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

Data Acquisition & Processing Report

Type of Survey Hydrographic Survey

Field No. H12004, H12065, H12066, H12067

Registry No. OPR-P188-TE-09

LOCALITY

State Alaska

General Locality Unimak Pass

2009

CHIEF OF PARTY

Marta Krynytzky

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DATE January 2010

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(11-72)

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

HYDROGRAPHIC TITLE SHEET

REGISTRY No

Data Acquisition & Processing Report OPR-P188-TE-09

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. **H12004, H12065, H12066, H12067**

State Alaska

General Locality Unimak Pass

Sub-Locality Various

Scale N/A

Date of Survey May16th-August26th,2009

Instructions dated N/A

Project No. OPR-P188-TE-09

Vessel *M/V Bluefin, R/V Mt. Mitchell, R/V Mt. Augustine & Skiff Spare Rhib*

Chief of party Marta Krynytzky

Surveyed by TerraSond Ltd.

Soundings by echo sounder, lead line, pole Multibeam Echosounder

Graphic record scaled by N/A

Graphic record checked by N/A

Automated Plot N/A

Verification by N/A

Soundings in fathoms feet at MLW MLLW Meters at MLLW

REMARKS: Contract No.: DG133C-05-CQ-1079

Contractor: TerraSond Ltd.

All times recorded in UTC

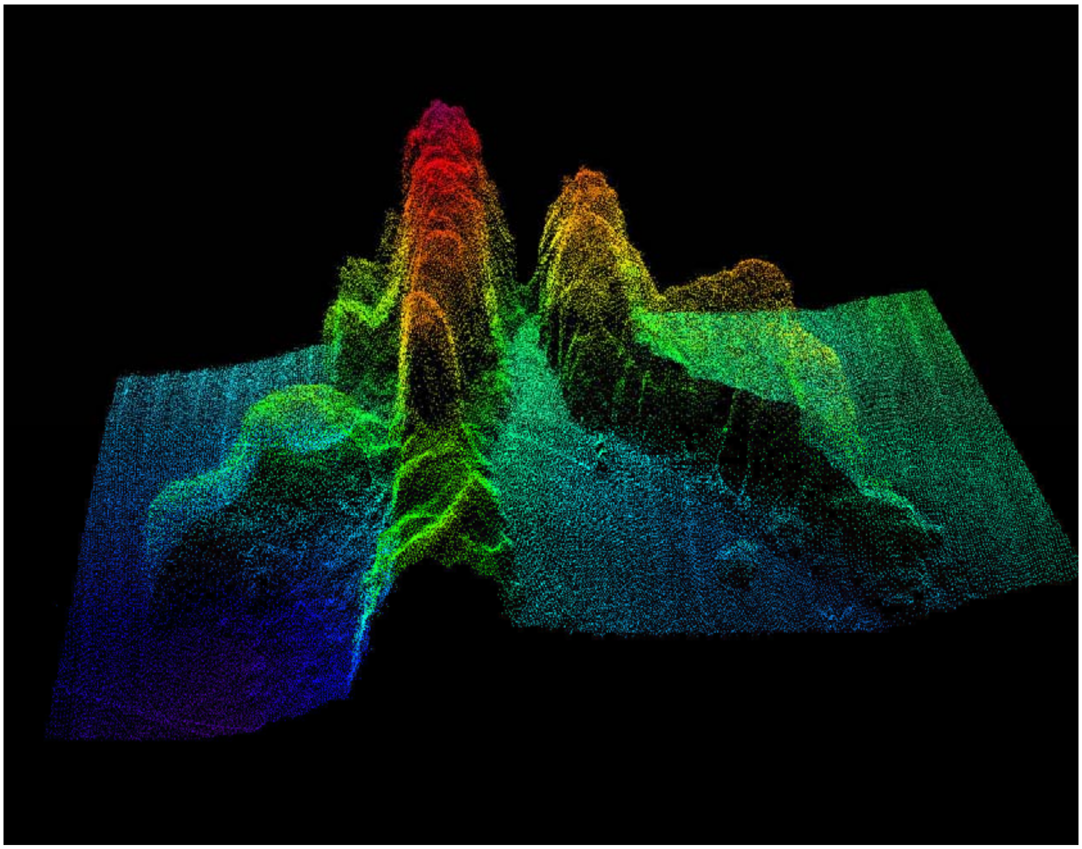
1617 South Industrial Way, Suite 3

Palmer, AK 99645

Data Acquisition and Processing Report

OPR-P188-TE-09

August 26, 2009



Vessels: ***M/V Bluefin, R/V Mt. Mitchell, R/V Mt. Augustine and skiff 'Spare Rhib'***

Locality: **Unimak Pass, Alaska**

Sublocalities:

H12004 - Unimak Pass, AK
H12065 - 10 NM SE of Unimak Is, AK
H12066 - 26 NM SW of Sanak Is, AK
H12067 - 15 NM South of Sanak Is,

Lead Hydrographer: **Marta Krynytzky**

TERRASOND

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FIGURES

TABLES

A. Equipment

A.1. Vessels

All data for this survey was acquired using the *Motor Vessel Bluefin*, the *Research Vessel Mt. Mitchell*, the *Research Vessel Mt. Augustine*, and a rigid hull inflatable skiff *Spare Rhib.* The *R/V Mt. Augustine* was used to acquire multibeam data that was not practical or accessible to survey with the *M/V Bluefin.* The *R/V Mt. Mitchell* was used to acquire multibeam data in an area where the survey depth was beyond the range of the sonars mounted on either the *M/V Bluefin* or *R/V Mt. Augustine.* The *Spare Rhib* was used to acquire detached positions and other shoreline data. The *R/V Mt. Augustine* and *Spare Rhib* were also used to assist in shore visits to the tide stations.

A.1.1. M/V Bluefin

Multibeam echosounder and bottom sample data for surveys H12004, H12065, H12066 and H12067 were acquired using the *M/V Bluefin.* The *M/V Bluefin* survey was conducted concurrently with operations by the *R/V Mt. Augustine, R/V Mt. Mitchell* and *Spare Rhib.*

Figure 1 – M/V Bluefin at anchor in Akun Bay, AK.

The *M/V Bluefin*, shown at anchor in Figure 1, is a 53.64 meter steel hulled vessel with an 11.58 meter beam and a 3.96 meter draft. The ship is powered by two 950 HP 16V-149 General Motors diesel engines connected to 4-blade, fixed pitch propellers. The vessel also has a 300 HP Marco T-80 hydraulic bow thruster. Electrical power was provided by two CAT 3406 325 kW generating plants located in the engine room. The *M/V Bluefin* was outfitted with a hull-mounted Reson SeaBat 8101 Multibeam Echosounder System. Detailed vessel drawings showing the location of all primary survey equipment are included in *Section C* of this report.

A.1.1.1. Equipment Overview

The equipment on the *M/V Bluefin* performed well, with the exception of the following:

1. The Applanix POS IMU was not mounted near the natural center of rotation of the *M/V Bluefin*; rather it was mounted towards the bow of the vessel directly above the Reson sonar head. The center reference point of the M/V Bluefin was maintained at the center of the top of the Applanix POS IMU. The center of rotation was determined to be 16 meters aft and 2 meters up from the *M/V Bluefin's* center reference point (CRP). Center of Rotation Lever Arm offsets were entered into the POS through the POS Controller software, resulting in the POS filtering out pitch induced heave and outputting motion data referenced to the CRP. No center of rotation lever arm was entered into the CARIS vessel file. It is noted that this configuration results in a non-zero average heave in the CARIS motion data.

2. An offset between *M/V Bluefin* and *R/V Augustine* soundings on the order of 0.20 m is apparent in the data, with *M/V Bluefin* data shoaler. An extensive investigation of all potential causes was undertaken while in the field, including examination of sensor offsets and software configurations such as the vessel configuration files. Frequent lead-line checks were taken on both vessels and the results compared to their respective vessel sonar systems with good results. After eliminating other potential error sources, pitch-induced heave due to the forward-mounted location of the POS MV IMU became suspect and the issue was thoroughly discussed with Applanix and CARIS to insure the POS MV was configured to compensate for the offset correctly and that HIPS was configured to apply the sensor data properly, with the consensus that the setup as implemented was correct. However, despite manufacturer re-assurances of the system's capability as configured to provide corrections for an IMU offset from a vessels center of gravity, TerraSond believes the offset to be caused by hardware and/or software mishandling of pitch-induced heave of the forward-mounted IMU on the *M/V Bluefin*. Though the exact cause of the error is undetermined, the data remains within the required accuracy specification on both vessels.

3. Twice during the project a roll artifact was noticed during onboard processing. Both times the *M/V Bluefin* was completely patch tested as soon as possible and all new patch values were implemented from the date the difference was observed. The first occurrence was noticed on data from 2009-199, on the first

lines collected after a weather period in which the *M/V Bluefin* could not collect data. A diver's hull inspection on July 22, 2009 (Julian Day 2009-203) in Dutch Harbor revealed no noticeable damage or changes to the sonar head or mount. The *M/V Bluefin* was patch tested on 2009-204 in Dutch Harbor.

The second occurrence was on 2009-236, directly after the *M/V Bluefin* had deployed a Sea Bird tide gauge and accidentally drifted over the floating buoys attached to the gauge. The sonar mount was inspected by a diver in Dutch Harbor on August 27, 2009 (Julian day 2009-239). The diver found no notable damage or changes to the sonar head or mount. The *M/V Bluefin* was patch tested on 2009-237 in Unimak Pass. In both incidences the new patch values removed artifacts observed in the data and no further alignment artifacts were observed.

4. On July 23, 2009 the Reson 81-P with serial number 8002007 on the *M/V Bluefin* was noticed to have an electrical malfunction. The Reson 81-P with serial number 8002007 was removed from service and the Reson 81-P with serial number 8002029 was taken from the *R/V Mt. Augustine* and installed on the *M/V Bluefin*. The *M/V Bluefin* was patch tested on July 24, Julian Day number 205 with the Reson 81-P with serial number 8002029. For the remainder of the project one good Reson 81-P with serial number 8002029 was swapped between the two vessels, such that only one vessel could be used for multibeam operations at a time. Since the Reson 81-P is a rack mount unit no further patch tests were conducted when the one functioning unit was swapped between the two vessels. While the *R/V Mt. Augustine* was collecting multibeam data with the functioning Reson 81-P, the *M/V Bluefin* acquired bottom samples. The *M/V Bluefin* was able to use the Reson 81-P with serial number 8002007 with the electrical malfunction to record depths for bottom samples. The depths for bottom samples are recorded in acquisition logs and agreed with the QINSy sounding grid (where available) within a few meters. The QINSy sounding grid is not tide corrected, thus a difference of a few meters was acceptable.

A.1.1.2. Major Operational Systems

***M/V Bluefin* Survey Equipment**

Description	Manufacturer	Model / Part	Serial Number
Multibeam Sonar	Reson	SeaBat 8101	276010
Sonar Processor	Reson	81-P	8002007
Sonar Processor	Reson	81-P	8002029
Positioning System	Applanix	POS MV V4	3167
Motion Sensor	Applanix	POS MV IMU	783
SV Casting Probe	Applied Microsystems	Micro SV&P	7508

Description	Manufacturer	Model / Part	Serial Number
SV Casting Probe	Applied Microsystems	SV Plus v2	3317
Differential Beacon Receiver	Hemisphere GPS	MBX-4	0817-7067-0011
Secondary Positioning System	Trimble	DSM-232	0225127531

Table 1 – Major survey equipment used aboard the M/V Bluefin.

A.1.1.3. Sounding Equipment

A Reson SeaBat 8101 multi-beam echosounder (MBES) system was used aboard the *M/V Bluefin* during OPR-P188-TE-09.

The 8101 is a 101-beam radial-array system. It employs a 1.5 degree along-track beam angle and a 1.5 degree across-track beam angle. Bathymetric data was output via Ethernet network connection to the acquisition computer. Range scales, power, gain and depth-filter limits were adjusted to maximize data collection and quality. Time Varied Gain (TVG) with spreading and absorption values were within recommended ranges for cold salt water.

A.1.1.4. Technical Specifications

Reson SeaBat 8101	
Sonar Operating Frequency	240 kHz
Beam Width, Across Track	1.5°
Beam Width, Along Track	1.5°
Number of Beams	101
Max Swath Coverage	150°
Max Range	300 m

Table 2 – Reson SeaBat 8101 multibeam echosounder technical specifications.

A.1.2. R/V Mt. Augustine

Multibeam echosounder and bottom sample data for surveys H12004 and H12065 were acquired using the *R/V Mt. Augustine*. The *R/V Mt. Augustine* survey was conducted concurrently with operations by the *M/V Bluefin* to acquire multibeam data that was not practical or accessible to survey with the *M/V Bluefin*.

Figure 2 – R/V Mt. Augustine underway.

The *R/V Mt. Augustine,* shown in Figure 2, is an aluminum hulled hydrographic survey vessel, 10.2 meters in length with a 3.3 meter beam and a 0.9 meter draft. For survey operations it was equipped with a Reson SeaBat 8101 multibeam echosounder mounted on a swing arm mount on the starboard side of the vessel. The *R/V Mt. Augustine* was powered by two Yanmar 6LPA-STP 315hp engines and Konrad Model 540 PRS out drives. Survey power was supplied by a Kohler 6EOD 110V 6kw generator and a Legend Trace Model 2512 inverter. Detailed vessel drawings showing the location of all primary survey equipment are included in *Section C* of this report.

A.1.2.1. Equipment Overview

The equipment on the *R/V Mt. Augustine* performed well with the exception of the following:

1. At approximately 19:30 on July 15, 2009 (Julian Day 2009-196) an inconsistent roll artifact was noticed in the multibeam data from the *R/V Mt. Augustine*. Times of roll value changes appeared similar to times at which the lever arm was raised and lowered. At 00:15 on July 16, 2009, the lever arm was lowered after a short transit and the roll value returned to its original value. Data acquired between 19:25 on July 15 and 00:14 on July 16 were omitted from the project and these areas were re-run at a later date.

2. Several crosslines from 2009-195 and 2009-196 were noticed to have an inconsistent roll offset. These lines were rejected during processing. All surveys for this project still exceeded the required four percent of linear nautical miles of Crosslines.

3. The next time the *R/V Mt. Augustine* participated in multibeam survey operations on July 24, 2009 (Julian Day 2009-205) the sonar arm was noticed to be unstable and not snug against the hull of the vessel. A chain come-a-long was used to secure the lever arm to its designed location with a stopper snug to the hull of the vessel. For the remainder of survey operations the *R/V Mt. Augustine* secured the lever arm into position in this fashion. Several lines were rejected from this day during processing due to significant roll artifacts.

A.1.2.2. Major Operational Systems

***R/V Mt. Augustine* Survey Equipment**

Description	Manufacturer	Model / Part	Serial Number
Multibeam Sonar	Reson	SeaBat 8101	3507006
Sonar Processor	Reson	81-P	8002029
Positioning System	Applanix	POS MV V4	3190
Motion Sensor	Applanix	POS MV IMU	778
SV Casting Probe	Applied Microsystems	SV Plus v2	3279
Differential Beacon Receiver	Hemisphere GPS	MBX-4	081770670018
Secondary Positioning System	Trimble	DSM-232	0225127581

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

A.1.2.3. Sounding Equipment

A Reson SeaBat 8101 multi-beam echosounder (MBES) system was used aboard the *R/V Mt. Augustine* during OPR-P188-TE-09.

The 8101 is a 101-beam radial-array system. It employs a 1.5 degree along-track beam angle and a 1.5 degree across-track beam angle. Bathymetric data was output via Ethernet network connection to the acquisition computer. Range scales, power, gain and depth-filter limits were adjusted to maximize data collection and quality. Time Varied Gain (TVG) with spreading and absorption values were within recommended ranges for cold salt water.

A.1.2.4. Technical Specifications

Reson SeaBat 8101	
Sonar Operating Frequency	240 kHz

Beam Width, Across Track	1.5°
Beam Width, Along Track	1.5°
Number of Beams	101
Max Swath Coverage	150°
Max Range	300 m

Table 4 – Reson SeaBat 8101 multibeam echosounder technical specifications.

A.1.3. Launch 'Spare Rhib'

Detached Position data for surveys H12004 and H12065 was acquired using the survey launch *Spare Rhib.* The *Spare Rhib* survey was conducted concurrently with operations by the *M/V Bluefin* to acquire detached position data that was not practical or accessible to survey with the *M/V Bluefin*.

Figure 3 – 'Spare Rhib' underway in Unimak Pass, Alaska.

The *Spare Rhib*, shown in Figure 3, is a fiberglass hulled inflatable vessel; 6.2 meters in length with a 2.7 meter beam and a 0.5 meter draft. The *Spare Rhib* was powered by two

Yamaha 60 hp engines. Survey power was supplied by a 750 Watt Vector power inverter.

A.1.3.1. Equipment Overview

The equipment on the *Spare Rhib* performed well with the exception of the following:

1. The Leupold Digital Range Finder model RX-IV has a manufactured stated accuracy of 1 yard (0.9144 m) and range of 1500 yards (1371.6 m) for a reflective target, 900 yards (822.9 m) for trees and 800 yard (731.5 m) for deer. Field conditions, such as reflection off water, small targets (tops of rocks only occasionally showing above water surface) were not ideal for this instrument.

A.1.3.2. Major Operational Systems

'*Spare Rhib*' Survey Equipment

Description	Manufacturer	Model / Part	Serial Number
Positioning System	Trimble DSM 212	DSM-212	0220218638
Range Finder	Leupold Digital Range Finder	RX-IV	R400142U

Table 5 – Major survey equipment used aboard the Spare Rhib.

A.1.4. R/V Mt. Mitchell

Multibeam echosounder data for survey H12067 was acquired using the *R/V Mt. Mitchell.*

Figure 4 – R/V Mt. Mitchell anchored in Akun Bay, Alaska.

The *R/V Mt. Mitchell*, shown in Figure 4, is a 70 meter steel-hulled vessel with a 12.7 meter beam and a 3.9 meter draft. The ship was powered by two 1200 HP EMD/567C General Motors diesel engines connected to two Bird-Johnson controllable-pitch propellers. Electrical power was provided by two Detroit Diesel 300 kW generating plants located in the engine room and one Detroit Diesel 75 kW auxiliary generator. The *R/V Mt. Mitchell* was outfitted with a hull-mounted Kongsberg EM 710RD Multibeam Echosounder System. Detailed vessel drawings showing the location of all primary survey equipment are included in *Section C* of this report. The *R/V Mt. Mitchell* was used to acquire multibeam data in areas that were beyond the depth range of the Reson 8101 MBES on the *M/V Bluefin*.

A.1.4.1. Equipment Overview

The equipment on the *R/V Mt. Mitchell* performed well during the survey.

A.1.4.2. Major Operational Systems

***R/V Mt. Mitchell* Survey Equipment**

Description	**Manufacturer**	**Model / Part**	**Serial Number**
Multibeam Sonar	Kongsberg	EM 710	201
Sonar Acquisition	Kongsberg	SIS	N/A
	QPS	QINSy	N/A

Description	Manufacturer	Model / Part	Serial Number
Positioning System	Applanix	POS MV V4	3034
Motion Sensor	Applanix	POS MV - IMU	727-412110
SV Probe	Lockheed Martin	XBT T-5	342813 – 342836
SV Probe	Lockheed Martin	XCTD-2	099922872-0922883
Surface SV Probe	Applied Microsystems	SV&T	5433
Differential Beacon Receiver	Primary: C-NAV	2050R NaviGator	601099
	Secondary: Hemisphere GPS	MBX-3	0171616000008

Table 6 – Major survey equipment used aboard the R/V Mt. Mitchell.

A.1.4.3. Sounding Equipment

A Kongsberg EM 710 multibeam echosounder (MBES) system was used aboard the *R/V Mt. Mitchell* during OPR-P188-TE-09.

The EM 710 is a 200-beam Mill's Cross system operating between 70 KHz and 100 KHz. It employs a 2 degree along-track beam angle and a 2 degree across-track beam angle. The EM 710 was set to high density equidistant mode to achieve 200 beams. Bathymetric datagrams from the EM710 were output via Ethernet connection to the acquisition software. The system's bottom tracking algorithm adjusts the gain, mode and range dependent parameters as required. The system uses a combination of phase and amplitude bottom detection to provide soundings with the best possible accuracy. The swath coverage was monitored and adjusted by the operator in order to maximize data contained within the quality specifications.

A.1.4.4. Technical Specifications

Kongsberg EM 710	
Sonar Operating Frequency	70 kHz – 100 kHz
Beam Width, Across Track	2.0°
Beam Width, Along Track	2.0°
Number of Beams	200 max
Max Swath Coverage	140°

Max Range	2000 m

Table 7 – Kongsberg EM 710 multibeam echosounder technical specifications.

A.2. Equipment

A.2.1. Tide Gauges

The United States Coast Guard (USCG) maintained National Water Level Observation Network (NWLON) tide stations at Unalaska, AK (946-2620), and King Cove, AK (945-9881) were used to provide predicted tide data for OPR-P188-TE-09. Two additional tide stations were installed in April, 2009 by John Oswald and Associates (JOA) of Anchorage, AK. Stations were installed at a historic USCG tide station Scotch Cap, Unimak Island, AK (946-2808) and a new tide station at Akun Bay, Akun Island, AK (946-2719). One supplemental station was installed by JOA at the historic site Sanak Harbor, Sanak Island, AK (945-9968), but was not used in the final tide zoning.

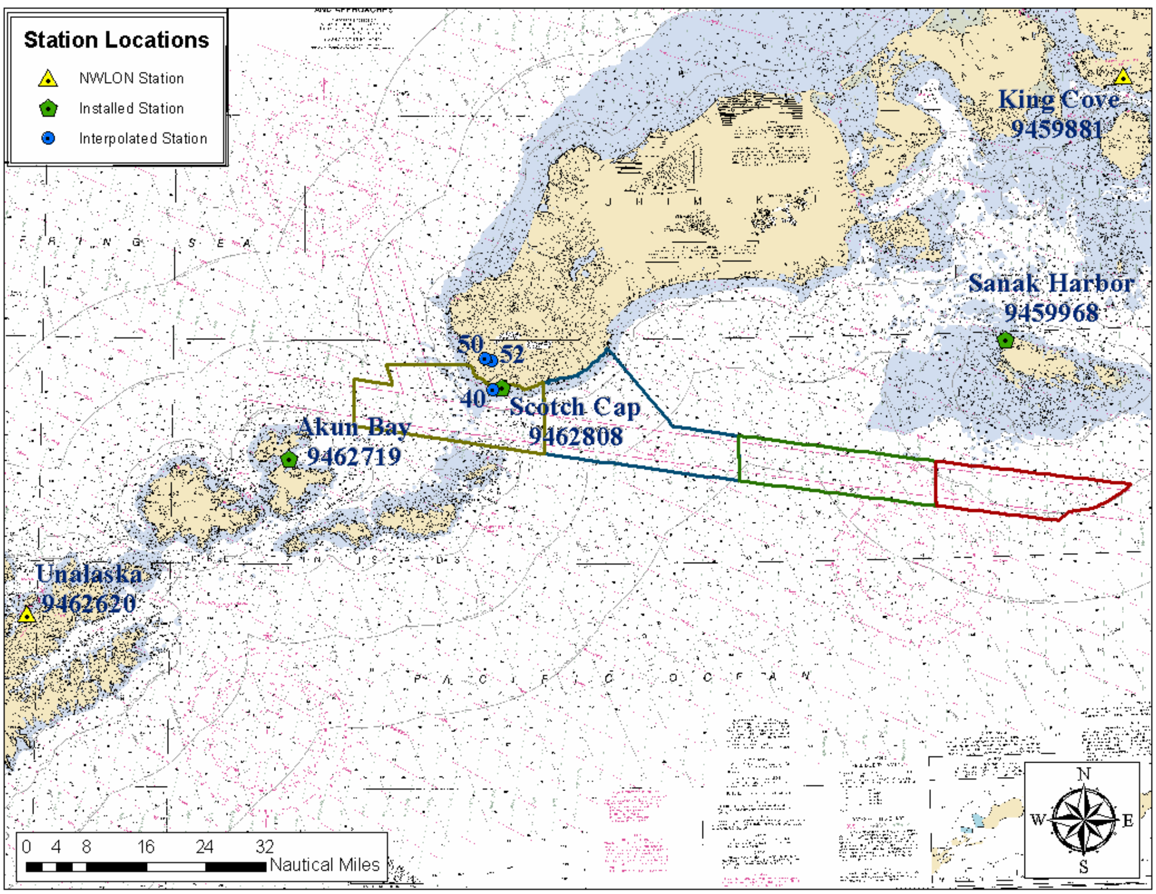

Figure 5 – Location of tide stations used in OPR-P188-TE-09. Chart 16520, 23rd Edition, August, 2008. Soundings in Fathoms

JOA installed one WaterLOG series DAA H350XL bubbler gauge at Scotch Cap (54°23’39”N, 164°44’38”W) with a cable out to the orifice from a temporary tide station utilizing ruins from the original USCG Station built on the bluff. JOA installed three Sea-Bird SBE 26plus Wave & Tide Recorder submersible tide gauges at Scotch Cap to provide final tide data. The three gauges were placed in close proximity to each other in order to provide redundancy and minimize the potential for gaps in the tide record. All three gauges were equipped with LinkQuest UWM1000 Underwater Acoustic Modems which permitted the downloading of tide data periodically throughout the project. A barometer installed at this location recorded meteorological data for this project. Data from the tide gauges was downloaded at the completion of the survey, combined with the staff observations and meteorological data collected during the project.

Two WaterLOG series H-355 “bubbler” gauges were installed at Akun Bay (54°14’21”N, 165°32’30”W) with cable to the orifices from a temporary tide shack built on a bluff near the shoreline. One Sea-Bird SBE 26plus Wave & Tide Recorder submersible tide gauge was installed at Akun Bay to provide final tide data. Data from the tide gauge was downloaded at the completion of the survey, combined with the staff observations and meteorological data collected during the project. Data for the Sea-Bird SBE 26plus was downloaded after the conclusion of MBES data collection.

The water level measurement sensors at Scotch Cap and Akun Bay were transmitted via GOES radios and antennas to enable near real time QC/QA. The transmission rate was set to once every hour.

JOA installed an additional tide station at Sanak Harbor (54°29’06”N, 162°49’06”W) equipped with one Sea-Bird SBE 26plus Wave & Tide Recorder submersible tide gauge with a LinkQuest UWM1000 Underwater Acoustic Modem. Data from the tide gauge was downloaded at the completion of the survey, combined with the staff observations and meteorological data collected during the project.

Three additional Sea-Bird SBE 26plus Wave & Tide Recorder submersible tide gauges were set in strategic deployment areas for planned periods during survey operations. Data from the Sea-Bird tide gauges were downloaded each time a gauge was retrieved before being redeployed. Data from these gauges was used during quality control review of the tide zones.

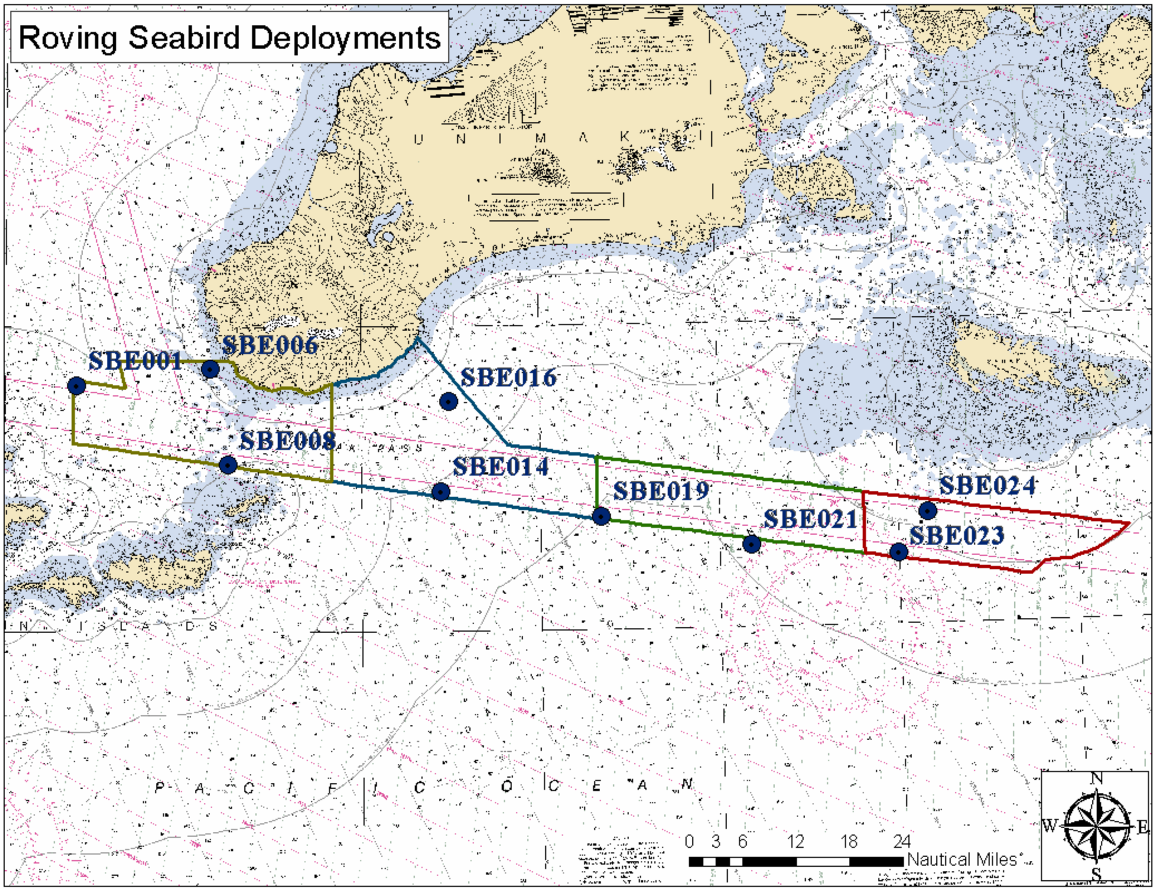

Figure 6 – Location of roving Sea-Bird deployment locations used in Unimak Pass

Location Name	Sea-bird Serial #	Deployed (Julian Day #)	Retrieved (Julian Day #)	Days on site	Latitude	Longitude
SBE006	1120	134	178	44	54-25-58.22 N	164-55-15.16 W
SBE008	1221	135	160	25	54-16-31.78 N	164-52-16.66 W
SBE021	1212	154	197	43	54-09-50.60 N	163-25-25.7 W
SBE014	1221	160	191	31	54-13-48.12 N	164-16-34.43 W
SBE016	1120	178	234	56	54-22-36.78 N	164-15-08.18 W
SBE019	1221	191	233	42	54-11-10.24 N	163-49-45.06 W
SBE024	1212	197	213	16	54-10-59.71 N	162-54-56.00 W
SBE023	1212	213	232	10	54-07-13.10 N	163-00.14.38 W
SBE001	1212	235	238	2	54-24-19.08 N	165-17-51.89 W

Table 8 – Roving Sea-Bird deployments and retrievals.

Final processing of the tide data was completed by TerraSond, Ltd. and John Oswald and Associates, LLC (JOA) of Anchorage, Alaska.

Refer to the Vertical and Horizontal Control Report (VHCR) for detailed information regarding the installation and data processing procedures used for these stations.

A.2.2. Speed of Sound

Speed of Sound data was collected by vertical casts on the *M/V Bluefin* using an ODIM MVP 200 with an Applied Microsystems (AML) Micro SV&P sound speed sensor. An auxiliary AML SV Plus v2 was used for weekly comparison casts. The *R/V Mt. Augustine* was equipped with an AML SV Plus v2 sound speed sensor. The *R/V Mt. Mitchell* was equipped with Lockheed Martin XBT T-5 and XCTD-2 expendable sound velocity profilers and an AML SV&T for surface sound speed measurements.

Sound speed profiles were taken as deep as possible and were geographically distributed within the survey area. Sound speed profiles taken from the *R/V Mt. Augustine* were lowered by hand and extend to the sea floor. Sound speed profiles taken with an MVP from the *M/V Bluefin* extend to 5-10 meters above the seafloor. MVP casts taken in over 100 m depth extend 90-95% to the seafloor. MVP casts taken in 50 m of water extend 80-90% to the seafloor. MVP casts taken in 25 m of water extend 60-80% of the seafloor. Mechanical problems with the MVP for a portion of the survey required sole use of the AML SV Plus v2 probe s/n 3317, with the second probe (s/n 3279) used for comparison checks.

Sound speed profiles taken from the *R/V Mt. Mitchell* were either XBT T-5 or XCTD-2. Sound speed profiles on the Mitchell extended to >85% of the anticipated water depth to a maximum depth of ~1200m. This was the functional depth limit of the Sippican XBT and XCTD probes. Sound velocity profiles were assumed to change minimally below this depth and were modified to repeat the final valid SV value at a user defined depth of 12,000m. This was necessary for SVP application in Kongsberg SIS acquisition software as SIS modifies its absorption coefficient algorithms based on a full range of ocean depths. An SV&T was used as a surface sound velocimiter aboard the *R/V Mt. Mitchell* for proper function of the flat array EM 710 multibeam system.

Sound speed profiles are representative of local and diurnal variability. This region has high temporal and spatial variability; some data quality issues related to speed of sound measurements were expected during the survey. This was addressed by increasing frequency of measurement profiles to 2 hour intervals in mixing zones. Deeper offshore areas allowed for decreased frequency of measurement profiles. For further details refer to each sheet's Descriptive Report (DR).

Confidence checks of the primary sound speed system were conducted at least once per week over the majority of the survey duration. Sound speed data was collected with both the primary and a secondary independent sound speed measurement system at the same location and time. These profiles were processed and reduced to measurements at one meter intervals and compared. On the *M/V Bluefin* the MVP Micro SV&P sensor was compared with an SV Plus v2 sensor. On the *R/V Mt. Augustine* two different SV Plus v2 sensors were compared. These weekly checks and the original field check showed that one probe (the Applied Microsystems Ltd SV Plus v2 s/n 3279) read consistently 1m deeper than the other probes. This error was not considered to significantly affect the sounding quality. On the *R/V Mt. Mitchell* an XBT probe was compared with a SV Plus v2 sensor.

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.

The following instruments were used to collect data for sound speed:

***M/V Bluefin* Sound Speed Equipment**

Sound Velocity & Pressure Sensor	Micro SV&P sensor
Manufacturer	Applied Microsystems, Ltd. Sydney, British Columbia, Canada
Serial number	7508 used in MVP fish
Calibrated	03/05/09

Velocimeter (sound speed profiler)	SV Plus v2
Manufacturer	Applied Microsystems, Ltd. Sydney, British Columbia, Canada
Serial number	3317
Calibrated	02/26/09

Velocimeter (sound speed profiler)	SV Plus v2
Manufacturer	Applied Microsystems, Ltd. Sydney, British Columbia, Canada
Serial number	3279
Calibrated	02/16/09

***R/V Mt. Augustine* Sound Speed Equipment**

Velocimeter (sound speed profiler)	SV Plus v2
Manufacturer	Applied Microsystems, Ltd. Sydney, British Columbia, Canada

Serial number	3279
Calibrated	02/16/09

Velocimeter (sound speed profiler)	SV Plus v2
Manufacturer	Applied Microsystems, Ltd. Sydney, British Columbia, Canada
Serial number	3317
Calibrated	02/26/09

R/V Mt. Mitchell Sound Speed Equipment

Expendable Temperature Profiler	XBT T-5
Manufacturer	Lockheed Martin Sippican Marion, Massachusetts, USA
Serial number	342813 – 342836
Calibrated	Prior to Shipment

Expendable Conductivity and Temperature Profiler	XCTD-2
Manufacturer	Lockheed Martin Sippican Marion, Massachusetts, USA
Serial number	099922872 – 0922883
Calibrated	Prior to Shipment

Surface Sound Velocity and Temperature Sensor	SV&T
Manufacturer	Applied Microsystems Ltd. Sydney, British Columbia, Canada
Serial number	5433
Calibrated	02/23/2009

Table 9 – Sound speed measuring equipment used during OPR-P188-TE-09.

Sound speed processing procedures are discussed in *Section C*: *Corrections to Echo Soundings.*

Copies of the manufacturer's calibration reports are included in the DR, *Separate II* for each survey sheet.

A.2.3. Positioning Systems

Position control for the *M/V Bluefin*, *R/V Mt. Mitchell* and the *R/V Mt. Augustine* was provided by an Applanix POS MV V4 system. In the field the *M/V Bluefin* and the *R/V Mt. Augustine* received differential correctors from CSI Wireless MBX-4 beacon receivers. Correctors were received from the USCG Continually Operating Reference Station (CORS) BAY5 located in Cold Bay, AK (Station ID 898), operating at a frequency of 289 kHz. On July 31, 2009 (Julian Day 212) the Cold Bay station went down for over an hour. During this time DGPS correctors could not be received and no multibeam data was acquired. Within a few hours the correctors were received again and data collection continued. For several days the Cold Bay station was listed as 'out of service' by the USCG, but correctors continued to be received by all vessels on site which where rigorously monitored for DGPS outages.

The *R/V Mt. Mitchell* used a C-NAV 2050R NaviGator system. The C-NAV uses a global network of positioning corrections broadcast by geostationary satellites eliminating the need for local reference stations. The *R/V Mt. Mitchell* was outfitted for the Pribilof Canyon job (OPR-R144-KR-09) which required her to be out of range of any CORS. The C-NAV system meets survey requirements with a worldwide accuracy of 0.1 meters horizontally and 0.2 meters vertically. In Unimak, the *R/V Mt. Mitchell* used the CSI with Cold Bay correctors for position control while the C-NAV system was used as a back- up. Vessel positions were recorded using QPS QINSy data acquisition software at 1Hz intervals using National Marine Electronics Association (NMEA) message $GPGGA.

Differential Global Positioning System (DGPS) confidence checks were conducted real-time with Trimble DSM 232 beacon receivers on the *M/V Bluefin* and *R/V Mt. Augustine*. Positions obtained by the POS MV and DSM 232 receivers were simultaneously logged using QINSy. Screen grabs of the real-time position plot of the POS MV and DSM 232 position were taken as position confidence checks. In a few cases, screen grabs were not available. In these cases, position differences were analyzed in the field using Microsoft Excel to ensure position quality. Position confidence checks were conducted on the *R/V Mt. Mitchell's* C-NAV system using the Cold Bay CORS before and after the survey. Comparison was made between the C-NAV system and a CSI Wireless MBX-3.

The POS data acquired by the *M/V Bluefin*, *R/V Mt. Mitchell* and the *R/V Mt Augustine*, was processed using POSPac proprietary software. The processed data was then written to an SBET file which was used to apply the horizontal positioning of the PPK data to the line files in CARIS. Tables in Section C of the DRs summarize any lines which did not have horizontal PPK data applied to them. Issues with applying the PPK data were related to intermittent IMU drops, or when the raw POS file stopped logging too soon after the end of line.

Three base station locations were used to produce PPK (Post Processed Kinematic) navigation data. One PPK base station was located at Scotch Cap tide station, one PPK base station was located at the Akun tide station and two more were located at the Sanak tide station location. The secondary base station at Sanak was a backup and was not used for processing. See Table 10 below for base station coordinates.

Station Location	Station Number / ID	Latitude	Longitude
Scotch Cap, Unimak Island	0056	54° 23' 42.45" N	164° 44' 41.89" W
Akun Bay, Akun Island	5240	54° 14' 20.13" N	165° 32' 27.78" W
Sanak Harbor, Sanak Island	1784	54° 28' 47.17" N	162° 48' 49.16" W

Table 10 – PPK base station locations set up for OPR-P188-TE-09.

Refer to each DR, *Separate I: Acquisition and Processing Logs* for a summary of weekly position confidence checks.

Specific details addressing horizontal control activities associated with this project are discussed in the VHCR.

A.2.4. Attitude Sensors

On each vessel an Applanix POS MV Inertial Measurement Unit was used to measure heave, pitch and roll values to be used to correct for the motion in the sounding data from the *M/V Bluefin*, *R/V Mt. Mitchell* and *R/V Mt. Augustine*. Detailed descriptions of all attitude corrections are provided in *Section C: Corrections to Echo Soundings*.

A.3. Data Collection

A.3.1. Overview

The survey was conducted using multibeam techniques with the *M/V Bluefin*, *R/V Mt. Mitchell* and *R/V Mt. Augustine*. No singlebeam data was collected. On the *M/V Bluefin* and the *R/V Mt. Mitchell*, data was collected on a 24 hour basis using two crews with shift changes every 12 hours. *R/V Mt. Augustine* operated as a launch from the *M/V Bluefin*, weather permitting, and was used to develop areas that were too shoal or fouled to permit access by the *M/V Bluefin*. The *Spare Rhib* was operated as a skiff from the *M/V Bluefin*, weather permitting, and was used for shoreline verification.

A.3.2. Coverage

Survey line passes were spaced to yield 100% or greater multibeam bottom coverage seaward of the 8-meter curve for all surveys in this project.

A.3.3. Line Planning

Line plans were not used in the survey. The various vessels painted their respective multibeam coverage in such a way as to ensure 100% or greater bottom coverage. In general, survey passes were run the length of each sheet parallel to the survey limits or in shorter lines parallel to depth contours.

A.3.4. Ping Rates

The NOS HSSD 2008, *Section 5.1.2.2* was met for this survey in accordance with correspondence with the Office of Coast Survey included in *Appendix V: Supplemental Survey Records & Correspondence* of each DR for this project. As a general rule, engine RPM were adjusted minimally throughout a survey line to obtain a vessel speed over the ground (SOG) appropriate for the sonar range and bottom depth to maintain ping spacing within specifications. During this survey, the achieved ping rate met or exceeded the specifications set forth in NOS HSSD 2008, Section 5.1.2.2. In some instances, strong current and winds prevented surveying at low speeds. In these instances reduced line spacing and increased line overlap were employed to meet specifications.

A.3.5. Software and Hardware Summary

Multibeam data were acquired on an Intel Pentium IV PC using QPS QINSy data collection software operating in a Microsoft Windows XP environment. QINSy was used to generate a real-time digital terrain model (DTM) during each survey line. The DTM was used in the field to determine whether the survey pass had been completed with adequate bottom coverage. The DTM was only used as a field quality assurance tool and was not used during subsequent data processing. All raw bathymetric, position and sensor data was recorded in a QINSy native .db format for follow-up processing using CARIS Hydrographic Information Processing System (HIPS). *R/V Mt. Mitchell* raw bathymetric data was recorded in both .db and .all file formats. The .all files were used for follow-up processing in HIPS. Final survey coverage determination was made following data processing with CARIS HIPS 6.1.

CARIS HIPS hydrographic data processing software was used for multibeam and quality assurance. Data post-processing procedures are described in detail in *Section B* of this report.

Shoreline point and line data were acquired on a Panasonic Toughbook using CARIS Notebook data acquisition software in the Microsoft Windows XP environment. When it was unsafe to approach objects or rocks with the *Spare Rhib*, positions were corrected for range and bearing using a Leupold Digital Range Finder RX-IV. CARIS Notebook was used for Detached Position acquisition, processing and production of final S-57 product. Refer to sections B.1 and D.2.1 of the DRs for further detail.

Table 11 lists the software used on the *M/V Bluefin*, *R/V Mt. Mitchell*, *R/V Mt. Augustine* and *Spare Rhib* during the survey. Table 12 lists the software used in the office during pre-survey planning and post-survey processing:

A.3.6. Vessel Software

Program Name	Version	Date	Primary Function
Reson SeaBat	1.08-C215	2002	Reson SeaBat 8101 firmware (wet)
Reson SeaBat	2.09-E34D	2000	Reson SeaBat 8101 firmware (dry)
QPS QINSy	8.0	2008	Multibeam data collection suite
Kongsberg EM 710			Sonar firmware
Kongsberg SIS	3.4.1		Kongsberg MB controller software
POS MV V4	3.4.0.0	2007	Positioning
POS MV IMU			Attitude Sensor
MV PosView	3.4	2007	Pos MV setup, monitoring, and logging
Nautical Software Inc. Tides and Currents for Windows	2.2	1996	Predicted tides
CARIS Notebook	3.0	2007	Digital data collection in the field
TerraSond, Ltd. Simple SVP	1.0	2007	Convert sound speed raw data to CARIS compatible format.

Table 11 – Software used aboard the M/V Bluefin, R/V Mt. Mitchell, 'Spare Rhib' and R/V Mt. Augustine.

A.3.7. Office Software

Program Name	Version	Date	Primary Function
CARIS HIPS	6.1	2006	Multibeam data processing software
CARIS Notebook	3.0	2007	Shoreline data and S-57 attribution and management software
CARIS BASE Editor	2.3	2009	Bathymetry compilation and analysis software
POSPac MMS	5.1	2008	Post processing kinematics, HDOP analysis
Autodesk Auto Civil 3D	n/a	2008 & 2009	Drafting software
AutoDesk Raster Design	n/a	2008 & 2009	Drafting software
Blue Marble Geographics Geographic Transformer	6.0	n/a	Image geo-referencing and re-projection software
MapInfo Professional	8.5	2006	Desktop mapping software

Program Name	Version	Date	Primary Function
ESRI ArcGIS	9.3	2009	Desktop mapping software
Corpscon	5.11 & 6.0	2001 & 2004	Coordinate conversion software

Table 12 – Software used in the office during post processing.

B. Quality Control

B.1. Overview

Every effort was made to ensure the traceability and integrity of the sounding and POS MV Positional and Inertial data as it was moved from the collection phase through processing. Consistency in file and object 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 and adjustments made to the raw data, and all 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 and GNSS were used for processing the Inertial and GPS data.

B.2. Equipment Calibration

Survey equipment was calibrated prior to the survey to assess the accuracy, precision, alignment, timing error, value uncertainty, and residual biases in roll, pitch, heading, and navigation. MBES equipment calibration was completed using patch tests prior to transiting to the survey area and periodically during the survey when the survey equipment configuration changed. Sound velocity instruments were factory calibrated within the past year. All bubbler type tide gauges were factory calibrated within the past year. All tide gauges were tested by JOA before and after the project and were deemed to meet necessary accuracy requirements. Furthermore, there were confidence checks run prior to and throughout this survey of Unimak Pass.

B.3. Periodic Confidence Checks

On the *M/V Bluefin* and *R/V Mt. Augustine*, GPS data from POS MV system coupled with a MBX-4 DGPS receiver and a Trimble DSM-232 DGPS receiver were recorded concurrently in QPS QINSy. The GPS data included position information, number of satellites, maximum horizontal dilution of precision (HDOP), and DGPS verification. All data were time-referenced at 1-second intervals. On board the *M/V Bluefin* and *R/V Mt. Augustine* formal position confidence checks were calculated weekly between the two systems, by either real time plot or post processing calculations. The *R/V Mt. Mitchell* used a C-NAV 2050R NaviGator system receiving positioning corrections from a network of geospatial satellites. Position confidence checks were conducted by the *R/V Mt. Mitchell* at the beginning and end of the survey using the Cold Bay CORS (Station ID 898).

Crosslines were run as a confidence check for the multibeam sonar. The total linear nautical miles of crosslines exceeded four percent of the linear nautical miles of main scheme lines. Initial data processing was performed on the collection vessel upon the completion of each survey day. Adjustments were then made to equipment settings based on preliminary processing and, if necessary, survey lines were rerun.

Nadir beam checks were performed on the MBESs each week, weather and location permitting. The confidence checks on the *M/V Bluefin*, *R/V Mt. Mitchell* and *R/V Mt. Augustine* consisted of comparing lead line depths with depths logged by the MBES nadir beams. The calibration checks were performed by measuring the depth under the ship with a calibrated sounding lead line and comparing the value with the nadir-beam depths recorded by the MBES. All measurements were corrected to the survey vessels central reference point (CRP). The lead line used for the calibration checks was constructed from a metric fiberglass survey tape with a lead ball attached to the end. The ball was attached in such a way that the bottom of the ball was 0.0 m. The lead line and nadir-beam MBES values agreed consistently throughout the survey. Coincident lines were also used as a nadir beam check. The various vessels regularly ran a similar line in a short time frame to allow for a vessel to vessel comparison.

The differences between measured and observed values were within sounding error limits specified for this survey.

The DR, *Separate I* contains a summary of the calibration checks performed for each survey.

B.4. Data Collection

On the *M/V Bluefin and R/V Mt. Augustine*, multibeam data collection was performed using QPS QINSy data acquisition software. File naming conventions were established to ensure that individual survey line runs had unique names. Lines were assigned consecutive numbers with a letter designator corresponding to the sheet being surveyed. QINSy software generated database files using associated filenames, with the extension ".db" which contained survey data and equipment settings specific to each line. All raw data files were stored on the acquisition computer's hard drive. On the *R/V Mt. Mitchell*, Kongsberg SIS ".all" files were collected concurrently with QINSy ".db" files. The ".all" files were solely used in the final product.

Chronological logs containing information specific to each line were maintained as an independent reference to aid in data integration and error tracking. Multibeam logs included the line name, start and end times, vessel speed and heading and any additional comments deemed significant by the operator. The DR *Separates I: Acquisition & Processing Logs* contains the acquisition logs.

POS MV GPS and positional data were also collected in Applanix POSView software. Generally, two files were collected per survey day and were named with the year, Julian day and letter extension to establish unique names for each file.

B.5. Initial File Handling

Initial multibeam data processing was completed on the survey vessel. At the end of each survey day, the raw data file and converted ".xtf" file were organized by vessel and Julian day into a CARIS directory on the local network server. Each Julian day was divided into two sub-folders according to file type (e.g. ".db", ".xtf"). The ".xtf" files were then converted to CARIS compatible files using CARIS HIPS. These files were organized in a directory on the network server based on project name, vessel name and Julian date.

POS MV data files were collected onto the local drive of a PC and transferred at their completion to the POS folder on the ship's data server.

All server data was backed up once each day onto LTO3 tapes. The system of using data storage servers with redundant disk arrays, frequent backups and moving copies of the data off site minimized the potential for data loss due to equipment malfunction or failure.

B.6. Field Data Processing

Preliminary multibeam data processing was completed aboard the survey vessel. CARIS HIPS software was used to create a folder structure organized by project, vessel and Julian day to store data. Multibeam raw data (.db) files were converted to Triton Extended Format (".xtf") files using the QPS QINSy ExportXTF module. The ".xtf" files were then imported into CARIS HIPS using the CARIS conversion wizard module. The wizard was used to create a directory for each line and separate the ".xtf" files into sub-files which contained individual sensor information. All data entries were time-referenced using the time associated with the ".xtf" file to relate the navigation, azimuth, heave, pitch, roll and slant range sensor files.

Following the initial file conversion and backup, sound speed and predicted tide data were merged with the sounding data and each line was examined for heave, roll, pitch and navigation errors. The data was then cleaned using CARIS HIPS subset editor and a BASE Surface was created to verify coverage and provide quality control feedback to the survey crew.

The focus of the preliminary processing was to provide timely information during data acquisition. All data was processed using conservative procedures to ensure adequate survey coverage while in the project area. The field processed data were not used during the final office processing phase.

B.6.1. Office Data Processing

TerraSond, Ltd. incorporates a systematic, rigorous approach to the editing and development of survey data received from the field. This ensures the maintenance of data integrity throughout the editing process.

Raw ".xtf" files were sent to the office from the field. The ".xtf" files were then imported into CARIS HIPS using the CARIS conversion wizard module. The wizard was used to create a directory for each line and separate the ".xtf" files into sub-files which contained individual sensor information. All data entries were time-referenced using the time associated with the ".xtf" file to relate the navigation, azimuth, heave, pitch, roll and slant range sensor files.

CARIS HIPS was used for the majority of the editing and adjustments made during multibeam data processing. CARIS HIPS does not allow raw data manipulation during processing. All raw data is maintained in the original, unmodified, format to ensure data integrity. TerraSond, Ltd. uses well defined procedures during the development of the final navigation surfaces and all actions are tracked to ensure that no steps are omitted or performed out of sequence.

Sensor data were reviewed and edited with CARIS HIPS to remove obvious systemic errors or environmental artifacts.

Sound speed and tide corrections were applied during initial data processing. A dynamic draft table was applied in the HIPS Vessel File (HVF), which was derived from squat settlement data and based on vessel speed. Daily static draft observations were entered in the HIPS vessel file.

Preliminary soundings were tide adjusted using predicted tide data from the NWLON stations at Unalaska, AK (946-2620) and King Cove, AK (945-9881) through August 26, 2009. A modified ".zdf" file referencing a combination of verified tide data from the King Cove (945-9881) station and preliminary tide data from the Akun (946-2719) tide gauge was applied to the data as soon as tide data became available. Refer to *Section C: Corrections to Echo Soundings*, of this report for detailed information concerning final sounding reduction and the VHCR for tidal zoning methods and operations.

Sound speed data were acquired using vertical casts on the *M/V Bluefin*, *R/V Mt. Mitchell* and *R/V Mt. Augustine* following standard vertical cast procedures.

Sound speed raw data were converted to a CARIS compatible format using TerraSond, Ltd. proprietary SVP software. All profiles were combined into a file for each vessel using data headers to indicate the time and position of each cast. Prior to their application in CARIS HIPS, all sound speed profiles were reviewed for erroneous sound speed values, time stamps and positions. The sound speed adjustment in CARIS HIPS uses slant range data, applies motion correctors to determine launch angles, and adjusts for range and ray-bending resulting in a sound speed-corrected observed-depths file.

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. Data were queried for time, position, delta time, speed and status and, if necessary, the status of the data was changed from accepted to rejected. Azimuth, heave, pitch and roll data were viewed in the CARIS Attitude Editor which displayed simultaneous graphical representation of all attitude data using a common x-axis scaled by time. The Attitude Editor, like the Navigation Editor, was used to query the data and reject erroneous values. After inspecting the navigation and attitude data, the tide and sound speed corrected data were merged with the navigation and attitude data. The merging process calculates final depths and positions for soundings based on all relevant inputs such as observed depths, navigation, vessel dynamics, attitude and tides.

True heave was loaded to the CARIS line files from the raw POS data in order to better model the heave data. A small number of lines could not be loaded with true heave as the POS stopped logging prior to the end of the line or immediately after the end of line which causes an error when applying true heave in CARIS HIPS. Lines that could not be loaded with true heave are listed in the individual DRs for these surveys.

SBET solutions were loaded to the CARIS line files in order to take advantage of the increase in accuracy associated with PPK data over DGPS corrections. Analysis of the PPK data and DGPS data revealed that the DGPS solution was slightly skewed to the Northeast by a value on the order of 0.3 m. This difference is likely due to the substantial length of the DGPS baseline corrections in contrast to the shorter baselines of the PPK base stations, as well as the Northwest proximity of the DGPS correction station from the survey area.

In order to facilitate HIPS final processing a filter was occasionally used to reject the outer five beams (1-5 and 96-101) of survey lines presenting outer beam spreading and/or noise. Reviews of each survey ensured that no holidays in the CUBE surfaces were created nor were shoal soundings of significant features rejected by this process. No filters were applied to data collected by the *R/V Mt. Mitchell* in survey H12067.

Figure 7 illustrates the major steps in the data acquisition and reduction process. The text above provides a detailed explanation of each step.

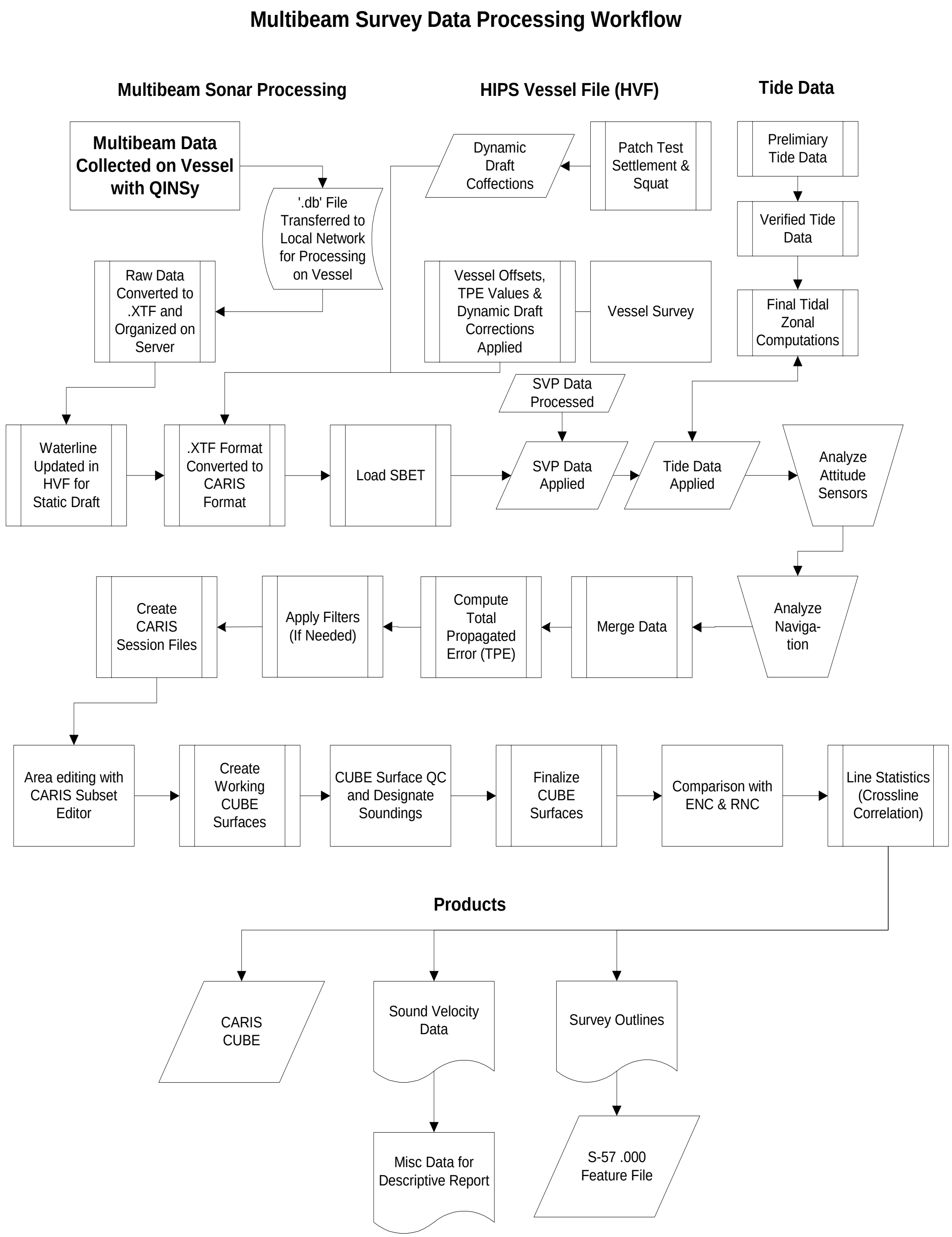

Figure 7 – Data Acquisition and Processing Flow Diagram

B.6.1.1. Post Processing Kinematics

POS MV GPS and Inertial data were processed with Applanix POSPac proprietary software in order to provide post processed kinematic GPS data to replace the DGPS navigation data originally collected in QINSy. Prior to opening POSpac software the base station data was converted from ".t01" format to ".dat".

Upon opening the POSPac software the "Extract" tool was used to convert the POS MV ".000" into ".gpb" format. The base station data was then brought into POSPac and converted from ".dat" to ".gpb" files and imported to POSPac where the files were concatenated into a single file per day in the POSGNSS module.

The "Autostart" routine was employed to associate the vessel rover data with the base data. Kinematic Ambiguity Resolution (KAR) points were automatically added during initial processing. KAR's were added where the POSGNSS was having difficulty attaining initialization before the "Process GNS Differential" routine was utilized to find a final position for the rover data. Manual KAR's were also added to the Rover data in problematic areas when automatic KAR's had not been added.

The trackline was exported from the POSGNSS module into POSPac MMS module and then the combined solution processes were used to merge the inertial and PPK GPS data and smoothing the resulting trackline into a Smooth Best Estimate Trajectory (SBET) file, which provided navigational tracklines for the MBES data, and a text file which aided tidal zoning.

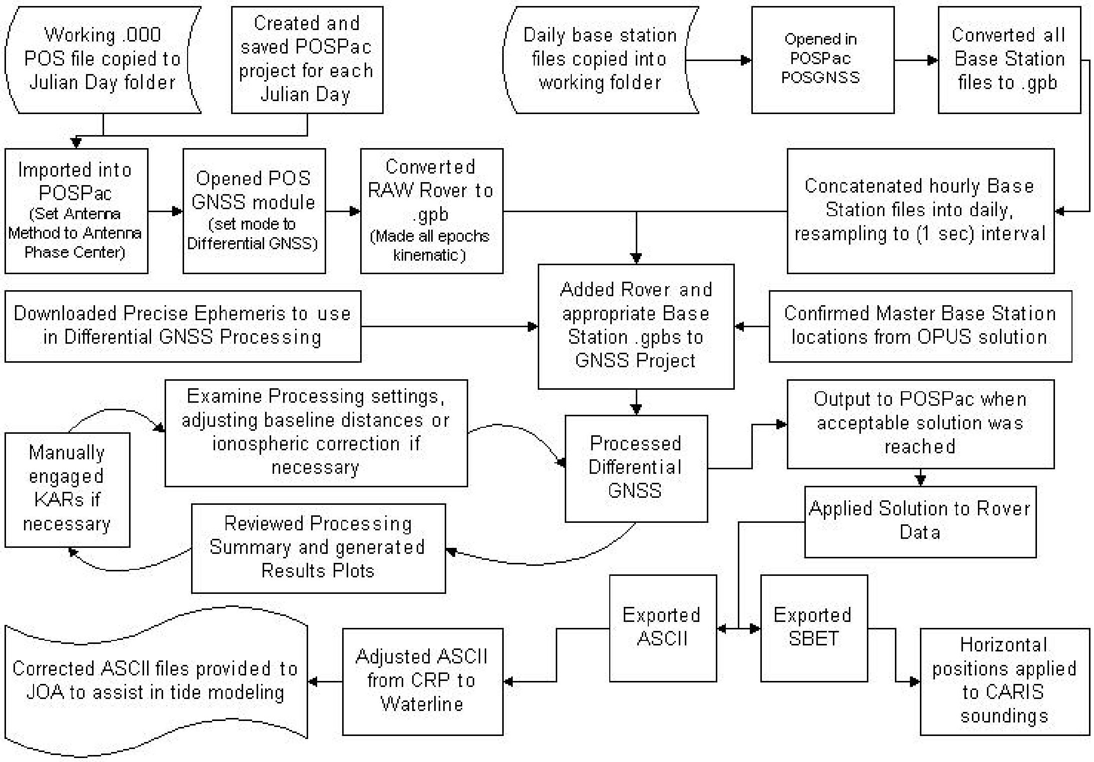

Figure 8 – PPK Processing Flow Diagram

B.6.1.2. HIPS Final Processing

Three editing/QC phases were employed during HIPS final processing; area-based sounding editing, identification of rocky seabed areas and CUBE surface QC. During area-based sounding editing, Subset Editor was used to identify and reject spurious soundings. The entire survey was reviewed in this manner. Next, Several rocky seabed areas were identified in shoal areas of surveys H12004 and H12065 and are included in the S-57 feature files. In these areas the number of designated soundings was limited to represent the most significant features. During CUBE surface QC, “working” CUBE surfaces were reviewed as reference surfaces in Subset Editor to ensure that the surfaces honored shoal soundings and preclude the surface from honoring any remaining spurious soundings. Verified tides and a final zoning scheme containing 3 tide stations were tested and applied to the survey area prior to these editing processes.

B.6.1.2.1. Area-Based Editing

In the first phase of area editing, processors examined the entire survey area in CARIS HIPS Subset Editor and rejected outlying soundings unsupported by data from adjacent survey lines. Simultaneously, the data were scrutinized for any potential tide, dynamic draft, heave and sound velocity issues that would require further investigation.

During subset editing, the operator was presented with two-dimensional views of the soundings and a moveable bounding box to restrict the number of soundings being reviewed. These perspectives, as well as controlling the size and position of the bounding box, allowed the operator to compare lines, view features from different angles, measure features, query soundings and change sounding status flags. Soundings were also examined in the three-dimensional window as points, wireframe or a surface which could be rotated on any plane. Vertical exaggeration was increased as required to amplify trends or features.

B.6.1.2.2. Rocky Seabed Areas

In surveys H12004 and H12065, several areas were identified as rocky seabed areas in shoal regions near the southern shores of Unimak Island. Due to the high density of rocks in this area, an excessive number of designated soundings would be required to ensure the finalized CUBE surface honors the shoalest depth on each rock. Instead, the Lead Hydrographer digitized several polygon ".hob" files in these areas using CARIS Notebook. These were later developed into rocky seabed area S-57 objects submitted with surveys H12004 and H12065. Processors reviewed each of the polygons using Subset Editor with a bounding box size ranging from 50 to 100 square meters, depending on the density of rocks. Viewing each bounding box in the 3-d window, the shoalest sounding on the feature with the least vertical clearance (i.e. largest percentage of water column) was designated. The subset box was then moved to a new location within the polygon and the process was repeated. Therefore, while not every rock was designated, the finalized CUBE surface will honor those most significant to navigation.

B.6.1.2.3. CUBE Surface QC

Each survey was reviewed again using Subset Editor, this time with the appropriate resolution CUBE surface for a given depth loaded as a reference surface. The purpose of this review was to ensure that soundings were designated according to specification and conversely to preclude spurious soundings from inclusion in the gridded surface. In depths less than 20 meters, soundings were designated when the distance between the CUBE surface and reliable shoaler soundings exceeded ½ the IHO error budget for the depth. In depths greater than 20 meters, soundings were designated when the difference was greater than the IHO error budget for that depth. This review also allowed processors to identify any remaining tide, motion, sedimentation or sound velocity issues.

B.6.1.3. TPU

CARIS HIPS and SIPS TPU calculation assigned a horizontal and depth error estimate to each sounding. TPU values represent, at a 95% confidence level, the difference between computed horizontal and vertical sounding positions and their true position values. CARIS HIPS and SIPS computed TPU error values by aggregating individual error sources such as navigation, gyro (heading), heave, pitch, roll, tide, latency, sensor offsets and individual sonar model characteristics. Stored in the HIPS Vessel File, these error sources were obtained from manufacturers during the instrument calibration process, determined during the vessel survey (sensor offsets) or while running operational tests (patch test, settlement and squat). The error budgets for the *M/V Bluefin*, *R/V Mt. Mitchell* and *R/V Mt. Augustine* are found in Tables 13, 14 and 15 on the following pages.

***M/V Bluefin* TPU Values**

Error Source	Method	Error Value
Motion Gyro	Published by Manufacturer	0.020 (deg)
Heave	Published by Manufacturer	0.050 (m) or 5% (whichever is greater)
Roll	Published by Manufacturer	0.020 (deg)
Pitch	Published by Manufacturer	0.020 (deg)
Position Navigation	TerraSond Standard	1.000 (m)
Transducer Timing	Estimated	0.005 (sec)
Navigation Timing	Estimated	0.005 (sec)
Gyro Timing	Estimated	0.005 (sec)
Heave Timing	Estimated	0.005 (sec)
Pitch Timing	Estimated	0.005 (sec)
Roll Timing	Estimated	0.005(sec)
Offset X	Direct Measurement	0.002 (m)
Offset Y	Direct Measurement	0.002 (m)
Offset Z	Direct Measurement	0.002 (m)
Vessel Speed	Speed is derived from position	0.0 (m/s)
Loading	Direct Measurement	0.050 (m)
Draft	Published by Manufacturer	0.050 (m)
Delta Draft	Published by Manufacturer	0.050 (m)
MRU Alignment Gyro	TerraSond Standard	0.1 (m)
MRU Alignment Roll/Pitch	TerraSond Standard	0.1 (m)
Sound Velocity	TerraSond Standard	1 (m/sec)
Tide Gauge	TerraSond Standard	0.01 (m)

Table 13 – M/V Bluefin error values used in computing Total Propagated Uncertainty (TPU).

***R/V Mt. Augustine* TPU Values**

Error Source	Method	Error Value
Motion Gyro	Published by Manufacturer	0.020 (deg)
Heave	Published by Manufacturer	0.050 (m) or 5% (whichever is greater)
Roll	Published by Manufacturer	0.020 (deg)
Pitch	Published by Manufacturer	0.020 (deg)
Position Navigation	TerraSond Standard	1.000 (m)
Transducer Timing	Estimated	0.005 (sec)
Navigation Timing	Estimated	0.005 (sec)
Gyro Timing	Estimated	0.005 (sec)
Heave Timing	Estimated	0.005 (sec)
Pitch Timing	Estimated	0.005 (sec)
Roll Timing	Estimated	0.005(sec)
Offset X	Direct Measurement	0.002 (m)
Offset Y	Direct Measurement	0.002 (m)
Offset Z	Direct Measurement	0.002 (m)
Vessel Speed	Speed is derived from position	0.0 (m/s)
Loading	Direct Measurement	0.050 (m)
Draft	Published by Manufacturer	0.050 (m)
Delta Draft	Published by Manufacturer	0.050 (m)
MRU Alignment Gyro	TerraSond Standard	0.1 (m)
MRU Alignment Roll/Pitch	TerraSond Standard	0.1 (m)
Sound Velocity	TerraSond Standard	1 (m/sec)
Tide Gauge	TerraSond Standard	0.01 (m)

Table 14 – R/V Mt. Augustine error values used in computing Total Propagated Uncertainty (TPU)

***R/V Mt. Mitchell* TPU Values**

Error Source	Method	Error Value
Motion Gyro	Published by Manufacturer	0.020 (deg)
Heave	Published by Manufacturer	0.050 (m) or 5% (whichever is greater)
Roll	Published by Manufacturer	0.020 (deg)
Pitch	Published by Manufacturer	0.020 (deg)
Position Navigation	TerraSond Standard	1.000 (m)
Transducer Timing	Estimated	0.005 (sec)
Navigation Timing	Estimated	0.005 (sec)
Gyro Timing	Estimated	0.005 (sec)
Heave Timing	Estimated	0.005 (sec)
Pitch Timing	Estimated	0.005 (sec)
Roll Timing	Estimated	0.005(sec)
Offset X	Direct Measurement	0.002 (m)
Offset Y	Direct Measurement	0.002 (m)
Offset Z	Direct Measurement	0.002 (m)
Vessel Speed	Speed is derived from position	0.0 (m/s)
Loading	Direct Measurement	0.050 (m)
Draft	Published by Manufacturer	0.050 (m)
Delta Draft	Published by Manufacturer	0.050 (m)
MRU Alignment Gyro	TerraSond Standard	0.1 (m)
MRU Alignment Roll/Pitch	TerraSond Standard	0.1 (m)
Sound Velocity	TerraSond Standard	1 (m/sec)
Tide Gauge	TerraSond Standard	0.01 (m)

Table 15 – R/V Mt. Mitchell error values used in computing Total Propagated Uncertainty (TPU).

B.6.2. Sounding Reduction / Final QC

Since final, processed multibeam depths are no longer delivered as a fixed-scale smooth sheet of selected, shoal-biased soundings, it was not necessary to decimate multibeam data to this extent. However, a sounding selection process was performed as a final quality control check and to provide a means of effectively comparing processed survey depths to those appearing on the current editions of the Raster Nautical Charts (RNC) and Electronic Navigation Charts (ENC) common to the survey area. Although depth contouring, a component of the fixed-scale smooth sheet, is no longer required, contours were generated from 8 meter resolution CUBE surfaces at intervals matching those on the largest scale RNC. 2009 Survey contours were then compared with charted contours for each survey. This comparison was used for evaluating the adequacy of the RNC/ENC and for making future charting recommendations that are included in each DR, *Section D.2: Additional Results*. Areas involving a charting recommendation, such as the addition of a new feature or shoaling area were thoroughly examined.

B.6.3. Gridded Surfaces

The final depth information for this survey is submitted as a CARIS BASE CUBE surface which best represents the seafloor at the time of survey. The submittal of several grids of varying resolution was necessary due to the wide depth range and varying bathymetry found throughout the survey area. All grids are projected to UTM Zone 3 North, NAD 1983. For specific grid resolutions, depths and naming conventions refer to the DRs.

2009 survey depths were submitted as a CARIS BASE CUBE surface using Density and Locale as the Disambiguity method and the 2009 NOAA CUBE parameter .xml based on resolution as the advanced CUBE parameters. Cube parameters were used that meet the NOS 2009 Specifications and Deliverables. The Cube parameters are included with the digital data deliverables.

A data set containing a single S-57 (.000) file and supporting files was submitted in conjunction with each 2009 survey deliverables. The S-57 file contains information on objects not represented in the depth grid, including, but not limited to, rocky seabed areas, shoreline data and the nature of the seabed (bottom samples). In surveys H12004 and H12065 areas of bedforms were identified using the multibeam data and attributed as sandwave areas. Each feature object includes the mandatory S-57 attributes, contract specific attributes, and any additional attributes assigned.

B.6.4. 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 2m resolution BASE surface created from the mainscheme 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.

A summary of the results for each sheet is in the relevant DR. The QC Reports are included in the *Separate IV: Checkpoint Summary & Crossline Reports* for each DR.

B.6.5. Shoreline Verification

All shoreline verification performed during OPR-P188-TE-09 took place on hydrographic surveys H12004 and H12065 which both bordered Unimak Island. Limited shoreline verification was performed in conjunction with the offshore bathymetric survey. Limited verification was performed from the 8-meter contour and consisted primarily of a comparison of NGS-verified remote sensing shoreline data with the shoreline observed in the field. Observed shoreline was also compared with charted features from Nautical Charts 16531_1 and 16520_1 and Electronic Navigation Charts (ENCs) US3AK61M and USAK6FM.

CARIS Notebook 3.0 was used in conjunction with a Trimble DSM 212 for position control, to record detached positions (DP) and to log comments about specific features. A Leupold Digital RX-IV Laser Rangefinder was used to acquire range and bearing for features that were unsafe to approach. S-57 mandatory attributes were completed for all new features located during the survey. Detached position forms were created for all new point features. The DR *Appendix II: Survey Features Report* contains scanned copies of the detached position forms. New area and line features were approximated from the vessel's position in conjunction with multibeam data, existing point data and new DPs. Additionally printed boat sheets of the provided Remote Sensing Data (RSD) shape files from OPR-P188-TE-09 were used as visual aids and for supplemental notes during the survey.

Heights on objects were recorded in the field and adjusted using final tide data. Final tide data was applied using final zones and the appropriate correction for the nearest 6-minute tide interval to the time of acquisition. Objects over 10m in height were not tide corrected.

New features, with field verified position and attribute information were edited, processed and exported from CARIS Notebook to produce a fully attributed S-57 (.000) file. Confirmed RSD and shoreline ENC objects are included in the S-57 files. Confirmed raster charted objects that did not have a corresponding ENC object are not included in the S-57 file but are addressed in the *Appendix II* of the DRs.

C. Corrections to Echo Soundings

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

C.1. Vessel Offsets

All sensor locations were established with a precise survey of each vessel using conventional survey instruments. Sensors for all vessels were referenced to previously established control points. Sensor offsets, stationing and elevations were determined and applied during the appropriate sensor or data processing stage. Separation distances between the two POS MV GPS antennas were measured directly with a survey tape and then authenticated during the Applanix POS MV calibration. The azimuth offset between the antenna baseline and the sensor head was resolved during a patch test, and applied in the "yaw bias" in the CARIS HIPS and SIPS Vessel File (HVF). Detailed vessel drawings and offset descriptions are provided in the next section.

C.1.1. Vessel Surveys

C.1.1.1. M/V Bluefin Vessel Survey

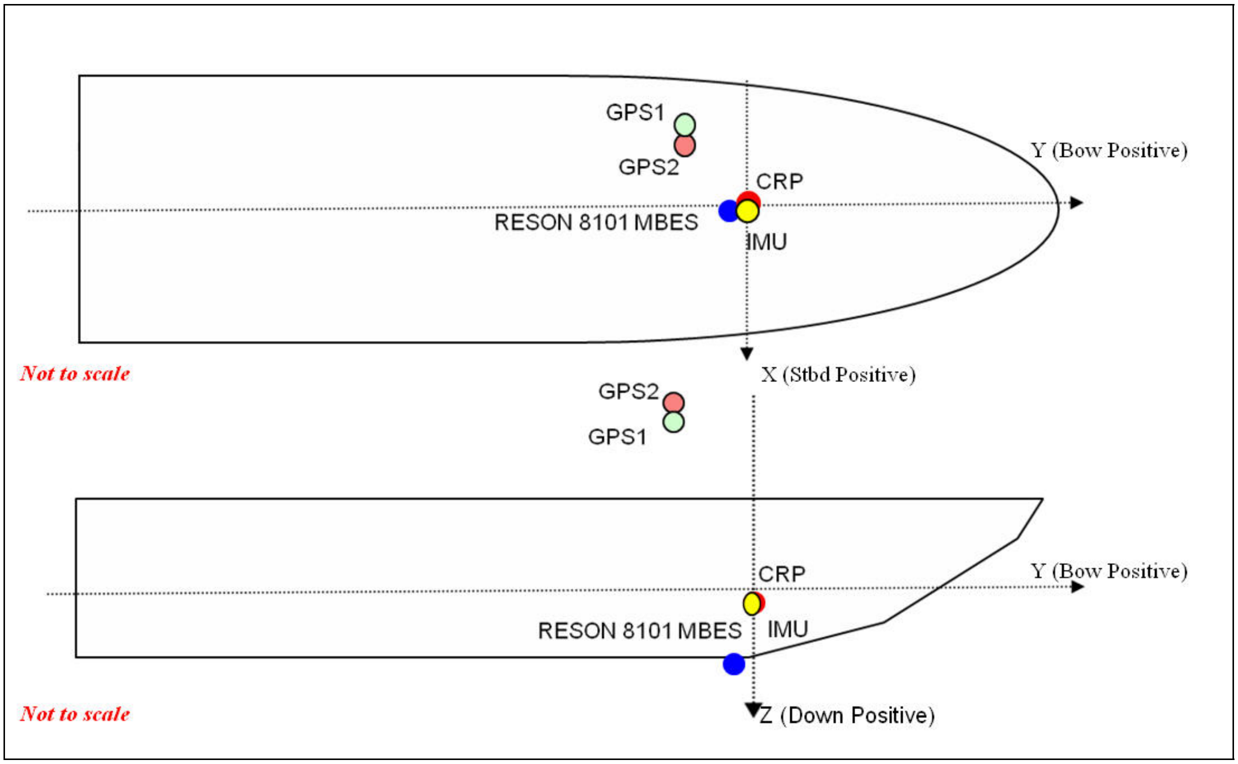

Figure 9 – M/V Bluefin vessel survey showing the relative positions of the installed survey equipment.

Equipment	Manufacturer / Model	Offset from CRP (m) based on CARIS Convention		
		X	Y	Z
IMU	Applanix POS MV	0.000	0.000	0.000
MB Transducer	Reson 8101	0.000	-0.247	+2.195
GPS1 (Primary/Port)	Trimble Zephyr	-3.648	-5.539	-19.619
GPS2 (Secondary/STBD)	Trimble Zephyr	-1.818	-5.599	-19.620

Table 17 – M/V Bluefin offset measurements determined during the initial vessel survey. The CARIS convention of + down (z), + starboard (x) and + forward (y) was used for all measurements.

C.1.1.2. R/V Mt. Augustine Vessel Survey

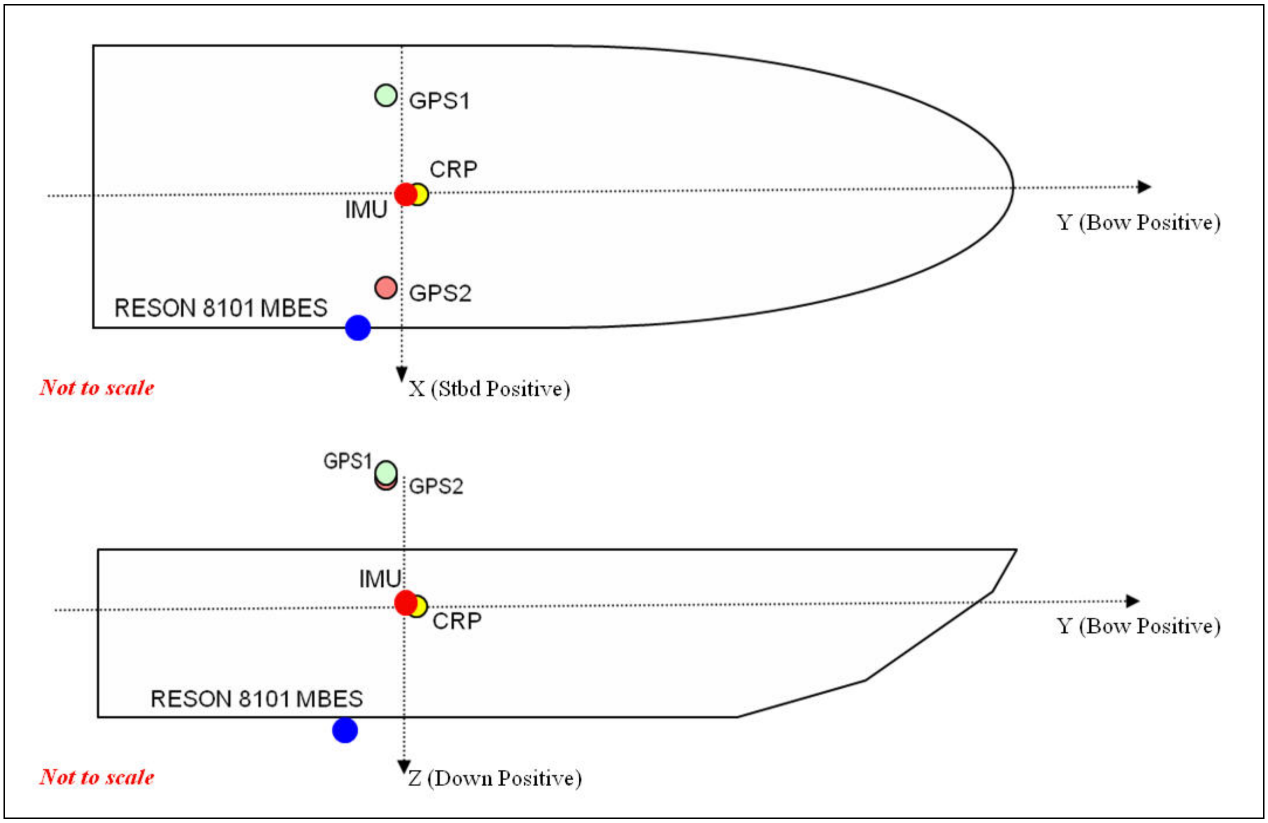

Figure 10 – R/V Mt. Augustine vessel survey showing the relative positions of the installed survey equipment.

Equipment	Manufacturer / Model	Offset from CRP (m) based on CARIS Convention		
		X	Y	Z
IMU	Applanix POS MV	0.000	-0.162	+0.054
MB Transducer	Reson SeaBat 8101	+1.383	-0.508	+1.320
GPS 1 (Primary/Port)	Applanix Zephyr	-1.031	-0.378	-2.619
GPS 2 (Starboard/STBD)	Applanix Zephyr	+1.031	-0.374	-2.619

Table 18 – R/V Mt. Augustine offset measurements determined during the initial vessel survey. The CARIS convention of + down (z), + starboard (x) and + forward (y) was used for all measurements.

C.1.1.3. R/V Mt. Mitchell Vessel Survey

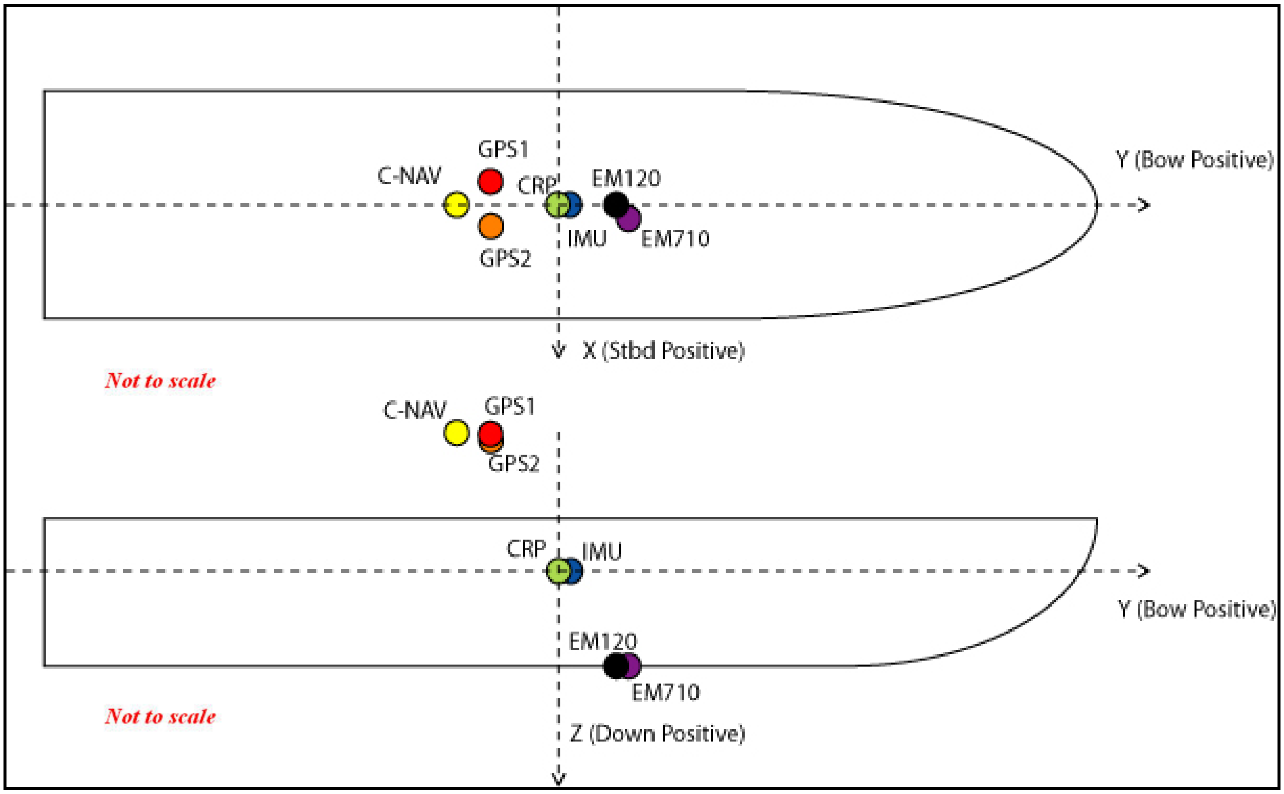

Figure 11 – R/V Mt. Mitchell vessel survey showing the relative positions of the installed survey equipment.

Equipment	Manufacturer / Model	Offset from CRP (m) based on CARIS Convention		
		X	Y	Z
IMU	Applanix POS MV	0.072	0.261	-0.168
MB Transducer	Kongsberg EM 710	+1.00	+3.685	+2.553
MB Transducer	Kongsberg EM 120	+.024	+2.764	+2.593
GPS1 (Primary Ant.)	Applanix POS MV	-1.085	-4.791	+14.499
GPS2 (Secondary Ant.)	Applanix POS MV	+0.913	-4.789	+14.497
C-NAV (Antennae)	C-NAV	-0.09	-5.506	+14.2

Table 19 – R/V Mt. Mitchell offset measurements determined during the initial vessel survey. The CARIS convention of + down (z), + starboard (x) and + forward (y) was used for all measurements.

C.1.2. Heave, Roll and Pitch

Heave, roll and pitch data for the *M/V Bluefin, R/V Mt. Mitchell* and *R/V Mt. Augustine* were measured using Applanix POS MV Attitude and Positioning Systems. The system provided output as a binary data string via RS-232 serial cable to the QINSy acquisition software at 25Hz. Heave, roll and pitch corrections were applied during the sound velocity correction process in CARIS HIPS.

C.1.3. Patch Test Data

Patch tests were performed on *M/V Bluefin, R/V Mt. Mitchell* and the *R/V Mt. Augustine* to determine the composite offset angles (roll, pitch and azimuth) for the transducer and motion sensor and the latency (time delay) from the positioning system. The initial patch tests were run over the same feature for confidence checking between vessels and systems. The *M/V Bluefin* and the *R/V Mt. Augustine* were initially patch tested in Seattle while the *R/V Mt. Mitchell* was initially patch tested in Unimak Pass over a feature which the *M/V Bluefin* also patch tested on.

C.1.3.1. Navigation/Latency

One survey line was run twice, in the same direction, at different speeds over a distinct slope or object.

C.1.3.2. Pitch

After determining and entering the corrector values for time delay, pitch offset was determined by running two pairs of reciprocal survey lines at the same speed over a distinct slope or object and comparing profiles.

C.1.3.3. Azimuth (Yaw)

After compensating for time delay and pitch offset, the azimuth offset was calculated by running two adjacent pairs of reciprocal lines at the same speed alongside a distinct object on the sea bed. Each line was run on a different side of the object and the longitudinal displacement of the bathymetric feature between the lines was measured.

C.1.3.4. Roll

The roll offset was determined after the time delay, pitch and yaw offsets had been calculated and compensated for by running a pair of reciprocal survey lines at the same speed over a regular and flat sea floor.

The offset values for pitch, yaw, roll and navigation latency from the positioning system were resolved using the calibration editor in CARIS Subset Editor. The time-referenced values were then stored in the appropriate HVF file. Offset and latency corrections were applied to the raw sounding data during the merge process in CARIS.

Patch tests were conducted prior to the beginning of the 2009 survey and whenever there was a configuration change involving the position of the multibeam transducer. A listing of the patch tests performed for the 2009 survey is provided in Table 20.

Vessel	Julian Date	Location	Latitude / Longitude	Reason
M/V Bluefin	2009-122	Shilshole Bay Seattle, WA	47° 40’ 25.2” N 122° 25’ 22.7” W	Initial patch test
M/V Bluefin	2009-161	Unimak Pass, AK	54° 28’ 45.9” N 165° 00’ 30.4” W	Added center of rotation lever arm in POS
M/V Bluefin	2009-204	Dutch Harbor, AK	53° 54’ 06.4” N 166° 29’ 44.2 W	Noticed roll artifact in multibeam data starting on 2009-199
M/V Bluefin	2009-205	Akun Bay, AK	54° 14’ 10.0” N 165° 25’ 07.3” W	Replaced Reson 81-P
M/V Bluefin	2009-237	Unimak Pass, AK	54° 28’ 45.9” N 165° 00’ 30.4” W	Noticed roll artifact in multibeam data starting on 2009-236
R/V Mt. Augustine	2009-122	Shilshole Bay, Seattle, WA	47° 40’ 25.2” N 122° 25’ 22.7” W	Initial patch test
R/V Mt. Augustine	2009-140	Unimak Pass, AK	54° 28’ 45.9” N 165° 00’ 30.4” W	Changed MBES swing arm stop
R/V Mt. Mitchell	2009-154	Unimak Pass, AK	53° 53’ 30” N 166° 34’ 30” W	EM710 Initial calibration
R/V Mt. Mitchell	2009-163	Pribilof Canyon	56° 07’ 00” N 169° 20’ 00” W	EM710/120 Official Calibration

Table 20 – Patch tests performed for instrument calibration during OPR-P188-TE-09.

C.2. Speed of Sound through Water

Sound speed profile data for OPR-P188-TE-09 was collected using ODIM MVP 200 with Applied Microsystems, Ltd. (AML) Micro SV&P sensor, two AML SV Plus v2 sound velocity sensors, and Lockheed Martin Sippican XBT T-5 and XCTD-2 expendable bathymetric thermographs. Surface sound speed data was collected using an AML SV&T aboard the *R/V t. Mitchell.*

The SV Plus v2 sensors were set to record one sample per second during casts and were lowered through the water column at approximately one meter per second. The raw sound speed data were downloaded using HyperTerminal and saved as a text document. The raw pressure data was converted from dBars to depth in meters using a conversion equation provided by Applied Microsystems, Ltd. (Saunders and Fofonoff (1976)) using the TerraSond, Ltd. Simple SVP program. A CARIS compatible file containing geo- and time-referenced listing of sound speed vs. depth was produced.

The AML Micro SV&P writes the sound speed data to a ".raw" text file while casting. The data files were run through the TerraSond, Ltd. Simple SVP program to interpolate the data to one measurement per meter.

Sound speed corrections were then applied to the raw sounding data. Previous in time sound speed data was applied to the soundings from the *R/V M/V Bluefin* and *R/V Mt. Augustine*, with the exception a of few lines noted in the DRs, which were sound speed corrected using nearest in time. Sound velocities for the *R/V Mt. Mitchell* were applied using nearest in time in order to compensate for infrequencies in sound speed casts. The DR, *Separate II* contains sound speed comparisons and calibration reports. Individual cast data can be found in the CARIS ".svp" file submitted with the digital data of each survey.

The surface sound speed data from the AML SV&T aboard the *R/V Mt Mitchell* was entered in to the SIS acquisition software during acquisition for beam forming and launch angle of the flat array EM 710 system. The Reson 8101 systems aboard the *M/V Bluefin* and the *R/V Mt. Augustine* are curved arrays and do not require surface sound velocity correction during acquisition.

C.3. Static Draft

Static draft was determined for the *R/V Mt. Augustine* and *R/V Mt. Mitchell* by measuring from a control point on the hull of the port and starboard side of each survey vessel to the waterline. Static draft for the *M/V Bluefin* was recorded using a stilling tube with metric scale labeled during the vessel survey. The draft was recorded twice daily in the Measure-down Log except when sea state or vessel operations precluded measurement. The static draft readings were subsequently recorded in the HVF and used in conjunction with settlement and squat data to create a dynamic draft which was applied to sounding data during final processing.

C.4. Settlement and Squat

C.4.1. M/V Bluefin

Settlement and squat measurements for *M/V Bluefin* were collected on July 3, 2009 using Post Processed Kinematics (PPK) GPS Survey Procedures in Akutan Bay near Akun, AK. A PPK ellipsoid height survey was conducted which was processed in Caris in order to extract horizontal positions as well as ellipsoid heights necessary to determine the squat/settlement changes at varying RPM's.

POS M/V ".000" and QINSy ".db" files were logged for three minutes in static drift; the engine RPM was then increased to the desired RPM. Once the vessel was at the desired RPM, measurements were again logged for three minutes, followed by another three minute drift segment. The reciprocal line was then run at the same RPM. Data were recorded in 100 RPM increments from 700 RPM to 1500 RPM, which range was selected as representative of practical operational limits producing vessel speeds between 2 and 10 kts.

The POS file was processed in POSPac MMS 5.1 with data from the Akun Bay base station to produce an SBET file that was used to apply horizontal and vertical GPS position to the line files in CARIS. CARIS was then used to compute GPS tide, which accounts for vessel offset as well as heave. After the navigation data was loaded in CARIS, the GPS tide was computed and extracted for the final settlement computation. For comparison, GPS heights were also exported straight from POSPac and used to run a comparison settlement computation.

The final settlement computations were calculated using an excel spreadsheet. Settlement was determined by calculating the change in tide from the static drift before each run to the static drift immediately following that run. This was used to determine the tide height at each run, which was subtracted from the dynamic value to give the settlement value. A graph was then constructed to illustrate settlement changes as a function of the vessel RPM. From this graph, a linear best fit line was determined that modeled the settlement behavior of the vessel.

As the CARIS Vessel Configuration draft table uses speed rather than RPM, it was necessary to determine the relationship between speed and RPM for the *M/V Bluefin*. This was achieved by graphing samples of the RPM and speed data collected over the length of the survey, and determining linear best fit line. These two best fit lines were used to generate a final table of speed versus settlement values that were input into the draft table.

***M/V Bluefin* Settlement Results**

RPM	SPEED (kts)	Settlement (m)
500	3.626	-0.012
600	4.026	0.003
700	4.426	0.018
800	4.826	0.032
900	5.226	0.047

RPM	SPEED (kts)	Settlement (m)
1000	5.626	0.062
1100	6.026	0.077
1200	6.426	0.091
1300	6.826	0.106
1400	7.226	0.121
1500	7.626	0.136
1600	8.026	0.151

Table 21 – M/V Bluefin average RPM vs. speed and settlement measurements

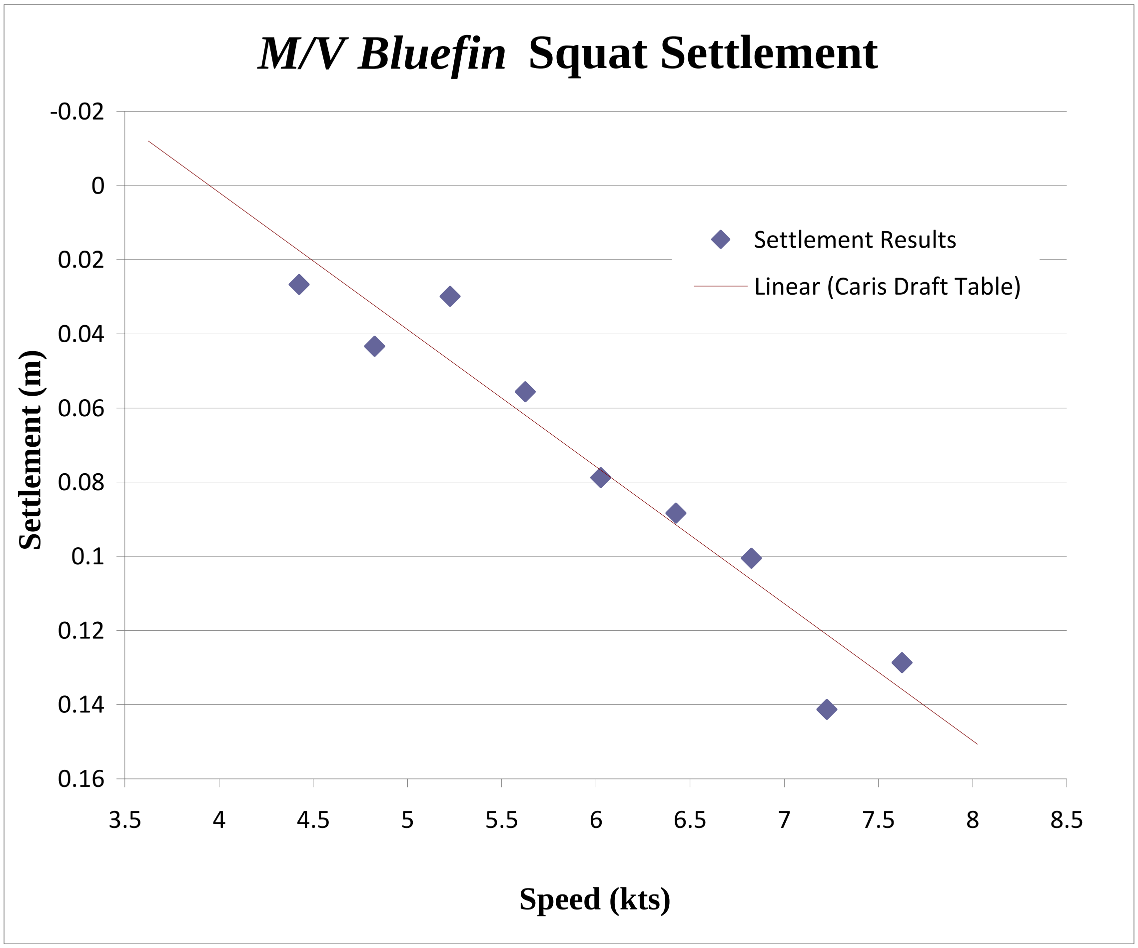

Figure 12 – M/V Bluefin Settlement Results and CARIS Draft Table values.

C.4.2. R/V Mt. Augustine

Settlement and squat measurements for R/V Mt. Augustine were conducted on May 3, 2009 using Real Time Kinematic (RTK) GPS Survey Procedures in Shilshole Bay near Seattle, WA. The settlement and squat was performed with the multibeam transducer deployed in its survey position.

Measurements were made using a Trimble SPS 880 GPS receiver, internal radio and a POS MV attitude and positioning sensor on board the vessel. The vessel GPS configuration yielded ellipsoid heights which were referenced to the COG of the R/V MT. Augustine. Data was recorded in 200 RPM increments from 800 RPM to 3400 RPM. The RPM range was selected as representation of practical operational limits producing vessel speeds between 2 and 30 knots.

A kinematic base station (Trimble R8) was set up on shore a few kilometers from the survey vessel. The base station used a Trimark 2 radio to transmit Real Time Carrier Phase corrections to the POS MV installed on R/V Mt. Augustine. The rover receiver (Trimble SPS 880) used the carrier phase corrections to determine the position of the navigation antenna on the R/V Mt. Augustine relative to the base station with a vertical accuracy under 2 cm. The measurements were logged in real-time using QINSy data collection software. An output file for each drift and dynamic session were created from the beginning of the first drift to the end of the final drift that contained time, Easting, Northing and height.

Measurements were logged for three minutes in static drift; the engine RPM was then increased to the desired RPM. Once the vessel was at the desired RPM, measurements were logged for three minutes, followed by a three minute drift segment. The reciprocal line was then run at the same RPM. This procedure was followed for each RPM range, and concluded with a final three minute drift period.

The final settlement computations were calculated using an excel spreadsheet. Settlement values were determined by removing the change in tide between the two static drift sessions performed directly before and after each dynamic session. The tide value during each dynamic session was determined by solving for a linear equation between the two corresponding static sessions. A graph was then constructed to illustrate settlement changes as a function of the vessel RPM.

***R/V Mt. Augustine* Settlement Results**

RPM	Speed-(kts)	Settlement (m)
800	3.687	0.012
1000	4.705	0.031
1200	5.196	0.026
1400	5.846	0.044

RPM	Speed- (kts)	Settlement (m)
1600	6.393	0.040
1800	6.848	0.057
2000	7.371	0.061
2200	7.985	0.061
2600	9.751	0.012

Table 22 – R/V Mt. Augustine average RPM vs. speed and settlement measurements

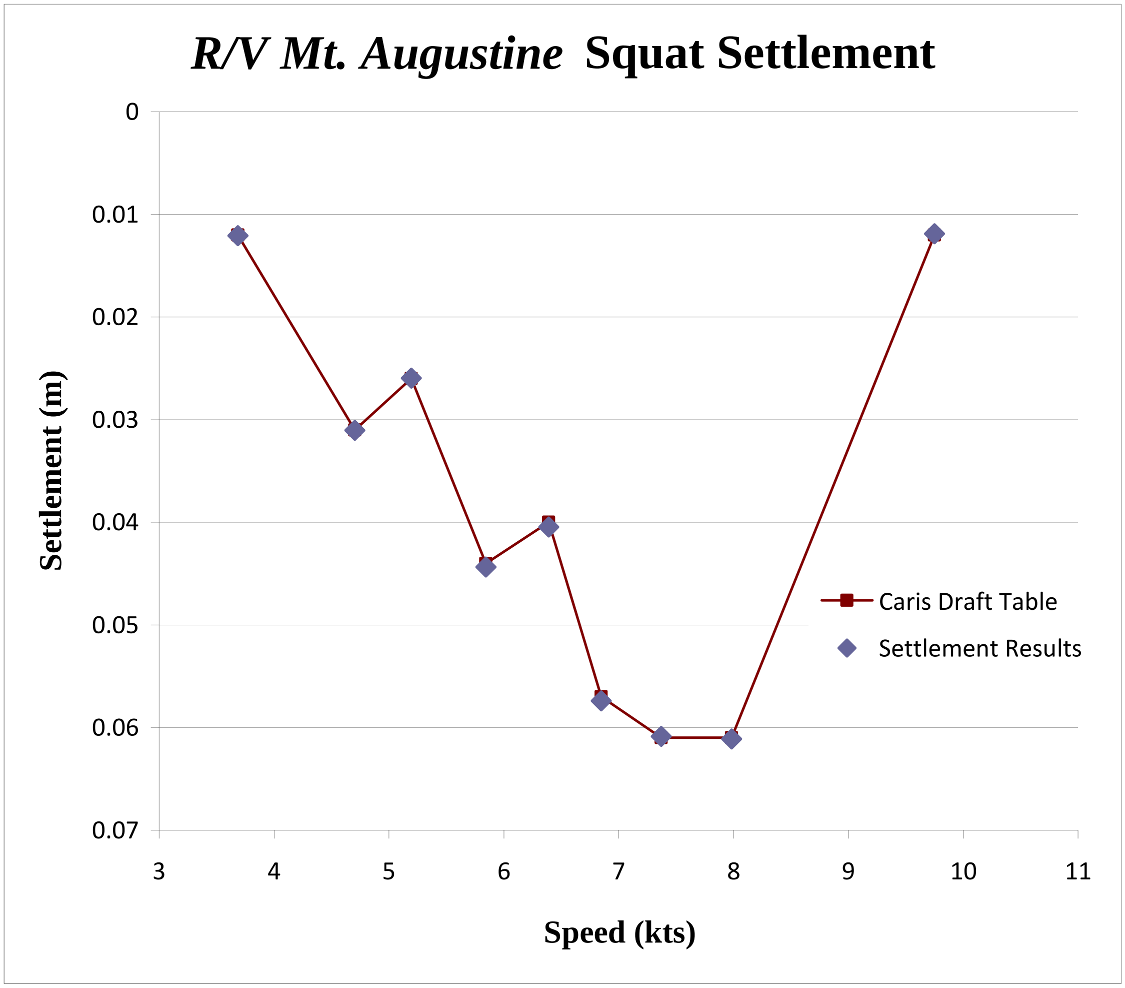

Figure 13 – R/V Mt. Augustine Settlement Results and CARIS Draft Table values.

C.4.3. R/V Mt. Mitchell

Settlement and squat measurements for *R/V Mt. Mitchell* were conducted using Post Processing Kinematic (PPK) GPS Survey Techniques in Akun Bay on June 21, 2009. Measurements were made using a POS M/V attitude and positioning sensor, and settlement values were recorded during vessel propeller pitches ranging from 10–80 percent. These pitches were selected to represent the practical operational limits of propeller pitches during the survey.

The Squat Settlement was recorded as follows: A static session was logged for three minutes with no way on; the engine RPM / propeller pitch was then increased to achieve the desired vessel pitch. Once the vessel was at the desired pitch, and at constant speed, measurements were logged for three more minutes. Power was then removed and the vessel was brought to a drift. Three more minutes of static data was then logged. This procedure was repeated throughout the RPM / propeller pitch range used when surveying.

The POS file was processed in POSPac MMS 5.1 with data from the Akun Bay base station to produce an SBET file that was used to apply horizontal and vertical GPS position to the line files in CARIS. CARIS was then used to compute GPS tide, which accounts for vessel offset as well as heave. After the navigation data was loaded in CARIS, the GPS tide was computed and extracted for the final settlement computation. For comparison, GPS heights were also exported straight from POSPac and used to run a comparison settlement computation.

The final settlement computations were calculated using an excel spreadsheet. Settlement was determined by calculating the change in tide from the static drift before each run to the static drift immediately following that run. This was used to determine the tide height at each run, which was subtracted from the dynamic value to give the settlement value. A graph was then constructed to illustrate settlement changes as a function of vessels pitch. Draft modifications in the CARIS HIPS Vessel Configuration file take into consideration speed instead of vessel pitch, however. To bridge this gap, propeller pitch was graphed versus average vessel speed (sampled in two directions), and then speed was graphed versus settlement, and the table was assembled.

***R/V Mt. Mitchell* Settlement Results**

Pitch	Speed (kts)	Settlement (m)
25	3.099	-0.014
35	4.997	0.016
45	6.750	0.049
55	8.724	0.064
65	10.078	0.123

Pitch	Speed (kts)	Settlement (m)
75	11.273	0.165

Table 23 – R/V Mt. Mitchell average pitch vs .speed and settlement measurements

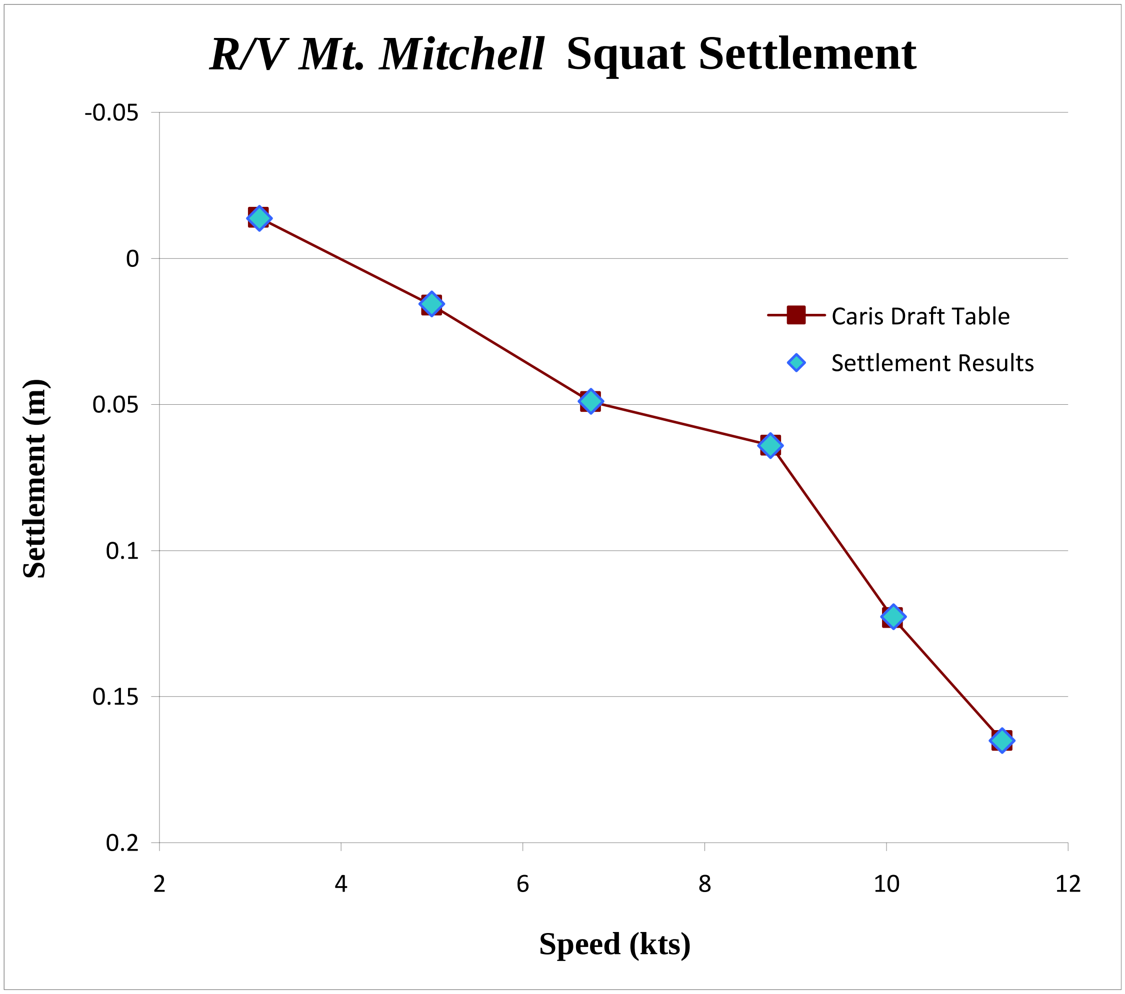

Figure 14 – R/V Mt. Mitchell Settlement Results and CARIS Draft Table values.

C.5. Tide Correctors

The tidal datum for the survey was Chart Datum, Mean Lower Low Water (MLLW). The National Water Level Observation Network NWLON stations at Unalaska, AK (946-2620) and King Cove, AK (945-9881) provided predicted tide data which were used during the data acquisition portion of the survey. Predicted tide data were downloaded from the NOAA Tides and Currents Predicted Tides website in ASCII format and applied to the raw data in CARIS HIPS during the merge step of initial data processing.

Verified tides were downloaded as soon as they were available for download from the NOAA Tides and Currents Verified Tides website. Verified tides were applied to the data as soon as tide data became available.

Final zones were applied using a modified zone file referencing verified tide data from the King Cove (945-9881), Akun (946-2719), and Scotch Cap AK (946-2808) tide gauges. Refer to the VHCR *Appendix I* for tide zone methods and operations.

C.6. Project Wide Tide Correction Methodology

The tidal zoning scheme was provided in the statement of work. The NWLON station at King Cove, AK (945-9881), an installed gauge at the historic tide station Scotch Cap (946-2808), and a new station at Akun Bay (946-2719) were used as the reference station for the zoning scheme. Refer to the VHCR *Appendix I* for tide zone methods and operations.

LETTER OF APPROVAL

Registry Numbers: H12004, H12065, H12066, H12067

This report and the accompanying digital data are respectfully submitted.

Field operations contributing to the accomplishment of surveys H12004, H12065, H12066 and H12067 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 as per the Statement of Work. Other reports submitted with OPR-P188-TE-09 include the Descriptive Reports and the Vertical and Horizontal Control Report.

I believe 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
Date: 2010.01.13 18:33:55 -09'00'

Marta Krynytzky, Lead Hydrographer

TerraSond, Ltd.

Date__________January 13, 2009____________