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-R341-KR-11

Time Frame July – September 2011

LOCALITY

State ALASKA

General Locality Kuskokwim River Approaches

2011

CHIEF OF PARTY

MARTA KRYNYTZKY

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DATE **December 21, 2011**

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NOAA FORM 77-28 (11-72) U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION	REGISTER NO.
HYDROGRAPHIC TITLE SHEET	**H12325, H12326, H12327, H12328**
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 KUSKOKWIM RIVER APPROACHES

Locality MOUTH OF KUSKOKWIM RIVER TO WEST OF JACKSMITH BAY

Scale 1:40,000 Date of Survey JULY 7, 2011 to SEPTEMBER 17, 2011

Instructions dated MARCH 11, 2010 Project No. OPR-R341-KR-11

Vessel M/V DREAM CATCHER

Chief of party MARTA KRYNYTZKY

Surveyed by TERRASOND PERSONNEL (C. GILL, M. HILDEBRANDT, M. KRYNYTZKY, T. LANDRY, B. MACK, A. ORTHMANN, P. PACK, S. SHAW, M. STEVIE, ET. AL.)

Soundings taken by echo sounder, hand lead, pole ECHOSOUNDER -- RESON SEABAT 8101 (POLE MOUNTED)

Graphic record scaled by N/A

Graphic record checked by N/A

Protracted by N/A Automated plot by N/A

Verification by

Soundings in METERS at MLLW

REMARKS:

The purpose of this work is to provide NOAA with modern and accurate hydrographic survey data for the approaches to the Kuskokwim River, Alaska.

Contract No. DG133C-08-CQ-0005

ALL TIMES ARE RECORDED IN UTC

Hydrographic Survey:

TerraSond Ltd.
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-R341-KR-11

December 21st, 2011

View from Small Plane in Route from Bethel to Popokamute Base Station

Vessels: ***M/V Dream Catcher***

Locality: ***Kuskokwim River Approaches, Alaska***

Sublocalities:

> ***H12325 – 7 NM SW of Warehouse Creek***
> ***H12326 – 11 NM West of Kanektok River***
> ***H12327 – 8 NM West of Kanektok River***
> ***H12328 – 13 NM West of Jacksmith Bay***

Lead Hydrographer: ***Marta Krynytzky***

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A. *Equipment*

A.1. Echosounder Systems

To collect sounding data, this project utilized a Reson SeaBat 8101 Multibeam Echosounder (MBES).

A.1.1. Multibeam Echosounders

A Reson SeaBat 8101 MBES system was used on this project. The Reson SeaBat 8101 is 240 kHz radial-array system which forms 101 separate beams. The system was configured to output bathymetric data including snippets and backscatter via Ethernet network connection to an acquisition PC running QPS QINSy, which logged XTF and DB files. To conserve disk space, QPS QINSy was configured to log backscatter and snippet data to DB file only.

Range scales, power, gain, pulse width, and depth-filter settings were adjusted as a function of water depth and data quality. Settings were tracked in the survey line logs (see *Separate I* of the Descriptive Report (DR)). Spreading and absorption values were set to manufacturer recommended ranges for a mix of salt and fresh water.

The Reson 8101 was synchronized to UTC time via a serial input from QPS QINSy. QPS QINSy was configured using its “SeaBat Synchronizer” driver to output a UTC string to the Reson, which re-synced its internal clock at a rate of 1 Hz.

During data acquisition, optimal sonar range scales along with limited vessel speed were used to ensure the Reson 8101 was operated in a manner that maximized swath width and data quality.

A.1.2. Echo-sounder Technical Specifications

Reson SeaBat 8101	
Firmware Version (Dry)	8101-2.09-E34D
Firmware Version (Wet)	8101-1.08-C215
Sonar Operating Frequency	240 kHz
Beam Angle, Across Track	1.5°
Beam Angle, Along Track	1.5°
Number of Beams	101
Max Swath Coverage	150°
Max Depth Range	300 m

Table 1 – Reson SeaBat 8101 multibeam echosounder technical specifications

A.2. Vessels

All data for this survey was acquired using the *M/V Dream Catcher*

A.2.1. M/V Dream Catcher

The *M/V Dream Catcher*, shown in Figure 1, was used to collect multibeam data. It is a 28.96 meter aluminum hulled vessel with a 7.16 meter beam and a 1.68 meter draft, manufactured by Alaska Dreamventures, Inc. The vessel is powered by twin 380Hp Volvo diesel drive engines. Electrical power is provided by a 40KW Northern Lights Genset and a 30KW Northern Lights Genset. The vessel has a 10” dual-prop bow thruster by American Bow Thruster.

Figure 1 – M/V Dream Catcher near the mouth of the Kuskokwim River, AK

The *M/V Dream Catcher* was equipped with a POSMV 320 V4 and a pole-mounted Reson SeaBat 8101 MBES system. Detailed vessel drawings showing the location of all primary survey equipment are included in Section C of this report.

Line orientation for the *M/V Dream Catcher* was generally perpendicular to the river during 200 meter line spacing data collection and parallel to the river channel during 50 meter line spacing data collection.

The survey equipment on the *M/V Dream Catcher* performed well with no major issues encountered.

***M/V Dream Catcher* Survey Equipment**

Description	Manufacturer	Model / Part	Serial Number
Multibeam Transducer	Reson	SeaBat 8101	3507006
Multibeam Processor	Reson	81-P	8002029
Positioning System	Applanix	POS MV 320 V4	3190
Motion Sensor	Applanix	POS MV IMU	783
MVP 200	Odim	200	n/a
SV Casting Probe	Applied Microsystems	Micro SV&P	7508, 7509
SV Casting Probe	Applied Microsystems	SV Plus v2	3259
RTK Signal Receiver	Pacific Crest	RFM96W	n/a
RTK Signal Receiver	Pacific Crest	RFM96W	n/a
Secondary Positioning System	CSI Vector	804-0021-09A	0616-24479-0001
Tertiary Positioning System	Trimble	DSM232	0225127581

Table 2 – Major survey equipment used aboard the M/V Dream Catcher

A.3. Speed of Sound

Speed of sound data was collected by vertical casts on the *M/V Dream Catcher* using a Moving Vessel Profiler (Odim MVP 200) equipped with Applied Microsystems (AML) Micro SV&P and SV Plus v2 sensors. The sensors were calibrated prior to the start of survey operations and then normally compared weekly to each other with good results.

Sound-speed profiles were taken as deep as possible and were geographically distributed within the survey area. Profiles used to correct the survey data were lowered through the water column by the semi-automatic MVP. Comparison casts taken with the AML SV plus were lowered by hand.

Sound-speed casts were taken approximately on a 4-hour interval during MBES operations.

In general, sound-speed profiles were consistent with semi-mixed conditions, showing some variance through the water column and between casts.

Refer to the CARIS ".SVP" file submitted with the digital data for specific cast positions and times. Refer to each DR, *Separate II: Sound Speed Data* for the sound-speed comparison checks.

Copies of the manufacturer's calibration reports are included in the DR, *Separate II* for each survey sheet. The following instruments were used to collect data for sound-speed:

A.3.1. Sound-Speed Sensors

Sound-Speed Gauge	Manufacturer	Serial Number	Calibration Date
Micro SV&P	Applied Microsystems, Ltd. Sydney, British Columbia, Canada	7508 7509	3/10/201 SV & 3/22/2011 Pressure 3/14/2011 SV & 3/22/2011 Pressure
SV Plus v2	Applied Microsystems, Ltd. Sydney, British Columbia, Canada	3259	March 16, 2011

Table 3 – Sound-Speed Gauges and calibration dates.

A.3.2. Sound-Speed Sensor Technical Specifications

Applied Microsystems Micro SV&P	
SV Accuracy	0.05 m/s
SV Resolution	25Hz
Pressure Precision	0.03 % of full scale
Pressure Accuracy	0.05 % of full scale
Pressure Resolution	0.005 % of full scale

Table 4 – AML Micro SV&P 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

A.4. Positioning and Attitude Systems

To provide positioning data and attitude corrections, the survey vessel was equipped with an Applanix POSMV 320 V4 Position and Orientation system. The system utilized two Trimble Zephyr Geodetic dual-frequency GPS antennas and an IMU (inertial measurement unit) to generate position, heave, pitch, roll, and heading data. The data was output from the POSMV via RS-232 serial cables to an acquisition PC where it was logged in conjunction with bathymetry in QPS QINSy software.

For real-time GPS corrections, the POSMV was interfaced with a Pacific Crest radio which received Real Time Kinematic (RTK) Corrections transmitted from base stations established by the survey crew on shore.

An Ethernet interface between an acquisition PC and with the POSMV allowed logging of a ".POS" file continuously during survey ops. The POS file contained the raw accelerometer and GPS data necessary for post-processing. Applanix POSPac software, including base station data was utilized for post-processing. The POS file also contained TrueHeave records which were loaded into each survey line in processing.

The POSMV also provided the timing synchronization for the survey systems. The POSMV was configured to output a 1-PPS over coax and a ZDA time string over serial connection to QPS QINSy.

The POSMV is self-calibrating upon startup except for its GPS Azimuth Measurement Subsystem (GAMS) – a component of the system's heading computations – that requires an initial calibration. GAMS calibrations were done once after mobilization on the vessel, prior to the vessel patch test. During GAMS calibration the POSMV computes the separation between the primary and secondary antennas and the vector between them. Results are shown in the table below.

POSMV GAMS Calibration Results			
POS MV V4 S/N	GAMS Cal Date	Ant. Separation	Baseline Vector (X, Y, Z)
783	2011-187 at 22:40	3.924 m	-0.211, 3.917, 0.087

Table 6 – POSMV GAMS Calibration Results

To provide a real-time positioning confidence check, each vessel was outfitted with a CSI Wireless Vector PRO GPS Compass and Positioning System. The CSI Vector provides position and heading using dual GPS antennas, DGPS beacon, single-axis gyro, and tilt sensor. Although outside of the nominal range of USCG DGPS corrections the beacons did receive corrections semi-continuously from the Continually Operating Reference System (CORS) station at Cold Bay. Alerts were set up in the QPS QINSy acquisition system to notify the surveyor if position differences strayed outside acceptable limits.

Additional positioning confidence was provided by a Trimble DSM 232 beacon receiver receiving DGPS corrections. Alerts were set up in the QPS QINSy acquisition system to notify the surveyor if position differences strayed outside acceptable limits.

Detailed position confidence checks were compiled weekly by processing using Applanix POSPac software. Refer to Section B of this report for methods used to compute weekly checks and to each DR, *Separate I: Acquisition and Processing Logs* for position confidence check results.

A.4.1. Position and Attitude System Technical Specifications

Applanix POS MV 320 V4	
Firmware Versions	SW04.22-Feb02/09
Roll, Pitch Accuracy	0.01° with RTK
Heave Accuracy	5 cm or 5% for periods of 20 sec or less
Heading Accuracy	0.02° with 2 m antenna baseline
Position Accuracy	0.02 - 0.10 m with RTK
Velocity Accuracy	0.03 m/s horizontal
Ethernet Logging	50 Hz

Table 7 – Applanix POS MV V4 technical specifications

CSI Wireless Vector Pro	
Horizontal Accuracy	< 1 m 95% (DGPS)
Position Updates	5 Hz
Heading Accuracy	< 0.5°
Heading Updates	10 Hz

Table 8 – CSI Wireless Vector PRO technical specifications

Trimble DSM 232	
Accuracy (WAAS enabled)	Typically 1.0 m horizontal
Accuracy (DGPS)	Typically 0.01 m horizontal
Antenna Type	DGPS

Table 9 – Trimble DSM 232 technical specifications

A.5. Vessel Engine RPM Logging

Dynamic draft corrections for this project were engine RPM (revolutions per minute) based. Speed-based corrections were not used. Due to the strong river outflow and tidal currents, often averaging more than 3 kts, RPM-based corrections more accurately captured vessel vertical response.

To replace error-prone manual notation of engine RPMs used in the past, a TerraTach system was utilized on this project. TerraTach is an in-house custom designed device and software package that interfaced with the vessel engines and continuously computed and logged engine RPM data for purposes of dynamic draft corrections. TerraTach was previously and successfully utilized on TerraSond's 2010 Kuskokwim surveys as well.

On the vessel, TerraTach was interfaced with both engines and configured to accept a ZDA time string from the POSMV. It then computed each engine's RPM by measuring the time of each engine cycle with a resolution of +/- 1 RPM and output the time-tagged result at 1 Hz over serial interface to a PC where it was logged to text file in Windows HyperTerminal. During the project a logging program for TerraTach was written that eventually replaced the use of HyperTerminal (Julian Day 212).

TerraTach would occasionally lose the ZDA time string from the POSMV. When this occurred, the software used presented a warning to the operator and meanwhile used the PC clock to time-tag the written RPM values. The PC clock was automatically synchronized with ZDA therefore the effect on time tag accuracies was usually insignificant (PC clock drift between ZDA syncs occurred but were adjusted for in processing). The output RPM files contained a tag describing which timing method was used for the time tag (ZDA or PC).

The RPM file was later used in office processing for application of delta draft. For a small number of lines an RPM file was not available for the entire or part of the line file. For these lines the RPM values were interpolated after analysis concluded that RPM used was similar to adjacent lines run in the same direction. Affected lines are listed in the DRs.

During pre-project testing and periodically through the survey, TerraTach was compared to each vessel's own tachometers with good results.

A.6. Vessel Waterline Height Measurements - TerraSonic

Both traditional measure downs and a newly developed in-house custom TerraSonic system were utilized on the Dream Catcher for this project.

The TerraSonic system was developed by TerraSond for this project as a better way of measuring draft. Traditional, manual draft measurements are error-prone and end up as a best-guess measurement due to wave action. However, even in 7-8 foot seas, TerraSonic continued to give reliable and accurate values when traditional measure downs would not be safe, practical or accurate.

The TerraSonic system was comprised of two ultrasonic sensors, mounted port and starboard, which were coupled to a PC running in-house custom software. The sensors were mounted on retractable extension arms about 0.7m in length near the surveyed measure down points and acoustically measured the distance to the water surface continuously during survey operations.

The arms were designed to extend further than the bow wave to avoid erroneous measurements from hull influence, as shown in the photo below. The *M/V Dream Catcher* did not operate at high speeds and the formation of a bow wave was minimal. Both TerraSonic sensors were calibrated by using a standard measure tape after installation so that the sonic measurements matched the manual, traditional measure down. A fixed correction of -0.03m was applied to port-side sonic measurements, while starboard-side sonic measurements required zero correction.

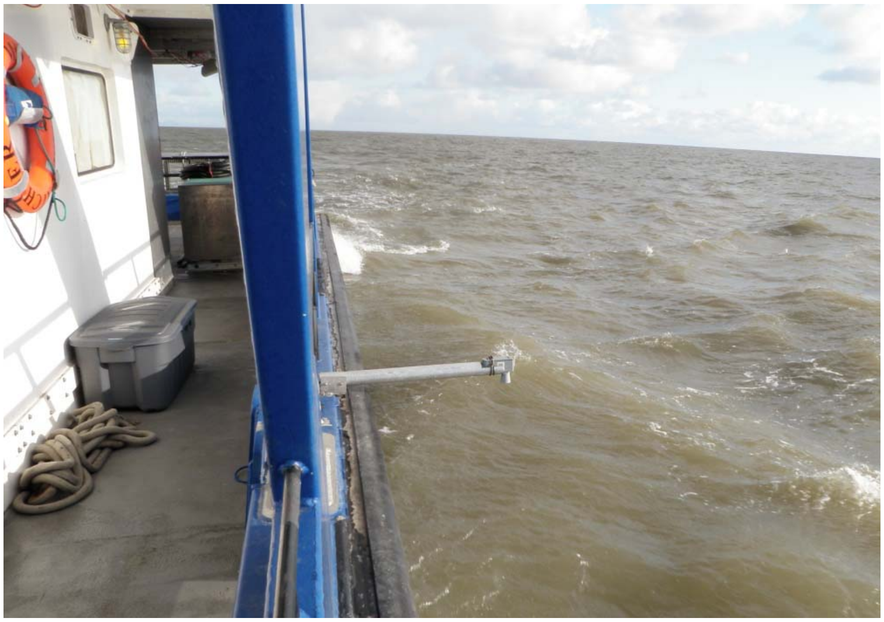


Figure 2 – TerraSonic sensor mounted on short extension arm on the port side of the M/V Dream Catcher

The TerraSonic system took readings continuously at approximately 5 Hz with an accuracy of 0.01m for raw measurements. Date, time, raw values, averages, smoothing, filter settings, and any offset values were continuously recorded in the TerraSonic software to text file with a "TSO" file extension during operations. TerraSonic applied time stamps using PC time which was regularly synced to UTC time.

The TerraSonic software allowed application of a number of user-adjustable filters and smoothing. For this project, a gate filter was used to automatically remove grossly erroneous data points, 20-second moving average to smooth the raw results, and port and starboard measurements were averaged. This combination of settings greatly minimized the influence of vessel roll and sea conditions.

As a QC check on TerraSonic, approximately once per day with the vessel at rest a traditional (manual) static draft measurement and the smoothed average TerraSonic value were recorded in the Static Draft Log (included in *Separate I* of each DR). TerraSonic values agreed very well with traditional measure downs. See graph below for comparison of traditional and TerraSonic values.

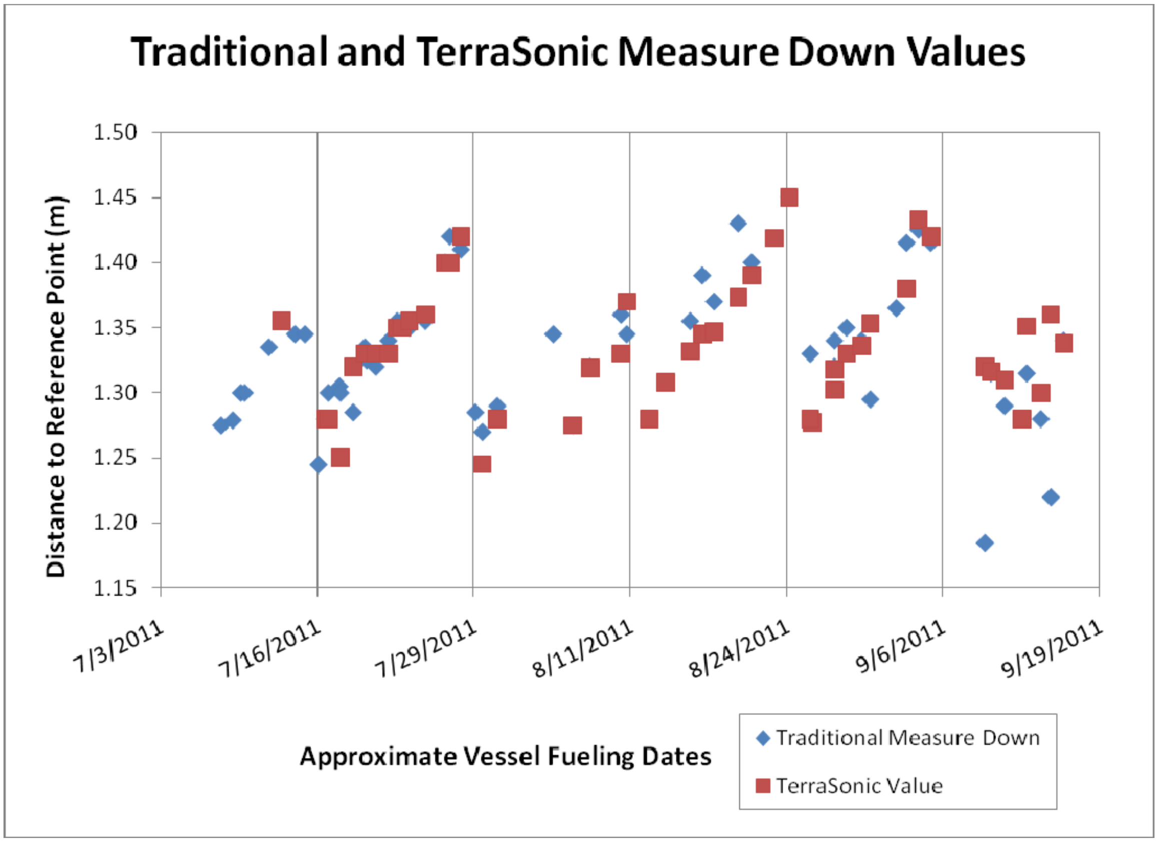


Figure 3 – Measure Down and TerraSonic Measure Down Values

Waterline corrections in the CARIS HVF are primarily composed of TerraSonic-derived values with some traditional measure down values included when TerraSonic values were not available. It is important to note that though draft data was produced and logged continuously by the system, only measurements taken when the vessel was at-rest were utilized in the CARIS HVF to ensure effects of dynamic draft did not bias the results. See graph of water line values below.

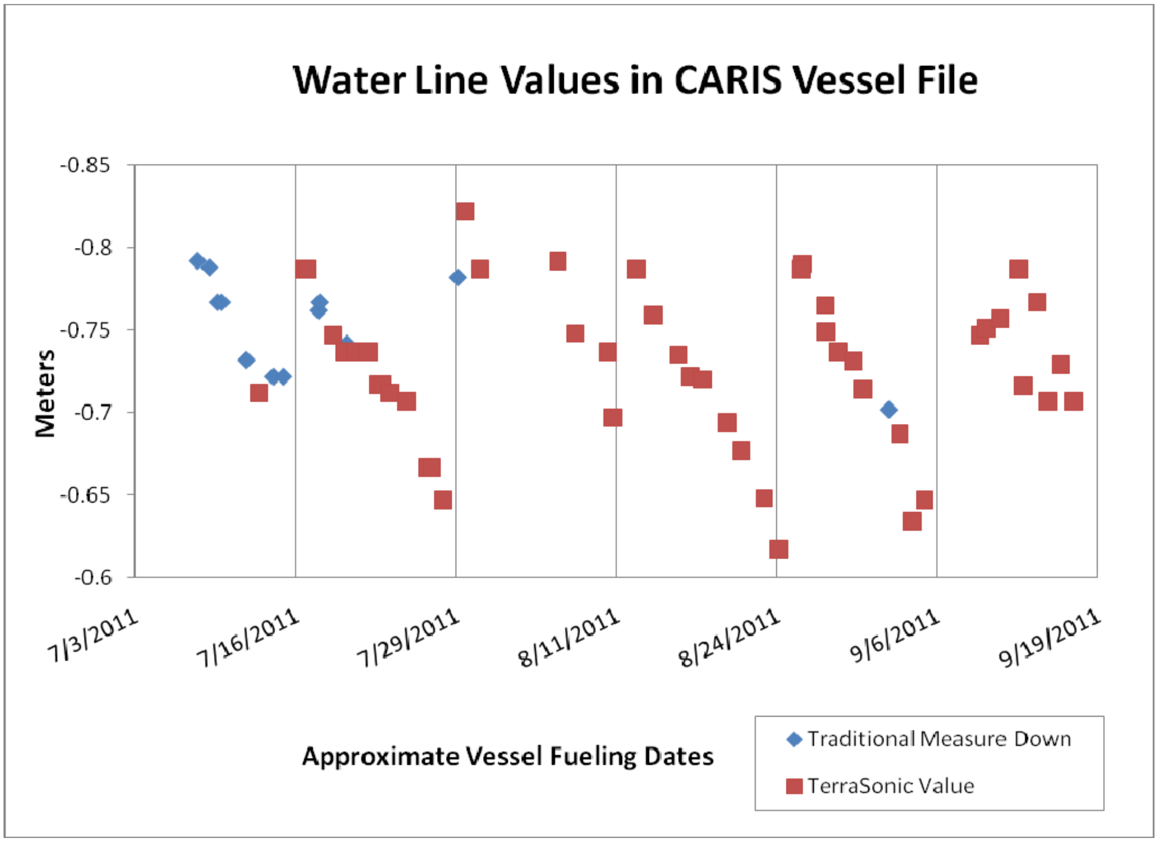


Figure 4 – Water Line Values in CARIS Vessel File (HVF). Correlation with fueling dates is apparent.

A.7. Base Stations

Base stations were utilized on this project to provide real-time corrections and provide dual frequency GPS data to apply post-processed kinematic (PPK) techniques. A total of four base stations were deployed at three strategically chosen locations. Two were logging-only (PPK) and two were logging and transmitting (RTK).

The RTK base stations were deployed at the village of Quinhagak, AK and near Carter Bay tide station to provide overlapping RTK radio coverage. Two additional logging PPK base stations were installed: one at the Popokamute tide station and one at the Carter Bay RTK Station.

Each RTK base station consisted of a Trimble NetRS GPS receiver with Zephyr Geodetic Antenna interfaced with a Pacific Crest PDL radio with antenna. In addition to logging dual frequency GPS data to internal memory at a rate of 1 Hz, the stations were configured to broadcast “CMR+” (Trimble format) corrections over 464.6 and 464.7 MHz using a 35-watt transmission power for best possible range.

Each PPK base station consisted of a Trimble 5700 GPS receiver with Zephyr Antenna setup over a new temporary rod benchmark. The 5700 was set to log dual frequency GPS data to a compact flash card at a rate of 1 Hz.

Power requirements differed between sites necessitating a custom power solution for each. Two 75-watt solar panels provided ample power for the single logging 5700 at Popokamute while the higher-draw RTK/PPK system at Carter required four 75-watt solar panels and a 400-watt wind generator. Quinhagak was supplied by village grid power. All sites utilized a number of 12V deep-cycle batteries that provided sufficient reserve capacity to ensure continuous operation of connected equipment during low power production periods and outages.

The survey vessel was configured to receive the CMR+ signal via Pacific Crest Bluebrick radios, which output the correction message to the vessel POSMV to compute an RTK solution. Reception of the signal was highly distance and line-of-sight dependent with interruptions common.

Base station data logged in a Trimble (*.T01) format. The data was downloaded periodically from the network-accessible NetRS units and when practical by data-card swap from the 5700 units periodically throughout the survey. The accuracy of base station solutions was checked often using position confidence checks with good results. See Section *B.4.4* and *B.4.5* of this report for information regarding base station position confidence checks.

Overall, base station data logging performance was good. Data logged at Popokamute and Quinhagak was rarely interrupted. Base data from both the Carter Bay NetRS and 5700 is only available for specific time periods due to memory issues and difficulty in physically visiting the site. However the interruptions in Carter base data did not affect survey data processing because an alternate, nearby station was always logging.

RTK reception was remarkably good considering the distances involved, especially from the more centrally-located Quinhagak site. CMR+ corrections broadcast from the Quinhagak site were used for real-time corrections for the majority of the survey, with a relatively consistent signal received up to 20 miles away, though reception sometimes was achieved up to 30 miles.

Base station data logged at each of the project sites with the addition of data logged at Continuously Operating Reference Station (CORS) sites were used to produce the final PPK navigation solution applied to all data. Section *B.3.6* of this report contains more information regarding processing of PPK data using these base stations, and Section *B.2.5* describes base stationing installation and retrieval QC measures. An example base station setup is shown below.

Figure 5 – RTK/PPK Base Station at Carter Bay

A.7.1. Base Station Equipment Technical Specifications

Trimble NetRS	
Accuracy (Static)	Horizontal 5 mm + 1 ppm RMS Vertical 10 mm + 1 ppm RMS
Output Standard Used	CMR+

Table 10 – Trimble NetRS specifications

Trimble 5700	
Accuracy (Static)	Horizontal 5 mm + 0.5 ppm RMS Vertical 5 mm + 1 ppm RMS

Table 11 – Trimble 5700 specifications

Pacific Crest PDL (High Power Base)	
Power (TX nominal)	110 Watts (35W)
Power (RX nominal)	1.9 Watts

Pacific Crest PDL (High Power Base)	
External Antenna	50 Ohm, BNC
Link Protocol	TRIMTALK™
Frequencies Used	464.6 and 464.7 MHZ

Table 12 – Pacific Crest PDL radio specifications

A.8. Tide Gauges

In support of this survey, three tide stations were installed in May and June 2011 by JOA Surveys, LLC (JOA) of Anchorage, AK. Stations were installed at historic U.S. Coast and Geodetic Survey tide stations Quinhagak, AK (946-5831) and Popokamute, AK (946-6057) and a new tide station at Carter Bay, AK (946-6328).

JOA installed two WaterLOG series DAA H350XL bubbler gauges near Popokamute (60°07'23.8"N, 162°30'01.3"W). Data from the tide gauges was monitored remotely via GOES and downloaded periodically throughout the survey to be combined with the staff observations and meteorological data collected during the project.

Two Sea-Bird SBE pressure gauges were installed at each of the remaining sites: offshore Quinhagak and offshore Carter Bay. These two locations had stretches of shoals extending far offshore that made use of bubbler-style gauges impractical. One gauge at each site was picked each month, downloaded, and then redeployed so that data quality could be monitored throughout the project. Digital barometers were deployed onshore near these sites to correct for the influence of atmospheric pressure.

All gauges were calibrated prior to the start of survey operations. In the field they were installed in pairs to ensure continuous tidal record and for comparison for quality control. Standard staff-shot observations methods were used to check installation stability normally bi-weekly at the bubbler gauges at Popokamute and monthly at the submerged gauges at Quinhagak and Carter.

In addition, for zoning purposes, Sea-Bird SBE 26plus Wave and Tide Recorder submersible tide gauges were set in four strategic locations within the survey extents for minimum 18-day periods during survey operations. The gauges were synced to UTC and set to log at a 6-minute interval using a 181 second averaging period and logged to internal memory. The gauges were downloaded upon retrieval prior to re-deployment at other sites. Barometric pressure was logged concurrently on the vessel for approximately an hour before and after each deployment to provide atmospheric pressure corrections. Data from the gauges with accompanying PPK water level data was used to assist with tide zoning and to provide additional ellipsoid to MLLW ties. The Sea-Bird gauges were calibrated prior to the start of the survey season.

Final processing of the tide data was completed as a joint effort between TerraSond Ltd. and JOA. Refer to the Horizontal and Vertical Control Report (HVCR) for detailed information regarding the calibration, installation, and data processing procedures used for these stations.

A.8.1. 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 13 – 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 14 – Sea-Bird SBE26plus specifications

A.9. Software Used

A.9.1. Acquisition Software

The *M/V Dream Catcher* was outfitted with two dual-core PCs running Windows XP Professional. A summary of the primary software installed and used on this system during data collection follows.

- QPS QINSy (Quality Integrated Navigation System) hydrographic data acquisition software was used on the acquisition vessels for navigation and to log all bathymetric, position, and sensor data to ".DB" format. Along with the DB file, QINSy was configured to simultaneously write an ".XTF" format file which was compatible with CARIS HIPS processing software.
- 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 software in conjunction with base station data. The POS file also contained TrueHeave records which were loaded into each survey line in processing.
- Applied Microsystems SmartTalk software was used to communicate with, configure, and download data from the AML SV+ v2 sound velocity sensor.

- MVP Controller software was used to control, monitor, and record MVP and AML Micro SV&P sound speed data.
- Windows HyperTerminal and in-house TerraTach software were used to continuously log RPM data generated by the TerraTach tachometer to file.
- Microsoft Office applications – particularly Excel – were used on-board for log keeping, including recording of position and results of bottom sample collection.
- Trimble GPS Configurator was used as necessary to configure common options in the Trimble 5700 base station receivers prior to deployment.
- Sea-Bird Seasoft was used to configure the Sea-Bird tide gauges prior to deployment and to download the data after retrieval.
- TerraSonic is a TerraSond proprietary software used to monitor, log, and process waterline height data collected by the TerraSonic system.

Program Name	Version	Date	Primary Function
QPS QINSy	8.00.2011.06.09	2011	Multibeam acquisition and navigation
Applanix POSMV POSView	5.4	2011	POSMV setup, monitoring, and logging
Applied Microsystems SmartTalk	2.27	2007	Configuration and download of AML SV Plus v2 sound-speed sensor
MVP Controller Software	2.380	2007	Control and monitor MVP, monitor and record AML Micro SV&P sound speed sensor
Windows HyperTerminal	5.1	2001	Logging of engine RPM data; download of Odom Digibar data
Microsoft Office	2007	2007	Log-keeping
Trimble GPS Configurator	n/a	2008	Configuration of Trimble 5700
Trimble Configuration Toolbox	6.9.0.2	2011	Configuration of Trimble 5700
Sea-Bird Seasoft	2.0	2007	Configuration and data download for Sea-Bird SBE26 Plus tide gauges
TerraSonic	n/a	2011	Monitoring, logging, and processing of TerraSonic waterline measurements
TerraTach	n/a	2011	Monitoring and logging of engine RPM data

Table 15 – Software used aboard the survey vessels

A.9.2. Processing and Reporting Software

Processing and reporting was done on dual-core PCs running Windows XP 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 7.1 was used extensively as the primary data processing system. HIPS was used to apply all necessary corrections to soundings including corrections for motion, sound speed, and tide. HIPS was used to clean and review all soundings and to generate the final BASE surfaces.
- CARIS Notebook was used to create the S-57 deliverables. Bottom samples and survey extents were imported and edited in Notebook. The Final Feature Files are submitted in CARIS Notebook (.hob) format.
- ESRI ArcGIS was used for pre-survey line planning, during survey operations to assist with tracking of work completed, and during reporting for chartlet creation and other documentation.
- Applanix POSPac MMS 5.4 was used extensively to produce post-processed kinematic (PPK) data. POSPac produced a smooth best estimate of trajectory files (.SBET) which were directly read by CARIS HIPS and applied to all lines.
- TerraSond TerraLog was used to process sound-speed profiles. This in-house software decimated raw profile data to a consistent depth interval of 0.1 meter and produced a CARIS-compatible output.
- Trimble Terramodel was used during planning to convert the SBES line plan created in ESRI ArcGIS to a format readable in QPS QINSy.

Program Name	Version	Date	Primary Function
CARIS HIPS and SIPS	7.1	2011	Multibeam data processing software
CARIS Notebook	3.1	2009	Feature attribution and creation of S-57 deliverables
ESRI ArcGIS	9.3.1	2009	Desktop mapping software
POSPac MMS	5.4	2011	Post-processed kinematic GPS positioning and confidence checks
TerraSond Ltd. TerraLog	n/a	2011	Convert sound-speed raw data to CARIS compatible format.
Trimble Terramodel	10.4	2004	Conversion of ArcGIS lines to QPS QINSy compatible format

Table 16 – Software during processing and reporting

A.10. Bottom Samples

Bottom Samples for this project were collected by the *M/V Dream Catcher*. At a planned interval of 4.8 kilometers, a Van Veen grab sampler was lowered and a bottom sample collected. Aboard the vessel, the sample was examined and its S-57 (SBDARE object) attributes noted along with time and position in an Excel log sheet.

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

A.11. Shoreline Verification

There was no Shoreline requirement for this project.

B. *Quality Control*

B.1. Overview

The traceability and integrity of the echosounder data, POSMV positional and inertial data, 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 multibeam data-processing tasks on this project. 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. Applanix POSPac MMS was used for processing the inertial and GPS data.

Frequent and comprehensive quality control checks were performed throughout the survey on all survey equipment and survey results. In addition, as standard practice, all edits and corrections done were reviewed at least twice before deliverable production.

The following sections outline the quality control efforts used throughout this project in the context of the procedures used from acquisition through processing and reporting.

B.2. Data Collection

B.2.1. QPS QINSy

QPS QINSy data acquisition software was used to log all multibeam data and to provide general navigation. The software features an abundance of quality assurance tools which were taken advantage of during this survey.

Using the raw echosounder depth data, QINSy generated a real-time digital terrain model (DTM) during data logging that was tide- and draft- corrected. To accomplish real-time tide correction QINSy applied a user-specified datum offset to the RTK altitude from the POSMV. This offset was entered by the survey crew into QINSy depending on area from a table of preliminary MLLW-ellipsoid separation values.

The DTM was displayed as a layer in the QINSy "Navigation" view. The vessel position was plotted on top of the DTM along with other common data types including line plan files, CAD files containing waypoints and boundaries, S-57 charts, and Geo-tiff images exported from CARIS HIPS.

The DTM was used to determine when required minimum depth was achieved and greatly assisted in preventing over-surveying (where depths significantly shoaler then required are collected) and under-surveying (where the survey vessel would need to return to an area to develop it further). The DTM was also instrumental in allowing real-time coverage analysis, displaying most data holidays immediately to the survey crew.

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 QINSy and later imported into CARIS HIPS.

In addition to the DTM and standard navigation information, QINSy was configured with various tabular and graphical displays that allowed the survey crew to monitor data quality in real time. Alarms were setup to alert the survey crew immediately to certain quality-critical situations. These include but are not limited to:

- Alarm for loss of PPS/ZDA timing string from POSMV
- Alarm for loss of attitude or positioning data from POSMV
- Alarm for loss of positioning data from CSI Vector or DSM232
- Alarm for age-of-RTK correction exceeding 35 seconds
- Alarms for differences in position between the three navigation sources exceeding 10m.

B.2.2. POSMV POSView

Applanix POSMV POSView was the interface software for the POSMV. It was used to continuously log the ".POS" files used by processing to apply TrueHeave and post-processed kinematic navigation.

POSMV POSView was also used to monitor the POSMV's constantly-updated error estimates for its attitude and position computations. POSView was used to monitor the estimated accuracies to ensure the POSMV was operating normally. Additionally POSView would alert the survey crew if accuracy thresholds for position, velocity, attitude, or heading were exceeded.

B.2.3. Draft and Sound-Speed Measurements

Vessel static draft was measured by two methods at least once daily. 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 points on the vessel gunwales. The measurements were taken on both sides of the vessel and an effort made to ensure the vessel was loaded similarly to that experienced during survey operations. Time and measurement values were noted in the “Running Draft Logsheet.”

Additionally, waterline heights were measured by the TerraSonic devices installed on both gunwales. TerraSonic files were collected continuously, broken into two 12-hour files. At the time the physical measure-down was collected, the 20 second moving averages of both sides were also averaged and recorded in the “Running Draft Logsheet.” The TerraSonic values demonstrated to be more reliable, accurate and robust in all weather conditions. See the Section *A.6* of this report for more details on the use and implementation of the TerraSonic System. Waterline corrections in the CARIS HVF file were derived primarily from TerraSonic values. Sources of all CARIS HVF values are noted in the “Running Draft Logsheet.”

Sound-speed profiles were collected normally at a 4-hour interval during MBES data collection. After an initial investigatory period where profiles were collected every two hours, more frequent profiles were deemed unnecessary as there was typically little variation between profiles. Upon transiting a large distance (generally more than 10 kilometers) or entering a new survey sheet an additional profile was normally collected to ensure any spatial component of changes in sound speed were accounted for. Final sound-speed profiles were applied in CARIS using a setting of “closest in distance within 4 hours.”

Operationally, a Moving Vessel Profiler (MVP) was utilized to collect the sound speed casts. The MVP towfish with sound speed sensor was deployed at the start of a survey line and a series of casts taken along the line. Prior to end of line, the towfish was retrieved to allow for vessel maneuvering. After four hours had elapsed the pattern was repeated. This helped ensure that profiles were temporally and geographically dispersed throughout the survey area. Occasionally only one cast would be collected for an MVP deployment if the line was particularly short. Cast files (.RAW format) contained the time and position of the profile, and immediate processing allowed the survey team to examine profile data quality in real-time.

B.2.4. Log sheets

Log sheets were kept continually during survey operations. At the start of each Julian Day, a new Excel log sheet was started. The log sheet was used to record all significant events which could affect data quality or assist with data processing and reporting. The log sheet was used simultaneously by acquisition and processing personnel. At the end of each Julian Day, two copies of the log sheet were stored and only one “Processing” copy was edited further with any necessary processing records.

The following common events along with the event time were normally recorded by the survey crew in the log sheets:

- Generic line information including line name and start and stop times
- Sonar setting changes during MBES ops including range, gain and power
- RTK stations in use and status

- POS filename(s)
- Sound-speed filenames and positions
- Comments on any unusual observations or problems

Static draft measurements, lead line and bar checks were logged to separate "Running Draft," "Sonar Depth Check" and "Bar Check" log sheets.

Log sheets are available in the DR, *Separates I: Acquisition & Processing Logs*.

B.2.5. Base Station Deployment

Base stations were deployed near tide station locations. Specific equipment utilized is described previously in this report in section *A.6*.

During deployment, the GPS antenna was leveled and its tripod secured to minimize movement. If the station was located over a bench mark, the antenna height was recorded and checked by at least one other surveyor. At Quinhagak, the GPS antenna was mounted on a fixed antenna mount, and the base of the antenna was used as the reference point for this station. Battery voltage, logging status, and other important parameters were logged to a base station deployment log sheet.

When stations were revisited or retrieved the levelness of the GPS antenna was checked. If out of level it was re-leveled. Antenna height was measured again. Battery voltage, logging status, and other important parameters were again noted in the base station deployment log sheet.

Antenna height discrepancies between visits were typically less than 0.03 m. For simplicity, during PPK processing the beginning antenna height was used instead of end antenna height. However, if the difference was 0.02m or greater, start and end heights were averaged and used in processing. The base station deployment log sheets as well as base station confidence checks are available in the project HVCR.

B.2.6. File Naming and Initial File Handling

A file-naming convention was established prior to survey commencement for all raw files created in acquisition. Files were named in a consistent manner with attributes that identified the originating vessel, survey sheet and processing block (for sheet-specific data types), and Julian day (for non-sheet-specific data types).

The consistent file-naming convention assisted with data management and quality control in processing. Data was more easily filed in its correct location in the directory structure and more readily located later when needed. The file-naming system was also designed to reduce the chance of duplicate file names in the project.

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

Type	Source / Contents	Example Filenames
.DB	QPS QINSy – all sensor data input into QINSy including Reson backscatter and snippets (when applicable).	0001-A4-A01900.DB (for MBES ops)
.XTF	QPS QINSy – produced coincident with DB file. For conversion into CARIS. Configured to contain only necessary data fields.	0001-A4-A01900.XTF (for MBES ops)
.SVP	AML Micro SV& P or SV Plus – sound-speed profile.	2011-190-0001.RAW (from MVP system) 2011-190-1545.SVP (from AML SV Plus)
.POS	POSView – POSMV data for PPK/TrueHeave	2011-190-1920-1A.POS
.RPM	TerraTach RPM meter – vessel RPM record.	2011-190-1921-1A.RPM
.TSO	TerraSonic log file	2011-190-1921-1A.TSO
.XLS	Excel – daily log sheet	2011-190-Logsheet-1A.xls
.HEX	Seasoft – binary file from Sea-bird tide gauge	2010_212-236_SN1155_D4.hex
.T01	Trimble 5700 Receiver – base station GPS data	00562380.t01
.T00	Trimble NetRS Receiver – base station GPS data	Quin201107311200a.T00
.A0x	WaterLOG tide gauges – bubbler download files from tide stations	94628081.A05

Table 17 – 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. As each file was completed, it was copied to a network directory for processing personnel to check the file against the log sheet entries and moved to the proper folder. Raw data was stored in its unaltered state in an “Acquisition” directory.

Initial data processing was then conducted in as close as possible to real-time. This provided immediate feedback for acquisition personnel about data quality. To ensure the continued integrity of the raw data, all processed data was stored within "Processing" and "CARIS" directory structures that were independent of the Acquisition directory.

All server data was backed up once each day onto LTO3 tapes. Additionally a full copy of all data was sent off the vessel to TerraSond's Palmer office at regular intervals. The system of using data storage servers with redundant disk arrays, automatic backups and off site data copies minimized the potential for data loss due to equipment malfunction or failure.

B.3. Data Processing

Preliminary data processing was done in the field, aboard the *M/V Dream Catcher*. Raw data was converted, cleaned, and checked on site. This method provided coverage determination and infill analysis in the field.

All checks and data corrections applied by processors were recorded in the acquisition log sheets which were also used to track processing tasks. These are available in each DR, *Separate I: Acquisition and Processing Logs.*

B.3.1. Conversion into CARIS HIPS

CARIS HIPS software was used to create a directory structure organized by project, vessel and Julian day to store data. The XTF files written by QINSy were imported into CARIS HIPS using the HIPS XTF conversion wizard module. The wizard created a directory for each line and parsed the XTF components into sub-files which contained individual sensor information. All data entries were time-referenced using the time associated within the XTF file to relate the navigation, azimuth, heave, pitch, roll, and slant range sensor files.

The HIPS vessel file (HVF) was then updated with a new waterline value. Port and starboard measure-downs recorded in the "Running Draft Logsheet" daily were averaged and reduced to the vessel's reference point using the surveyed vessel offsets to determine the static draft. In most conditions, especially rough seas, a 20-second moving average of the TerraSonic draft measurement was determined to be more accurate than the physical measure-down, and was used in its place. 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.

B.3.2. Load TrueHeave

After conversion, "TrueHeave" data was loaded into each line using the HIPS "Load TrueHeave" utility from the applicable POS file. TrueHeave is a better estimate then real-time heave for actual heave experienced by the vessel. Computed by the POSMV 110 seconds after the valid time, TrueHeave application requires that the POS file be logged for at least three minutes after end of line. A small number of lines could not be loaded with TrueHeave using this method as the POS file logging started too soon after a Saturday/Sunday Julian Day rollover. All of these lines are in sheet H12528 on Julian Day 226, details of processing these lines are in the DR for that survey.

Additionally some POS files could not be read by the Load TrueHeave utility. Usually this occurred when the POS file was logged over the GPS week-rollover on Saturday. In these cases TrueHeave was still available but needed to be extracted from the POS file to text and imported using the "Generic Data Parser" (GDP) utility. Note that this method overwrites the real-time heave record and that the line will not show as having TrueHeave loaded in a HIPS query. Lines that could not be loaded with TrueHeave or were loaded through GDP are listed in the acquisition and processing logs included with each DR.

B.3.3. Sound-Speed Corrections

Sound-speed profiles were processed using TerraLog, a TerraSond in-house program. The software was used to graph and review each profile for erroneous sound-speed values and to output a CARIS-compatible format at a regular 0.1-meter interval. The output was checked for incorrect time stamps and positions. The output was appended to the appropriate master CARIS SVP file based on survey sheet.

Profile data shoaler then 2.0 m was removed from all CARIS SVP files in the final office-based processing phase. This was done since the MVP system used did not reliably produce data for depths shoaler then 2 m and TerraLog output interpolated data for this part of the water column. This had no effect on the corrected data since the multibeam sonar head was mounted greater than 2 m below the water surface (typically at around 2.3 m).

After loading TrueHeave, each line was corrected for sound speed using HIPS' "Sound Velocity Correction" utility. "Nearest in distance within time" was selected for the profile selection method. For the time constraint, four hours was used for MBES data, except in specific instances. 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. Any deviations from this method are described in the corresponding DR.

B.3.4. Total Propagated Uncertainty

After sound-speed correction, HIPS was used to compute total propagated uncertainty (TPU). The 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, pitch, roll, tide, latency, sensor offsets, and 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, settlement and squat). The individual system uncertainties used on this project are shown below.

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)	0.005 sec. for Reson MBES	Reson synced to UTC and time tagging bathymetry prior to output over network. No timing error evident above 0.005 seconds
Timing – (Gyro, Heave, Pitch, and Roll)	0.005 sec.	All sensors computed with same system (POSMV) and therefore have the same timing uncertainty. QINSy synced with POSMV via 1-PPS and ZDA. No timing errors evident above 0.005 seconds
Offset (X and Y)	0.050 m	It is estimated that the X and Y offsets of the MBES acoustic center relative to the vessel RP were determined to within 0.050 m
Offset Z	0.025 m	Bar-checks had a standard deviation in results of 0.015 m, while estimated accuracy of the Z component of the vessel survey was 0.010 m. Therefore, 0.025 m was used for the "Offset Z" error
Vessel Speed*	1 knot	1 knot was selected as a place-filler. However, this will not affect TPU computations because no lines were corrected for dynamic draft using vessel speed (RPM-based corrections were loaded instead)
Loading*	0.030 m	0.030 was the standard deviation of differences between subsequent measure downs
Draft*	0.010 m	Static draft was measured to within 0.010 meters. This includes manual measurements and TerraSonic measurements
Delta Draft*	0.020 m	Delta draft was measured to within 0.020 meters
MRU Align StdDev Gyro	0.010°	The standard deviation of multiple patch test iterations (gyro results) was 0.010°
MRU Alight StdDev Roll/Pitch	0.018°	The standard deviation of multiple patch test iterations (roll & pitch combined) was 0.018°

Table 18 – TPU values used

* Note that errors associated with draft, delta draft, vessel speed, and loading are negated when using the GPSTide method since these items are components included in the total error of GPS vertical positioning. However they were still computed separately here to account for potential additional GPS vertical positioning error and to provide practical TPU for tide-based comparisons of the same data.

For “MRU to Trans” offsets under “TPU values”, the offset from the vessel’s IMU to the sonar was entered. This duplicated the values already entered under “Swath 1” since the IMU also served as the vessel reference point.

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

For “Trans Roll,” the value for the IMU to sonar misalignment determined by multibeam patch test was entered. This duplicated the value for roll entered under “Swath 1.”

During TPU computation a value of 0.050 meters was entered for tide error. This value accounts for vertical error from GPS positioning and is derived from the estimated average peak RMS error reported for the PPK SBET solution in Applanix POSPac. For tide zoning error, a value was entered that represented the average estimated error associated with the MLLW – ellipsoid separation model used. Specific entries for the tide zoning error varied by sheet (from 0.195 m to 0.204 m) and are described in the appropriate DR.

For final processing, different measured sound-speed error values were used for each sheet. For each sheet representative sets of casts at 4-hour intervals throughout the survey time span were selected and analyzed. The standard deviation of variance between consecutive casts was used for the measured sound-speed error. Specific values, which ranged from 1.68 m/s to 3.23 m/s, are described in the appropriate DR.

B.3.5. Compute GPSTide and Merge

To assist with initial cleaning and QC, the “Compute GPS Tide” utility in HIPS was run on each line to provide tide corrections. During field processing, the options for “Apply Dynamic Heave” and “Apply Waterline Offset” were chosen. For sounding datum, a preliminary model file was selected which accounted for the varying changes in the ellipsoid to MLLW separation across the survey area. The model file was a text file containing positions and their datum separation in a CARIS-compatible format.

This separation was initially established by JOA at each tide station using short-term tide data series tied to GPS benchmarks. To provide non-step transitions between tide sites a linear relationship was assumed to exist between stations for the purpose of modeling. Note that this preliminary model was replaced in office processing when the final model—built from longer data series and more data points—was loaded and GPSTide recomputed prior to final surface creation.

In field processing GPSTide was frequently computed prior to the application of navigation and GPS height from SBET. This was possible because most real-time GPS heights were RTK corrected with good accuracies, and usually necessary because of the lag time associated with PPK processing and lack of predicted tidal data for the area. However, the accuracy of the real-time GPS heights was a function of quality of RTK reception aboard the vessel, which varied from excellent to spotty or non-existent. SBETs were therefore loaded into each line as soon as they were available, and GPSTide recomputed. It is important to note that without exception, all real-time altitudes and positions were replaced with PPK from SBETs.

After computation of GPSTide, all lines were merged with HIPS' "Merge" utility. The option to "Apply GPS tide" was selected.

B.3.6. Post-processed Kinematics

Vertical accuracy of positioning was critical for this project due to the dependence on ellipsoid-based surveying for tide reduction. For this reason as well as the lack of dependable DGPS coverage, the project made extensive use of RTK positioning in real-time. However, the RTK radio link was highly susceptible to interruption and interference. Therefore post-processed kinematic (PPK) data was applied to all survey lines, replacing the real-time positions.

PPK processing utilized Applanix POSPac MMS software. POSPac makes use of dual-frequency GPS data logged at nearby shore base stations (Rinex format, converted from ".T01") and dual-frequency GPS and inertial data logged on the vessel (".POS" format) to produce a smooth best estimate of trajectory (".SBET") file. The SBET file was directly readable by CARIS HIPS.

This process produced results superior to RTK for the following reasons:

- Uninterrupted overlapping rover / base data
- A backwards-in-time processing step not available in real-time
- A solution that is tightly coupled with inertial data versus loosely coupled in real-time, therefore more tolerant of PDOP spikes and loss of satellite lock
- The ability to select closest or better base stations when incorrect station may have been used in real-time.
- The ability to use precise ephemeris or orbital data
- In Applanix SmartBase (ASB) mode, the capability of using the data from multiple base stations bracketing the rover data to further remove the effects of atmosphere-induced error at the rover position

RTK and PPK positions compared well (< 0.03 m vertically) when RTK was operating in its higher accuracy, "narrow-lane" mode.

To produce an SBET file, a project was setup in POSPac with the same name as the POS file being processed. The POS file was imported, and extracted by the software into component sensors. By examining the time extents and position of the logged POS data, the processor would select a base station to import. Rinex files belonging to the selected base stations would be then imported.

In the field preliminary SBET files were created via single-base mode using the network-accessible base station at Quinhagak. This allowed preliminary SBETs to be applied within about 16 hours of data acquisition.

After the completion of field operations and availability of all data, final SBETs were created using Applanix SmartBase (ASB) mode in the office and applied to the data. Surfaces were created using the ASB SBET corrected data and compared to data corrected using single-base SBETs. It was found (with few exceptions) that matchup between adjacent lines and internal data consistency was better in the ASB surfaces. Therefore the ASB SBETs were deemed to be of higher-accuracy and were loaded into all lines and superseded preliminary (single-base) SBET applications. Exceptions are rare and are noted in the applicable DR.

Applanix SmartBase Processing

As noted above, final positions with few exceptions were computed using Applanix Smart Base (ASB) mode in POSPac MMS 5.4.

ASB produces positioning results that are typically better then single-base mode, especially for long baselines. Single-base is generally restricted to baselines of 20 kilometers or less for the best possible accuracy. However, due to its offshore location, much of the of the survey area of this project exceeded 20 km from a base station, in some cases up to 30 km.

ASB uses multiple base stations that bracket the survey area to produce a model of ionospheric, tropospheric, satellite clock and orbital errors through interpolation within the network. A virtual reference station (VRS) is then computed for each epoch of the rover track as if an actual reference station exists at the rover location.

For best results, ASB requires that the survey area be enclosed in a network. Project base stations did not fully bracket the survey area, but when CORS (Continuously Operating Reference Station) sites were added (notably AB08 to the west on Nunivak Island) the network requirement was met for the majority of POSPac projects.

Following the import of POS rover data into POSPac, the TerraSond base stations were imported in Rinex format. “Coordinate Manager” was used to enter the critical information concerning the base station deployment. This included non-varying parameters such as benchmark coordinates, and deployment-specific settings taken from the base station deployment log sheet which consisted of antenna type, antenna height, and antenna measurement method. Base station and deployment used was tracked on the PPK processing log sheet, which is available in each DRs, *Separate I*.

Next, CORS base station data was imported. AB08 on Nunivak Island, AB12 at Platinum, and BET1 at Bethel were imported to complete the network. Precise ephemeris (orbital) data was also downloaded at this time to be used in place of broadcast ephemeris.

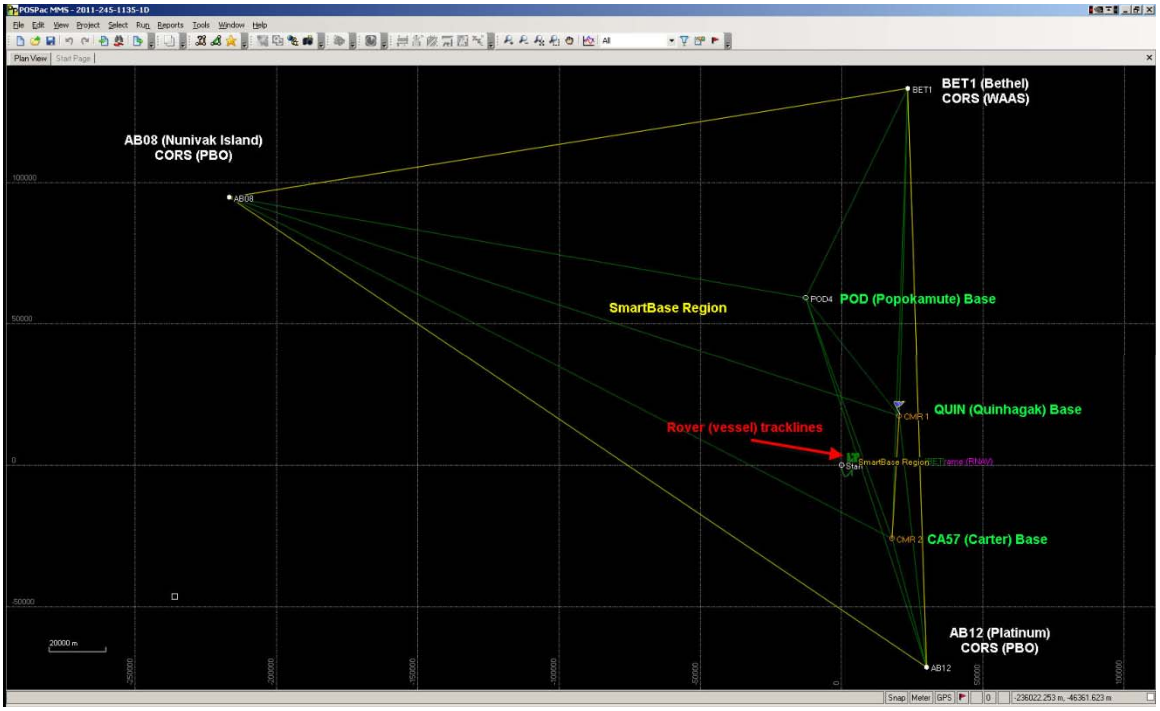


Figure 6 – Example ASB network geometry from POSPac 5.4 MMS for this project

ASB requires a minimum of four base stations. For this project, a total of at least five stations were used with most projects processed using six.

Following import of base data, the project base station at Quinhagak was selected as "Control". Quinhagak was used as "Control" on all POSPac ASB projects because it was the most central of the project base stations and also had longer data series along with a fixed antenna mount (on a roof a permanent structure, not tripod-mounted).

"Smart Base Quality Check" was run next. This feature analyzed the position of all base stations relative to the selected control station for consistency of position and reported horizontal and vertical differences. Stations were coordinates off by more than 0.05 m or without 18 hours of continuous good data were flagged. For each site, adjusted coordinates were computed which brought the site into better agreement with the control station.

Adjusted coordinates for all stations other then the control were then output for use in computing the ASB network. Project (TerraSond) base stations were adjusted by the software typically by only up to 0.03 m horizontally and up to 0.05 m vertically, while CORS sites required adjustments on the order of about 1.36 m horizontally and 0.63 m vertically. The relatively large shift in CORS sites was due to the fact that POSPac imports CORS sites referenced to ITRF, while the project stations were referenced to NAD83. This adjustment corresponds to the difference between NAD83 and ITRF in this area. It should be noted that POSPac natively produces ITRF-referenced SBETs but this step forces the software to produce SBETs with positioning referenced to NAD83.

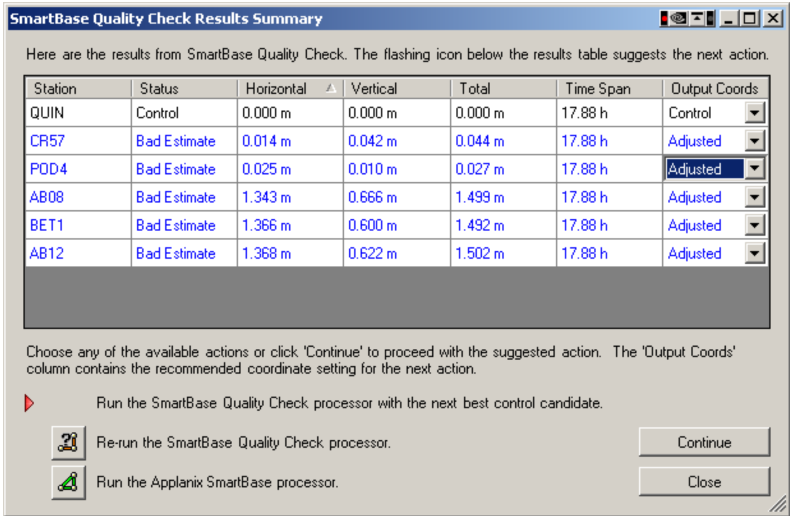


Figure 7 – Example adjustment done in SmartBase Quality Check

Following adjustment, the “Applanix SmartBase processor” was ran which computed the SmartBase model and corresponding VRS.

Finally the “GNSS-Inertial Processor” utility was run. “IN-Fusion SmartBase” was selected as GNSS mode, with “ASB” used as base station. This processed the inertial and GPS data forwards in time, backwards in time, and then combined the tightly-coupled solution into an SBET file.

POSPac constantly computes error estimates and provides a number of plots and tables to QC the post-processed position quality. “Smoothed Performance Metrics” were examined for every POSPac project at a minimum to ensure RMS error was low with no unusual spikes or high uncertainties. An example is shown below.

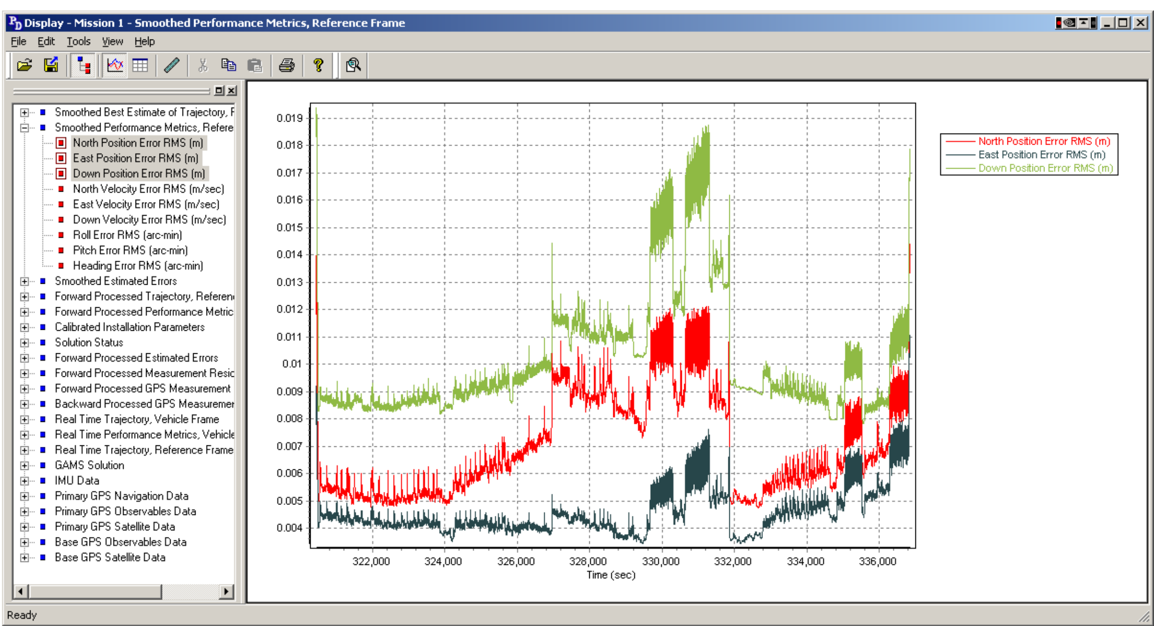


Figure 8 – Example of POSPac estimated RMS errors of positioning of an SBET file

When spikes or periods of unusually large uncertainty were encountered they were noted in the POS processing log sheet and further investigated. Spikes in RMS error were checked against computed altitude to determine if the error carried through to altitude. Spikes usually corresponded to periods of transit. If altitude was negatively affected the time of the spike was compared to actual survey times. If the vessel was not surveying at the time of the spike, which was usually the case, the SBET would be applied as is. If vessel was surveying the corresponding lines were marked for further examination and were sometimes rejected and rerun.

After QC was complete on the solution status, the SBET was copied and renamed to match the POS file and was ready to load in to CARIS HIPS. The RMS error values in graphical format were also exported in order to allow quick future QC without requiring POSPac, along with a number of other QC graphs available in POSPac. The graphs and other QC files were submitted with the project deliverables.

Single Base Processing

Single-base mode was used in the field for creating preliminary SBETs. It was also used on a small number of final SBETs.

Single base differed from ASB in that only one project base station would be imported instead of multiple project base stations. ASB checks were not applicable to this mode, and the "GNSS-Inertial Processor" utility was run in "IN-Fusion Single Baseline" mode.

In isolated line-by-line cases, better results were achieved with single-base SBETs. When this occurred the single-base SBETs were used for final positions instead of ASB SBETs. Affected lines are itemized in the appropriate DR.

The following flow charts outline the PPK process with POSPac, including both single base and ASB modes.

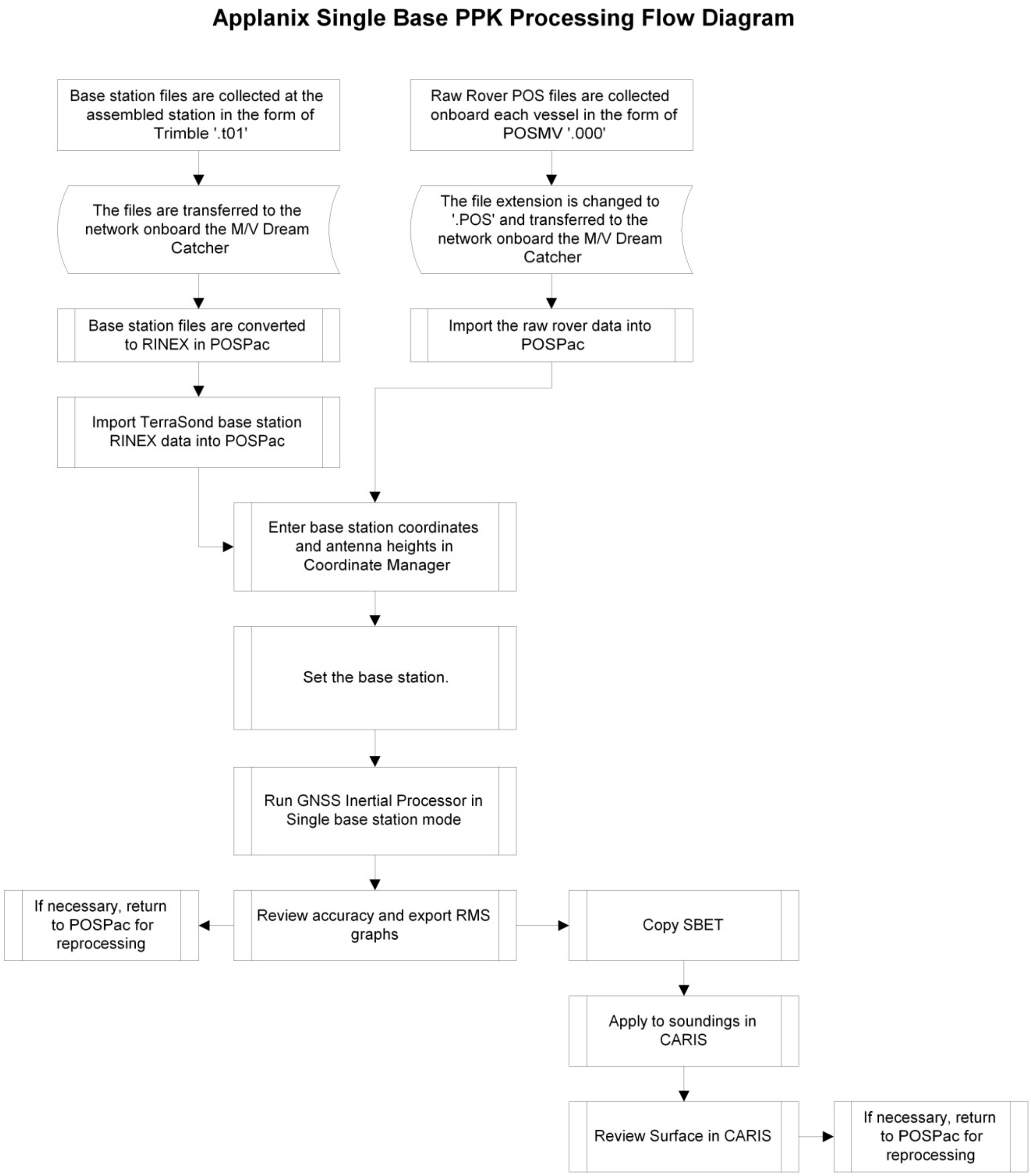


Figure 9 – Field PPK Single Base Station Processing flow overview

Figure 10 – Office PPK Smart Base Station Processing flow overview

The settings used in POSPac for producing the SBET were checked at least twice to ensure correct parameters were used for benchmark position, antenna height and type, and antenna measurement method. Any errors found were corrected and the PPK processing procedure repeated producing a new SBET which was applied to the applicable lines.

More information concerning base stations as well as the RMS error graphs are available with the project HVCR.

B.3.7. Load Navigation and GPS Height

The HIPS "Load Attitude/Navigation" utility was used to import PPK navigation and GPS height records from SBET file into each survey line. This utility replaced the real-time positioning data with the more accurate data from the SBET files. Gyro, pitch, and roll sensors were not loaded into the survey lines due to the negligible difference between their real time and PPK versions. After loading, HIPS output window was checked to confirm application and any application errors reconciled. GPSTide was then recomputed to use the new heights.

Note that in the field preliminary SBET files were created via PPK Processing from a single network accessible base station which allowed preliminary SBETs to be loaded and reviewed within about 16 hours of data acquisition. Final SmartBase processing was completed in the office after the completion of all data acquisition and superseded all preliminarily SBET applications, with a very few exceptions which are listed in the DRs. GPSTide was recomputed and lines re-merged following application of final SBETs.

B.3.8. Navigation and Attitude Sensor Checks

Navigation data were reviewed using the CARIS "Navigation Editor." The review consisted of a visual inspection of plotted fixes noting any gaps in the data or unusual jumps in vessel position. Discrepancies were rare and were handled on a case-by-case basis. Unusable data were rejected with interpolation using a loose Bezier curve. Fixes were queried for time, position, delta time, speed and status and, if necessary, the status of the data was changed from "accepted" to "rejected."

Attitude data was reviewed for every line in HIPS "Attitude Editor." This involved checking for gaps or spikes in the gyro, pitch, roll, heave, and TrueHeave sensor fields. Like navigation, spikes and gaps in the attitude data was extremely uncommon but were addressed when found, typically by rejection of incorrect data points. Any large drop outs in the attitude data would prompt rejection of the affected data and re-run.

Checks done on the sensors were tracked in the line logsheets, available in each DR's, *Separate 1: Acquisition and Processing Logs*.

B.3.9. Multibeam Editing

Prior to manual editing, multibeam data was filtered in CARIS HIPS. Optimal filter settings were determined for the project area which eliminated low quality and outer beam data. These settings were stored in a HIPS filter file (65_01.HFF, provided with the survey deliverables) and reused for all lines. The filter automatically rejected beams greater than 65° from nadir and beams flagged by the Reson system as quality “0” and quality “1.” However, filtered beams were sometimes reaccepted by processing to fill gaps or better define a feature when necessary.

The multibeam data was examined and edited in HIPS subset mode at least three times over the course of the survey. These phases of editing are as follows:

1. Course cleaning: Initial cleaning of a vessel’s full shift of data using RTK-derived tides. This was completed as each line was surveyed and handed off to processing. Allowed for immediate feedback on data quality to acquisition crew and identification of definite data gaps which could be re-run.
2. Fine cleaning: Sheet-wide cleaning using PPK-derived tides. Began when preliminary PPK SBETs available and applied to all lines. This process was performed on an on-going basis in the field. Fine cleaning allowed for gaps or coverage issues to be identified and sent back to acquisition for rerun as necessary.
3. Final review: Sheet-wide reviews, re-edits, and designate soundings. Done after all final correctors including SBETs were applied, prior to deliverable production.

In all phases HIPS was used to create a BASE surface using the CUBE algorithm. CUBE parameters and resolutions for depth ranges were compliant with the 2011 HSSD.

Course cleaning consisted of two phases. Data was initially reviewed in Swath-Editor mode, allowing gross fliers and obvious noise to be cleaned out. A second phase of cleaning used the de-Trend option in Swath Editor to allow the processor to view the data with the average slope removed, so that fliers were not hidden by topography. “Devil-horn” noise near nadir—an artifact common to the Reson 8101 in certain conditions—was also more apparent and rejection simplified using de-Trend.

During fine cleaning, data was reviewed in HIPS 2D-Subset and 3D-Subset modes in a surface-based editing approach, whereby soundings were rejected ONLY when they adversely affected the surface greater than the allowable error budget for depth. It is important to note that this approach means noisy soundings are still evident in the data set. However, gross fliers were also rejected regardless of their effect on the surface to ensure they did not contribute to the final BASE surfaces.

Designated soundings were selected during the final review. These were selected in accordance with the 2011 HSSD, whereby soundings that were shoaler then the BASE surface by ½ of the allowable error budget for depths less than 20 m (and equal to the error budget for deeper depths) were designated.

Per the HSSD survey scale was considered during the designation process as well. Soundings were generally NOT designated if a shoaler part of the BASE surface existed within 2mm at survey scale (80 meters ground distance), even if the sounding was shoaler by greater then ½ the error specification for the depth from the BASE surface. This situation was commonly encountered in this project on slopes or near the river bank.

The following table illustrates the difference between the three multibeam cleaning phases.

Course Cleaning	Fine Cleaning	Final Review
<u>Tides:</u> ☐ PPK-derived tides applied <u>Data Cleaning Editor:</u> ☒ Swath Editor ☐ Subset Editor <u>Surface Data Source:</u> ☒ Single shift MBES data ☐ All MBES data in sheet <u>Corrections and Reductions:</u> ☒ Preliminary Applied ☐ Final Applied <u>Edits:</u> ☒ Reject gross fliers ☒ Reject fliers that exceed error budget ☒ Check for busts or artifacts, note and investigate ☐ Designate soundings	<u>Tides:</u> ☒ Single base PPK-derived tides applied <u>Data Cleaning Editor:</u> ☐ Swath Editor ☒ Subset Editor <u>Surface Data Source:</u> ☐ Single shift MBES data ☒ All MBES data in sheet <u>Corrections and Reductions:</u> ☒ Preliminary Applied ☐ Final Applied <u>Edits:</u> ☒ Reject gross fliers ☒ Reject fliers that exceed error budget ☒ Check for busts or artifacts, note and investigate ☐ Designate soundings	<u>Tides:</u> ☒ Applanix SmartBase PPK-derived tides applied <u>Data Cleaning Editor:</u> ☐ Swath Editor ☒ Subset Editor <u>Surface Data Source:</u> ☐ Single shift MBES data ☒ All MBES data in sheet <u>Corrections and Reductions:</u> ☐ Preliminary Applied ☒ Final Applied <u>Edits:</u> ☒ Reject gross fliers ☒ Reject fliers that exceed error budget ☒ Check for busts or artifacts, note and investigate ☒ Designate soundings

Table 19 – Multibeam editing phases

B.3.10. Final BASE Surfaces

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

Multibeam surfaces were created at 1-meter resolution as CUBE surfaces. “Density and Locale” was chosen as the disambiguity method and NOAA CUBE parameter .XML based on resolution as the advanced CUBE parameters. The CUBE parameters used meet the 2011 <u>HSSD</u>. These parameters are included with the CARIS digital data deliverables. Note that although the HSSD calls for 2 m surfaces in depths greater than 20 m, only a very small portion of the survey area fell into this range. In the set-line spacing approach required for this survey there was no advantage in creating 2 m surfaces.

All surfaces are projected to UTM Zone 3 North (NAD83). For specific grid resolutions, depths and naming conventions refer to the DRs.

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. For multibeam surfaces, depth thresholds were applied based on resolution when warranted.

A data set containing a single CARIS Notebook (.HOB) file and supporting files was submitted in conjunction with each 2011 survey deliverable. The CARIS Notebook file contains information on objects not represented in the depth grid, including nature of the seabed (bottom samples), sand-wave areas, and meta-data objects. Each feature object includes the mandatory S-57 attributes and NOAA custom attributes that may be useful in chart compilation.

B.3.11. 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 1m resolution surface created from the main scheme data.

The differences in depth were grouped by beam number and statistics computed, which included the percentage of soundings compared whose differences from the BASE surface fall within IHO survey Order 1. Beams where at least 95% of the soundings exceed IHO Order 1 were considered to "pass," while beams where less than 95% of the soundings compare within IHO Order 1 were considered to "fail."

A discussion concerning the methodology of crossline selection, as well as a summary of results for each sheet, is available in the relevant DR. The QC Reports are included in each DRs, *Separate IV: Crossline Comparisons.*

B.3.12. Processing Workflow Diagram

The following diagram outlines the processing flow.

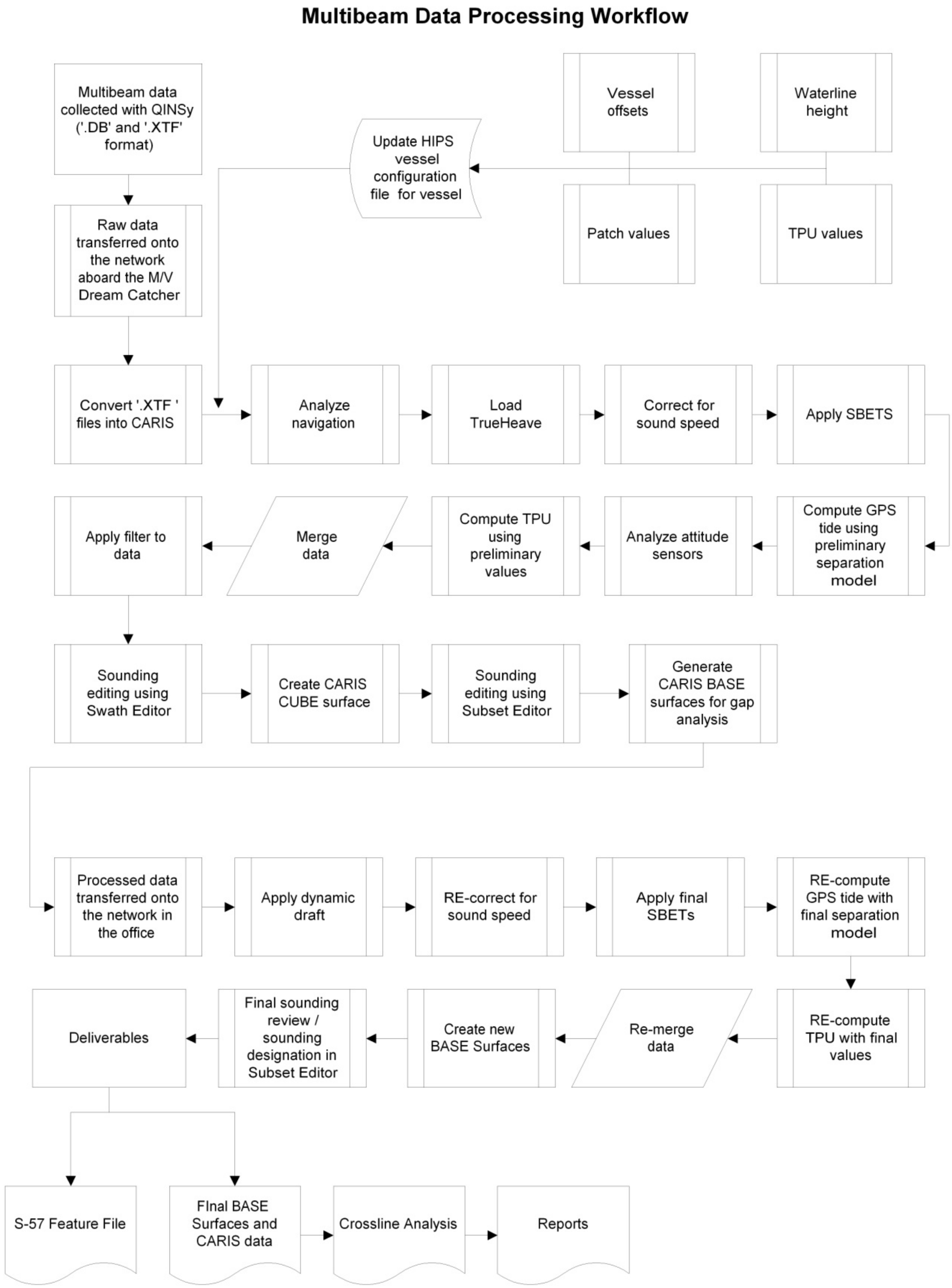


Figure 11 – Processing flow overview

B.4. Confidence Checks

In addition to the QC steps relating to acquisition and processing procedure outlined in the above sections, frequent formal confidence checks were undertaken throughout the survey to ensure the best possible accuracy and precision was achieved. These were designed to exceed the minimum requirements outlined in the 2011 HSSD.

The following table summarizes the formal confidence checks.

Confidence Check	Purpose	Normal Frequency
Bar Checks	Ensure echosounder accuracy Determine and refine Z offsets	4 times over survey
Lead Line	Ensure echosounder stability	Weekly, conditions permitting
SVP Comparison	Check SVP sensors for consistency	Weekly
Base station position check	Ensure consistent base station position	Weekly
Base station site confirmation	Confirm base station position accuracy	Once
Vessel position confidence check	Check for consistent vessel positioning	Weekly
Staff Shots	Check of tide gauge stability	Bi-weekly to monthly

Table 20 – Summary of confidence checks

B.4.1. Bar Checks

For this survey bar-checks were employed to determine or refine Z offsets and to check the absolute accuracy of the MBES system.

For bar checks a steel grid, roughly 1 meter square, was hung by cable from the vessel's gunwale. The bar cable was marked at an interval of 1 meter from the bar, measured by tape.

A sound velocity profile was collected and the average velocity entered into the echosounder. Static draft was measured.

With QPS QINSy logging and the sonar tuned to track the bar instead of the bottom, the bar was lowered by 1 meter increments directly below the vessel's transducer while bar depth and time was noted in the log. Bar check max depth – which ranged from 4 to 12 meters on this survey – was determined by ability to maintain a sonar lock on the bar (usually a function of the current) and depth in the area.

The bar depth was read relative to the waterline for later comparison to the HIPS results, as well as relative to the gunwale measure down points for determining or checking the acoustic center offset. Bar depth versus HIPS results always compared to better then 0.10 m, but usually better than 0.03 m.

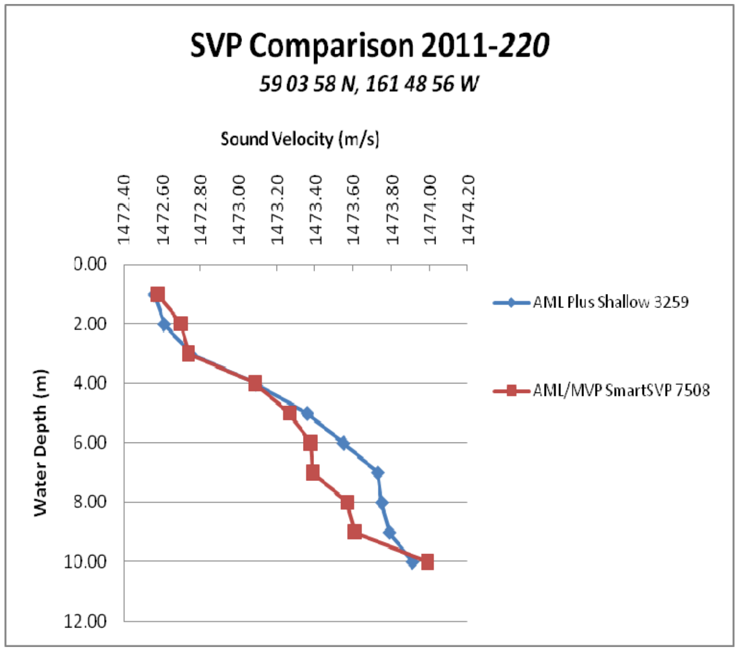
In addition to confidence checks, bar checks were used to refine acoustic center offsets measured during the vessel survey.

Bar check processing logs are available in *Separate I* of each project's DR. Bar check data in CARIS format is available in the CARIS project.

B.4.2. SVP Comparison

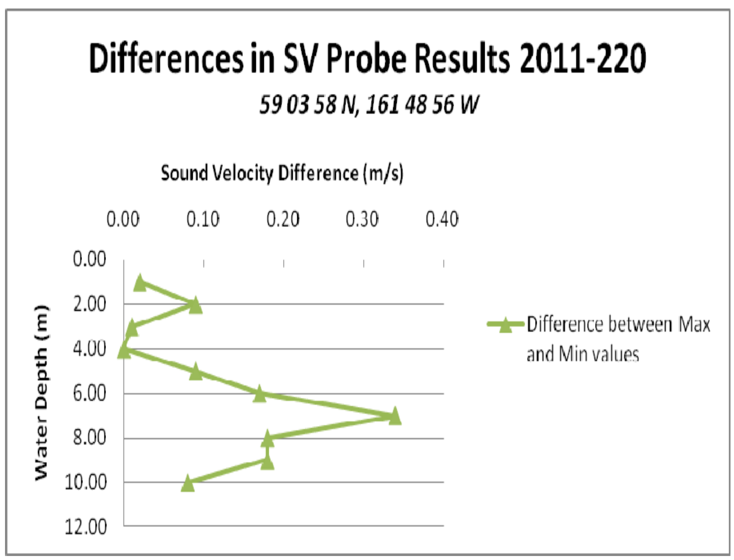
Direct comparisons were normally completed weekly between the sound-speed sensors in use on the project. A cast was taken with both sensors within the same time frame. The data underwent standard processing and was then compared depth-by-depth in an SVP comparison logsheet (see example below). Results were good between sensors, with measurements comparing typically to 0.30 m/s or better. Individual test results are available in *Separate I* of each DR.

SV Probe Results		
Probe:	AML	MVP
S/N	3259	7508
Date/time:	220/19:50	220/19:43:02
Depth	Sound Velocity (m/s)	
1.00	1472.56	1472.58
2.00	1472.61	1472.70
3.00	1472.75	1472.74
4.00	1473.09	1473.09
5.00	1473.36	1473.27
6.00	1473.55	1473.38
7.00	1473.73	1473.39
8.00	1473.75	1473.57
9.00	1473.79	1473.61
10.00	1473.91	1473.99
11.00	1473.93	1474.15
12.00	1474.19	1474.37
13.00	1474.58	1474.67
14.00	1474.80	1475.10



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

Statistics on the SV Probe results			
	Sound Velocity (m/s)		
Depth	Max	Min	Difference
1.00	1472.58	1472.56	0.02
2.00	1472.70	1472.61	0.09
3.00	1472.75	1472.74	0.01
4.00	1473.09	1473.09	0.00
5.00	1473.36	1473.27	0.09
6.00	1473.55	1473.38	0.17
7.00	1473.73	1473.39	0.34
8.00	1473.75	1473.57	0.18
9.00	1473.79	1473.61	0.18
10.00	1473.99	1473.91	0.08
11.00	1474.15	1473.93	0.22
12.00	1474.37	1474.19	0.18
13.00	1474.67	1474.58	0.09
14.00	1475.10	1474.80	0.30



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

Figure 12 – Example of typical SVP comparison results

B.4.3. Base Station Position Checks

Positions of base station benchmarks were established using NOAA NGS' OPUS (Online Positioning User Service) by upload of the first 24-hour GPS static session from each initial base station deployment. This position became the accepted, "surveyed" position.

To ensure that the benchmark did not subsequently shift over the course of the survey and to check repeatability of the surveyed position, static sessions were uploaded to OPUS approximately weekly and the results compared in an Excel spreadsheet to the surveyed position.

Results were good, with subsequent occupations and checks always comparing to better then 0.03 m (both horizontally and vertically) but usually better than 0.01 m. See the HVCR for more information regarding specific results and the base station position check log sheet.

B.4.4. Base Station Site Confirmation

As an additional check of base position accuracy and to ensure no site specific issues existed, a site confirmation was done once for each base station. For this check, an established CORS (Continually Operating Reference System) base station was used as the "rover" and each project base station used as the "base." The selected rover was either the BET1 site in Bethel or the AB12 site in Platinum, whichever was closest to the installed base station. Rinex data downloaded for BET1 or AB12 was imported into Applanix POSPac (GNSS 5.1 module) and processed using the project base station. The resulting computed position for BET1 or AB12 was then compared to the CORS published position of BET1 or AB12 respectively.

Results were good considering the large distances between CORS and installed base stations. Computed positions of BET1 and AB12 comparing to actual positions were better than 0.04 m horizontally and 0.08 m vertically. See the HVCR for more information and specific site confirmation results.

B.4.5. Vessel Positioning Confidence Check

To ensure that vessel positioning was consistent regardless of the base station in use – and as independent check of vessel positioning – vessel position confidence checks were typically done on a weekly basis

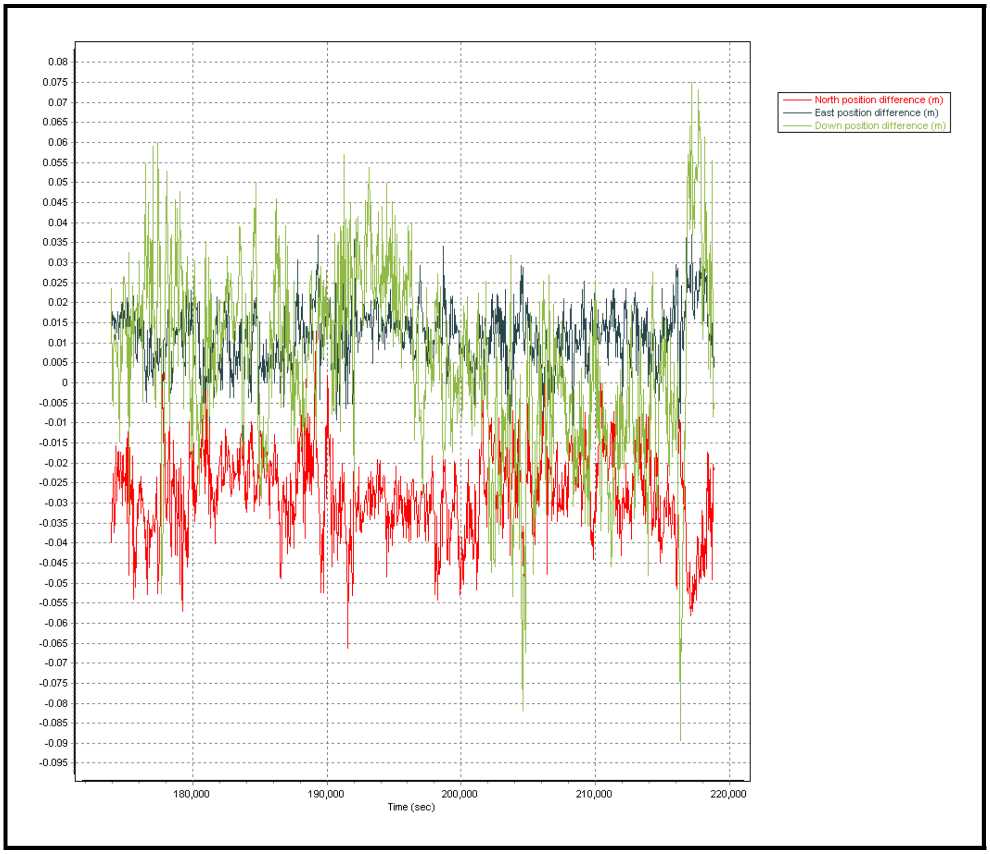
To complete this check, a random POS file was selected from the week and processed using normal procedures with the one base station (typically Quinhagak), producing an SBET file. The POS file was then re-processed with an independent but usually more distant secondary base station, producing a second SBET. Due to the lack of nearby CORS sites in the area, the secondary station was another project base station.

The two SBETs were differenced using the "NavDif" utility available in Applanix POSPac. This produced a difference plot, which was reported on a vessel positioning confidence check form. Considering the distances between base stations, results were good, returning differences better than 0.15 m horizontally and 0.26 m vertically. A series of comparisons were also done between SBETs created using single-base and Applanix

SmartBase modes, which also compared well. See the vessel positioning confidence check logs in *Separate I* of each DR for specific results. An example is shown below.

Positioning Confidence Check

POS file: 2011-222-1132-1A.POS **Date:** 2011-222 **Vessel:** Dream Catcher



(Figure 1- Position difference between 2011-222-1132-1A.POS processed with CORS station Popo versus Quin.)

Base Station

Base Station Name	**Approx. Min. Baseline Distance (m)**	**Max. Baseline Distance (m)**
Quinhagak	20,000	33,000
Popokamute	23,000	66,000

(Table 1- Baseline minimum and maximum distance)

Statistics

Position	**Approx. Min. Difference (m)**	**Approx. Max. Difference (m)**
North	-0.066	0.014
East	-0.010	0.036
Down	-0.083	0.075

(Table 2-Approximate minimum and maximum difference)

Comments: N/A

Figure 13 – Example positioning confidence check. M/V Dream Catcher JD222

B.4.6. 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 2011 HSSD were done at each tide station. These were typically completed bi-weekly or monthly, according to the schedule set in the TerraSond Technical Proposal dated 5/12/11. See the HVCR for more information.

Standard leveling procedures were used to determine the difference in elevation between a tide station benchmark and the water surface. At least one hour of observations were collected at each visit, at a six minute interval that started on the hour. When Seabird gauges were downloaded monthly, two hours of staff shots were collected before and after the gauge being lifted. The staff-shot readings were timed to coincide with data collected by the Seabird or WaterLOG tide gauges which were synced to UTC.

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 Surveys (JOA). JOA would then 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.

C. *Corrections to Echo Soundings*

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

C.1. Vessel Offsets

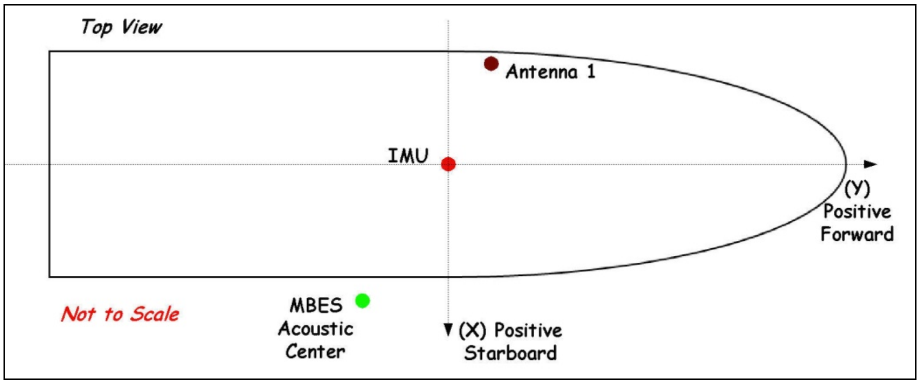
Sensor locations were established with a pre-season survey of the vessel using conventional survey instruments. Acoustic center offsets were refined through bar check method. IMU to primary antenna offset was refined through "Calibrated Installation Parameters" in POSPac, while secondary antenna offset was determined by translation of the GAMS calibration baseline vector. The top center of the POSMV's IMU was selected as the center reference point (CRP) – or point from which all offsets were referenced. The IMU was mounted as close as practical to the estimated center of gravity of the vessel.

All vessel-related offsets were applied in CARIS HIPS by means of the HVF except the primary GPS antenna to reference point offset. This offset was entered into POSMV at the start of the project as a lever arm offset and was required for optimal POSMV performance. This resulted in the POSMV outputting positions already corrected to the CRP. The POSMV also computed the primary to secondary antenna separation during GAMS calibration and used the value internally during heading calculations.

All offsets received numerous checks including reality test by survey tape and bar check. Checks reveal a total offset uncertainty of 0.050 m horizontally and 0.025 m vertically. POSPac was also utilized to check lever arm offsets through its lever arm calibration plots.

Vessel outlines and offset descriptions are provided below.

C.1.1. M/V Dream Catcher Vessel Survey



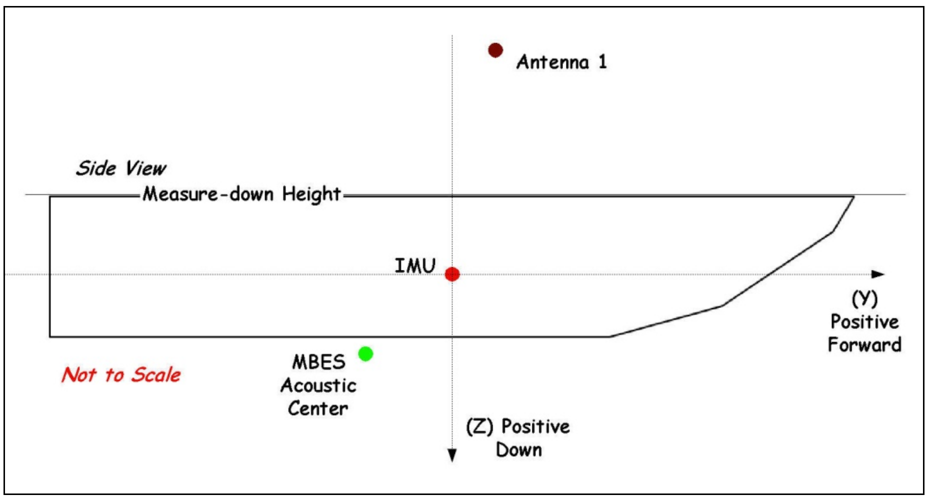


Figure 14 – M/V Dream Catcher vessel survey showing the relative positions of the installed survey equipment

Equipment	Offset from CRP (m) based on CARIS Convention		
	X (+ stbd)	Y (+ fwd)	Z (+ down)
IMU	0.000	0.000	0.000
MBES Acoustic Center	2.861	-3.147	1.639
GPS1 (Primary/Port)	-1.968	2.160	-11.730
Draft Measure-down Points*	n/a	n/a	-2.067

Table 21 – M/V Dream Catcher offset measurements determined during vessel survey. *Draft Measure-down points were tightly constrained to the vessel's gunwale plane

C.2. Attitude and Positioning

As described in previous sections of this report, heave, roll, pitch, heading, and positioning data for the three vessels were measured using Applanix POSMV. The system provided output as a binary data string via RS-232 serial cable to the QINSy acquisition software at 50Hz. The data was also logged to POS file for post-processing of positions and application of TrueHeave. Heave (or TrueHeave), roll and pitch corrections were applied during the sound velocity correction process in CARIS HIPS. Uncertainty associated with these measurements is discussed in Section B of this report.

C.3. Patch Test Data

Patch tests were performed on the vessel to determine any offset angles (roll, pitch and azimuth) and latency between the transducer and motion sensors. These tests were done over a significant sand wave feature. The patch test data is available for review with the CARIS deliverables in the "Calibrations" project.

C.3.1. Navigation Latency

To determine latency, a survey line was run twice – in the same direction – at different speeds over a distinct feature. The data was examined in HIPS "Calibration" mode. Any horizontal offset of corresponding nadir beams on the feature indicated latency between the positioning and sounding systems. A value (in seconds) that improved the matchup was determined and entered into the HVF.

C.3.2. Pitch

After determining and correcting for any latency, pitch offset was determined. The same survey line run twice over a distinct feature, in opposite directions, was examined in Calibration mode. Any horizontal offset of corresponding nadir beams indicated a pitch offset between the sounder and motion sensor reference frames. A value that improved matchup was determined and entered into the HVF.

C.3.3. Azimuth (Yaw)

After determining and correcting for any latency and pitch, the azimuth (yaw) offset was determined. Survey lines run in opposite directions with outer beams overlapping on a distinct feature were examined in Calibration mode. Any horizontal offset of corresponding nadir beams indicated a yaw offset between the sounder and motion sensor reference frames. A value that improved matchup was determined and entered into the HVF.

C.3.4. Roll

The roll offset was determined after the latency, pitch, and yaw offsets had been determined and corrected. The same survey line run twice over flat bottom topography, in opposite directions, was examined in Calibration mode. Any vertical offset of outer beams indicated a roll offset between the sounder and motion sensor reference frames. A value that improved matchup was determined and entered into the HVF.

C.3.5. Patch Test Results

Patch test values and latency corrections were applied to the raw sounding data during the merge process in CARIS HIPS. Refer to Section B of this report for uncertainties associated with patch test results. The following table summarizes the patch tests and the results.

Note: The data for the JD247 patch test is included with the project CARIS deliverables. However, patch test data from JD155 and other intermediate patch tests run for test purposes are not included because their values are not applied to the final data.

Vessel	Echo Sounder	Time (sec)	Pitch (deg)	Roll (deg)	Yaw (deg)	Patch Test Date	Quality, Purpose
M/V Dream Catcher	Reson MBES	0	-1.30	-1.18	1.80	June 4, 2011 (JD155)	Poor Quality Lines, Preliminary Values
M/V Dream Catcher	Reson MBES	0	-1.02	-1.166	0.588	Sept 4, 2011 (JD247)	Good Quality Lines, Final Values. Pre-dated in HVF to 7/7/11 (JD188)

Table 22 – Patch tests performed for instrument calibration during OPR-R341-KR-11

C.4. Speed of Sound Corrections

Sound-speed profile data for OPR-R341-KR-11 was collected using an AML Micro SV&P sensor and an AML SV Plus sensor.

Profiles were collected by acquisition normally on a 4-hour interval during MBES operations. They were processed in TerraSond's TerraLog software which produced a CARIS compatible format at 0.1-meter depth intervals. The output was appended to the master HIPS SVP file by vessel and sheet.

Sound speed measurements were removed from the output for depths shoaler then 2.0 m. This was done because the in-use MVP system did not consistently provide data for these depths. This had no effect on the data since the multibeam sonar was mounted at a depth of approximately 2.3 m below the water surface.

Sound-speed corrections were applied in processing to the raw sounding data through HIPS sound velocity correction. Nearest in distance within time was selected for the correction method, with four hours used for most lines. Exceptions are noted in the Daily Event Logsheets, included in the DR, *Separate I*. The DR, *Separate II* contains sound-speed comparisons and calibration reports. Individual cast data can be found in the ".SVP" file submitted with the digital CARIS data for each survey.

C.5. Static Draft

Static draft was measured at least once daily on each 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 the daily acquisition log sheets.

HIPS vessel files (HVF) were then updated by processing with a new waterline value. The port and starboard measure-downs recorded in the daily acquisition log sheet 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.

Additionally, waterline heights were measured ultrasonically by the TerraSonic devices installed on both gunwales. TerraSonic files were collected continuously, broken into two 12-hour files. At the time the physical measure-down was collected, the 20-second running averages of both sides were also averaged and recorded in the measure-down log sheet. These values were typically used instead of the physical measure-down since they were determined to be more accurate, particularly in adverse weather conditions.

The waterline correction was applied to the soundings by HIPS during sound velocity correction. The waterline correction was also applied to GPS altitudes during the compute GPS tide process. Waterline correction values are available in each HVF available with the CARIS deliverables.

C.6. Dynamic Draft Corrections

Dynamic draft corrections were determined using PPK GPS methods for all vessels. The values were computed from squat-settlement tests. Corrections were determined for a range that covered normal survey speeds and engine RPMs.

C.6.1. Squat Settlement Tests

During squat-settlement tests, the vessel logged position data to POS file while a nearby shore base station logged dual frequency GPS data. A survey line was setup in the direction of the current and run up-current and then down-current at incrementing engine RPM ranges. Between each set as well as at the start and end of the test a "static" was collected whereby the vessel would sit with engines in idle, and log for a minimum of two minutes. The survey crew would note in the acquisition log sheet the precise time and average engine RPM of each event. The entire test was repeated with the multibeam sonar deployed to account for different vessel response due to the increased drag.

The POS file was later processed with the nearby base station data in Applanix POSPac to produce an SBET. The SBET was examined to determine vessel speeds for each RPM range. Altitudes were extracted from the SBET and imported into Microsoft Excel.

In Excel the altitude records were separated and grouped according to RPM range or static. Each range was averaged to remove heave and motion. A 4^{th} order polynomial equation was computed that best fit the static periods and used to remove the tide component from the RPM ranges. The residual result was the difference from static or dynamic draft. Interpolated RPM ranges were inserted when necessary to eliminate steps. This resulted in a table of corrections for draft as a function of engine RPM.

C.6.2. Application of Dynamic Draft

Dynamic draft corrections for this project were engine RPM-based instead of speed-based. Due to the strong river and tidal currents, typically averaging 3 kts, RPM-based corrections more accurately captured vessel vertical response. For this reason the HVF does not contain a draft-speed table.

As described previously, RPM data was computed and logged continuously using TerraTach. Excel was used to process the logged RPM data to produce a dynamic draft correction file. In Excel, the RPM data that had been time tagged and logged continually during survey operations was imported and a lookup table used to exchange RPM with the appropriate dynamic draft corrections determined for the vessel.

A CARIS-compatible output was produced and loaded into all lines in CARIS with the HIPS "Load Delta Draft" utility. The dynamic draft files are available with the CARIS survey deliverables in the "tide" directory.

On very rare occasions RPM files were logged late or logged without time stamps. These lines have interpolated RPM values and are individually noted when applicable in the DRs.

Subsequently all lines were sound-speed corrected again and GPSTide re-computed (dynamic draft option turned on) and lines re-merged in HIPS to apply the correctors.

C.6.3. M/V Dream Catcher Results

A squat-settlement test was completed on the *M/V Dream Catcher* on August 23 – 24, 2011 (JD235-236). The test was done with the multibeam transducer in the deployed position. The *M/V Dream Catcher* typically surveyed at engine RPMs below 1900. The results are shown below.

***M/V Dream Catcher* Settlement Table**

RPM	Settlement (m) (+ down)
0	0.000
500	-0.011
600	-0.008
700	-0.006
800	-0.003
900	-0.001

1000	0.001
1100	0.004
1200	0.008
1300	0.012
1400	0.016
1500	0.022
1600	0.029
1700	0.038
1800	0.048
1900	0.060
2800*	0.060

*Value of 2800 RPM inserted to include any possible survey RPMs above 2800

Table 23 – M/V Dream Catcher Settlement Results

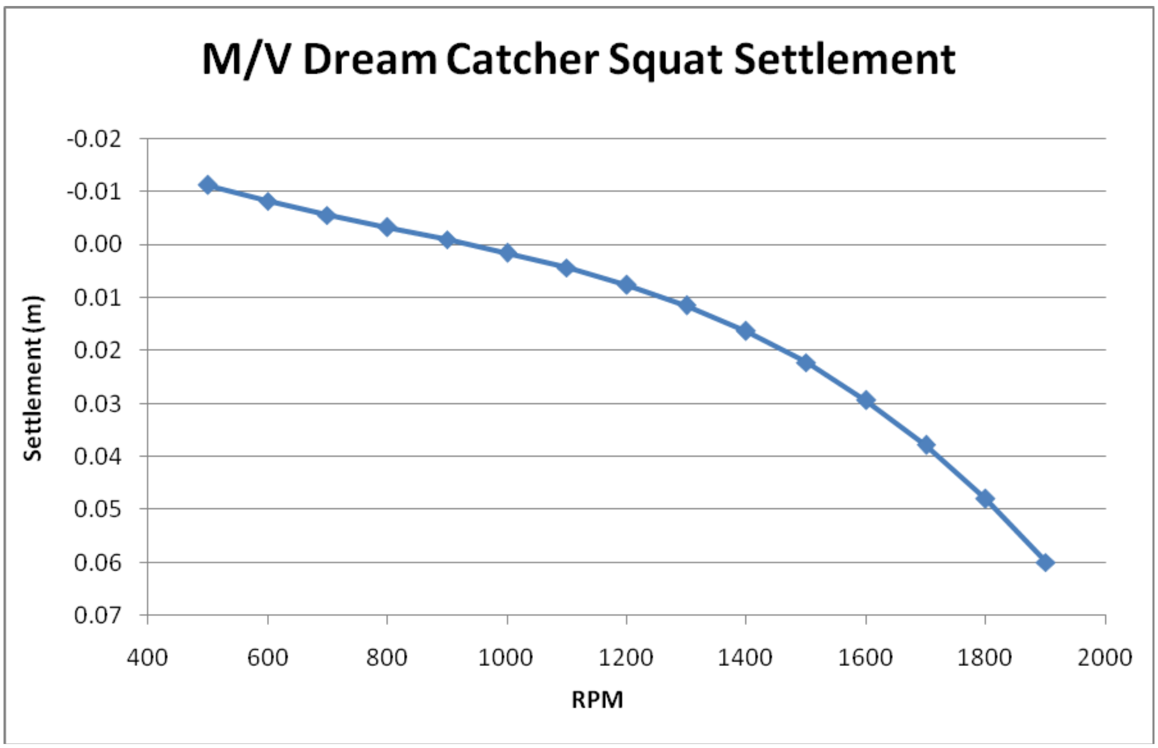


Figure 15 – M/V Dream Catcher Settlement Results

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

Ellipsoid Referenced Surveying (ERS) methods were used for tide correction on this project. All survey lines were loaded with accurate NAD83(CORS96) ellipsoid heights from SBET files as outlined previously in this document. To reduce the ellipsoid heights to MLLW, a separation model was developed by JOA and applied to the lines in CARIS HIPS. The model utilized the GPS to MLLW datum separations computed for installed tide stations at Quinhagak, AK (946-5831), Popokamute, AK (946-6057), station and Carter Bay, AK (946-5601). Expansive shoal areas in front of the sites made it impossible to install bubbler tide stations at Carter Bay and Quinhagak, necessitating the installation of submersible Sea-Bird tide gauges for these stations. At Popokamute two bubbler type gauges were installed. Additionally, four short-term “roving” Sea-Bird tide instrument deployments were completed throughout the project to provide supplementary data for zoning purposes. See the project HVCR for more information regarding the MLLW separation values and the separation model.

APPROVAL SHEET

For

H12325 through H12328

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 DR (one for each survey sheet) and the Horizontal and Vertical Control Report.

This survey is complete and adequate for its intended purpose.

Marta Krynytzky

Digitally signed by Marta Krynytzky
DN: CN = Marta Krynytzky, C = US, O = TerraSond Ltd., OU = Charting
Reason: I attest to the accuracy and integrity of this document
Location: Palmer, AK
Date: 2011.12.21 16:48:42 -09'00'

Marta Krynytzky
Lead Hydrographer
TerraSond Ltd.

Andrew Orthmann

Digitally signed by Andrew Orthmann
DN: CN = Andrew Orthmann, C = US, O = TerraSond LLC
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Location: Palmer, AK
Date: 2011.12.22 14:24:46 -09'00'

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