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

Data Acquisition & Processing Report

Type of Survey Hydrographic Survey

Field No. H11837, H11838, H11839, H11840, H11841, H11842

Registry No. OPR-P385-TE-08

LOCALITY

State Alaska

General Locality Northern Cook Inlet

2008

CHIEF OF PARTY

Kathleen Mildon

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DATE November 2009

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(11-72)

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

HYDROGRAPHIC TITLE SHEET

REGISTRY No **Data Acquisition and Processing Report OPR-P385-TE-08**

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. **H11837, H11838, H11839, H11840, H11841, H11842**

State Alaska

General Locality Northern Cook Inlet

Sub-Locality Various

Scale N/A

Date of Survey June 22 – August 17, 2008

Instructions dated March 3, 2008

Project No. OPR-P385-TE-08

Vessel *R/V Mt. Mitchell & R/V Mt. Augustine*

Chief of party Katie Mildon

Surveyed by TerraSond Ltd.

Soundings by echo sounder, lead line, pole Multibeam Echosounder, Side Scan Sonar

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.
1617 South Industrial Way, Suite 3
Palmer, AK 99645

All times recorded in UTC

Data Acquisition and Processing Report

OPR-P385-TE-08
2008
Northern Cook Inlet

R/V Mt. Augustine onboard R/V Mt. Mitchell

H11837
H11838
H11839
H11840
H11841
H11842

Vessels: ***R/V Mt. Mitchell and R/V Mt. Augustine***

State: **Alaska**

Locality: **Northern Cook Inlet**

Year: **2008**

Lead Hydrographer: **Kathleen Mildon**

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A. EQUIPMENT

A.1. Vessels

All data for this survey was acquired using the *Research Vessel Mt. Mitchell* and the *Research Vessel Mt. Augustine.*

A.1.1. *R/V Mt. Mitchell*

Multibeam echosounder, side scan sonar, and bottom sample data for surveys H11837, H11838, H11839, H11840, H11841 and H11842 was acquired using the *R/V Mt. Mitchell.*

The *R/V Mt. Mitchell,* shown in Figure 1, 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 Bird-Johnson controllable-pitch propellers operating between 10% and 80% pitch. 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 Echo Sounder System and EdgeTech 4200FS Side scan Sonar System. Detailed vessel drawings showing the location of all primary survey equipment are included in *Section C.* of this report.

Figure 1 – R/V Mt. Mitchell anchored in Seward, Alaska.

A.1.1.1 Equipment Overview

The equipment on the *R/V Mt. Mitchell* performed well and within required specifications during the survey.

A.1.1.2 Major Operational Systems

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

Description	Manufacturer	Model / Part	Serial Number
Multibeam Sonar	Kongsberg	EM 710	201
Side scan Sonar	EdgeTech	4200FS	32760
Sonar Acquisition	QPS	QINSy	N/A
Positioning System	Applanix	POS M/V V4	3034
Motion Sensor	Applanix	POS M/V - IMU 200	727-412110
SV Probe	AML AML	Mirco SV&P Smart SV&T	7508 5433
Differential Beacon Receiver	Primary: Hemisphere GPS Secondary: Trimble	MBX-4 DSM-212	081770670011 0220232566

Table 1 – Table showing the major survey equipment used aboard the R/V Mt. Mitchell.

A.1.1.3 Sounding Equipment

An EdgeTech 4200FS side scan sonar system and a Kongsberg EM 710 multi-beam echo sounder (MBES) system were used aboard the *R/V Mt. Mitchell* during OPR-P385-TE-08.

The 4200FS is a dual simultaneous frequency side scan system. It features either 100/400 kHz or 300/600 kHz dual simultaneous frequency sets up to a 2000 meter depth rating. For the survey of Northern Cook Inlet, the High Frequency, High Definition ping mode was used; employing the 400 kHz frequency. The horizontal beam width ranges from 0.3°-1.26° and operates at a maximum range of 120-500 meters, depending on the chosen frequency setting. Bathymetric data was transmitted over single coaxial tow cable lengths to the collection computer. Video Display Gains were adjusted during data collection for visual real time bottom inspection. Time Varied Gain (TVG) with spreading and absorption values was within recommended ranges for cold salt water. The range scale was held constant at 100m.

The EM 710 is a 128-beam radial-array system. It employs a 2-degree along-track beam angle and a 2-degree across-track beam angle. Bathymetric datagrams from the EM 710 were output via an 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 have all data contained within the quality specifications.

A.1.1.4 Technical Specifications

Kongsberg EM 710	
Sonar Operating Frequency	70 kHz
Beam Width, Across Track	2.0°
Beam Width, Along Track	2.0°
Number of Beams	128
Max Swath Coverage	140°

Table 2 – Kongsberg EM 710 multibeam echosounder technical specifications.

EdgeTech 4200FS	
Sonar Operating Frequency	100/400 kHz
Beam Width, Across Track	500/150 m
Beam Width, Along Track	1.26/0.4°
Number of Beams	2
Swath Coverage	1000/300 m

Table 3 – EdgeTech 4200FS side scan sonar technical specifications.

A.1.2. *R/V Mt. Augustine*

Multibeam echosounder, side scan sonar, and bottom sampling data for survey H11837, H11838, H11839, H11840, H11841, and H11842 was acquired using the *R/V Mt. Augustine*. The *R/V Mt. Augustine* survey was conducted concurrently with operations by the *R/V Mt. Mitchell* to acquire multibeam and side scan data that was not practical or accessible to survey with the *R/V Mt. Mitchell*. The *R/V Mt. Augustine* was also used for crew support exchanges, assisting in anchor retrievals and bottom sampling.

The *R/V Mt. Augustine*, shown underway 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 echo sounder and an EdgeTech 4200FS side scan sonar. The *R/V Mt. Augustine* was powered by two Yanmar 6LPA-STP 315hp engines and Konrad Model 540 PRS outdrives. 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.

Figure 2 – R/V Mt. Augustine underway in Northern Cook Inlet, Alaska.

A.1.2.1 Equipment Overview

The equipment on the *R/V Mt. Augustine* performed well and within required specifications.

A.1.2.2 Major Operational Systems

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

Description	Manufacturer	Model / Part	Serial Number
Multibeam Sonar	Reson	SeaBat 8101	276010
Side scan Sonar	EdgeTech	4200FS	32761
Sonar Processor	QPS	QINSy	N/A

Description	**Manufacturer**	**Model / Part**	**Serial Number**
Positioning System	Applanix	POS M/V V4	2147
Motion Sensor	Applanix	POS M/V - IMU 200	135 402 628
SV Casting Probe	Applied Microsystems	SV Plus V2	3598
Differential Beacon Receiver	Primary: Hemisphere GPS Secondary: Trimble	MBX-4 DSM-212	081770670018 0220273384

Table 4 - Table showing the major survey equipment used aboard the R/V Mt. Augustine.

A.1.2.3 Sounding Equipment

An EdgeTech 4200FS side scan sonar system and a Reson SeaBat 8101 multi-beam echo sounder (MBES) system were used aboard the *R/V Mt. Augustine* during OPR-P385-TE-08.

The 4200FS is a dual simultaneous frequency side scan system. It features either 100/400 kHz or 300/600 kHz dual simultaneous frequency sets up to a 2000 meter depth rating. For the survey of Northern Cook Inlet, the High Frequency, High Definition ping mode was used; employing the 400 kHz frequency. The horizontal beam width ranges from 0.3°-1.26° and operates at a maximum range of 120-500 meters, depending on the chosen frequency setting. Bathymetric data was transmitted over single coaxial tow cable lengths to the collection computer. Video Display Gains were adjusted during data collection for visual real time bottom inspection. Time Varied Gain (TVG) with spreading and absorption values was within recommended ranges for cold salt water. The range scale was held constant at 100m.

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°

Table 5 – Reson SeaBat 8101 multibeam echosounder technical specifications.

EdgeTech 4200FS	
Sonar Operating Frequency	100/400 kHz
Beam Width, Across Track	500/150 m
Beam Width, Along Track	1.26/0.4°
Number of Beams	2
Swath Coverage	1000/300 m

Table 6 – EdgeTech 4200FS side scan sonar technical specifications.

A.2. Tide Gauges

NOAA tide stations at Anchorage, AK (945-5760) and Nikiski, AK (945-5920) were used to provide predicted tide data for OPR-P385-TE-08 preliminary data processing. Two historic USC&GS tide stations Point Possession, AK (945-5866) and North Foreland, AK (945-5869) were also used. At Point Possession, 61°02’04”N and 150°24’12”W, two Design Analysis Associates, Inc. WaterLog series H-355 “bubbler” gauges were installed with approximately 1500’ of line and cable out to the orifices from a temporary tide shack built on the bluff. The standard accuracy of these gauges was 0.01% of full scale to 30 meters. At North Foreland, 61°02’34”N and 151°09’49”W, John Oswald and Associates installed and maintained two DAA H3611i radar sensors. The standard range is up to 22 meters with an accuracy of +/-3mm (when range is less than 10m).

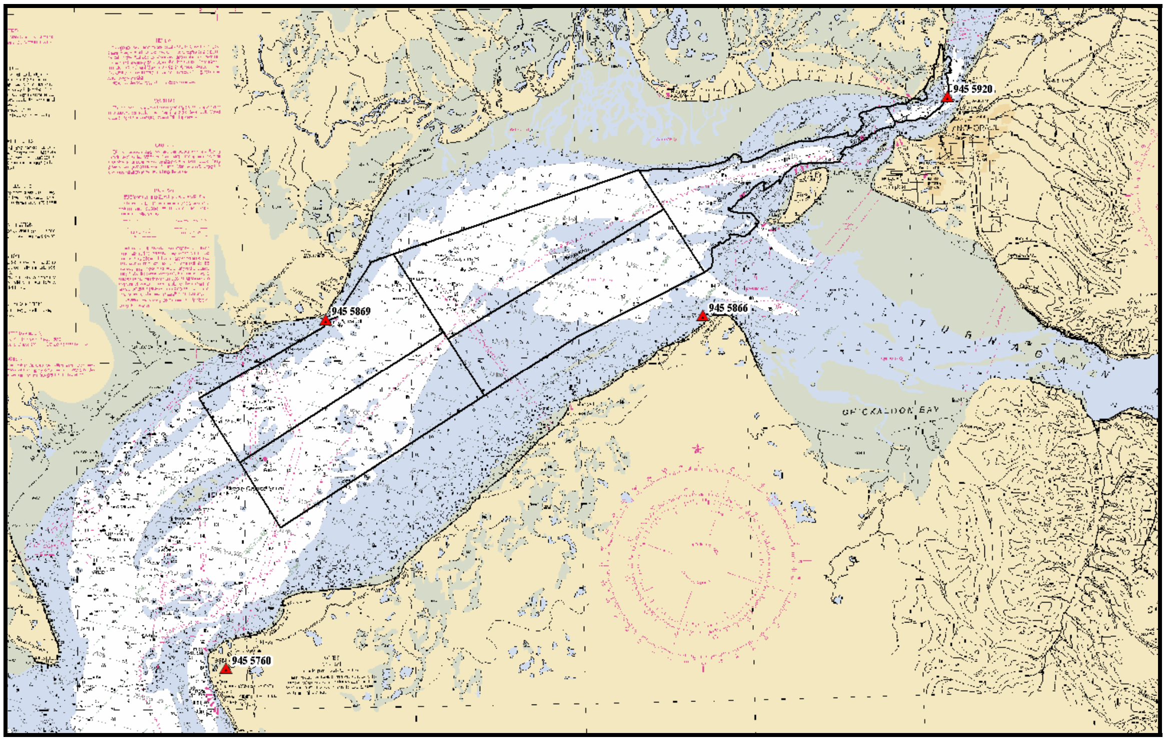


Figure 3 - Location of tide stations used in OPR-P385-TE-08. Chart16660 30th Edition, June 2006

Sea-Bird SBE 26plus Wave & Tide Recorder submersible tide gauges were set in strategically planned deployment areas during survey operations.

Data from the Sea-Bird tide gauges was downloaded each time a gauge was retrieved before being redeployed. The water level measurement sensors at North Foreland and Point Possession were transmitted via GOES radios and antennas to enable near real time QC/QA. The transmission rate was set to once every ten minutes. Final processing of the tide data was completed by TerraSond, Ltd. and John Oswald and Associates, LLC (JOA) of Anchorage, Alaska.

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

A.3. Speed of Sound

Speed of Sound data was collected by vertical casts on the *R/V Mt. Mitchell* using an ODIM MVP 200 with an Applied Microsystems Micro SV&P sound speed sensor and an Applied Microsystems SV+ V2 sound speed sensor on the *R/V Mt. Augustine.*

Sound speed profiles were taken as deep as possible and were geographically distributed within the survey area to meet the criteria specified in NOS Hydrographic Surveys Specifications and Deliverables for water depths of 30 m or less, 30 m to 100 m, and greater than 100 m. All sound speed profiles extended to 95% of the anticipated water depth and are representative of local and diurnal variability. No data quality issues related to speed of sound measurements were encountered during the survey.

Sound Speed data is submitted as part of the CARIS project.

The following instruments were used to collect data for sound speed profiles for this survey.

R/V Mt. Mitchell

Moving Vessel Profiler	**MVP 200 – Caster for free fall fish**
Manufacturer	ODIM, Brooke Ocean Dartmouth, Nova Scotia, Canada
Serial number	10552
Calibrated	N/A

Sound Velocity & Pressure Sensor	Micro SV&P sensor
Manufacturer	Applied Microsystems Ltd. Sydney, British Columbia, Canada
Serial number	7508 used in MVP fish, 7509 spare sensor
Calibrated	12/18/07

Sound Velocity and Temp. Sensor	**Smart SV&T**
Manufacturer	Applied Microsystems Ltd. Sydney, British Columbia, Canada
Serial number	5433
Calibrated	03/11/2008

R/V Mt. Augustine

Velocimeter (sound speed profiler)	**SV Plus V2**
Manufacturer	Applied Microsystems Ltd. Sydney, British Columbia, Canada
Serial number	3598
Calibrated	01/31/08

Table 7 – Table listing the sound speed measuring equipment used during OPR-P385-TE-08.

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

Copies of the manufacturer's calibration reports are included in the Descriptive Report, *Separate II: Sound Speed Profile Data,* for each survey.

A.4. Positioning Systems

Position control for the *R/V Mt. Mitchell* and the *R/V Mt. Augustine* was provided by an Applanix POS M/V V4 positioning system. Both vessels received differential correctors from CSI Wireless MBX-4 beacon receivers. Vessel positions were recorded using QPS QINSy data acquisition software at 1Hz intervals using National Marine Electronics Association (NMEA) message $GPGGA. POS Files were logged at a 20Hz interval. These position and motion files were Post Processed in Applanix POSPac software. A Smoothed Best Estimate Trajectory (SBET) was output after processing. The SBET was applied in CARIS to the sounding data as the navigation and final height source. Refer to *Section B: Quality Control* for processing and application of the SBET.

Differential Global Positioning System (DGPS) confidence checks were conducted real-time with Trimble DSM 212 beacon receivers on each vessel. Positions obtained by the POS M/V and DSM 212 receivers on the *R/V Mt. Mitchell* and *R/V Mt. Augustine* were simultaneously logged using QINSy. Position differences were then analyzed using Microsoft Excel to ensure position quality. Position differences, when compared with the fixed baseline length between the receiver antennas on each vessel, were well within the required 10-meter accuracy for this survey. Refer to the Descriptive Report, *Separate I: Acquisition and Processing Logs* included with each survey for a table of quality control checks to ensure positional accuracy.

Specific details addressing horizontal control activities associated with this project are discussed in the Horizontal and Vertical Control Report.

A.5. Attitude Sensors

An Applanix POS M/V Inertial Measurement Unit (IMU) 200 was used to measure heave, pitch and roll values to be used to correct for the motion in the sounding data from the *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.6. Data Collection

A.6.1. Overview

The survey was conducted using side scan sonar and shallow-water multibeam techniques with the *R/V Mt. Mitchell* and *R/V Mt. Augustine*. No single-beam data was collected. On 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

R/V Mt. Mitchell, weather permitting, and was used to develop areas that were too shoal or fouled to permit access by the *R/V Mt. Mitchell*.

A.6.2. Coverage

Survey line spacing was 90 meters yielding significant multibeam bottom coverage and 100% or greater side scan coverage seaward of the 8-meter curve, in Sheets C, D, E and F. Sheets A and B were strictly multibeam coverage at 90 meter line spacing. Multibeam developments were run in all regions where a significant contact was found in the side scan coverage and no multibeam soundings existed over the shoaling feature.

A.6.3. Line Planning

Line spacing and the resultant line numbering scheme was pre-planned. Pre-planned processing blocks were developed for each assigned sheet prior to the survey to aid in processing organization.

In general, survey lines were run the length of each sheet parallel to the survey limits.

A.6.4. Ping Rates

The NOS Hydrographic Survey Specifications and Deliverables, *Section 5.1.1.*, requires "…that no less than 3.2 beam footprints, center-to-center, fall within 3 m, or a distance equal to 10 percent of the depth, whichever is greater, in the along track direction." To meet specifications, the survey vessels either surveyed at high speeds with a rapid ping rate (reduced range), or at lower speeds with a reduced ping rate (increased range).

As a general rule, engine RPM was held constant throughout a survey line and the ping rate was selected as a function of vessel speed over the ground (SOG). During this survey, the selected ping rate met or exceeded the specifications set forth in NOS Hydrographic Survey Specifications and Deliverables, *Section 5.1.1*. Surveying at vessel speeds at or below 8 kts ensured a minimum of 3 pings on a 1 m target at a range of 100 m.

A.7. Software and Hardware Summary

Multibeam and side scan data were collected on an Intel Pentium IV PC using QPS QINSy data collection software (multibeam & side scan) 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 line 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) and CARIS Sonar Information Processing System (SIPS). Final survey coverage determination was made following data processing with CARIS HIPS and SIPS as well as with Chesapeake SonarWiz.MAP.

CARIS HIPS and SIPS hydrographic data processing software was used for multibeam and quality assurance. Chesapeake SonarWiz.MAP data processing software was used for side scan post processing and quality assurance. Data post-processing procedures are described in detail in *Section B. Quality Control.*

Table 8 lists the software used on the *R/V Mt. Mitchell* and *R/V Mt. Augustine* during the survey and Table 9 lists the software used in the office during pre-survey planning and post-survey processing:

A.8. Vessel Software

Program Name	**Version**	**Date**	**Primary Function**
Reson SeaBat	1.06-3EEB	2002	Reson SeaBat 8101 firmware (wet)
Reson SeaBat	2.04-96C1	2000	Reson SeaBat 8101 firmware (dry)
Kongsberg EM 710			Sonar firmware
SIS			Kongsberg MB controller software
QPS QINSy	8.0	2008	Multibeam data collection suite
POS MV V4			
POS MV IMU – 200			
Corpscon	5.11	2001	Coordinate conversion
Nautical Software Inc. Tides and Currents for Windows	2.2	1996	Predicted Tides
TerraSond Ltd. SV Software	1.0	2007	Convert sound speed raw data to CARIS compatible format.

Table 8 – Software used aboard the R/V Mt. Mitchell and R/V Mt. Augustine.

A.9. Office Software

Program Name	**Version**	**Date**	**Primary Function**
CARIS HIPS & SIPS	6.1	2008	Multibeam data processing software
CARIS HOM	3.3	2006	S-57 Compilation
CARIS BASE Editor	2.1	2007	Bathymetry compilation and analysis software
CARIS GIS Professional	4.4	2006	Marine GIS information

			management software
Chesapeake SonarWiz.MAP	4.0	2008	Side scan data processing software
Autodesk MAP 3D 2006	4.0	2006	Drafting software
Blue Marble Geographics Geographic Transformer	5.2	2006	Image georeferencing and reprojection software
MapInfo Professional	8.5	2006	Desktop mapping software
ESRI ArcGIS	9.0	2008	Desktop Mapping software
Applanix POSPac	4.4 & 5.1	2007 & 2008	PPK Data Processing and SBET production
Corpscon	6.0	2005	Coordinate conversion software

Table 9 – Software used in the office during post processing.

B. QUALITY CONTROL

B.1. Overview

Every effort possible was made to ensure the traceability and integrity of the sounding and POS M/V 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 and SIPS was used for the multibeam data processing tasks on this project. HIPS and SIPS 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.

Chesapeake SonarWiz.MAP was used for the side scan data processing tasks on this project. SonarWiz.MAP 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 was used for processing the Inertial and GPS data. Steps were taken in TerraSond's workflow to preserve the raw data in its original format. Both the base station and rover data were sent through a rigorous process to ensure that the post processed combined solution of Inertial and GPS data was of a high quality. The final navigation and height data from the POSPac SBET was applied in CARIS to the sounding data.

B.2. Equipment Calibration

Each item of 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. All sound velocity and water surface measurement instruments were factory calibrated within the past year. Furthermore they were confidence checked prior to their use on this survey of Upper Cook Inlet.

B.3. Periodic Confidence Checks

GPS data was collected with a Trimble DSM-212 DGPS receiver concurrently with the position, attitude and sounding data being recorded in QPS QINSy. The GPS data included position information, number of satellites, maximum horizontal dilution of precision (HDOP), and DGPS verification. All data was time-referenced at 1-second intervals.

Crosslines were run as a confidence check for the multibeam sonar. The total linear nautical miles of crosslines exceeded five 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 line. 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 MBES each week, weather permitting. The confidence checks on the *R/V Mt. Mitchell* and *R/V Mt. Augustine* consisted of comparing lead line depths with depths logged by the MBES nadir beams. The two vessels regularly ran a similar line in a short time frame of one another, to allow for a vessel to vessel comparison. 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. Secondary confidence checks were performed by running the same survey line with both vessels simultaneously.

Total sounding error limits were determined using the following equation:

$$\pm\sqrt{[a^2 + (b*d)^2]}$$

where: **<u>for d < 100 meters</u>**

a=0.5 m
b=0.013 m
d=depth (m)

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

B.4. Data Collection

Multibeam and side scan sounding data collection was performed using QPS QINSy data acquisition software. File naming conventions were established to ensure that individual survey lines 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.

Chronological logs containing information specific to each line were maintained as an independent reference to aid in data integration and error tracking. Multibeam and side scan logs included the line name, start and end times, ping rate, range and power settings, and any additional comments deemed significant by the operator.

POS M/V GPS and motion data were also collected in Applanix POSView software. Generally, one file was collected per survey day and was named with a ".000" extension.

On days when survey operations dictated additional files be logged an incremental extension “.001”, “.002”, etc was assigned by the software to differentiate between files.

Additionally, Terrasond installed a continuously operating GPS base receiver in Tyonek AK which was internet accessible for the purpose of downloading data. 24 files were logged per day and were broken on the hour. This data was used to post process the vessels POS GPS and motion data in POSPac.

B.5. Initial File Handling

Initial multibeam data processing was completed on the survey vessel. At the end of each survey shift, the raw data file and converted “.xtf” file were organized by survey sheet and Julian day into a CARIS as well as into a Chesapeake 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 and SIPS. The .xtf files were also converted to Chesapeake compatible files using SonarWiz.MAP. These files were organized in a directory on the network server based on project name, vessel name, and Julian date.

POS M/V data files were collected onto the local drive of a PC and transferred at their completion to the POS folder of the ship’s data server.

All server data was backed up twice each day onto LT02 tapes. This system of data storage and frequent backups minimized the potential for data loss due to equipment malfunction or failure.

B.6. Field Data Processing

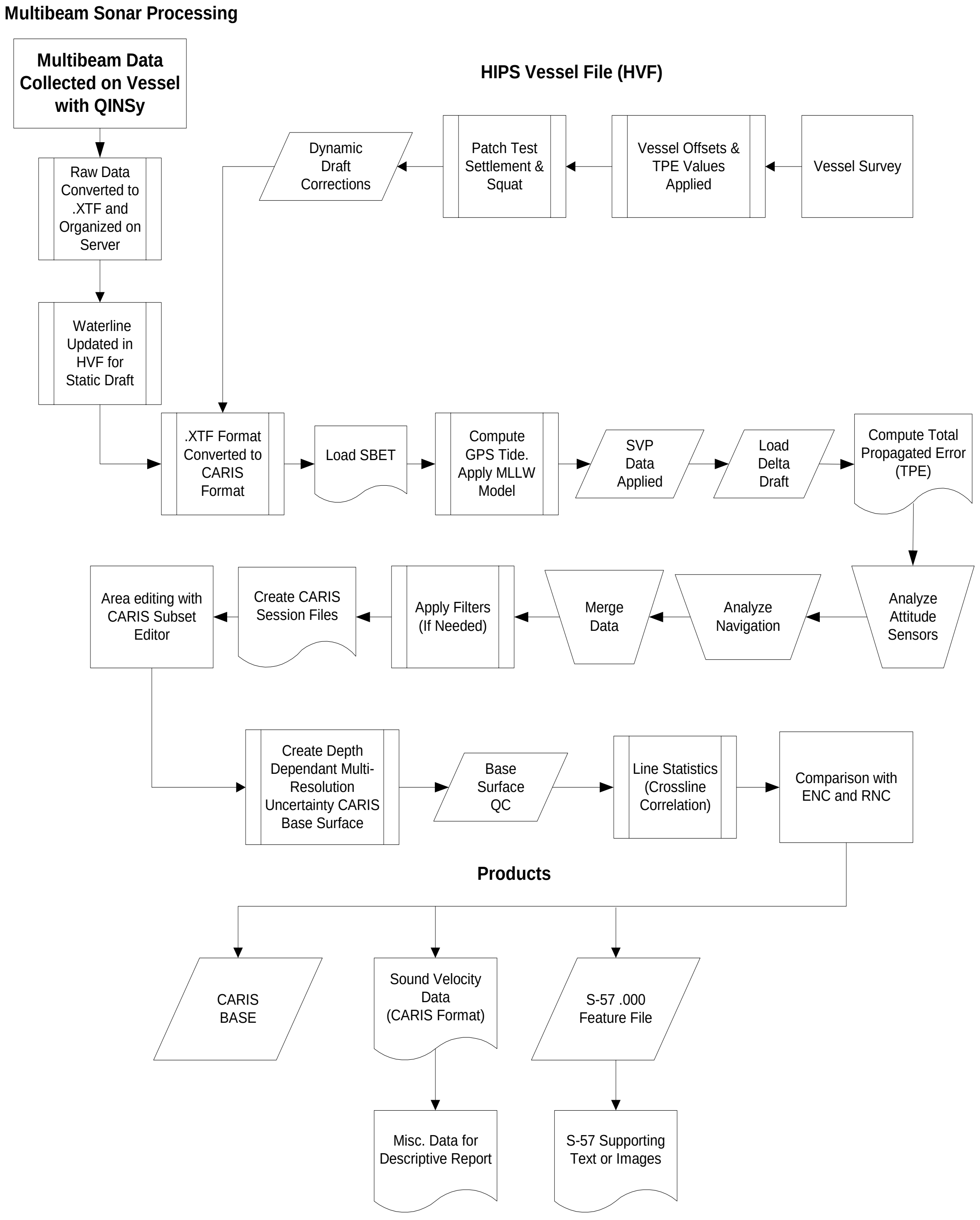
Preliminary multibeam data processing was completed aboard the survey vessel. Following the initial file conversion and backup, sound speed and predicted tide data were merged with the sounding data and each line was examined for heave, roll, pitch, and navigation errors. The data was then cleaned using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

Preliminary side scan data processing was also completed aboard the survey vessel. Side scan data was checked for navigation, bottom tracked, and reviewed for Dangers to Navigation, DTONs. Preliminary bottom tracking was used for determining coverage and for measuring DTONs, final bottom tracking was performed in the office. DTONs were reviewed by measuring object heights, reviewing towfish altitude, and then applying predicted tides and towfish offsets to the water line. Large objects found in side scan were reviewed with Subset Editor in CARIS HIPS and SIPS. If the preliminary least depth of the feature was 10% shoaler than depths on Chart 16660 30th Edition, updated June 2006, a preliminary report was sent to the lead hydrographer. The preliminary report included CARIS data of the most shoal point, as queried from CARIS.

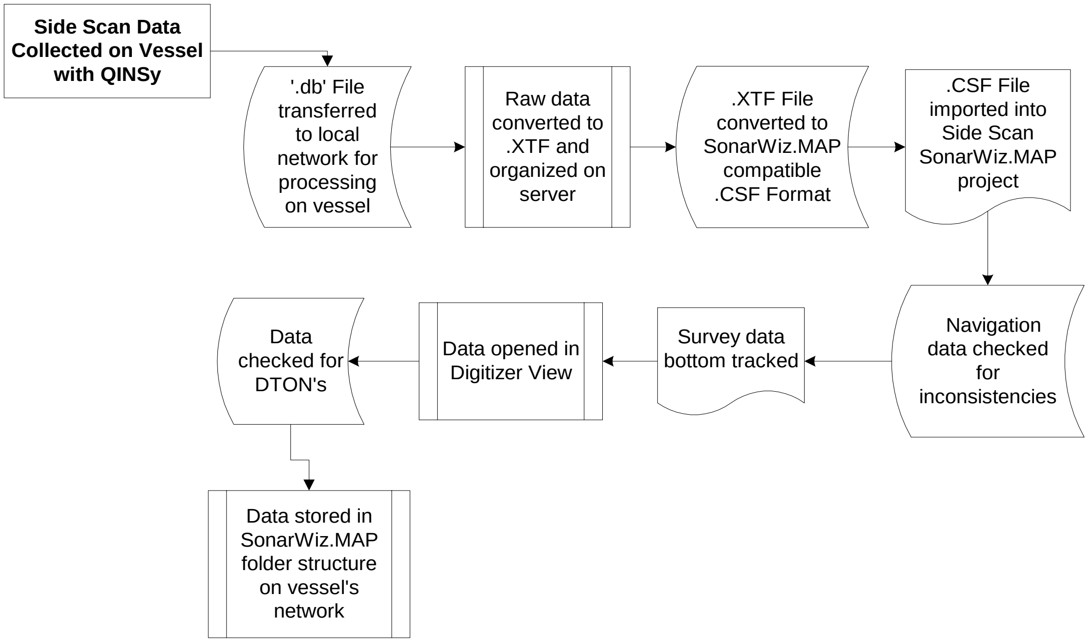
The focus of the preliminary processing was to provide timely information during data acquisition. All data was processed using very conservative procedures to ensure adequate survey coverage while in the project area. The field processed data were not used during the final office processing phase.

Figure 4 illustrates the major steps in the data acquisition and reduction process. The text following the diagrams provides a detailed explanation of each step.

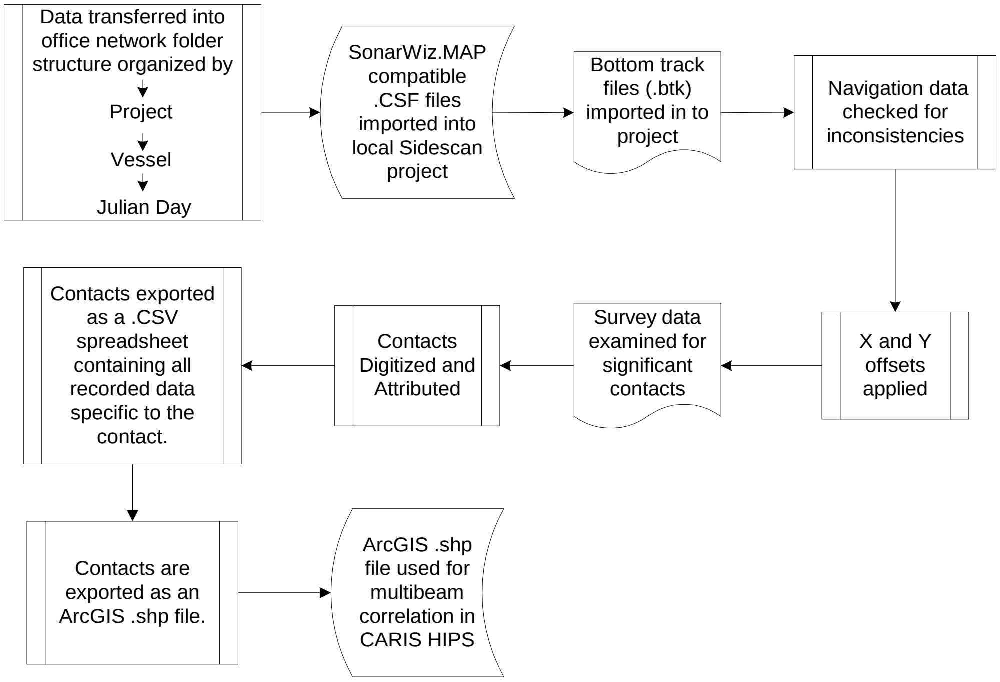
Multibeam Survey Data Processing Workflow



Side Scan Survey Field Data Processing Workflow



Side Scan Survey Office Data Processing Workflow



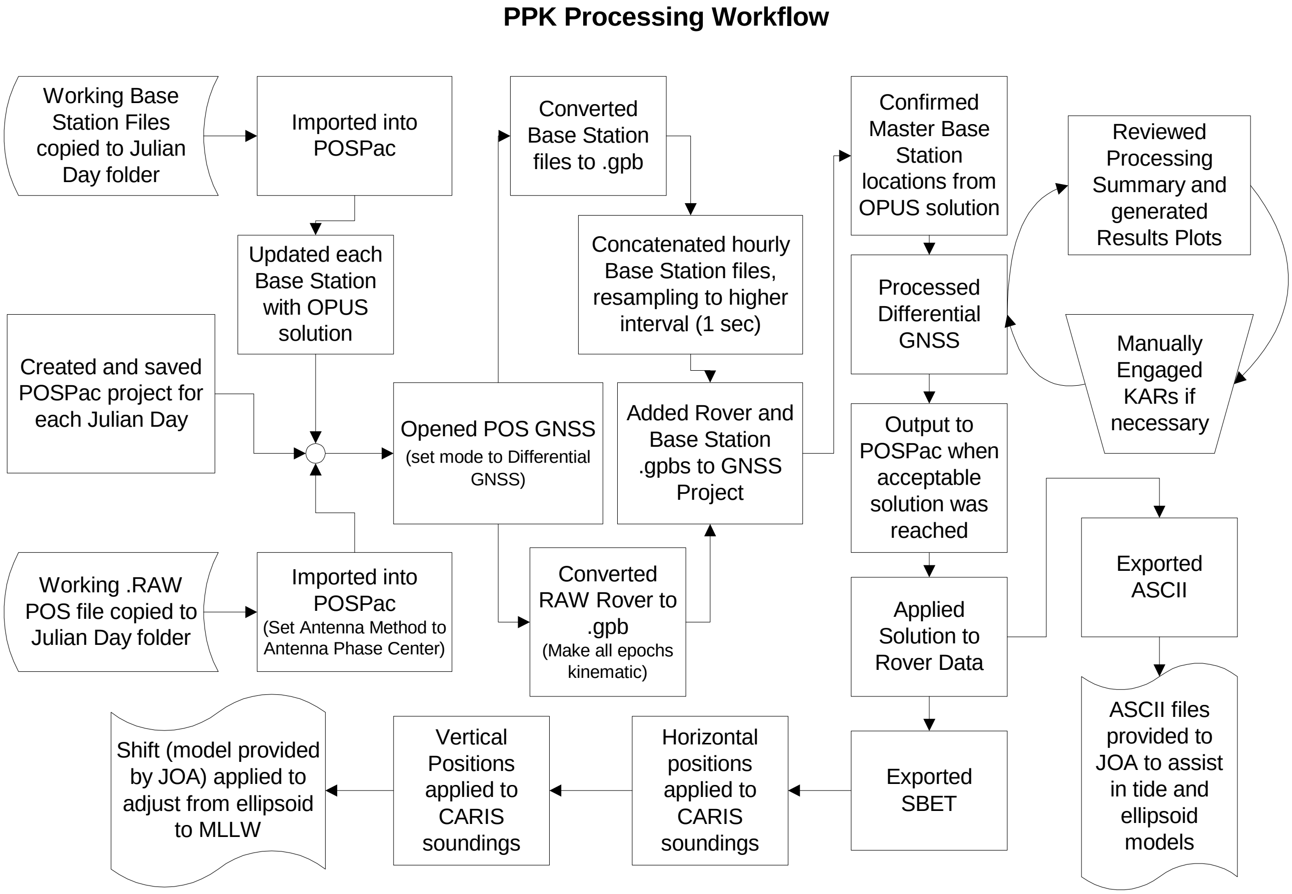


Figure 4 - Data Acquisition and Processing Flow Diagrams

B.7. 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.

B.7.1. Multibeam Data Processing

CARIS HIPS and SIPS 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 and SIPS 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 depths sensor files.

CARIS HIPS and SIPS was used for the majority of the processing and adjustments made during sounding reduction. CARIS HIPS and SIPS 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 sounding reduction process and all actions are tracked to ensure that no steps are omitted or performed out of sequence.

Sound speed and tide corrections were applied during initial data processing. Delta draft was not yet available and therefore was not applied.

Preliminary soundings were tide adjusted using predicted tide data from the National Water Level Observation Network (NWLON) station at Anchorage, AK (945-5760) and Nikiski, AK (945-5920) through August 20th, 2008. Upon completion of Applanix POSPac (PPK) processing, soundings were referenced to the ellipsoid and adjusted to MLLW during the compute GPS tide process in CARIS HIPS and SIPS. Refer to *Section C. Corrections to Echo Soundings*, of this report, for detailed information concerning preliminary sounding reduction and the Horizontal and Vertical Control Report (HVCR) for tidal zoning methods and operations.

Sound speed data were acquired using vertical casts on the *R/V Mt. Mitchell* and *R/V Mt. Augustine* using Odim MVP 200 and Applied Microsystems, Ltd. SV Plus and SV Plus (V2) deep water sound velocimeters 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 of each cast. The sound speed adjustment in CARIS HIPS and SIPS 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. Field collected sound speed data and delta draft were applied during final processing.

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, sound speed corrected data were merged with the navigation and attitude data. The merging process converted time-domain data into spatial-domain, geographically referenced soundings.

During field and preliminary office processing, daily static draft observations were entered in the HIPS vessel file. Since HIPS does not interpolate between static draft measurements, during final processing a project-wide interpolated static draft table was created and used to replace the daily static draft values previously entered in the HIPS vessel file for the *R/V Mt. Mitchell*. This was accomplished in order to account for abrupt changes in vessel loading between static draft measurements. Static draft values in the *R/V Mt. Augustine* vessel file were measured directly.

A RPM-based delta draft file was loaded into the CARIS HIPS and SIPS projects for both vessels in lieu of the speed-based draft table in the vessel file. Measures were taken to ensure the delta draft file loaded properly and the correct draft values were used to calculate processed depths.

The number and time of sound velocity profiles per survey day were tracked graphically to ensure that time-appropriate profiles were applied to the entire survey.

Smoothed best estimated trajectory (SBET) files were loaded to all CARIS HIPS & SIPS projects. GPS tide was computed using an ellipsoid to MLLW model in order to bring soundings to chart datum. Refer to the Horizontal and Vertical Control Report for detailed information regarding the development of the ellipsoid/MLLW model. Survey lines with missing or corrupt SBET files were processed using a verified tide and zoning scheme.

B.7.2. Area Editing

Following final processing and quality assurance of draft and GPS tide applications, several area-based editing processes in CARIS HIPS and SIPS Subset Editor were performed during the office review of survey soundings. During subset editing, the operator was presented with two and three-dimensional views of the soundings and a moveable bounding box to restrict the number of soundings being reviewed. Using the two-dimensional window, soundings were viewed from the south (looking north), from the west (looking east) and in plan view (looking down). 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. Least depths of all significant features (> 2 meters proud of the seafloor) were flagged as designated in order for these depths to be retained in the finalized surface and to correlate features to SSS contacts.

In the first phase of area editing, processors examined the entire survey area in CARIS HIPS and SIPS Subset Editor and rejected outlying soundings unsupported by data from adjacent survey lines. Simultaneously, the data were scrutinized for any potential tide, GPStide, and sound velocity issues that would require further investigation. Final area editing is discussed in *Section B.7.8 Sounding Reduction/Final QC.*

B.7.3. Side scan Sonar Data Processing

CTI SonarWiz.MAP software was used to create a folder structure organized by project, vessel, and Julian day to store data. Side scan 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 SonarWiz.MAP using the SonarWiz.MAP Import side scan Files function, which converted the sonar files into SonarWiz.MAP compatible .csf format.

SonarWiz.MAP was used for all side scan processing and adjustments made during data processing. SonarWiz.MAP 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 side scan data processing and all actions are tracked to ensure that no steps are omitted or performed out of sequence.

Side scan data was imported into SonarWiz.MAP.MAP using the Import Wizard and filed by sheet, vessel, and Julian Date. After conversion, vessel navigation data was visually scanned for jumps in speed, distance and course made good. When the navigation check was completed, the side scan lines were opened in the SonarWiz.MAP.MAP Bottom Track Editor where towfish altitude was manually digitized. The final process applied to the side scan sonar data was the application of XY offsets to represent the tow point with respect to the central reference point (CRP) of the vessel to correctly position the data geographically. This step is comparable to the recompute towfish navigation process in CARIS HIPS and SIPS. The towfish was hull-mounted and therefore no layback computations were necessary.

The side scan record was carefully examined for significant contacts using slant range corrected data. Significant contacts included, but were not limited to, contacts with a shadow length indicating a contact height of 2.0 m or greater in depths of 20 meters or less. Contacts were digitized using the contact tool in SonarWiz.MAP Side scan Digitizer View. Each contact was automatically assigned a unique identifier based on the date, time, and channel (port or starboard). Once identified, the contact's length and width were measured with the Measure Length and Measure Width tools and the contact shadow length was measured using the Measure Shadow tool. SonarWiz.MAP automatically calculates contact height once the shadow length is measured. Additionally, all contacts were assigned an S-57 classification attribute and feature name. Any other remarks pertaining to the target were added at this time. SonarWiz.MAP generated an image of each digitized target and included a corresponding text file containing all recorded information specific to the contact and placed the contact in the project folder.

Swath coverage was tracked throughout the project using the Coverage Tool in SonarWiz.MAP. The coverage tool exports a geotiff of swath coverage in which each layer of 100% coverage is represented by a separate color. A mosaic of all survey lines was exported for each survey as a final demonstration of coverage.

The local area network on the *R/V Mt. Mitchell* experienced extremely high traffic during the acquisition portion of the survey from JD 197 – JD 213. The Applanix POS system was found to be broadcasting to all computer systems on the network. This caused a back up of side scan data packets. When the data packets reached their Time-To-Live value they were then dropped. On JD 213 the POS MV was isolated from the network and connected directly to the acquisition computer through an available ethernet port. This resolved the issue.

Through the entire survey the multibeam was directed to the acquisition station via a separate network switch and therefore was not affected by this issue. Side scan was only used to locate significant contacts which needed further development with the multibeam. Extensive precautions were taken in the field to ensure that contacts were developed. As there are a great number of contacts in Cook Inlet long lines were run to develop multiple contacts at once, this lead to the assurance that a contact was developed even though the positioning of the side scan may not be as accurate as the multibeam.

The network problem caused a random latency issue in the raw side scan sonar .db files which resulted in dropped or out of sequence pings in the side scan sonar record. Extensive research with QPS and Chesapeake Technology Inc. (CTI) was conducted to alleviate this problem. CTI developed tools to renumber pings during raw side scan sonar data conversion which alleviated the out of sequence ping problem. However, the final result of the issue was that a non-systematic distribution of contacts in each survey from overlapping lines representing the same feature were offset in the along track direction. These occurrences were random and considering over 27,000 contacts identified project wide, it was impossible to isolate each one. All possible measures were taken to resolve this issue and minimize its effect on SSS contact positioning.

This issue affected only the horizontal positioning of side scan contacts, not the system's ability to detect objects. Additionally, since each contact was later developed fully by multibeam, and only multibeam positions were used in the creation of the S-57 features, all final contact positions meet the horizontal positioning accuracy requirements described in the 2007 Specifications and Deliverables. The average horizontal distance between all S-57 features and corresponding side scan contacts for each survey are as follows:

H11839: 6.84 meters
H11840: 6.19 meters
H11841: 5.28 meters
H11842: 8.33 meters

B.7.4. S-57 Feature Ranking

Thousands of significant SSS contacts (i.e. rocks >2m proud of the seafloor) were identified and attributed in each survey and further developed with multibeam echosounder data. In early September of 2008, Mark Lathrop, COTR for OPR-P385-TE-08, limited the number of features in the S-57 file to 200 per survey. These “top 200” features were ranked based on their height above seafloor, % of overall depth, spatial distribution and navigational significance. Since feature height carried a considerable weight in this process, the height measured in MBES data rather than the less accurate height measured in SSS data was used as ranking criteria. To derive heights of features identified in multibeam data, the least depth sounding on all significant features was flagged as designated. Additionally, a sounding proximal to the feature which best represents the depth of the prevailing seafloor was flagged as examined. Each examined and designated sounding per feature were correlated spatially using ESRI ArcGIS and the difference between the two depth values was computed to determine the height of each feature.

Once feature heights were determined, the “top 200” feature ranking process continued by applying a 60 meter sort on all significant (multibeam) features per sheet using feature height as the sort criteria. Thus, the tallest feature within 60 meters was parsed from the entire population of significant features. Next, the percentage of overall depth was calculated by dividing feature height by the depth of the examined sounding mentioned above. To ensure spatial distribution of the 200 features, each survey area was separated into ‘shoal” (<11 fathoms) and “deep” (>11 fathoms) areas. All features were flagged as falling in either area. Next, features in each area were ranked based on their percentage of overall depth. Finally, the features were plotted on the largest scale RNC common to the survey area and the lead hydrographer chose 150 features in the shoal area and 50 features in the deep area per survey based on percentage of overall depth and navigational significance.

B.7.5. MBES/SSS Correlation

As this was a fixed line spacing project, 200% SSS coverage was not attained and some features were impossible to identify and/or measure. While contact identification was used during field operations to identify significant features requiring multibeam development, few, if any, attributes observed in the SSS record were used in the development of the S-57 feature files. However, it was still necessary to fully vet the SSS contact list which requires correlation with attributes from multibeam features. In doing so, there were significant “top 200” features, attributed with multibeam data, which did not have correlating SSS contacts. Therefore, there are some records in the SSS contact list which lack SSS attributes. In these situations, the SSS columns were left blank and column 7 (Remarks) was used to provide a statement that correlation to SWMB data was not made.

The top 200 multibeam contacts were exported from CARIS to an ASCII file for correlation in ARCMap with the side scan data. During the ARCMap import process, positioning of the features was shifted by a few centimeters. This is due to the ARCMap transformation process. The shift was not enough to affect the location of the top 200 contacts. The positions were then exported to an .xls file for final processing with CARIS HOM.

B.7.6. Applanix POS M/V

POS M/V GPS, inertial and motion data were processed in the Applanix POSPac software in order to provide post processed kinematic GPS data to replace the multibeam navigation data originally collected in QINSy. First, the “Extract” tool in the POSPac software was used to convert the POS M/V “.000” into “.gpb” format. Next, the base data was brought into POSPac and converted from “.dat” to “.gpb” files and then 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 and Kinematic Ambiguity points were manually added at times in the Rover data 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. The trackline was exported from the POSGNSS utility into the main POSPac module and then the IIN/SMTH processes were used to combine and merge the inertial and PPK GPS data and smooth the resulting trackline into an SBET file, which provided navigational tracklines and height values for the MBES data.

B.7.7. TPE

Subsequent area-based editing incorporated uncertainty values derived from Total Propagated Error (TPE). CARIS HIPS and SIPS TPE calculation assigned a horizontal and depth error estimate to each sounding. TPE 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 TPE 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 *R/V Mt. Mitchell* and *R/V Mt. Augustine* are found in Tables 10 and 11 on the following pages.

Error Source	Method	Error Value
Motion Gyro	Published by Manufacturer	0.050 (deg)
Heave	Published by Manufacturer	0.050 (m)
Roll	Published by Manufacturer	0.050 (deg)
Pitch	Published by Manufacturer	0.050 (deg)
Position Navigation	Published by Manufacturer	1.000 (m)
Transducer Timing	Estimated	0.001 (sec)
Navigation Timing	Estimated	0.001 (sec)
Gyro Timing	Estimated	0.001 (sec)

Error Source	Method	Error Value
Heave Timing	Estimated	0.001 (sec)
Pitch Timing	Estimated	0.001 (sec)
Roll Timing	Estimated	0.001 (sec)
Offset X	Direct Measurement	0.002 (m)
Offset Y	Direct Measurement	0.002 (m)
Offset Z	Direct Measurement	0.002 (m)
Vessel Speed	Published by Manufacturer	1.000 (m/sec)
Loading	Published by Manufacturer	0.070 (m)
Draft	Published by Manufacturer	0.070 (m)
Delta Draft	Direct Measurement	0.005 (m)
MRU Alignment Gyro	Estimated	0.100 (deg)
MRU Alignment Roll/Pitch	Estimated	0.100 (deg)
Sound Velocity	Published by Manufacturer	0.05 (m/sec)
Tide Gauge	Published by Manufacturer	0.014 (m)

Table 10 – R/V Mt. Mitchell error values used in computing Total Propagated Error (TPE).

Error Source	**Method**	**Error Value**
Motion Gyro	Published by Manufacturer	0.050 (deg)
Heave	Published by Manufacturer	0.050 (m)
Roll	Published by Manufacturer	0.050 (deg)
Pitch	Published by Manufacturer	0.050 (deg)
Position Navigation	Published by Manufacturer	1.000 (m)
Transducer Timing	Estimated	0.001 (sec)
Navigation Timing	Estimated	0.001 (sec)
Gyro Timing	Estimated	0.001 (sec)
Heave Timing	Estimated	0.001 (sec)
Pitch Timing	Estimated	0.001 (sec)
Roll Timing	Estimated	0.001 (sec)
Offset X	Direct Measurement	0.003 (m)
Offset Y	Direct Measurement	0.003 (m)
Offset Z	Direct Measurement	0.003 (m)

Error Source	**Method**	**Error Value**
Vessel Speed	Published by Manufacturer	1.000 (m/sec)
Loading	Published by Manufacturer	0.140 (m)
Draft	Published by Manufacturer	0.140 (m)
Delta Draft	Direct Measurement	0.001 (m)
MRU Alignment Gyro	Estimated	0.100 (deg)
MRU Alignment Roll/Pitch	Estimated	0.100 (m)
Sound Velocity	Published by Manufacturer	0.05 (m/sec)
Tide Gauge	Published by Manufacturer	0.014 (m)

Table 11 –R/V Mt. Augustine error values used in computing Total Propagated Error (TPE).

Uncertainty values derived from CARIS HIPS and SIPS TPE computation were used to create International Hydrographic Organization (IHO) S-44 compliant datasets as well as calculate depth surfaces weighted by uncertainty. IHO uncertainty thresholds were determined using the following equation:

$$\pm\sqrt{[a^2+(b*d)^2]}$$

where:	**<u>for d < 100 meters</u>**	**<u>for d > 100 meters</u>**
	a=0.5 m	**a=1.0 m**
	b=0.013 m	**b=0.023 m**
	d=depth (m)	**d=depth (m)**

B.7.8. Sounding Reduction / Final QC

A final QC of soundings was accomplished by using CARIS HIPS and SIPS Field Sheet Editor to bin survey data to a shoal-biased, 20 meter grid. The binned surface was then assigned depth dependent color attributes to visually emphasize bins with unique depths. A final inspection of the survey data was then made using Subset Editor by investigating areas where bins disagreed with neighboring values.

Next, depth-dependent, multi-resolution CARIS BASE uncertainty surfaces were created as working deliverables for surface quality assurance. The surfaces were checked for anomalous depth values and the uncertainty and standard deviation layers were used to alert processors to areas which may require further attention. Additionally, designated soundings representing least depths of significant features were reviewed to ensure that the finalized uncertainty surfaces honor those critical soundings.

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 Electronic Navigation Charts

(ENC) and raster nautical Charts (RNC) common to the survey area. Although depth contouring, a component of the fixed-scale smooth sheet, is no longer required, contours were generated from the CARIS BASE uncertainty surfaces at intervals matching those on the largest scale RNC. 2008 Survey contours were then compared with charted contours for each survey. This comparison was used for evaluating the adequacy of the ENC/RNC and for making future charting recommendations that are included in each Descriptive Report *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.7.9. Gridded Surfaces

The final depth information for this survey is submitted as a CARIS BASE Uncertainty surface which best represents the seafloor at the time of survey. All steps have been taken to ensure the data have been correctly processed and appropriate designated soundings, representing the least depth of significant contacts, have been selected and retained in the finalized surface.

The submittal of several grids of varying resolution was necessary due to the wide depth range and varying bathymetry found throughout the survey area.

2008 survey depths were submitted as a CARIS BASE Uncertainty surface which was weighted by the greater of either the standard deviation of sounding values, or a priori uncertainty values derived from HIPS TPE calculation. Additionally, two sun-illuminated, geographically referenced Digital Terrain Model image depicting the coverage of the survey area was submitted; one representing the depth child layer and one representing the uncertainty child layer. All grids are projected to UTM Zone 5 North, NAD 1983. Naming conventions for each grid are as follows:

CARIS BASE Uncertainty Surface: H11xxx_1m_0to23m_Depth
or H11xxx_1m_0to23m_Uncertainty

- H11xxx represents the sheet (H11837-H11842)
- 1m represents the resolution
- 0to23m represents the depth range

Sun-Illuminated Elevation DTM: H11xxx_Uncertainty.tif
Uncertainty DTM: H11xxx_Coverage.tif

A data set containing a single S-57 (.000) base cell file and supporting files was submitted in conjunction with the other 2008 survey deliverables. The base cell contains information on objects not represented in the depth grid, including, but not limited to, shoreline and the nature of the seabed (bottom samples). Each feature object includes the mandatory S-57 attributes, contract specific attributes, and any additional attributes assigned.

B.7.10. 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 Descriptive Report (DR). The QC Reports are included in the *Separate IV: Checkpoint Summary & Crossline Reports* for each DR.

B.7.11. Shoreline Verification

There was no shoreline verification assigned for OPR-P385-TE-08

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 by a precise survey of each vessel using a combination of 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 M/V GPS antennas were measured directly with a survey tape and then authenticated during the Applanix POS M/V 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 at the end of this section.

C.1.1. Vessel Survey

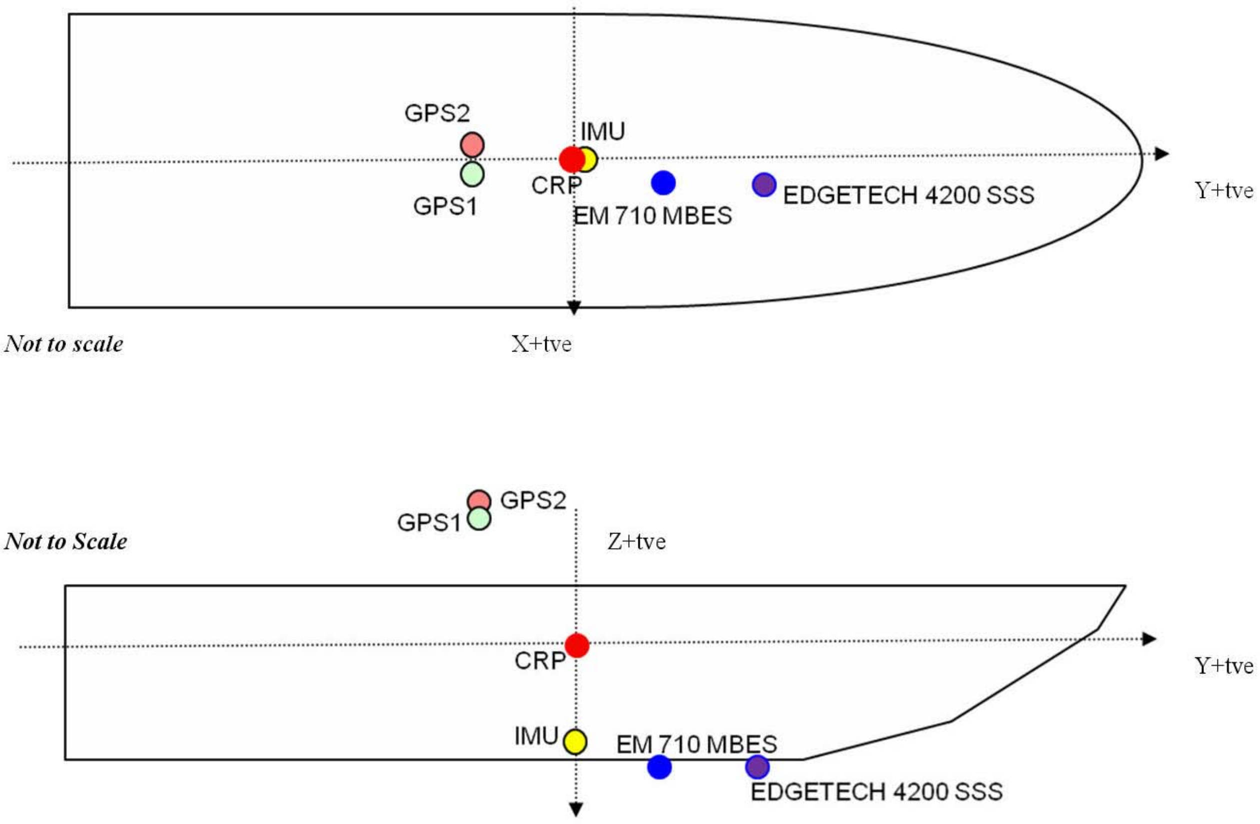


Figure 5 - R/V Mt. Mitchell vessel survey showing the relative positions of the installed survey equipment.

Equipment	**Manufacturer / Model**	**Offset from CRP (m) based on CARIS Convention**		
		X	**Y**	**Z**
MRU	Applanix POS M/V	+0.072	+0.261	-0.168
CRP	N/A	±0.000	±0.000	±0.000
MB Transducer-Tx	Kongsberg EM 710	+0.893	+4.319	+2.526
MB Transducer-Rx	Kongsberg EM 710	+1.000	+3.685	+2.553
SSS	EdgeTech 4200FS	+0.700	+10.794	+2.063
GPS1 (Primary)	Applanix Zephyr	-1.085	-4.791	-14.499
GPS2 (Secondary)	Applanix Zephyr	+0.913	-4.789	-14.497

Table 12 – 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.

R/V Mt. Augustine

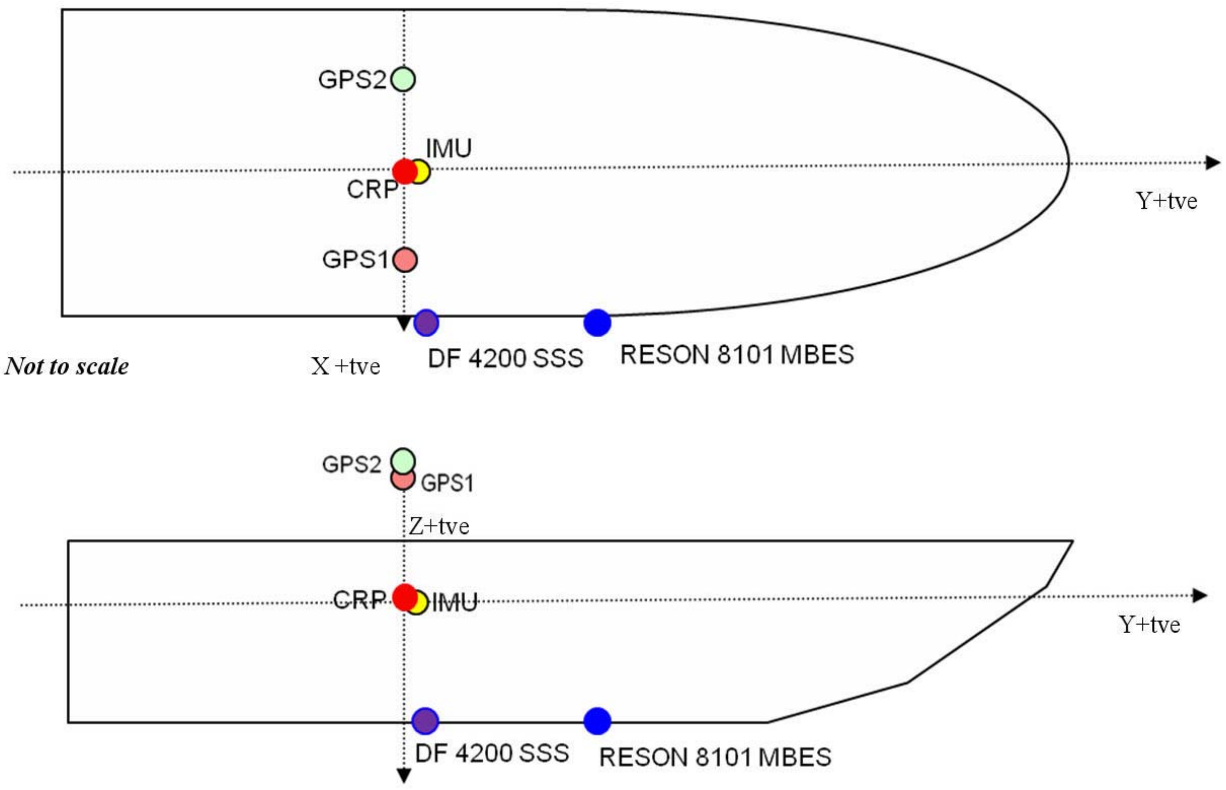


Figure 6 – R/V Mt. Augustine vessel survey showing the relative positions of the installed survey equipment.

Equipment	Manufacturer / Model	Offset from CRP (m) based on CARIS Convention		
		X	Y	Z
IMU	Applanix POS M/V	0.000	-0.162	+0.054
CRP	N/A	±0.000	±0.000	±0.000
MB Transducer	Reson SeaBat 8101	+1.372	+1.935	+1.401
SSS	EdgeTech 4200FS	+1.433	-0.508	+1.454
GPS 1 (Primary - Port)	Applanix Zephyr	-1.031	-0.378	-2.619
GPS 2 (Starboard)	Applanix Zephyr	+1.031	-0.374	-2.619

Table 13 – 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.1.2. Heave, Roll and Pitch

Heave, roll and pitch data for the *R/V Mt. Mitchell* and *R/V Mt. Augustine* was measured using an Applanix POS M/V Attitude and Positioning System. 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 and SIPS.

C.1.3. Patch Test Data

Patch tests were performed on *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.

Patch test lines were run as described to determine the following offsets:

C.1.4. Navigation/Latency

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

C.1.5. 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 up or down slope and comparing profiles.

C.1.6. Azimuth

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.1.7. Roll

The roll offset was determined after the time delay, pitch and azimuthal 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, azimuth, 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 2008 survey and whenever there was a configuration change involving the position of the multibeam transducer. A listing of the patch tests performed for the 2008 survey is provided in Table 14. Patch test values are listed in Table 15.

Vessel	Julian Date	Longitude (DMS)	Latitude (DMS)	Reason
R/V Mt. Mitchell	2008-169	151° 20’ 05.80” W	59° 35’ 10.05” N	Homer calibration
R/V Mt. Augustine	2008-171	151° 20’ 05.80” W	59° 35’ 10.05” N	Initial calibration
R/V Mt. Augustine	2008-185	Upper Cook Inlet	Sand wave	Head Removed

Table 14 – Patch tests performed for instrument calibration during OPR-P385-TE-08.

R/V Mt. Mitchell				
Date	**Pitch (deg)**	**Roll(deg)**	**Yaw(deg)**	**System**
2008-169	1.457	-0.820	0.435	Simrad EM710

R/V Mt. Augustine				
Date	**Pitch (deg)**	**Roll(deg)**	**Yaw(deg)**	**System**
2008-171	-2.567	-1.762	0.054	Reson SeaBat 8101
2008-185	-0.863	-1.716	-0.140	Reson SeaBat 8101

Table 15 – Patch tests values

C.2. Speed of Sound through Water

Sound speed data for OPR-P385-TE-08 was collected using ODIM MVP 200 with Applied Microsystems Ltd. (AML) Smart SV&P sensor, also one AML SV Plus V2 sound velocity sensor was used. The sensors were set to record one sample per second during casts and were lowered through the water column at approximately one meter per second. For the SV Plus V2 the raw sound speed data were downloaded using HyperTerminal and saved as a text document. The ODIM MVP 200 writes the raw data to text file while casting. The raw data text files were run through software program TerraSond ltd Simple SVP program. 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. SVP program and a CARIS compatible file containing geo- and time-referenced listing of sound speed vs. depth was produced.

Sound speed corrections were then applied to the raw sounding data. The most recent sound speed data was applied to the soundings, except where it was deemed more appropriate to apply the data from a cast that was geographically closer to the sounding location.

Sound Speed data is submitted as part of the CARIS project.

C.3. Static Draft

Static draft was determined by measuring from a control point on the hull of the port and starboard side of each survey vessel to the waterline. 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 vessel CARIS HIPS Vessel File (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

R/V Mt. Mitchell

Settlement and squat measurements for *R/V Mt. Mitchell* were conducted using Real Time Kinematic (RTK) GPS Survey Procedures in Kachemak Bay near Homer, Alaska on June 19, 2008 prior to transiting to the survey area. Measurements were made using a

Trimble R8 (or SPS) GPS receiver, Trimark2 radio, POS M/V heading, attitude and positioning sensor with a POS M/V attitude sensor and were recorded in increments for vessel pitches from 10 – 80 percent. These pitches were selected as representative of the practical operational limits of possible vessel survey pitches at various speeds and RPMs.

Pitch (%)	Settlement (m)
10	-0.001
20	0.019
30	0.017
40	0.054
50	0.085
60	0.127
70	0.157
80	0.202

Table 16– R/V Mt. Mitchell Pitch vs. settlement measured during Settlement & Squat survey on JD 2008-171.

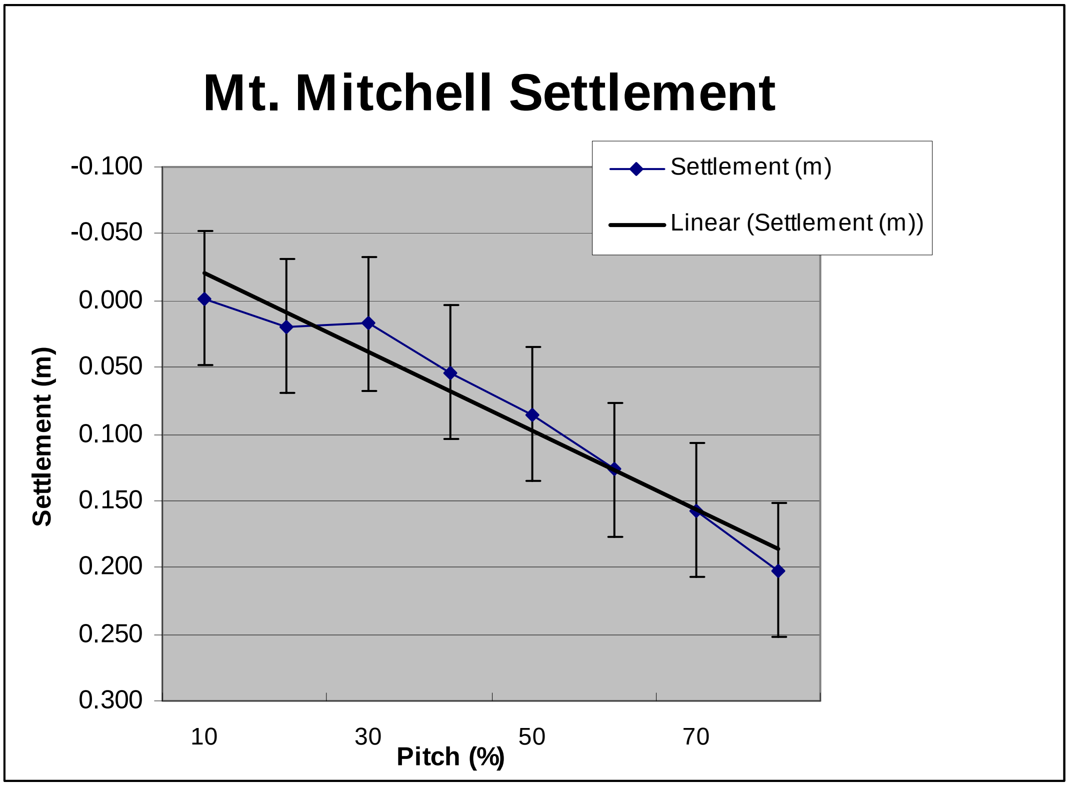


Figure 7 - R/V Mt. Mitchell Settlement & Squat Measurements.

A Kinematic base station (Trimble R8), was set up on shore a few kilometers from the survey vessel. The base station used a Trimark2 radio to transmit Real Time Carrier Phase corrections to the POS M/V installed on *R/V Mt. Mitchell*. The rover receiver (Trimble SPS) used the carrier phase corrections to determine the position of the navigation antenna on the *R/V Mt. Mitchell* relative to the base station with a vertical accuracy under 2 cm. The position of the antenna was reduced to the vessel's reference point (RP) using attitude data from the POS M/V and offset measurements made for each piece of equipment during a vessel survey. The measurements were made in real-time using QINSy data collection software. An output file was created from the beginning of the first drift to the end of the second drift that contained Time, Easting, Northing and Height.

Measurements were logged for several 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, measurements were logged for several more minutes. Power was then removed and the vessel was brought to a drift. Several more minutes of data was logged. This procedure was repeated throughout the RPM/propeller pitch range used when surveying.

Settlement was calculated by averaging the static measurements at the beginning and end of lines and comparing this average with the average measurements while the vessel was under way throughout the pitch range. A graph was then constructed to illustrate settlement changes as a function of vessels pitch.

R/V Mt. Augustine

Settlement and squat measurements for *R/V Mt. Augustine* were conducted on June 20th, 2008 using Real Time Kinematic (RTK) GPS Survey Procedures in Kachemak Bay near Homer, Alaska. All measurements were made with the multibeam transducer deployed in its survey configuration.

Measurements were made using a Trimble SPS GPS receiver, internal radio and a POS M/V attitude and positioning sensor and were recorded in 200 RPM increments from 900 RPM to 2100 RPM. The RPM range was selected as representative of practical operational limits producing vessel speeds between 2 and 10 kts.

A Kinematic base station (Trimble R8) was set up on shore a few kilometers from the survey vessel. The base station used a Trimark2 radio to transmit Real Time Carrier Phase corrections to the POS M/V installed on *R/V Mt. Augustine*. The rover receiver (Trimble SPS) 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 position of the antenna was reduced to the vessel's reference point (RP) using attitude data from the POS M/V and offset measurements made for each piece of equipment during a vessel survey. The measurements were made in real-time using QINSy data collection software. An output file was 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 several minutes with no way on; the engine RPM was then increased to the desired RPM. Once the vessel was at the desired speed, measurements were logged for several more minutes. Power was then increased by 200 RPM and several more minutes of data were logged. This procedure was repeated throughout the RPM range used when surveying. After reaching the highest RPM value, 2100 RPM, all power was removed and the vessel was allowed to drift. The final measurements were logged with the vessel adrift with no way on.

RPM	Settlement (m)
900	0.028
1000	0.029
1100	0.030
1300	0.036
1500	0.046
1700	0.054
1900	0.057
2100	0.068

Table 17 – R/V Mt. Augustine average RPM vs. settlement measured during Settlement & Squat survey on JD 2008-172.

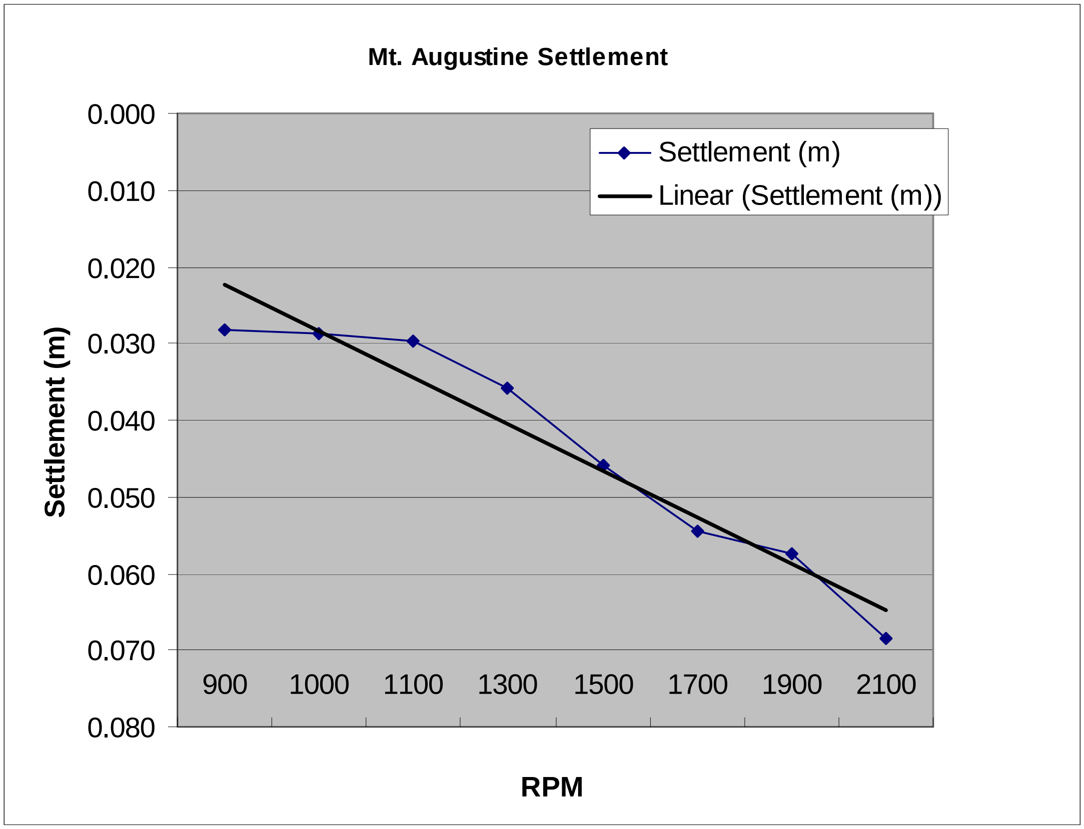


Figure 8 – R/V Mt. Augustine Settlement & Squat Measurements.

Settlement was calculated by averaging the static measurements at the beginning and end of the survey period and comparing this average with the average measurements while the vessel was under way throughout the speed range. A graph was then constructed to illustrate settlement changes as a function of the vessel RPM.

The results above are a product of the initial squat settlement survey preformed for the *R/V Mt. Augustine*. On July 21st, 2008 (Julian Day 204) the props on the *R/V Mt. Augustine* were replaced causing a change in pitch. Therefore it was necessary to perform a second squat settlement test before any further data collection was preformed.

The procedure was similar to the initial test and required the same equipment. The major difference was the location of the test. The second squat test was preformed in the Port of Anchorage.

Results are as follows:

RPM	Settlement (m)
900	0.038
1100	0.049

RPM	Settlement (m)
1300	0.060
1500	0.084
1700	0.090
1900	0.109
2100	0.119

Table 18 – R/V Mt. Augustine average RPM vs. settlement measured during Second Settlement & Squat survey on JD 2008-204.

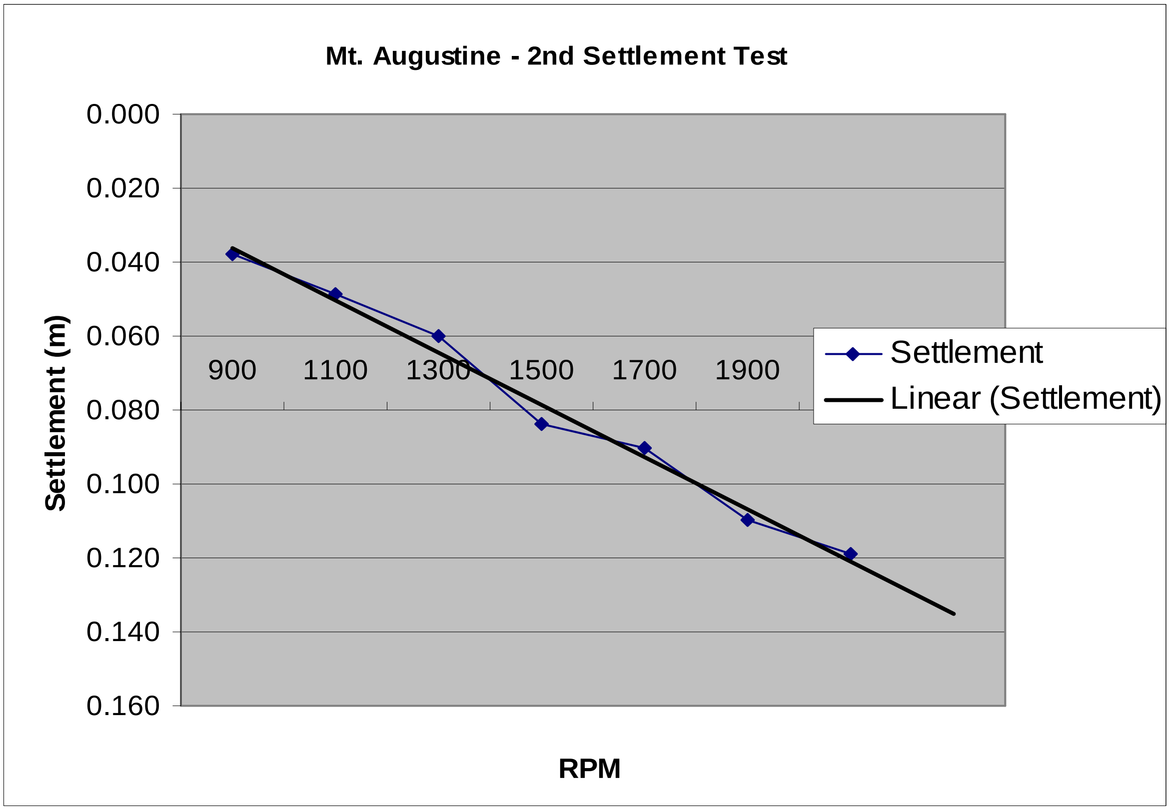


Figure 9 – R/V Mt. Augustine Settlement & Squat Measurements (Round 2)

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) station at Anchorage, AK (945-5760) and Nikiski, AK (945-5869) 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 and SIPS during the merge step of initial data processing.

Final sounding data were reduced using Post Processed Kinematic Smoothed Best Estimate Trajectory (PPK SBET). SBET's were applied to the sounding data through CARIS HIPS and SIPS. An offset model between Mean Lower Low Water and the Ellipsoid was used and GPS tides was applied. The ellipsoid model is in an ASCII XYZ format, where the Z values represent the shift from the ellipsoid to MLLW. The model is applied to soundings during the compute GPS tide process in CARIS HIPS and SIPS. The model is submitted with the CARIS project and can be found in the CARIS files folder. Refer to the Horizontal and Vertical Control Report (HVCR) for PPK methods and operations.

C.6. Project Wide Tide Correction Methodology

The tidal zoning scheme was provided in the statement of work. The historic water level station at Point Possession, AK (945-5866) and North Foreland, AK (945-5869) were used as the reference station for the zoning scheme. Refer to the Horizontal and Vertical Control Report for tide zone methods and operations.

LETTER OF APPROVAL

REGISTRY Numbers: H11837-H11842

This report and the accompanying digital data are respectfully submitted.

Field operations contributing to the accomplishment of surveys H11837- H11842 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-P385-TE-08 include the Descriptive Reports and the Horizontal and Vertical Control Report.

I believe this survey is complete and adequate for its intended purpose.

Kathleen Mildon Digitally signed by Kathleen Mildon
DN: cn=Kathleen Mildon, o=TerraSond Ltd,
ou=Charting, email=kmildon@terrasond.com, c=US
Date: 2009.11.23 18:19:37 -09'00'

Kathleen Mildon, Lead Hydrographer
TerraSond Ltd.

Date_November 23, 2009__________________