process SVP casts

Table 15 – Software used during processing and reporting.

A.9. Bottom Samples

Bottom samples were not acquired for this survey.

A.10. Shoreline Verification

Shoreline verification was not acquired for this survey.

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 was used for the single beam 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. HYPACK

HYPACK data acquisition software was used to log all single beam data and to provide general navigation for survey line tracking. The software features a number of quality assurance tools, which were taken advantage of during this survey.

Using the raw echosounder depth data, HYPACK generated a real-time digital terrain model (DTM) during data logging that was tide and draft corrected. To accomplish real-time tide correction, HYPACK applied a user-specified datum offset to the RTK altitude provided by the POSMV. This offset was entered by the survey crew into HYPACK using a single preliminary MLLW to ellipsoid separation value established for the Anchorage tide station.

The DTM was displayed as a layer in the HYPACK "Navigation" view. 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 GeoTIFFs exported from CARIS HIPS, 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 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:

- Simultaneous display of independent Trimble DSM position on the navigation window as real-time position reality checks.
- Alarm for loss of ZDA timing sync or positioning data from POS MV.
- Alarm for loss of attitude or positioning data from POSMV.
- Alarm for age-of-RTK correction exceeding 10 seconds.
- Alarm for loss of sonar input.

It should be noted that HYPACK automatically breaks and restarts RAW file logging at the Julian day rollover. This process takes a few 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 gap along-track lasting for 2-3 second. These small gaps are rare and were deemed insignificant, and re-ran only when necessary to better delineate a feature.

B.2.2. Draft and Sound Speed Measurements

Vessel static draft was measured at least once daily, as well as events causing potential significant change in draft such as fueling. 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 with an effort made to ensure that the vessel was loaded similarly to that experienced during survey operations. 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).

Sound speed profiles or “casts” were collected normally at a 12-hour (once per shift) interval during SBES data collection. Analysis of the sound speed variance in the survey area showed that more frequent profiles were unnecessary as there was typically little variation between profiles in this well-mixed environment.

Profiles were collected primarily in the center of the survey area and are thus not well distributed geographically. Due to the extreme tidal currents and resulting lack of sound speed stratification in the water column (mixing) along with the relatively small size of the survey area it was deemed more advantageous to data quality to obtain profiles near the center of the area.

Deployed by hand, the sound speed sensor was held at the surface for approximately one minute to achieve temperature equilibrium before being lowered slowly to the bottom (typically no more than 1 meter/second) and raised by hand in the same fashion. Though effort was made to ensure the probe reached the sea floor, on occasion, swift currents prevented this. 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 geo-tag and a timestamp. This greatly reduced the possibility of applying incorrect positions or timetags when later processing the cast.

B.2.3. Logsheets

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

TerraLog was designed to replace Excel-based logsheets for common log keeping tasks. Its primary purpose is to simplify 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 geo- 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 geo-tag all events. It was also configured to receive a RPM data string from TerraTach, which enabled TerraLog to automatically record RPM data with line events as well.

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 (.SDF file format). 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.

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.

The field SDF file covering each shift's data set would accompany the raw data to the office, where it would be merged with a master SQL server database file, which could be accessed by data processing personnel. Data processing personnel then continue taking the raw data through the processing workflow, tracking edits and corrections in TerraLog in context of the readily accessible acquisition-recorded information. Task completion and details of common processing tasks tracked in TerraLog included:

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

Figure 4 is an example of the TerraLog line processing interface.

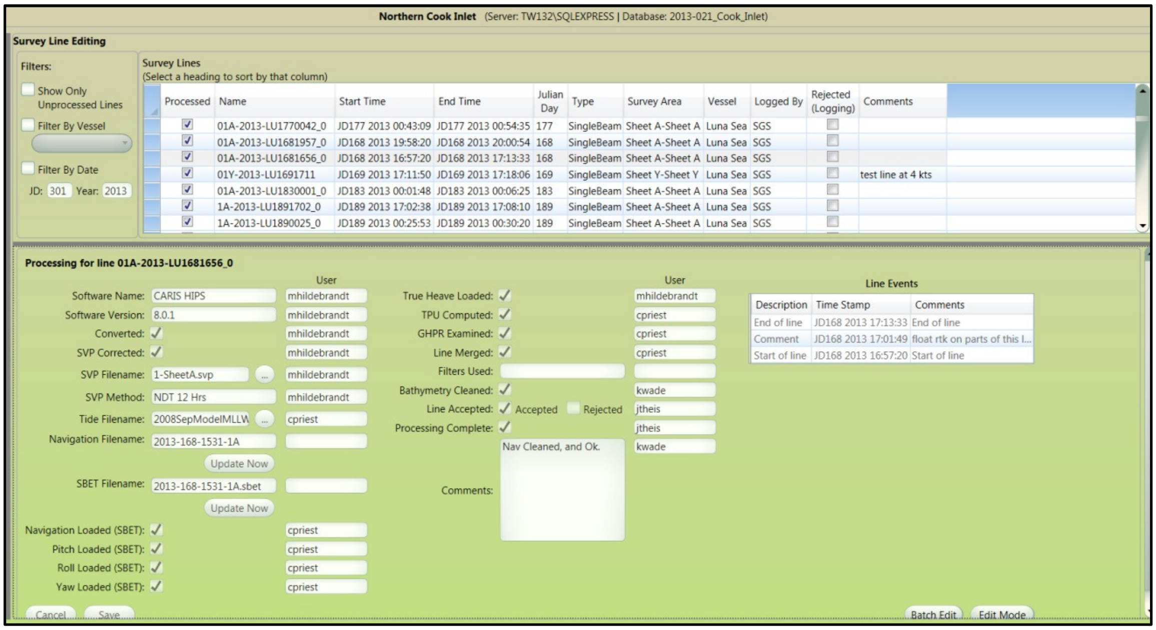


Figure 4 – TerraLog interface for line processing.

Following processing, logsheets were exported from TerraLog to PDF, which are available in the DR, *Separates I: Acquisition & Processing Logs*.

B.2.4. Base Station Deployment

One base station was installed prior to bathymetric data acquisition, and remained until survey operations were completed. The specific equipment utilized was described in Section A of this report.

In order to maximize base station data quality, care was taken to choose an optimum base station location that would cover the survey area. A building at the Port of Anchorage was ultimately selected for the following attributes, in order of importance:

- Little or no GPS satellite masking.
- Proximity to the survey area – largest baseline was 20 kilometers, though most of the area was much less.
- Close to vessel mooring dock, allowing survey crew easy physical access for inspection or maintenance, if necessary.
- In secure area of the port.
- 120V AC power available, minimizing complication of add-on power systems.

Installation of a secondary, or backup, GPS station was deemed unnecessary for this project due to the relative abundance of CORS (continuously operating reference stations) sites nearby in the Anchorage area, which could be used if necessary. Note that photos are not available of the base station for this project due to restrictions in place by the Port of Anchorage preventing the taking of photos in a secure area.

During deployment, the GPS antenna was leveled and secured to the side of a building with sufficient clearance from the building and roof to enable a clear view of the sky and prevent satellite masking. Battery voltage, logging status and other important parameters were logged in a base station deployment logsheet.

During the survey, proper operation was checked at least once daily. Real-time checks included battery voltage, logging status, and confirmation of satellite tracking. Data was also downloaded at least once daily, converted to Rinex format, and used to process the prior day's vessel GPS data – a process which served as a check on data integrity, as any issues with base station data quality would manifest itself as positioning problems during processing.

As a confidence check on antenna 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. Results were excellent with all subsequent measurements at 0.013 m, or better. The base station deployment logsheet, as well as base station confidence checks, are available with the project HVCR.

B.2.5. 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 16 lists raw data files commonly created in acquisition and transferred to data processing.

Type	Description		Example / Format
RAW and BIN	HYPACK Files: Bathy Data		Vessel/Sheet-Year/Boat/Day/Time
	Line Type	**Prefix**	**Example**
	Mainscheme Line	*VesselSheet-*	**1A-2013LU1680005.RAW**
	Cross Line	*VesselSheetXL-*	**1AXL-2013LU1831858.RAW**
	Test / Check / Lead Line / Bar Check	*VesselY-* *enter a comment for line purpose*	**1Y-2013LU1902357.RAW**
SVP	Text file from Digibar or AML		**1A-2013-190-1400.DIGI**
			1A-2013-190-1400.AML
			VesselSheet-Year-JD-Time.instrument

HEX	Raw file from Seabird tide gauge		*Location-SerialNumber-Year-StartDay-EndDay*
			A3-SN1221-2013-145-1522.HEX
T01	Trimble 5700 binary file (navigation)		
	Station	**Receiver SN**	**09871740.T01**
	Luna Sea	0987	*ReceiverSN/JD/FileSequenceNumber*
T00	Trimble NetRS binary file		
	Station	**ID**	**POA201306150000a.T00**
	Port of Anchorage	POA2	*Station_ID/Date/StartTime*
A0x	Bubbler download files from tertiary tide stations		**94628081.A05**
			Station_ID/JD/Sequential
POS	Raw positioning data (.000 file) from POSMV		**2013-177-1713-1A.POS**
			Year-JD-StartTime-VesselSheet
SDF	TerraLog logsheet data in SQL database format		**LunaSea-182.sdf**
			Vessel-JD

Table 16 – Common raw data files.

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 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 survey shift the data was consolidated and copied to a thumb drive and handed over to the Lead Processor in the office, who checked the raw data against the logsheets to ensure all files were included, then transferred the data to the office server, where the data was backed-up and processing began.

B.3. Data Processing

Data processing was carried out at TerraSond's Palmer, Alaska office.

Following transfer from the field, 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 within one day of acquisition, providing relatively rapid coverage and quality determination.

When preliminary processing of the data was completed – normally within one day – a data processing report was passed back to the field crew in order to relay general data quality feedback, or other specific issues. Approximately twice a week, a coverage .TIF file was generated from preliminary processed CARIS HIPS data and delivered to the field crew to display in HYPACK for progress tracking to ensure coverage requirements were being met.

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 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 software was used to create a directory structure organized by project, vessel and Julian day to store data. The RAW files written by HYPACK were imported into CARIS HIPS using the conversion wizard module (HYPACK RAW option). 1470 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 file to travel time for later sound speed correction. The wizard created a directory for each line and parsed the RAW components into sub-files, which contained individual sensor information. The BIN files, 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. 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. The static draft PDF report exported from TerraLog is available in each DR, *Separate I: Acquisition and Processing Logs.*

B.3.2. Load TrueHeave

Prior to sound speed correction, TrueHeave, or "delayed heave," was loaded into all survey lines. CARIS HIPS "Load TrueHeave" utility was utilized for this purpose, which pulled the TrueHeave records logged to POS file into each survey line. The TrueHeave records, when present, were utilized by CARIS HIPS by default for heave correction.

Additional processing was performed on the TrueHeave records for all lines run up through and including JD170 (06/19/13) to resolve an incorrect POSMV setting. The "Ref to Center of Rotation Lever Arm" setting, which should have had zero values for X, Y, Z, was found to have a remnant setting from a prior project. The setting, which affects Heave and TrueHeave computation only, resulted in non-zero values (Heave and TrueHeave that did not average out to zero), because the computation used pitch and roll to compensate for a non-existent offset point. The approximate magnitude of the error was 0.05 to 0.10 m. This was remedied on lines run from JD173 onwards by using the correct setting, and all affected lines were repaired.

The following process was used in processing to repair the TrueHeave data; TrueHeave was extracted to text file and passed through TerraSond's HeaveXtractor utility, an in-house software package that passed a 20-second moving average filter over the heave data and subtracted the result from each data point. The output was TrueHeave data centered on zero, as desired. The output was then loaded into the affected lines using CARIS HIPS "Generic Data Parser (GDP)" utility as the "Heave" record, and the erroneous "TrueHeave" records were removed. Results were examined and all data was within specifications. Note that as a result of this process, lines up through and including JD170 have TrueHeave applied, but will not appear to have a TrueHeave sensor in CARIS HIPS – the TrueHeave data instead exists within the Heave record. Figure 5 shows an example of this issue.

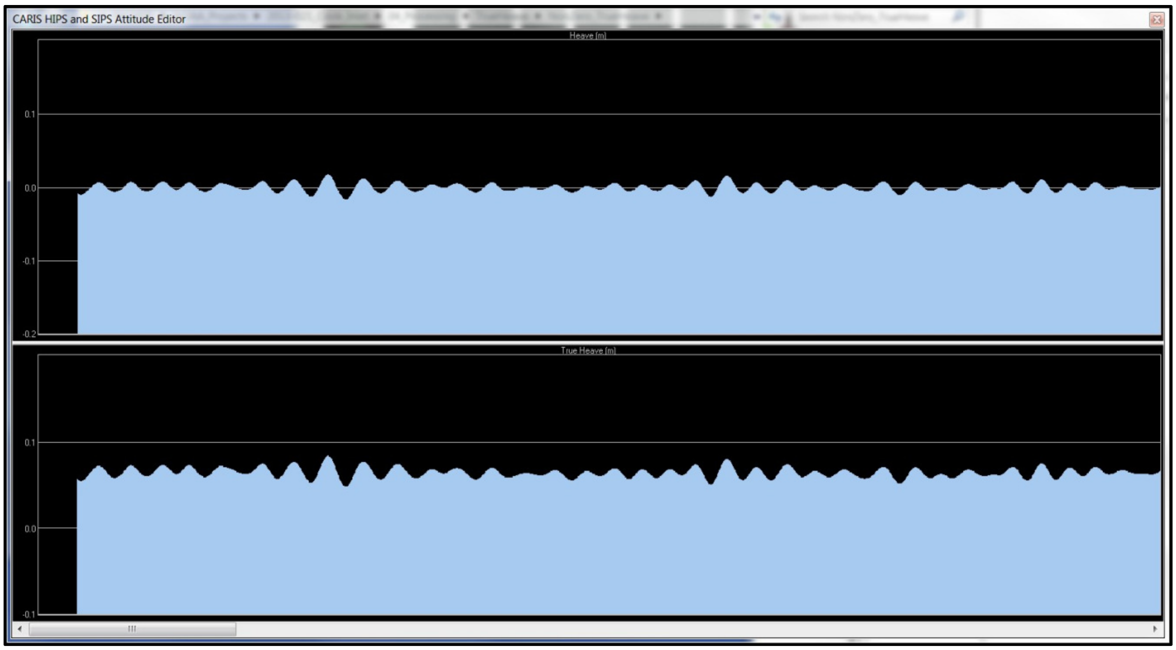


Figure 5 – Example from CARIS HIPS attitude editor showing corrected TrueHeave loaded as Heave (top record) and erroneous TrueHeave (lower record). The TrueHeave record was subsequently removed.

Lines run the beginning of JD174 (1740004 to 1740141) also required TrueHeave to be loaded through GDP, overwriting the Heave records. This was due to the known issue whereby CARIS HIPS TrueHeave utility does not load POS files loaded over the Saturday GPS week rollover. As with the non-zero heave issue, these lines will appear to not have TrueHeave record in CARIS HIPS, though TrueHeave was used.

B.3.3. Sound Speed Corrections

Sound speed profiles (casts) were processed using TerraLog, an in-house software package. During acquisition, the software assigned the cast a timestamp according to the average time recording in the SVP file, and also assigned a geographic position. During processing, TerraLog separated the profile into it's 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 time stamps and positions, and appended to the appropriate master CARIS HIPS .SVP file based on vessel and survey sheet.

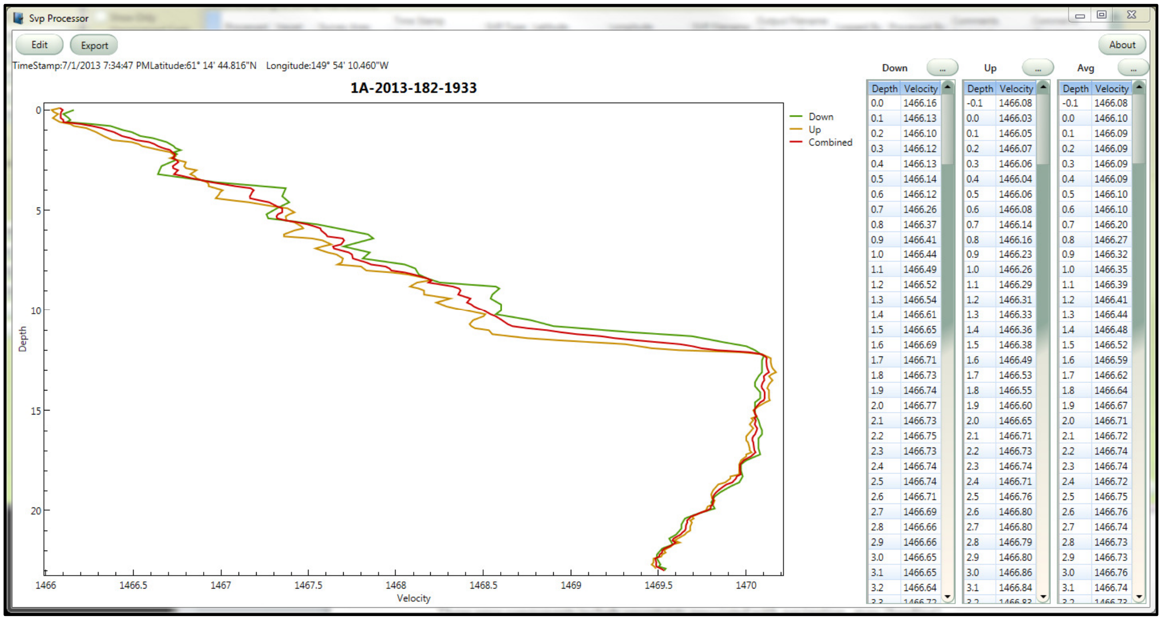


Figure 6 – Example SVP profile editing interface in TerraLog.

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, 12-hours was used. This value was chosen to match the cast interval done in acquisition, which was determined by examining the average variance, or difference between subsequent casts. During SVP correction, the option to apply smoothed delta draft was enabled to smooth spikey dynamic draft data. Any deviations from this method are described in the corresponding DR.

B.3.4. 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 17 describes the TPU values entered in the HVF.

TPU Entry	Error Value	Source
Gyro	0.020°	http://www.caris.com/tpu/gyro_tbl.cfm (Applanix POSMV 320 -- 2m baseline)
Heave	5% or 0.05m	http://www.caris.com/tpu/heave_tbl.cfm (Applanix POSMV 320 -- whichever is higher)
Roll and Pitch	0.010°	http://www.caris.com/tpu/roll_tbl.cfm (Applanix POSMV 320 -- RTK)
Navigation	0.10 m	PPK processing result reports indicate RMS positioning errors better than 0.10 m on average
Timing – (Transducer)	0.01 sec. for Odom SBES	HYPACK was time synced by ZDA time string. HYPACK sync utility indicated this level of sync or better.
Timing – (Gyro, Heave, Pitch, and Roll)	0.01 sec.	HYPACK was time synced by ZDA time string. HYPACK sync utility indicated this level of sync or better.
Offset (X and Y)	0.020 m	It is estimated that the X and Y offsets of the SBES acoustic center relative to the vessel RP were determined to this degree of accuracy.
Offset Z	0.010 m	Estimated accuracy of the Swath1 to RP bar check results.
Vessel Speed	6 knots	6 knots was selected as a place-filler as the max current experienced. However, this does not affect TPU computations because no lines were corrected for dynamic draft using vessel speed (RPM-based corrections were loaded instead).
Loading	0.000 m	0.000 was selected because as an ERS survey, the loading error is accounted for in the RMS error of the GPS vertical positioning.
Draft	0.000 m	0.000 was selected because as an ERS survey, the draft measurement error is accounted for in the RMS error of the GPS vertical positioning.
Delta Draft	0.000 m	0.000 was selected because as an ERS survey, the delta draft measurement error is accounted for in the RMS error of the GPS vertical positioning.
MRU Align StdDev Gyro	1.000°	As an SBES survey the MRU alignment stdev is not readily determinable. This is an estimate of the alignment parameters.
MRU Alight StdDev Roll/Pitch	1.000°	As an SBES survey the MRU alignment stdev for roll is not readily determinable. This is an estimate of the alignment parameters.

Table 17 – TPU values used.

For “MRU to Trans” offsets under “TPU values,” the offset from the POSMV IMU to the sonar was entered.

For “Nav to Trans” offsets, once again, the offset from the POSMV IMU to the sonar was entered. The offset from the primary GPS antenna was not entered because navigation error estimates are for the POSMV computed position of the IMU, not the GPS antenna.

CARIS HIPS “Load Error Data” function was also utilized to load SMRMSG (smoothed RMS) error data into all lines. SMRMSG files, produced by Applanix POSPac 6.2 MMS as part of the PPK process, contain error estimates that are of higher accuracy than the fixed estimates in the HVF. SMRMSG files were applied to all lines at a rate of 1 Hz for position, vertical (down option), roll, pitch, and gyro. During TPU computation the Uncertainty Source was selected as "Error Data," which had the effect of using the SMRMSG data instead of the HVF settings listed in Table 17 for the aforementioned sensors.

Note that all "TrueHeaveRMS" files within the CARIS HIPS directory structure were renamed with an underscore character ("_"). These files were created by CARIS HIPS as part of the Load TrueHeave process. Default CARIS HIPS 7.1 behavior is to use the TrueHeaveRMS for vertical error over all other sources if present, and as an ERS survey, it was more appropriate to use the SMRMSG vertical error estimate instead. Renaming the TrueHeaveRMS files rendered them unreadable by CARIS HIPS during TPU computation, forcing the use of vertical error from the SMRMSG instead.

During TPU computation, a value of 0.000 meters was entered for tide error. As an ERS survey, the positioning of the vessel relative to the ellipsoid is already accounted for in the GPS positioning (in the form of the SMRMSG vertical error), making entry of a value for tide error not applicable.

For tide zoning error, a value was entered that represented the average estimated error associated with the MLLW – ellipsoid separation model by survey block. Specific entries for the tide zoning error varied by sheet (ranging from 0.153 m to 0.206 m) and are shown in Figure 7.

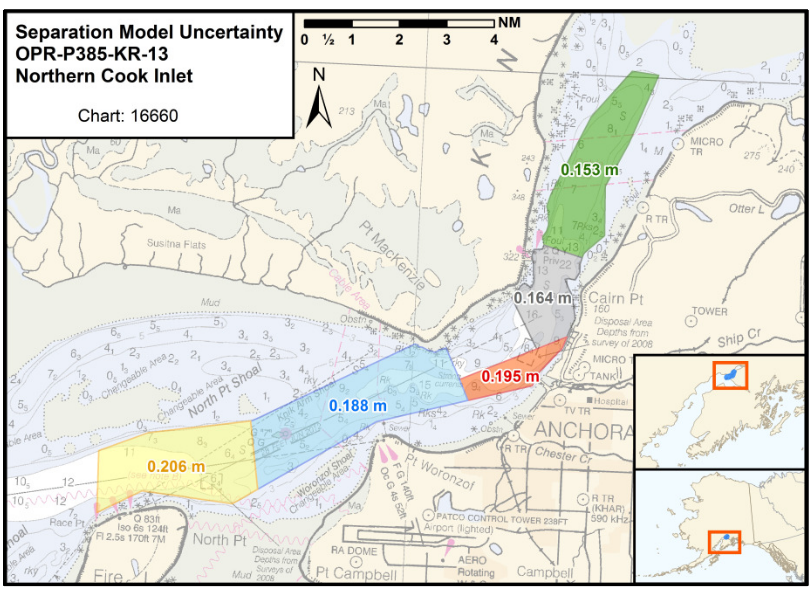


Figure 7 – Separation model uncertainty applied as zoning error by area (values at 1-sigma).

For estimated sound speed error, a value of 1.23 was entered. This value was derived from an analysis of the variance between subsequent sound speed casts. 0.000 was entered for surface sound speed error as surface sound speed was not applicable to this project.

B.3.5. Post-Processed Kinematic GPS

All final positions for this project were post-processed.

Though the project was located within USCG DGPS coverage, the requirement for ERS deliverables necessitated kinematic GPS. A real-time kinematic (RTK) GPS base station (see description A.6 earlier in this report) was established to transmit corrections to the survey vessel, enabling accurate 3D positioning in real-time via cellular link. However, the RTK radio link was still susceptible to interruption and interference. Therefore, post-processed kinematic (PPK) GPS methods were utilized for final positions.

PPK processing for this project utilized Applanix POSPac MMS 6.2 software. POSPac MMS made use of the dual-frequency 1 Hz GPS data logged at the project base station (Rinex format, converted from .T00), the known position of the base station on NAD83, and the raw inertial and positioning data logged from the POSMV (.POS format) to produce a smoothed best estimate of trajectory (SBET) file. The process also produced the SMRMSG file, which contained estimated root mean square (RMS) error for the SBET data, which was loaded and applied as described previously in this report.

To produce the SBET file, a POSPac MMS project was first established using the POS file requiring processing as the source name. Base station data was converted from the native Trimble .T00 format to Rinex using the POSPac "Convert to Rinex" utility and imported into the project, followed by the POS file.

Following successful importation of the base and POS data, the base station position was set to the known ITRF position established by OPUS using an initial 24-hour data set. For this survey, a base station antenna height of 0 meters was used because the ARP of the antenna was the survey reference point for the base station.

Next, the GNSS-Inertial Processor was run. "IN-Fusion Single Baseline" was selected as the GNSS processing mode using the project base station POA2. This performed the actual PPK processing step.

To ensure quality positioning, the QC plots produced by POSPac were reviewed for spikes, or abnormalities, 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(CORS96) reference frame. This made it so all final positions were NAD83. Note that there is no significant difference in this area between NAD83(CORS96) and the modern realization of NAD83(2011) – results produced in the two reference frames differ by 0 to 0.001 m on average. The custom SBETs were then applied in CARIS HIPS, described in the next section.

All POSPac products, QC plots, and log files are included with the survey data in the "ERS Data Deliverables" directory. The flow chart in Figure 8 is a generalized overview of the POSPac workflow used on this project.

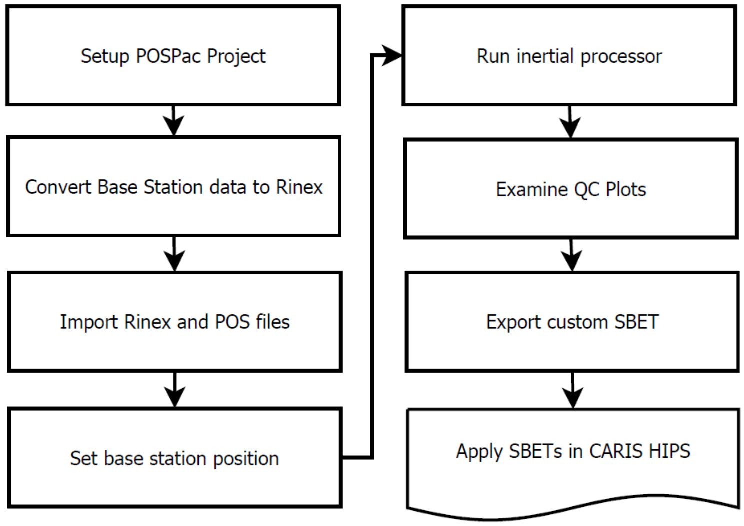


Figure 8 – Flow chart overview of POSPac workflow used on this project.

B.3.6. Load Attitude / Navigation Data

Following PPK processing, the SBETs were loaded into all survey 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.

In this process, each line's original (real-time) navigation, motion, gyro, and GPS height records were overwritten with the values from the SBET file. The name of the SBET applied to each survey line was recorded in the data processing logsheet.

It is important to note that this process replaced all real-time navigation and attitude originally converted from HYPACK RAW file with PPK navigation, without exception.

B.3.7. GPS Tide, Load Tide, and Merge

CARIS HIPS "Compute GPS Tide" function was used to compute the GPSTide sensor for all lines. During this process, CARIS HIPS used the ellipsoid to MLLW model file and GPS height records (loaded from SBET) to compute tide corrections relative to MLLW. The options "Apply Dynamic Heave," "Apply Antenna Offset," "Apply Dynamic Draft," and "Apply Waterline Offset" options were selected during computation in order to apply the same corrections to the GPS height that were applied to the sounding data, per CARIS HIPS guidance. Note that a preliminary ellipsoid to MLLW model file based on 2008 data was used during initial processing, but the final model file ("OPR-P385-KR-13_Sep_Model_MLLW-NAD83(2011).txt") was applied to all lines following availability of final tide data.

CARIS HIPS "Load Tide" function was used to load all lines with discrete tide zone data. The tide file "P385KR2013JOA20131112.zdf" was selected. This file referenced a file for two of the three project gauges that contained 6-minute tide data on MLLW. Note that discrete tides were loaded for comparison purposes only – final tide corrections were ERS-based.

The CARIS HIPS "Merge" function was used to apply final corrections. During this process the option "Apply GPS Tide" was selected so that CARIS HIPS would use the GPS Tide sensor for final tide corrections.

More information regarding the ERS model and discrete tide zones are available in the HVCR.

B.3.8. Navigation and Attitude Sensor Checks

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.

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.3.9. Single Beam Editing

Single beam data was manually cleaned using CARIS HIPS Single Beam Editor. Erroneous soundings exceeding error tolerances outlined in the 2013 Hydrographic Surveys Specifications and Deliverables (HSSD) 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) 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.

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

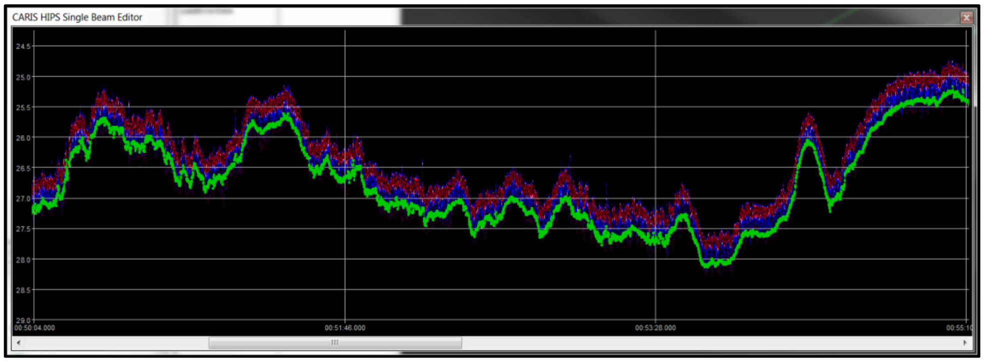


Figure 9 – Example of sounding (green) and digital trace data (magenta and blue) in CARIS HIPS Singlebeam Editor.

To ensure the single beam data was thoroughly cleaned with all erroneous soundings rejected, this process was repeated at least twice – once when the data first became available (typically the day after acquisition) and again in the office prior to deliverable production.

As a final check on the SBES data for gross fliers, all SBES data was loaded into CARIS HIPS Subset mode and reviewed line by line 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 systematically examine the data for matchup with crosslines and adjacent lines.

B.3.10. Dynamic Draft Corrections

Dynamic draft corrections were computed and applied for this survey.

Corrections were applied to all soundings using the CARIS HIPS "Load Delta Draft" function, but were also applied to the GPS altitudes during the Compute GPSTide process, which had the end result of no effect on the soundings. As an ERS survey, the dynamic draft component of vertical motion is already captured in the GPS altitudes making additional correction unnecessary. However, application of the corrections made it possible to do a comparison with discrete-tide zone corrected data, which do require dynamic draft correction.

As mentioned previously in this document, engine RPM data was logged continuously to text files using the TerraTach system. In processing, a VB.net script was written that paired each RPM value logged (interpolated at 1 RPM increments using a 4^{th} order polynomial based on the measured values) with the corresponding settlement value determined by squat settlement test. Although most of the hydrographic data was covered with concurrent RPM data, occasional gaps in the RPM data files became apparent while processing. These were interpolated across or filled with RPM data concurrently logged by TerraLOG. These occasional gaps were deemed inconsequential because dynamic draft corrections were used for the comparison results only.

The resulting correction file was loaded into all survey lines using CARIS HIPS "Load Delta Draft" function. Small spikes in delta draft were smoothed by running CARIS HIPS "Batch Editor" function, passing a 10-second moving average over the delta draft records. Lines were then re-SVP'd with the "Apply Smoothed Sensor – Delta Draft" option enabled.

The delta draft correction files are available in the tide directory of the submitted CARIS HIPS deliverables.

B.3.11. Final BASE Surfaces

The final depth information for this survey is submitted as a collection of BASE surfaces (CARIS HIPS 7.1 CSAR format), which best represent the sea floor at the time of survey.

Single beam surfaces were created at 4 m resolution, as per the 2013 HSSD, as CUBE BASE surfaces. "Density and Locale" was chosen as the disambiguity method and NOAA CUBE parameter .XML based on 4 m resolution selected as the advanced CUBE parameters. These parameters 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, though they were extremely rare on this project.

A data set containing a single S-57 file (in CARIS HIPS .HOB format) and supporting files was submitted in conjunction with each 2012 survey deliverable. The S-57 file contains information on objects not represented in the depth grid, including meta-data objects. Each feature object includes the mandatory S-57 attributes (including NOAA version 5.3.2 extended attributes) that may be useful for chart compilation.

B.3.12. 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 difference between each accepted crossline sounding and a 4 m resolution QC BASE surface created from the mainscheme data. Although crosslines are included in the final BASE surfaces, they were not included in the QC BASE surfaces so as to not bias the 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 investigated and typically determined to be a result of bottom change, steep slope or rough terrain, or a combination.

A discussion concerning the methodology of crossline selection, as well as a summary of results for the sheet, is available in the DR. The crossline reports are included in the DR, *Separate II: Crossline Comparisons.*

B.3.13. Processing Workflow Diagram

Figure 10 (below) outlines the general processing flow used for this project.

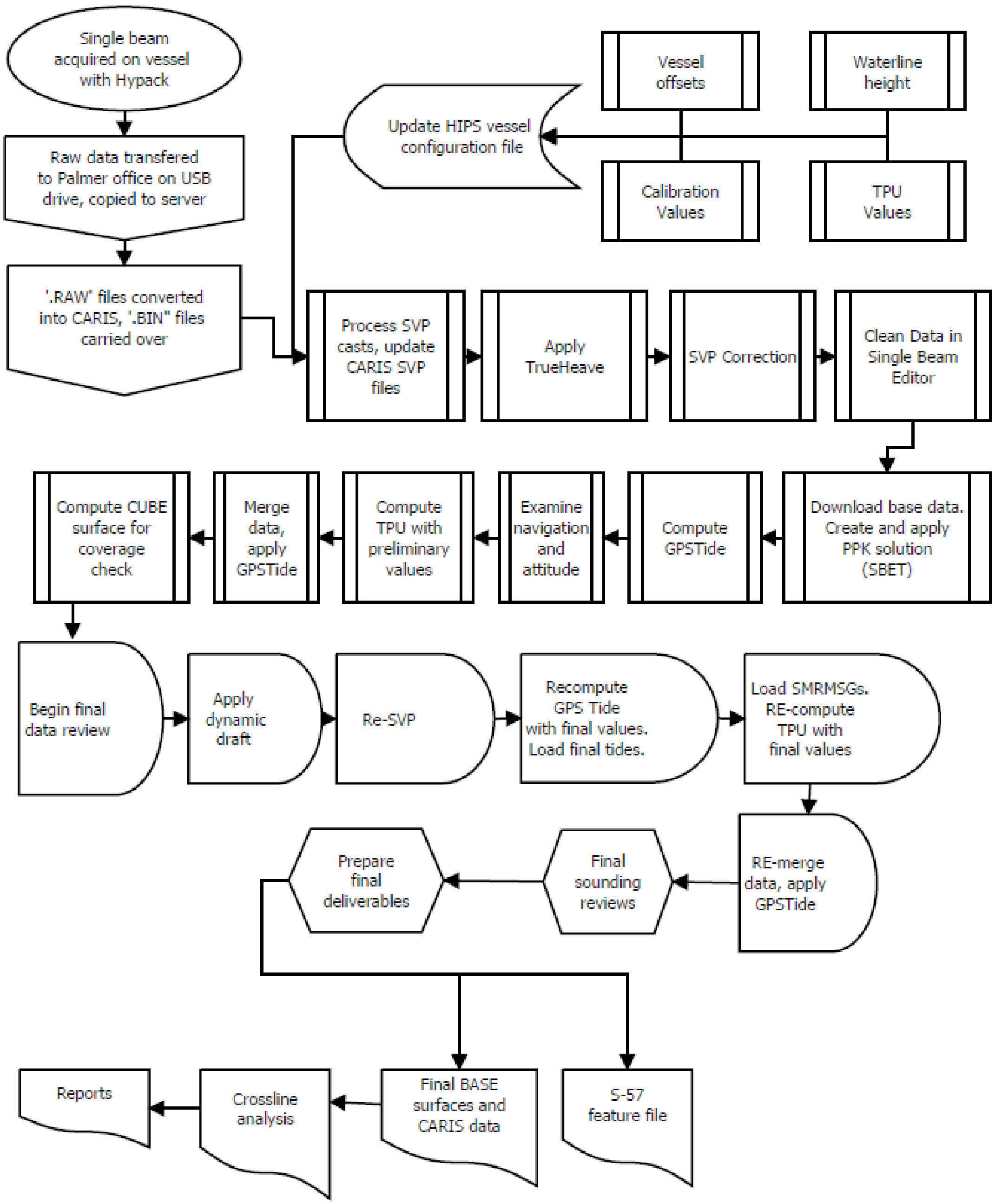


Figure 10 – Flow chart showing general processing workflow.

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 to minimize error.

Table 18 (below) summarizes the formal confidence checks.

Confidence Check	Purpose	Planned Frequency
Depth Checks (Bar and/or Lead Line)	Check depth accuracy Determine and refine Z offsets	Weekly
Echosounder Comparison	Overall check of consistency of survey system. Also used to recheck latency and pitch corrections.	Weekly
SVP Comparison	Check SVP sensors for consistency	Weekly
Base Station Position Check	Ensure stable base station position	Weekly
Vessel Position Confidence Check - Alternate Base Station	Check for accurate and consistent vessel positioning with independent base station	Weekly
Vessel Position Confidence Check – Independent GPS	Check for accurate and consistent vessel positioning with independent GPS source	Twice during project
Staff Shots	Check of tide gauge stability	Weekly to bi-weekly at each tertiary station
ERS - Discrete Tides Comparison	Compare ERS survey to discrete tide zone survey	Once, post-project

Table 18 – Summary of 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. These were planned to occur on a weekly basis, though mechanical, unplanned issues, or excessive current often caused the check to be postponed. These were completed three times over the course of the survey (on JD173, JD182, and JD189).

To perform the bar check, an aluminum grate, roughly eight inches in width and a length equivalent to the vessel beam, was hung by chains from guide points on the vessel’s gunwale. The bar chain 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, and static draft was measured.

With HYPACK logging and the sonar tuned to track the bar instead of the bottom, the bar was lowered by 1 m increments directly below the vessel’s transducer while bar depth and time were noted in the log. Bar check maximum depth, which ranged from 2 to 6 m on this survey, was determined by ability to maintain a sonar lock on the bar and depth, and was highly dependent on current.

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 reconfirming the acoustic center offset. Results obtained from CARIS HIPS always compared to better than 0.058 m of the actual bar depth, though on average compared to better than 0.01 m.

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 layout, however, the value remains fixed.

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

B.4.2. Lead Lines

Lead line checks were utilized to check the absolute accuracy of the echosounder and processing systems. These were planned to occur on a weekly basis, though mechanical, unplanned issues, or excessive current often caused the check to be postponed.

Lead lines were accomplished by lowering a calibrated measuring tape outfit with a 2-lb weight to the sea floor and noting the waterline level on the tape. This was done on both sides of the vessel in-line with the echosounder transducer, and averaged to help account for any slope and obtain a best-estimate of the depth at the transducer, which was roughly centered on the vessel.

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

For this project, lead lines proved very difficult to obtain accurately, even near slack tide at the dock. They were attempted on several occasions but were only successful twice (on JD182 and JD189). Lead lines agreed with the CARIS HIPS depth within 0.20 m or better. This was agreement was deemed satisfactory, given the unknown variables with lead lines, as well as the test conditions experienced.

Lead line logs are available in Appendix II of this report.

B.4.3. Echosounder Comparison

The same survey line was run weekly to serve as comparison. The echosounder comparison served as a confidence check on the total survey system.

Echosounder comparison checks served as a confidence check on the total survey system. They were also used to recheck latency and pitch calibration values. These were planned to occur on a weekly basis, though mechanical or unplanned issues often caused the check to be postponed.

Note that normally this comparison utilizes multiple survey platforms to confirm that each obtains the same results. However, with only one survey vessel assigned to this project, the vessel data was compared to itself only. Lead lines and bar checks served as the independent checks of depth accuracy on this survey.

To complete the test, the same survey line was run on three separate occasions (JD169, JD177, and JD190). On each occasion the line was run three times; direction '1' slow, direction '2' slow, and direction '1' fast – a pattern that could be used to check navigation latency and pitch offset.

The lines passed through the standard processing flow and were examined in CARIS HIPS for changes in the latency and pitch offset. Note for this survey the initial values obtained from JD169 for latency and pitch were found to not change in the subsequent tests.

Bottom agreement was examined in CARIS HIPS Subset Editor. Agreement was good overall, except there were differences of up to 1 m in some sections of the line sets that is attributable to bottom change in sand wave areas.

The echosounder comparison log is available in Appendix II of this report.

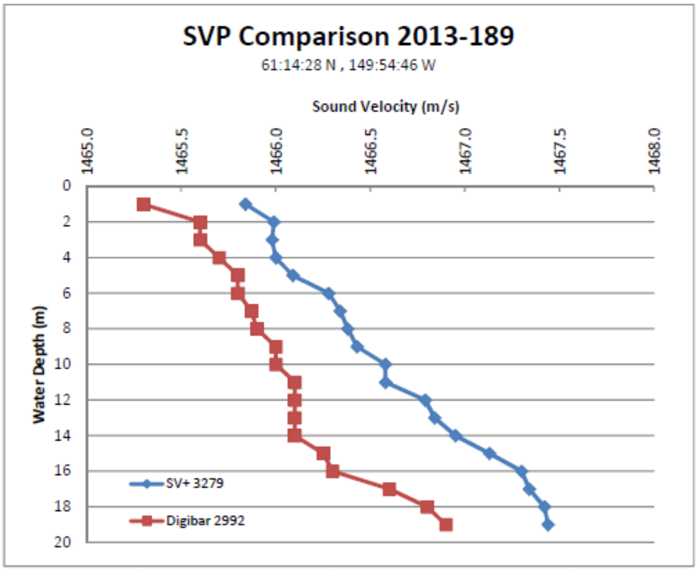
B.4.4. SVP Comparison

SVP comparisons were utilized to check the accuracy and consistency of the sound velocity probe data. These were planned to occur on a weekly basis, though mechanical or other unplanned issues often caused the check to be postponed.

To perform the test, a spare profiler probe was used to collect a cast coincident with the primary probe. The data from both probes underwent standard processing and were compared depth-by-depth in an SVP comparison logsheet (see Figure 11). Results were good, with sound speed at all depths comparing to better than 1.0 m/s, but usually to better than 0.50 m/s. Some of the variance is likely attributable to change over the slight differences in times of acquisition of the profiles.

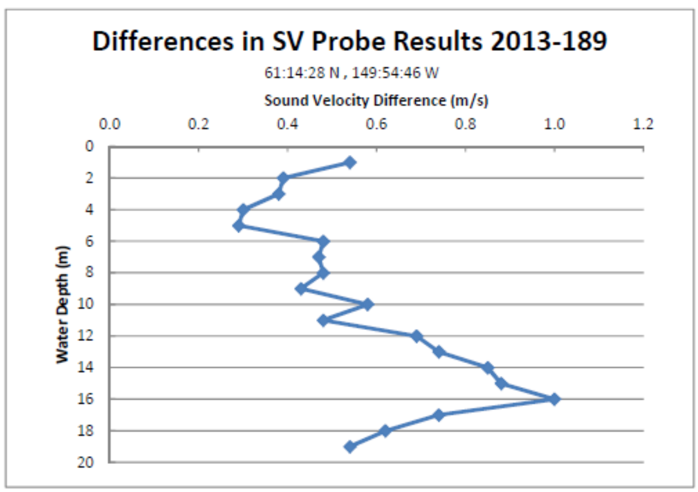
Individual test results are available in *Separate II* of the DR.

SV Probe Results		
S/N	SV+ 3279	Digibar 2992
Date/time:	JD189 20:44	JD189 20:44
Depth	Sound Velocity (m/s)	
1.00	1465.84	1465.30
2.00	1465.99	1465.60
3.00	1465.98	1465.60
4.00	1466.00	1465.70
5.00	1466.09	1465.80
6.00	1466.28	1465.80
7.00	1466.34	1465.87
8.00	1466.38	1465.90
9.00	1466.43	1466.00
10.00	1466.58	1466.00
11.00	1466.58	1466.10
12.00	1466.79	1466.10
13.00	1466.84	1466.10
14.00	1466.95	1466.10
15.00	1467.13	1466.25
16.00	1467.30	1466.30
17.00	1467.34	1466.60
18.00	1467.42	1466.80
19.00	1467.44	1466.90



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

Statistics on the SV Probe results	
Depth	Sound Velocity Difference (m/s)
1.00	0.54
2.00	0.39
3.00	0.38
4.00	0.30
5.00	0.29
6.00	0.48
7.00	0.47
8.00	0.48
9.00	0.43
10.00	0.58
11.00	0.48
12.00	0.69
13.00	0.74
14.00	0.85
15.00	0.88
16.00	1.00
17.00	0.74
18.00	0.62
19.00	0.54



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

Figure 11 – Example of typical SVP comparison results. JD189 SVP comparison.

B.4.5. Base Station Position Checks

Position of the base station was established using NOAA NGS OPUS (Online Positioning User Service) by upload of the first 24-hour GPS static session from the base station deployment. This position became the accepted, surveyed position.

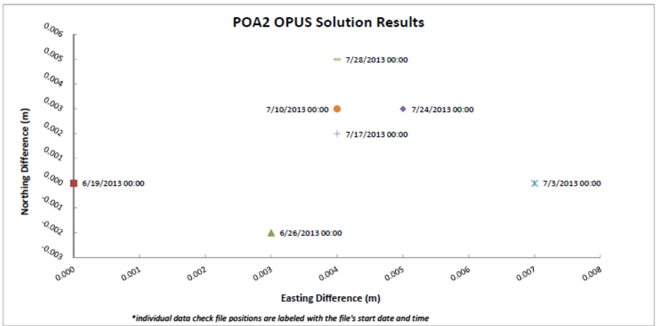
As a confidence check on antenna stability and to ensure repeatability, an OPUS solution was derived at least once weekly from a 24-hour data set and compared to the surveyed position. Results were excellent with a peak difference of 0.013 m, though usually compared to 0.005 m, or better. The base station confidence check logsheet is available with the project HVCR.

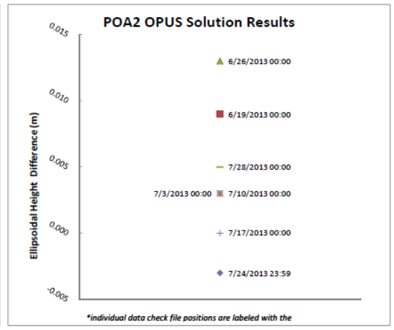
Base Station Position Checks

Base Name:	POA2		
Site Description:	Manson Construction Building Roof		
Receiver Type:	Trimble NETRS	**Serial:**	4412232926
Antenna Type:	Trimble Zephyr Geodetic (TRM41249.00)	**Serial:**	12682207
Project number:	OPR-P385-KR-13		
Horizontal Datum:	NAD 83 (2011)(EPOCH:2010)		
Projection:	UTM Zone 6N		
Ellipsoid:	GRS 80		

RTK Site Coordinate:		Latitude (dms)	Longitude (dms)	Northing(m)	Easting (m)	Ellipsoidal Height (m)
Surveyed*	24-hr OPUS 6/14/13	61 14 9.57793	149 53 25.19032	6792504.957	344870.487	18.628
Initial	6-hr OPUS 6/14/13	61 14 9.57792	149 53 25.19028	6792504.956	344870.488	18.638

Notes:
* *Surveyed position is from 24-hour OPUS solution filename "poa21650.13o"*
* *Fixed mounting location, antenna height is N/A. Antenna ARP is the surveyed point*





Base Station Position Uncertainty Check:

Times of OPUS solution			File Information		Antenna Height		OPUS Solution Results (NAD83)					RESULTS (DIFFERENCE) Delta (m) =OPUS solution check - Surveyed Coord.		
Deployment #	Start	End	Hours	OPUS Rinex File name	Measure Point	ARP(m)-Enter in OPUS	Latitude(dms)	Longitude(dms)	Northing(m)	Easting(m)	Ellipsoidal Height (m)	Northing (m)	Easting (m)	Ellipsoidal Height (m)
1	6/19/2013 00:00	6/19/2013 23:59	24.0	poaj1700.13o	Bottom of Antenna	0.000	61 14 9.57796	149 53 25.19030	6792504.957	344870.487	18.637	0.000	0.000	0.009
1	6/26/2013 00:00	6/26/2013 23:59	24.0	poaj1770.13o	Bottom of Antenna	0.000	61 14 9.57788	149 53 25.19014	6792504.955	344870.49	18.641	-0.002	0.003	0.013
1	7/3/2013 00:00	7/3/2013 23:59	24.0	poaj1840.13o	Bottom of Antenna	0.000	61 14 9.57797	149 53 25.18987	6792504.957	344870.494	18.631	0.000	0.007	0.003
1	7/10/2013 00:00	7/10/2013 23:59	24.0	poaj1910.13o	Bottom of Antenna	0.000	61 14 9.57804	149 53 25.19010	6792504.960	344870.491	18.631	0.003	0.004	0.003
1	7/17/2013 00:00	7/17/2013 23:59	24.0	poaj1980.13o	Bottom of Antenna	0.000	61 14 9.57802	149 53 25.19007	6792504.959	344870.491	18.628	0.002	0.004	0.000
1	7/24/2013 00:00	7/24/2013 23:59	24.0	poaj2050.13o	Bottom of Antenna	0.000	61 14 9.57804	149 53 25.19000	6792504.960	344870.492	18.625	0.003	0.005	-0.003
1	7/28/2013 00:00	7/28/2013 23:59	24.0	poaj2090.13o	Bottom of Antenna	0.000	61 14 9.57811	149 53 25.19007	6792504.962	344870.491	18.633	0.005	0.004	0.005

Comments: *Good agreement between all data points (with maximum delta of 0.013m), indicating the antenna installation remainded stable over the course of the project.*

	Northing (m)	Easting (m)	Ellipsoidal Height (m)
Max Delta:	0.005	0.007	0.013
Min Delta:	-0.002	0.000	-0.003
Std Dev:	0.002	0.002	0.005

Figure 12 – 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. These were planned for a weekly basis and were undertaken on JD168, JD176, JD186, and JD190.

To complete this check for each vessel, a random POS file was selected from the week and post-processed as normal with the project base station (POA2). POS file was then re-processed with a nearby CORS site, and the results differenced with POSPac MMS's "Navdif" utility and examined.

A difference plot was produced, which was recorded on a vessel positioning confidence form along with the comparison parameters and observations. For JD186, three different CORS sites were used to compare against the project base station to test if differing results would be obtained from choosing alternate CORS sites.

Results were excellent, with average differences agreeing to 0.035 m, or better (both horizontally and vertically). See the vessel positioning confidence check logs in *Separate I* of the DR for specific results.

Vessel Positioning Confidence Check

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

POS file: 2013-168-1531-1A.POS **Date:** June 17th, 2013 (JD168) **Vessel:** Luna Sea

Base Stations Used

Base Station Name	Operating Agency	Function	Data Rate	Min. Baseline Distance (m)	Max. Baseline Distance (m)
POA2	TerraSond	Project Primary	1 Second	150	13,200
ANC2	AKDOT	CORS Check	30 Second	4,100	8,900

Table 1- Base stations used for comparison

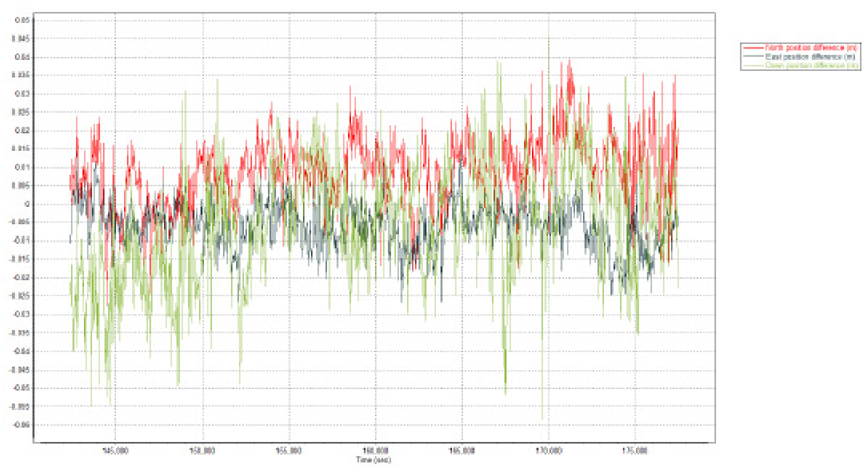


Figure 1 - Results of position difference between 2013-168-1531-1A.POS processed with POA2 and ANC2

Result Statistics

Position	Min. Difference (m)	Max. Difference (m)	Mean Difference (m)
North	-0.028	0.039	0.009
East	-0.028	0.015	-0.007
Down	-0.058	0.045	-0.006

Table 2 - Approximate minimum, maximum and mean differences

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

Figure 13 – Example of Vessel Positioning Confidence Check (Alternate Base Station).

B.4.7. Vessel Positioning Confidence Checks – Independent GPS

As an additional check on the vessel positioning system accuracy and repeatability, the post-processed navigation of the primary positioning system (POSMV) was compared to the post-processed navigation of the independent dual-frequency GPS system on the vessel -- a Trimble 5700 (T5700). The comparisons were completed for two randomly selected days: JD168 and JD190.

During this process, the SBET solution for the POSMV from Applanix POSPac MMS was exported to text at 1 Hz. Next, the T5700 data was post-processed in Applanix POSPac POSGNSS and also exported to text at 1 Hz. Finally, both were imported into Excel and differenced at the coincident times. Z results for the T5700 were corrected for the known offset between the T5700 antenna and the POSMV IMU. Results were graphed and examined.

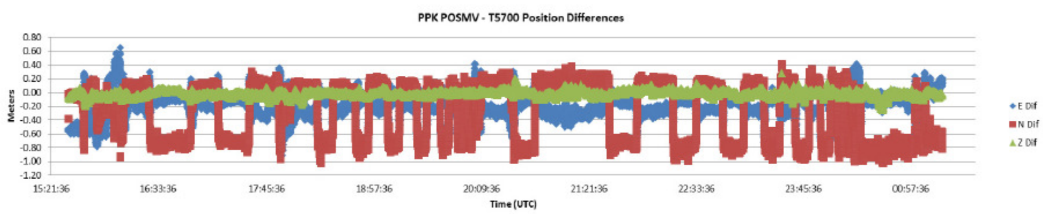
The two systems compared very well to each other. Altitude (Z) compared to within 0.036 m on average. Horizontally, the systems compared to within 0.30 m on average, which is considered acceptable as no offsets were applied for X and Y to the T5700 position to account for the difference in mounting location between the POSMV IMU and the T5700 Zephyr antennas. See the vessel positioning confidence check logs in *Separate I* of the DR for specific results.

Date: 6/17/13 (JD168) **Vessel Positioning Confidence Check** **Vessel:** Luna Sea

(Comparison of primary positioning system and independent alternate positioning system)

Navigation System	Type	Raw File name	Base Station Used	Processing Software
Applanix POSMV 320 V4 (POSMV)	Primary	2013-168-1531-1A.POS	POA2	Applanix POSPac MMS 6.2
Trimble 5700 (T5700)	Comparison	09871680.t01	POA2	Applanix POSPac POSGNSS 5.3
Data Overlap:	9.7 hours (6/17/13 15:33:33 to 6/18/13 01:18:25)			

	Minimum Difference	Maximum Difference	Average Difference	Comments
Easting	-0.911	0.651	-0.198	*No correction for T5700 offset to POSMV applied*
Northing	-1.026	0.411	-0.281	*No correction for T5700 offset to POSMV applied*
Altitude	-0.251	0.291	-0.017	*Applied T5700-POSMV Z difference (-4.5225 m) to T5700 altitudes*
Results Summary:	*Excellent results in altitude, with average difference of less than 2 cm. Slight differences in easting and northing are likely caused by no correction made for the 0.538 m horizontal separation between the T5700 antenna and the POSMV IMU.*			



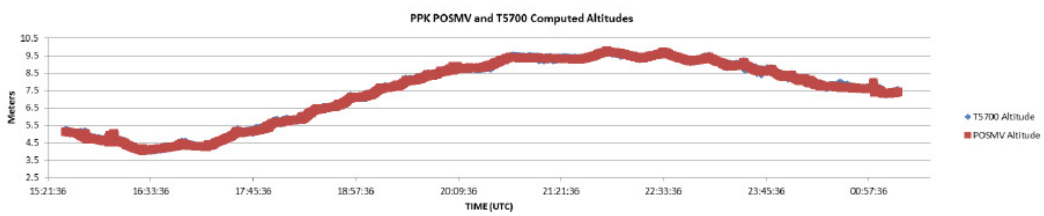


Figure 14 – Example of Vessel Positioning Confidence Check (Independent GPS).

B.4.8. Tide Station Staff Shots

To check the stability of tide gauge orifices and to collect data to assist with establishing MLLW to ellipsoid ties, staff shots consistent with requirements of the 2013 HSSD were done at each tide station. Typically, these were completed weekly at Goose Bay and twice monthly at Fire Island.

Standard leveling procedures were used to determine the difference in elevation between a tide station benchmark and the water surface. At least 2-hours of observations were collected at each visit, at a 6-minute interval that started on the hour. The staff shot readings were timed to coincide with data collected by the WaterLOG tide gauges, which were synced to UTC. If it had been more than one week since observations were collected, then at least two additional hours of observations were taken for each missed week. In any case, at least 8-hours of observations were completed per tide station each month.

Results were logged and compared to the values recorded by the tide gauge to compute a staff shot constant. The staff shot form along with downloaded gauge data was sent by email, normally within 24-hours of collection, to TerraSond's tide subcontractor, JOA. JOA would QC the data and send requests to the field for gauge maintenance, or other tasks, when necessary. See the HVCR for more information concerning tide operations and JOA's tide station reports (included with HVCR), which include the staff shot forms.

B.4.9. ERS to Discrete Tides Comparison

A detailed comparison of the final surface corrected to MLLW using ERS and final surface corrected to MLLW using discrete tide zones is included with the project DR, (with the Separates), as required in the work instructions.

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 vessel using conventional survey instruments. Acoustic center offsets were determined through bar check method for the SBES system. A point near the vessels estimated center of gravity was established as the center reference point (CRP) – or point from which all offsets were referenced.

The primary POSMV GPS antenna to POSMV IMU offset was applied automatically during data collection (and subsequent post-processing), while the remaining offsets were applied by way of the CARIS HIPS Vessel File (HVF).

All offsets received checks including reality tests by survey tape and bar check. Checks reveal an offset uncertainty of 0.020 horizontally and 0.010 vertically. Vessel outlines and offset descriptions are provided in Figures 15-16, and Tables 19-22.

C.1.1. M/V *Luna Sea* Vessel Offsets

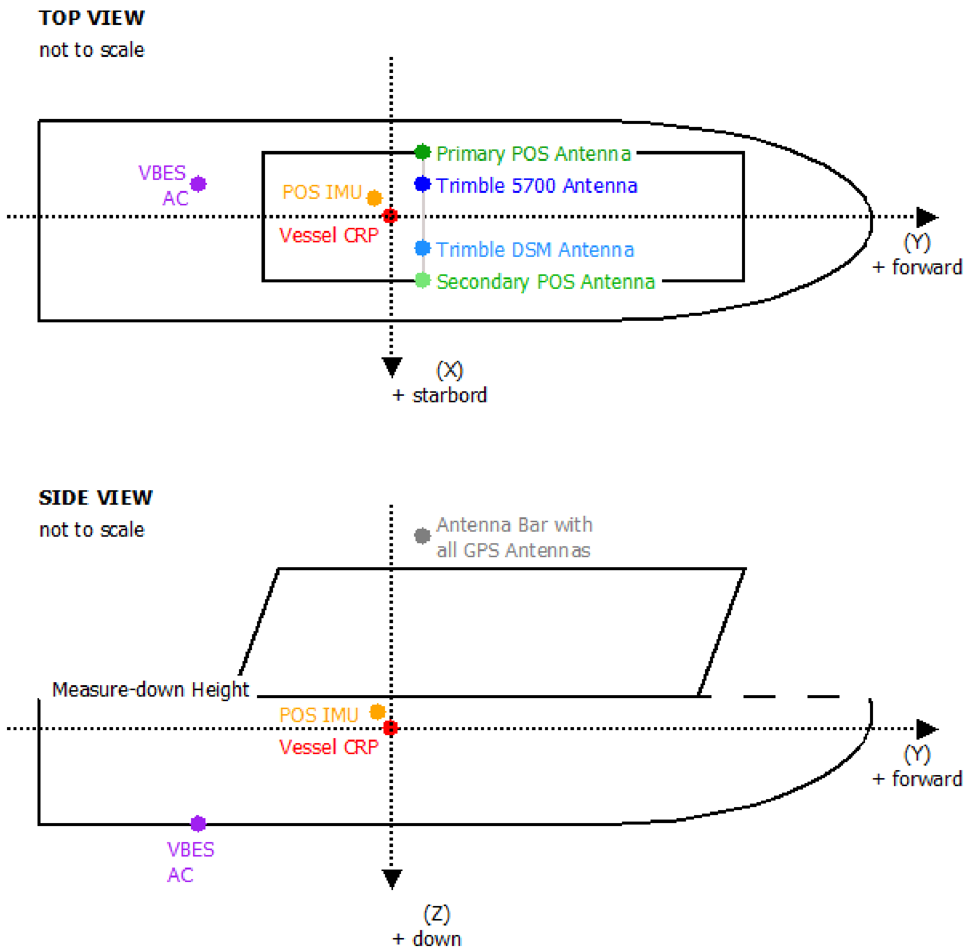


Figure 15 – M/V Luna Sea vessel survey showing relative positions of installed survey equipment.

Equipment	X (m) (+ stbd)	Y (m) (+ fwd)	Z (m) (+ down)	Comments
VBES Acoustic Center	-0.152	-3.072	0.548	Z value determined by bar check
POS MV Primary GPS Antenna (Zephyr)	-1.276	-0.035	-4.778	
POS MV Secondary GPS Antenna (Zephyr)	1.226	-0.081	-4.802	
POS MV IMU Reference Point	-0.124	-0.183	-0.265	
Trimble 5700 (Zephyr) Antenna	-0.640	-0.044	-4.787	
Trimble DSM Antenna	0.582	-0.067	-4.907	
Draft Measure-down Point (port side)	-	-	-1.070	
Draft Measure-down Point (stbd side)	-	-	-1.070	

Table 19 – M/V Luna Sea offset measurements from CRP, determined by vessel survey.

C.1.2. Attitude and Positioning

As described in previous sections of this report, primary positioning, heave, roll, pitch and heading data were measured on the vessel with an Applanix POSMV 320 V4 system. The system was configured to output attitude and position for the top-center of the system's IMU. The POSMV output positioning data to HYPACK as 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. Refer to Section B of this document for descriptions of uncertainties associated with the system.

The POSMV underwent a GAMS (GPS azimuth measurement system) calibration prior to the start of survey operations on JD166. The automated calibration process allowed the POSMV to compute the vector between its primary and secondary antennas in order to provide accurate heading information. The settings were saved to POS memory and used by the POSMV for the remainder of the project.

Date (JD)	A-B Ant Separation (m)	Baseline Vector (m)		
		X	Y	Z
2013-166	2.506	-0.064	2.505	-0.014

Table 20 – POSMV GAMS calibration results.

C.1.3. Calibration Test Data

Calibration tests were performed to determine latency and pitch offsets between the POSMV and the Odom echosounder systems. These tests were done over part of the survey area which had a combination of slope and sandwaves. Tests were performed on three separate occasions in order to establish and confirm that the offsets did not vary. The calibration test data is available for review with the CARIS HIPS deliverables in the Calibrations project.

C.1.3. Latency, Pitch, and Roll

To determine latency, a survey line was run twice – in the same direction – at low and high speeds over a sand wave covered slope. 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 the timing correction 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 (0.02 to -0.02) since the correction was being added to the Swath1 sonar times instead of the navigation sensor.

During the latency test, a third line was run at a low speed in an opposite direction of the other two lines. This was used to determine the pitch correction, as any remaining horizontal offsets of bottom features following latency correction indicated the pitch offset between the attitude and sounding systems.

Since roll was also logged and applied to the data, the line sets were also examined for roll offset. No roll offset was found, or at least the offset was too small to be discernible in the single beam data set.

Note that although heading data (gyro) was applied to the soundings, no attempt was made to determine the calibration offset as this would not readily be discernible in single beam data, and the potential effects of mistranslating vessel offsets by way of a small error in heading to the single beam transducer position are insignificant.

Refer to Section B of this report for uncertainties associated with patch test results. Table 21 summarizes the results.

Vessel	Latency results (seconds)	Pitch results (degrees)	Patch Test Date
M/V *Luna Sea*	-0.02 -0.02 -0.02	1.3 1.3 1.3	2013-169 (166 in HVF) 2013-177 2013-190

Table 21 – Calibration test results.

C.2. Speed of Sound Corrections

Sound speed profile data for OPR-P385-KR-13 was collected using an AML SV Plus. An Odom Digibar sensor was used for comparison casts. All profilers were factory calibrated prior to commencement of survey operations.

Profiles were collected by acquisition normally on a 12-hour interval (at least once daily). 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 vessel and sheet.

Sound speed corrections were applied in processing to the raw sounding data through CARIS HIPS "Sound Velocity Correction" utility. Nearest in distance within 12-hours was selected for the correction method.

Refer to Section B of this report for more information on acquisition and processing methodology. Refer to the project DR, *Separate II* for sound speed 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.3. Static Draft

Static draft was measured at least once daily on the vessel with an uncertainty of 0.01 m. Static draft was determined by measuring from a measure-down point on the gunwale of the port and starboard side of the survey vessel to the waterline. The measure-down values were recorded in TerraLog.

TerraLog averaged the port and starboard measure-down and reduced the result to the vessel's CRP using the surveyed offset value for the CRP to measure down point. This produced the CRP to waterline offset, which was entered as a new waterline value in the CARIS HIPS HVF, and checked to confirm the value fell within the normal range for the vessel.

The waterline correction was applied to the soundings by CARIS HIPS during sound velocity correction. As an ERS survey, the correction was also applied to GPS altitudes during the Compute GPS Tide process.

Static draft tables are available in the HVF with the CARIS HIPS deliverables.

C.4. Dynamic Draft Corrections

Dynamic draft corrections were determined 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.

Note that dynamic draft corrections were applied to all soundings using the CARIS HIPS "Load Delta Draft" function, but were also applied to the GPS altitudes during the Compute GPSTide process, which had the end result of no effect on the soundings. As an ERS survey, the dynamic draft component of vertical motion is already captured in the GPS altitudes, making additional corrections unnecessary. However, application of the corrections made it possible to do a comparison with discrete-tide zone corrected data, which does require dynamic draft correction. Note that a potential error (up to 0.09 m) in dynamic draft corrections, possibly due to unmeasured squat, was discovered during the comparison and is discussed in the ERS-Tide comparison report available with the project DR – this potential error does not affect the primary (ERS-based) survey deliverables, only the tide-corrected data used for the comparison.

C.4.1. Squat Settlement Test Procedure

During the squat settlement test, the vessel logged raw POSMV attitude and positioning data to the POS file while the nearby shore base station (POA2) logged dual-frequency GPS data at 1 Hz. A survey line was setup in the direction of the current and run up-current, then down-current, at incrementing engine RPM ranges. 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 engine RPM of each event. Additionally, the TerraTach system continually logged engine RPM at 1 Hz during the test.

The POS file was post-processed concurrent with the nearby base station data in Applanix POSPac MMS 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 range, or static. Each range was averaged to remove heave and motion. A 4th order 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 up-current and down-current results were averaged to eliminate any affect from the current.

The table of corrections for dynamic draft as a function of RPM was compiled from this data.

C.4.2. M/V *Luna Sea* Dynamic Draft Results

A squat settlement test was completed on the M/V *Luna Sea* on July 10th, 2013 (JD191). RPM values between 800 (idle) and 2200 (maximum used for survey) were tested in 200 RPM increments. Since the M/V *Luna Sea* demonstrated a large vertical response between the 200 RPM increments, 100 RPM increments were interpolated between the measured values linearly to smooth steps. Results are shown in Table 22.

RPM	Dynamic Draft (m) (positive down)
800	0
900	0.043
1000	0.086
1100	0.108
1200	0.130
1300	0.133
1400	0.135
1500	0.120
1600	0.106
1700	0.080
1800	0.054
1900	-0.014
2000	-0.083
2100	-0.177
2200	-0.271

Table 22 – M/V Luna Sea settlement results.

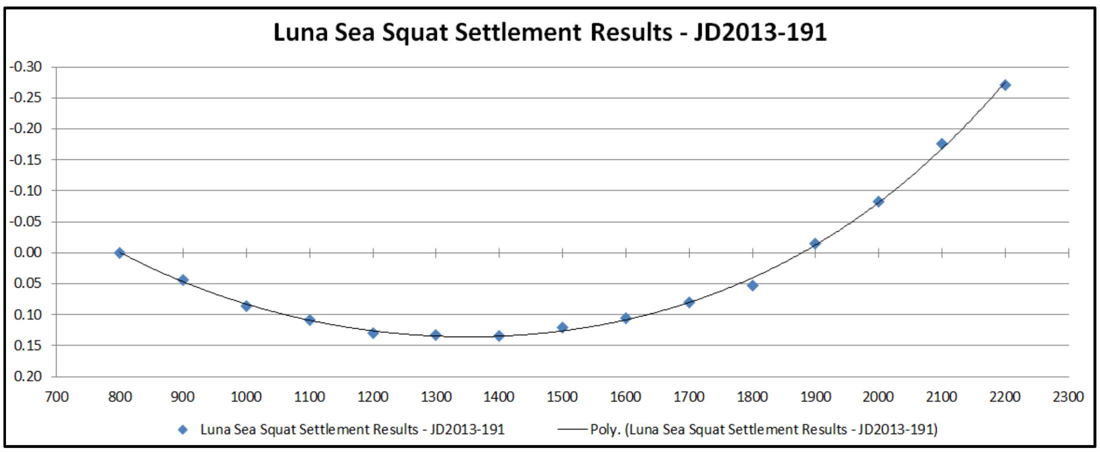


Figure 16 – M/V Luna Sea settlement results. Vertical units are meters, positive down.

C.5. Tide Correctors and Project Wide Tide Correction Methodology

To correct for tide and bring soundings to chart datum, ERS techniques were used on this survey. Post-processed kinematic (PPK) GPS methods were used to place the soundings relative to the NAD83 ellipsoid, which were then reduced to MLLW using a NAD83 to MLLW separation model. The PPK GPS methodology is detailed in Section B of this report.

The separation model was developed using data from the Anchorage NWLON tide station, the tertiary tide stations at Fire Island and Goose Creek, as well as four bottom-mounted pressure gauge deployments, and tide data from previous surveys. Refer to the HVCR appendices for details on tide data processing and separation model derivation, quality control, and uncertainty.

Discrete tide zone correctors were loaded into the lines, but were used for comparison purposes only; all final corrections for tide were made using ERS methods. Refer to the DR (Separates) for the comparison report.

APPROVAL SHEET

For

H12542

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*. Other reports submitted with this survey include the Descriptive Report and the Horizontal and Vertical Control Report.

This survey is complete and adequate for its intended purpose.

Signature Not Verified

Andrew Orthmann

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

Signature Not Verified

Marta Krynytzky

Date:
2013.11.26
11:30:07 -09'00'

Marta Krynytzky
ACSM Certified Hydrographer (2012), Certificate No. 273
Lead Hydrographer
TerraSond Limited