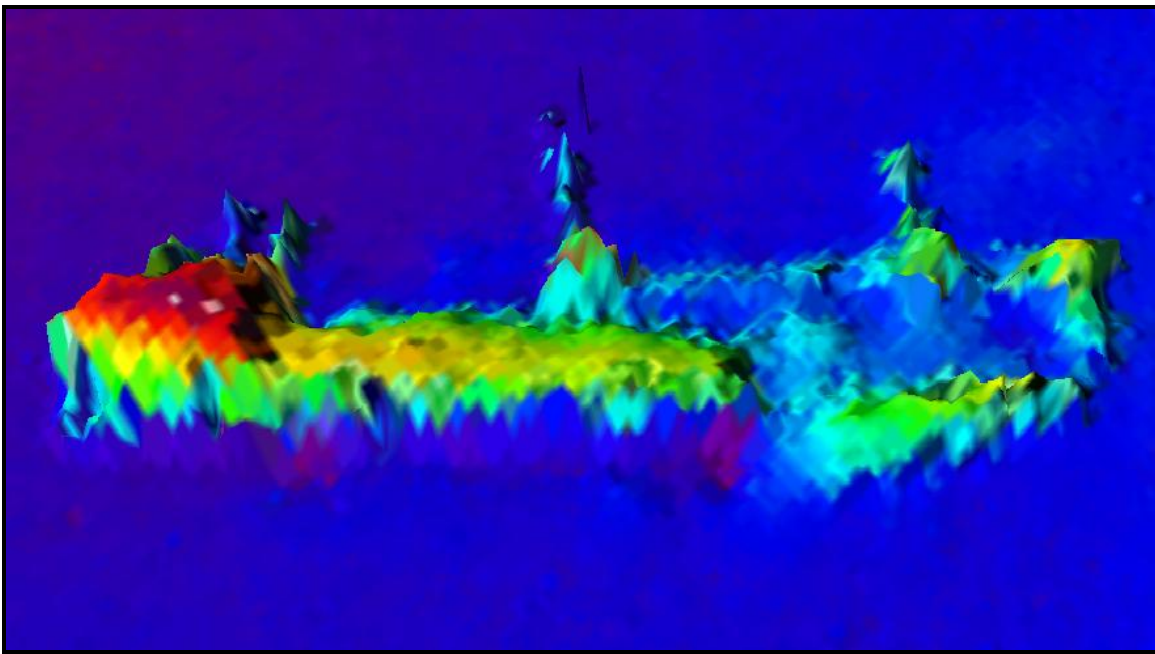


Data Acquisition and Processing Report

OPR-P188-KR-07

February 23, 2007

Unimak Pass



| |
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| H11643 |
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|--------|
| H11644 |
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R/V Kittiwake and Irish Ayes

State: Alaska

Locality: Unimak Pass

Year: 2007

Lead Hydrographer: Raj Bhangu

TERRASOND

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A. Equipment

A.1. Vessels

Soundings and shoreline verification data for this survey were acquired using the Research Vessel *Kittiwake* and the hydrographic survey vessel *Irish Ayes*.

A.1.1. *R/V Kittiwake*

Multibeam echosounder data for surveys H11643 and H11644 was acquired using the *R/V Kittiwake*.

The *R/V Kittiwake*, shown in Figure 1, is a 30 meter steel hulled converted crab fishing vessel with an 8 meter beam and a 3 meter draft. The ship was powered by two 325 HP Cummins Diesel engines operating between 600 and 1100 RPM connected to fixed-pitch propellers. Electrical power was provided by two John Deere 125 KW generating plants located in the engine room and one John Deere 40 KW auxiliary generator located in the foc'sle. The *R/V Kittiwake* was outfitted with a starboard-side, pole-mounted Reson 8101 Multibeam Echo Sounder System. Detailed vessel drawings showing the location of all primary survey equipment are included in Section C. of this report.



Figure 1 – R/V Kittiwake anchored off Cape Sarichef in Unimak Pass, Alaska.

A.1.1.1. Equipment Overview

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

A.1.1.2. Major Operational Systems

R/V Kittiwake Survey Equipment

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

| <i>Description</i> | <i>Manufacturer</i> | <i>Model / Part</i> | <i>Serial Number</i> |
|------------------------------|----------------------|---------------------|----------------------|
| Multibeam Sonar | Reson | SeaBat 8101 | 1301045 |
| Sonar Processor | Reson | SeaBat 81-P | 32030 |
| Positioning System | Seatex | Seapath 200 | 1476 |
| Motion Sensor | Seatex | MRU-5 | 1410 |
| SV Probe | Applied Microsystems | SV Plus | 3317 |
| SV Probe | Applied Microsystems | SV Plus (V2) | 4868 |
| Differential Beacon Receiver | Seapath | MBX-3S | 0716-1600-0007 |

A.1.1.3. Sounding Equipment

A Reson SeaBat 8101 multi-beam echo sounder (MBES) system was used aboard the *R/V Kittiwake* during OPR-P188-KR-07.

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 a serial connection to the collection computer. Range scales, power, gain and depth-filter limits were adjusted during data collection. Time Varied Gain (TVG) with spreading and absorption values within recommended ranges for cold salt water were used during the survey.

Nadir-beam calibration checks were conducted on a weekly basis, when practical. 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 36-ounce lead ball attached to the end. The ball was attached in such a way that the bottom of the ball was 0.1 m below the zero mark of the tape. The 0.1 m offset was added to the lead line reading when recording the weekly measurements. The lead line and nadir-beam MBES values agreed consistently throughout the survey.

Total sounding error limits were determined using the following equation:

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

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

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

The Descriptive Report SEPARATE I: ACQUISITION AND PROCESSING LOGS contains a summary of the calibration checks performed for each survey.

A.1.1.4. Technical Specifications

Table 2 – Reson SeaBat 8101 multibeam echosounder 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 |
| Swath Coverage | 150° |
| Depth Resolution | 1.25 cm |

| Range Scale | Ping Rate |
|--------------------|------------------|
| 3.5 | 40.00 |
| 5 | 40.00 |
| 7 | 40.00 |
| 10 | 40.00 |
| 15 | 40.00 |
| 20 | 35.63 |
| 25 | 28.63 |
| 30 | 23.92 |
| 35 | 20.55 |
| 40 | 18.01 |
| 50 | 14.44 |
| 75 | 9.65 |
| 100 | 7.24 |
| 125 | 5.80 |
| 150 | 4.84 |

| Range Scale | Ping Rate |
|-------------|-----------|
| 175 | 4.15 |
| 200 | 3.63 |
| 250 | 2.90 |
| 300 | 2.42 |
| 350 | 2.08 |
| 400 | 1.82 |

A.1.2. Irish Ayes

Multibeam echosounder and shoreline verification data for survey H11644 was acquired using the survey vessel *Irish Ayes*. The *Irish Ayes* survey was conducted following the completion of operations by the *R/V Kittiwake* to acquire multibeam data to the eight meter depth contour that was not possible to survey with the *R/V Kittiwake* due to the proximity to the shoreline. *Irish Ayes* was also used to support the shoreline verification portion of the survey.



Figure 2 – Irish Ayes underway in Unimak Pass, Alaska.

The *Irish Ayes*, shown underway in Figure 2, is an aluminum hulled hydrographic survey vessel 7.3 meters in length with a 2.6 meter beam and a 0.7 meter draft. During the survey it was equipped with a Reson SeaBat 8101 multibeam echo sounder. The *Irish Ayes* was powered by two 70 H.P. Yamaha outboard motors with one 2 KW Honda

Marathon generator and a Legend Trace Model 2512 inverter for electrical service. Detailed vessel drawings showing the location of all primary survey equipment are included in Section C. of this report.

A.2.1.1. Equipment Overview

The equipment on the *Irish Ayes* performed well and within required specifications.

A.2.1.2. Major Operational Systems

***Irish Ayes* Survey Equipment**

Table 3 - Table showing the major survey equipment used aboard the Irish Ayes.

| <i>Description</i> | <i>Manufacturer</i> | <i>Model / Part</i> | <i>Serial Number</i> |
|------------------------------|----------------------|---------------------|----------------------|
| Multibeam Sonar | Reson | SeaBat 8101 | 276010 |
| Sonar Processor | Reson | SeaBat 81-P | 8002007 |
| Positioning System | Trimble | DSM-212 | 0220218638 |
| Motion Sensor | Coda Octopus | F-180 | 0105019 |
| SV Casting Probe | Applied Microsystems | SV Plus | 3259 |
| SV Casting Probe | Applied Microsystems | SV Plus (V2) | 3598 |
| Differential Beacon Receiver | CSI Wireless | MBX-3S | 0706-1600-0008 |

A.2.1.3. Sounding Equipment

A Reson SeaBat 8101 multi-beam echo sounder (MBES) system was used aboard the *Irish Ayes* during OPR-P188-KR-07.

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 a serial connection to the collection computer. Range scales, power, gain and depth-filter limits were adjusted during data collection. Time Varied Gain (TVG) with spreading and absorption values within recommended ranges for cold salt water were used during the survey.

Nadir-beam calibration checks were conducted on a weekly basis, when practical. 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 36-ounce lead ball attached to the end. The ball was attached in such a way that the bottom of the ball was 0.1 m below the zero mark of the tape. The 0.1 m offset was added to the lead line reading when recording the weekly

measurements The lead line and nadir-beam MBES values agreed consistently throughout the survey.

Total sounding error limits were determined using the following equation:

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

where: **for d < 100 meters**
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.

The Descriptive Report SEPARATE I: ACQUISITION AND PROCESSING LOGS contains a summary of the calibration checks performed for each survey.

A.2.1.4. Technical Specifications

Table 4 – Reson SeaBat 8101 multibeam echosounder 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 |
| Swath Coverage | 150° |
| Depth Resolution | 1.25 cm |

| Range Scale | Ping Rate |
|--------------------|------------------|
| 3.5 | 40.00 |
| 5 | 40.00 |
| 7 | 40.00 |
| 10 | 40.00 |
| 15 | 40.00 |
| 20 | 35.63 |
| 25 | 28.63 |
| 30 | 23.92 |
| 35 | 20.55 |
| 40 | 18.01 |
| 50 | 14.44 |
| 75 | 9.65 |

| Range Scale | Ping Rate |
|-------------|-----------|
| 100 | 7.24 |
| 125 | 5.80 |
| 150 | 4.84 |
| 175 | 4.15 |
| 200 | 3.63 |
| 250 | 2.90 |
| 300 | 2.42 |
| 350 | 2.08 |
| 400 | 1.82 |

A.1.3. Tide Gauges

NOAA tide station Unalaska, Dutch Harbor, AK (946-2620) was used to provide predicted tide data for OPR-P188-KR-07. Three Sea-Bird SBE 26plus Wave & Tide Recorder submersible tide gauges were installed at the site of the historic USC&GS tide station Cape Sarichef, Unimak Island, AK (946-2787) to provide final tide data. The three submersible gauges were placed in close proximity to each other to provide redundancy and minimize the potential for gaps in the tide record. Two of the three gauges were equipped with LinkQuest UWM1000 Underwater Acoustic Modems which permitted the downloading of tide data periodically throughout the project.

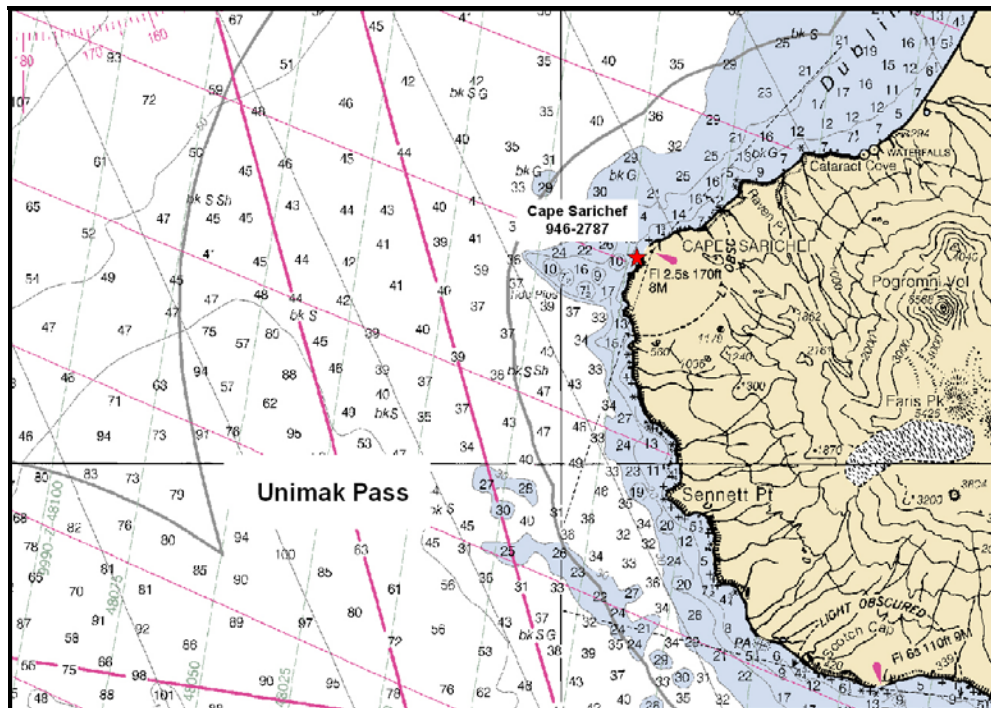


Figure 3 - Location of tide station used in OPR-P188-KR-07. Chart 16520, 22nd Edition, March 2004. Soundings in fathoms.

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. 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 this station.

A.1.4. Speed of Sound

Speed of Sound data was collected by vertical casts on the *R/V Kittiwake* and *Irish Ayes* using Applied Microsystems SV Plus and SV Plus (V2) sound speed sensors.

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 30m or less, 30m to 100m, and greater than 100m. 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.

Refer to the Descriptive Report SEPARATE II: SOUND SPEED DATA for detailed information about specific cast dates and procedures used.

The following instruments were used to collect data for sound speed profiles on the *R/V Kittiwake*.

R/V Kittiwake

Table 5 – Table listing the sound speed measuring equipment used during OPR-P188-KR-07.

| | |
|------------------------------------|---|
| Velocimeter (sound speed profiler) | SV Plus |
| Manufacturer | Applied Microsystems Ltd. Sydney, British Columbia, Canada |
| Serial number | 3317 |
| Calibrated | 02/3/2007 |

| | |
|------------------------------------|---|
| Velocimeter (sound speed profiler) | SV Plus (V2) |
| Manufacturer | Applied Microsystems Ltd. Sydney, British Columbia, Canada |
| Serial number | 3598 |
| Calibrated | 06/6/2007 |

Irish Ayes

| | |
|------------------------------------|---|
| Velocimeter (sound speed profiler) | SV Plus |
| Manufacturer | Applied Microsystems Ltd. Sydney, British Columbia, Canada |
| Serial number | 3259 |
| Calibrated | 02/22/2007 |

| | |
|------------------------------------|---|
| Velocimeter (sound speed profiler) | SV Plus (V2) |
| Manufacturer | Applied Microsystems Ltd. Sydney, British Columbia, Canada |
| Serial number | 3598 |
| Calibrated | 06/6/2007 |

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.1.5. Positioning Systems

Position control for the *R/V Kittiwake* was provided by a Seatex Seapath 200 positioning system while *Irish Ayes* used a Coda Octopus F-180 receiver for position control. Both vessels received differential correctors from CSI Wireless MBX-3 beacon receivers. Vessel positions were recorded using QPS QINSy data collection 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 212 GPS receivers on each vessel. Positions obtained by the Seapath 200 and DSM 212 receivers on the *R/V Kittiwake* and Coda Octopus F-180 and DSM-212 on *Irish Ayes* were simultaneously logged using QINSy. Position differences were then analyzed using Microsoft Excel to ensure position quality. Position inverses, 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 Vertical and Horizontal Control Report.

A.1.6. Attitude Sensors

A Seatex Seapath 200 heading, attitude and positioning sensor in combination with the Seatex MRU-5 marine motion sensor was used to correct sounding data for heave, pitch

and roll on the *R/V Kittiwake*. Attitude information on *Irish Eyes* was provided by a Coda Octopus F-180 Precision Attitude & Positioning System. Detailed descriptions of all attitude corrections are provided in Section C: Corrections to Echo Soundings.

A.2. Data Collection

A.2.1. Overview

The survey was conducted using shallow-water multibeam techniques with the *R/V Kittiwake* and *Irish Eyes*. No single-beam or side scan sonar data was collected. On the *R/V Kittiwake*, data was collected on a 24 hour basis using two crews with shift changes every 12 hours. *Irish Eyes* operated as a launch from the *R/V Kittiwake*, weather permitting, and was used for shoreline verification and to develop areas that were too shoal or fouled to permit access by the *R/V Kittiwake*.

A.2.2. Coverage

Full bottom multibeam coverage (100%) was obtained in the survey area seaward of the 8-meter curve except in areas of dense kelp forests bordering Unimak Island. Survey line spacing was determined by water depth and multibeam signal quality. Survey lines were run using the QINSy visual display to ensure adequate overlap in the outer beams. The display was set to show coverage with an angular sector exclusion of 60° - 75° to port and 60° - 75° to starboard. The grid displayed a swath-width that varied as a function of water depth but which, in all cases, was less than the actual coverage attained by the multibeam sonar. The helmsman set a course which overlapped the QINSy displayed grid and the resultant track ensured adequate overlap on all adjacent lines.

A.2.3. Line Planning

Line spacing and the resultant line numbering scheme was not pre-planned due to the variable spacing procedure used to ensure coverage, however, 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 shore.

A.2.4. Ping Rates

The NOS Hydrographic Survey Specifications and Deliverables, Section 5.2.2., 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). The disadvantage of surveying at high speeds is loss of swath width as the range scale necessary to meet the footprints/meter requirement is too small to pick up the outer beams. The disadvantage of surveying at lower speeds is reduced production.

Following the requirements set forth in the Specification and Deliverables, a simple formula was derived for determining ping rate:

$$3.2 \text{ pings per } 3 \text{ meters} = 1.1 \text{ pings per } 1 \text{ meter}$$

$$1.1 * \text{Speed over Ground (meters per second)} = \text{ping rate}$$

This formula, however, does not take the pitch of the survey vessel into account when determining the desired ping rate. In practice, the center-to-center beam footprint spacing is significantly affected by the pitch angle of the survey vessel. To compensate for pitch, the selected MBES range setting and measured sound velocity were combined with real-time input of vessel speed, sonar depth, and pitch angle to predict the center-to-center distance between soundings. Footprint spacing was calculated using the following formula:

$$\text{Sounding spacing} = (v * 2 r/s) + (d * |\text{TAN}(\theta) - \text{TAN}(\sigma)|)$$

Where: s = Sound velocity (m/sec)

r = MBES range setting (m)

d = MBES measured depth at ping 1 (m)

θ = Vessel pitch angle at ping 1 (°)

σ = Vessel pitch angle at ping 2 (°)

v = Vessel SOG (m/sec)

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 5.2.2. Surveying at vessel speeds at or below 6 kts ensured a minimum of 3 pings on a 1 m target at a range of 100m.

A.2.5. Software and Hardware Summary

Multibeam data was collected on an Intel Pentium IV PC using QPS QINSy data collection software (multibeam) operating in a Microsoft Windows 2000 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 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.

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

Table 6 lists the software used on the *R/V Kittiwake* and *Irish Ayes* during the survey and Table 7 lists the software used in the office during pre-survey planning and post-survey processing:

A.2.6. Vessel Software

Table 6 – Software used aboard the R/V Kittiwake and Irish Ayes.

| 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) |
| Reson SeaBat | 1.01-82D9 | 2000 | Reson SeaBat 8124 firmware (wet) |
| Reson SeaBat | 2.05-8C94 | 2000 | Reson SeaBat 8124 firmware (dry) |
| QPS QINSy | 7.5 | 2005 | Multibeam data collection software |
| Seapath 200 | 2.03.02 | 2005 | Seapath 200 Firmware |
| Seapath Control Center | 2.01.02 | 2002 | PC Interface to Seatex Seapath 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. |

A.2.7. Office Software

Table 7 – Software used in the office during post processing.

| Program Name | Version | Date | Primary Function |
|---|----------------|-------------|--|
| CARIS HIPS & SIPS | 6.1 | 2006 | Multibeam and side scan sonar data processing software |
| CARIS HOM | 3.3 | 2006 | Electronic chart data processing software |
| CARIS BASE Editor | 1.0 & 2.0 | 2006 | Bathymetry compilation and analysis software |
| CARIS GIS Professional | 4.4 | 2006 | Marine GIS information management 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 | 6.5 & 8.5 | 2001 & 2006 | Desktop mapping software |
| Corpscon | 5.11 | 2001 | Coordinate conversion software |

B. Quality Control

B.1. Overview

Every effort possible was made to ensure the traceability and integrity of the sounding 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 & SIPS was used for the majority of the data processing tasks on this project. HIPS & 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.

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.

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.

Cross lines 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 Kittiwake* and *Irish Ayes* consisted of comparing lead line depths with depths logged by the MBES nadir beams.

B.4. Data Collection

Multibeam sounding data collection was performed using QPS QINSy Multibeam data-collection 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 logs included the line name, start and end times, ping rate, range and power settings, and any additional comments deemed significant by the operator.

B.5. Initial File Handling

Initial multibeam data processing was completed on the survey vessel. At the end of each survey line, the raw data file and converted “.xtf” file were organized by sub-locality 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 & SIPS. These files were organized in a directory on the network server based on project name, vessel name, and Julian date.

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 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 & SIPS Swath 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 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 3 illustrates the major steps in the data acquisition and reduction process. The text following the diagram provides a detailed explanation of each step.

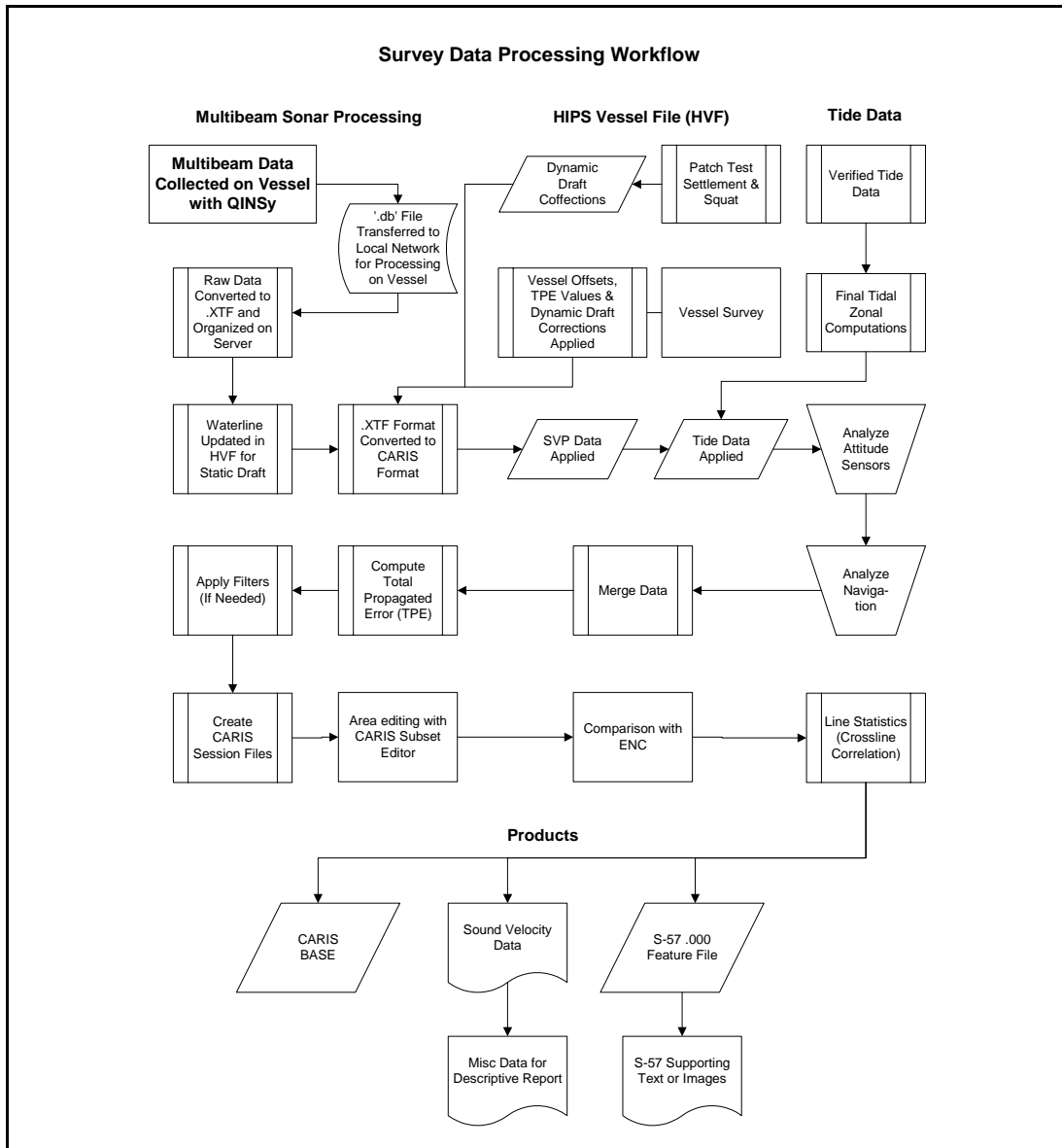


Figure 3 - Data Acquisition and Processing Flow Diagram

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 ensured the maintenance of data integrity throughout the editing process.

CARIS HIPS & 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 & 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 & SIPS was used for the majority of the processing and adjustments made during sounding reduction. CARIS HIPS & 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.

Sensor data were reviewed and edited with CARIS HIPS & SIPS to remove obvious systemic errors or environmental artifacts. Survey lines were opened in HIPS’ Swath Editor mode by selecting the project, vessel, day and desired line.

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 Unalaska, AK (946-2620) through August 8, 2007. Refer to Section C. Corrections to Echo Soundings, of this report, for detailed information concerning final 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 Kittiwake* and *Irish Eyes* using 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 line using data headers to indicate the time of each cast. The sound speed adjustment in CARIS HIPS & 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, the tide and 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.

B.1.6.1. HIPS Final Processing

A verified tide and zoning scheme was tested and applied to the survey area prior to the area-based and uncertainty-based editing processes. Daily static draft observations as well as dynamic draft values were entered in the HIPS vessel file. A special examination of vessel speed using Navigation Editor was conducted to ensure accuracy as HIPS interpolates draft values to depth positions during the merge process. 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.

B.1.6.2. Area Editing

Following the individual line (swath) editing and quality assurance of draft and tide applications, several area-based editing processes in CARIS HIPS & 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. 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. Soundings were flagged as accepted, rejected, designated, outstanding or examined.

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

B.6.2. TPE

Subsequent area-based editing incorporated uncertainty values derived from Total Propagated Error (TPE). CARIS HIPS & 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 & 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 Kittiwake* and *Irish Ayes* are found in Tables 8 and 9 on the following pages.

Table 8 – R/V Kittiwake 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 | 0.020 deg |
| Pitch | Published by Manufacturer | 0.020 deg |
| Position Navigation | Published by Manufacturer | 0.700 m |
| Transducer Timing | Estimated | 0.001 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 | 0.003 m |
| Offset Y | Direct Measurement | 0.003 m |
| Offset Z | Direct Measurement | 0.003 m |
| Vessel Speed | Published by Manufacturer | 0.200 m/sec |
| Loading | Published by Manufacturer | 0.010 m |
| Draft | Published by Manufacturer | 0.010 m |
| Delta Draft | Direct Measurement | 0.010 m |
| MRU Alignment Gyro | Direct Measurement | 0.150 m |
| MRU Alignment Roll/Pitch | Direct Measurement | 0.150 m |
| Sound Velocity | Published by Manufacturer | 0.05 m/sec |
| Tide Gauge | Published by Manufacturer | 0.02 m |

Table 9 – Irish Ayes 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 | 0.025 deg |
| Pitch | Published by Manufacturer | 0.025 deg |
| Position Navigation | Published by Manufacturer | 0.170 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 |
| Vessel Speed | Published by Manufacturer | 0.200 m/sec |
| Loading | Published by Manufacturer | 0.010 m |
| Draft | Published by Manufacturer | 0.010 m |
| Delta Draft | Direct Measurement | 0.010 m |
| MRU Alignment Gyro | Direct Measurement | 0.100 m |
| MRU Alignment Roll/Pitch | Direct Measurement | 0.100 m |
| Sound Velocity | Published by Manufacturer | 0.05 m/sec |
| Tide Gauge | Published by Manufacturer | 0.02 m |

Uncertainty values derived from CARIS HIPS & SIPS TPE computation were used to create International Hydrographic Organization (IHO) S-44 compliant datasets as well as calculate depth surfaces weighted by uncertainty. Following the TPE computation, all survey lines under 100m were filtered to reject soundings with uncertainty values that did not meet IHO Order 1 survey standards. Survey data deeper than 100m were filtered to

reject soundings with uncertainty values that did not meet IHO Order 2 standards. IHO uncertainty thresholds were determined using the following equation:

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

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

B.6.3. 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 Electronic Navigation Charts (ENC) of the area. CARIS HIPS & SIPS Field Sheet Editor was used to bin survey data to a 10 meter grid from which shoal-biased soundings were extracted on a 60 meter radius. The binned surface and soundings were then assigned depth dependent color attributes to visually emphasize soundings and/or bins with unique depths. A final inspection of the survey data was then made by investigating areas where soundings and/or bins disagreed with neighboring values. Areas involving a charting recommendation, such as the addition of a new feature or shoaling area were thoroughly examined. Although depth contouring, a component of the fixed-scale smooth sheet, is no longer required, ENC contours were compared with the variable Base surface enhanced false color depth gradients for each survey. This comparison was used for evaluating the adequacy of the ENC and for making future charting recommendations that are included in each Descriptive Report Section D.2 Additional Results.

B.6.4. 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.

2007 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, one sun-illuminated, geographically referenced Digital Terrain Model image depicting the coverage of the survey area is submitted. All grids are projected to UTM Zone 3 North, NAD 1983. Naming conventions for each grid are as follows:

CARIS BASE Uncertainty Surface: Sheet_A/B_0_40_2m.bms

- A/B represents the sheet (H11643 or H11644))
- 0_40 represents the depth range

- 2m represents the resolution

Sun-Illuminated Elevation DTM: H11643/4_1_OF_9.tif

Uncertainty DTM: H11643/4_1_OF_9_Uncertainty.tif

A data set containing a single S-57 (.000) base cell file and supporting files was submitted in conjunction with the other 2007 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.6.5. Crossline Analysis

Crossline comparisons for were completed by using the surface difference method.

Separate BASE surfaces were created in CARIS HIPS & SIPS for mainscheme line and crossline data with depths less that 100 meters and greater than 100 meters. The BASE surfaces were then opened in CARIS Base Editor and surface differences were created for each depth range.

Each surface difference was opened in CARIS HIPS & SIPS and an ASCII file containing X Y positioning information with corresponding surface difference values was created from the data. An ASCII file was also created from the crossline BASE surface data. The crossline data were used to provide depth information for each geo-referenced surface difference value.

Microsoft Access was used to evaluate surface difference values as a function of water depth using the total sounding error limits specified in NOAA, NOS Hydrographic Surveys Specifications and Deliverables, June 2006, section 5.2.1. using the following equation:

$$\pm\sqrt{[a^2 + (b*d)^2]} \quad \text{where:} \quad \begin{array}{ll} \text{for } d < 100 \text{ meters} & \text{for } d > 100 \text{ meters} \\ a=0.5 \text{ m} & a=1.0 \text{ m} \\ b=0.013 \text{ m} & b=0.023 \text{ m} \\ d=\text{depth m} & d=\text{depth m} \end{array}$$

A percentage of surface nodes failing to meet the accuracy standards for the depth range of the survey were then calculated.

The surface difference and a sheet-wide summary report are included in each Descriptive Report SEPARATE V: CROSSLINE REPORTS.

B.6.6. Shoreline Verification

All shoreline verification performed during OPR-P188-KR-07 took place on survey H11644 which bordered on Unimak Island. A combination of limited and traditional shoreline verification was performed in conjunction with the offshore bathymetric survey. Limited verification, shoreward of the 4-meter curve, consisted primarily of a comparison of digital shoreline shapefiles with the shoreline observed in the field.

Traditional verification, seaward of the 4-meter curve, was limited to delineating the boundaries of extensive kelp forests and the verification of one charted feature.

CARIS Notebook was used in conjunction with DGPS, for position control, to record detached positions (DP) and to log comments about specific features. S-57 mandatory attributes were completed for all new features located during the survey. Detached position forms were created for all items seaward of the 4-meter curve and any new items located inshore of the 4-meter curve. Printed verification aids, consisting of printed copies of the shoreline shapefiles, were also used as visual aids and for supplemental notes during the survey.

New features, with the field verified position and attribute information, were exported from CARIS Notebook as shapefiles and processed in AutoCAD and MapInfo. Final processing was performed using CARIS Hydrographic Object Manager (HOM) to produce a fully attributed S-57 (.000) file.

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, conventional survey of each vessel using a level and metric tape. 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 Seapath GPS antennas were resolved during the Seapath calibrations. 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 & SIPS Vessel File (HVF). Detailed vessel drawings and offset descriptions are provided in Figure 4 and Figure 5.

C.1.1. Vessel Survey

R/V Kittiwake

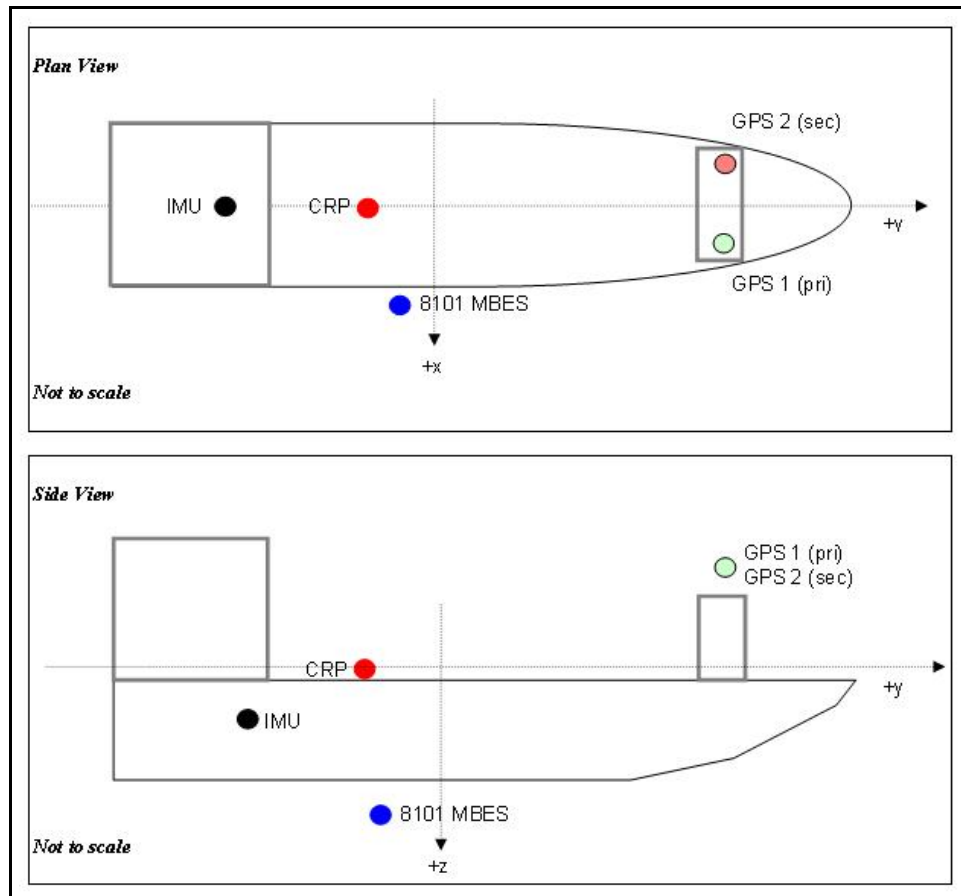


Figure 4 - R/V Kittiwake vessel survey showing the relative positions of the installed survey equipment.

Table 10 – R/V Kittiwake offset measurements determined during the initial vessel survey. The CARIS convention of + down (z), + starboard (x) and + forward (y) was used for all measurements.

| Equipment | Manufacturer / Model | Offset from CRP (m) based on CARIS Convention | | |
|------------------|----------------------|---|---------|--------|
| | | X | Y | Z |
| MRU | Seatex MRU-5 | -0.893 | -5.947 | +0.911 |
| CRP | N/A | ±0.000 | ±0.000 | ±0.000 |
| MB Transducer | Reson SeaBat 8101 | +4.251 | -1.217 | +3.575 |
| GPS1 (Primary) | Seapath 200 | +1.293 | +11.284 | -6.194 |
| GPS2 (Secondary) | Trimble DSM-212 | -1.205 | +11.284 | -6.197 |

Irish Ayes

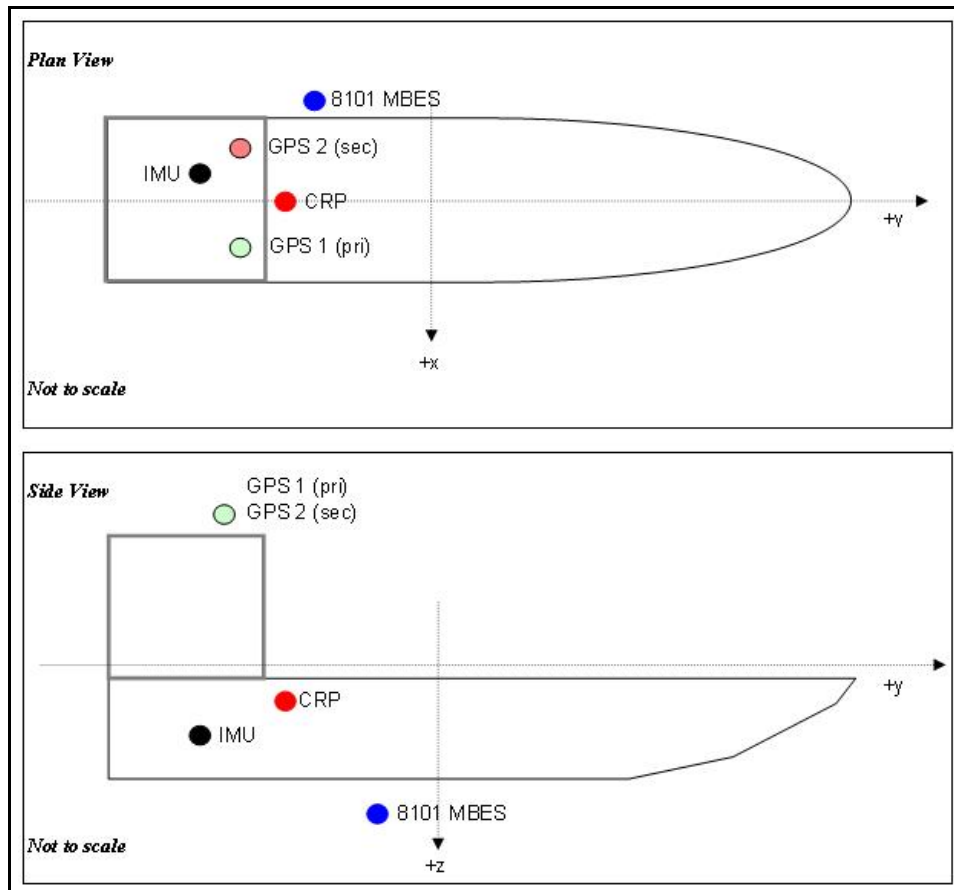


Figure 5 – Irish Ayes vessel survey showing the relative positions of the installed survey equipment.

Table 11 – Irish Ayes offset measurements determined during the initial vessel survey. The CARIS convention of + down (z), + starboard (x) and + forward (y) was used for all measurements.

| Equipment | Manufacturer / Model | Offset from CRP (m) based on CARIS Convention | | |
|-------------------|----------------------|---|--------|--------|
| | | X | Y | Z |
| IMU | Coda Octopus F-180 | -0.099 | +2.957 | -0.295 |
| CRP | N/A | ±0.000 | ±0.000 | ±0.000 |
| MB Transducer | Reson SeaBat 8101 | +0.000 | +7.154 | +1.991 |
| GPS 1 (Primary) | Coda Octopus F-180 | +1.472 | +2.283 | -5.101 |
| GPS 2 (Secondary) | Trimble DSM-212 | -1.436 | +2.298 | -5.108 |

C.1.2. Heave, Roll and Pitch

Heave, roll and pitch data for *R/V Kittiwake* was measured using a Seatex MRU-5 Marine Motion Sensor and a Coda Octopus F-180 Attitude and Positioning System was used on *Irish Ayes*. Each system provided output as a binary data string via RS-232 serial line to QPS QINSy acquisition software at 10Hz. 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 was performed on *R/V Kittiwake* and the *Irish Ayes* 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.

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 ($\delta\theta_p$) 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 and 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 2007 survey and whenever there was a configuration change involving the position of the multibeam transducer. A listing of the patch tests performed for the 2007 survey is provided in Table 12.

Table 12 – Patch tests performed for instrument calibration during OPR-P188-KR-07.

| Vessel | Julian Date | Latitude (DMS) | Longitude (DMS) | Reason |
|----------------------|-------------|------------------|-------------------|----------------------------|
| <i>R/V Kittiwake</i> | 2007-146/7 | 59° 35' 10.05" N | 151° 20' 05.80" W | Initial calibration |
| <i>R/V Kittiwake</i> | 2007-181 | 54° 28' 43.09" N | 165° 00' 33.77" W | Minor MBES pole damage |
| <i>R/V Kittiwake</i> | 2007-198 | 54° 22' 45.33" N | 165° 38' 25.01" W | Struck buoy with MBES pole |
| <i>Irish Ayes</i> | 2007-204 | 53° 52' 41.37" N | 166° 32' 46.31" W | Initial calibration |

C.2. Speed of Sound through Water

Sound speed data for OPR-J364-KR-06 was collected using Applied Microsystems Ltd. SV Plus and SV Plus (V2) sensors. 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. 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. 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.

The Descriptive Report SEPARATE II: SOUND SPEED DATA contains a detailed listing of the sound speed profiles and applicable cast dates used during the 2006 survey.

C.3. Static Draft

Static draft was determined by measuring from a control point on the hull 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 Kittiwake

Settlement and squat measurements for *R/V Kittiwake* were conducted using On The Fly Real Time Kinematic (OTF-RTK) GPS Survey Procedures in Kachemak Bay near Homer, Alaska on May 28, 2007 prior to transiting to the survey area. Measurements were made using a Trimble 4000 SSE GPS receiver, Pacific Crest radio modems, Seatex Seapath 200 RTK heading, attitude and positioning sensor with a Seatex MRU-5 attitude sensor and were recorded in 1 knot increments for vessel speeds from 2 – 6 knots. These speeds were selected as representative of the practical operational limits of possible vessel survey speeds.

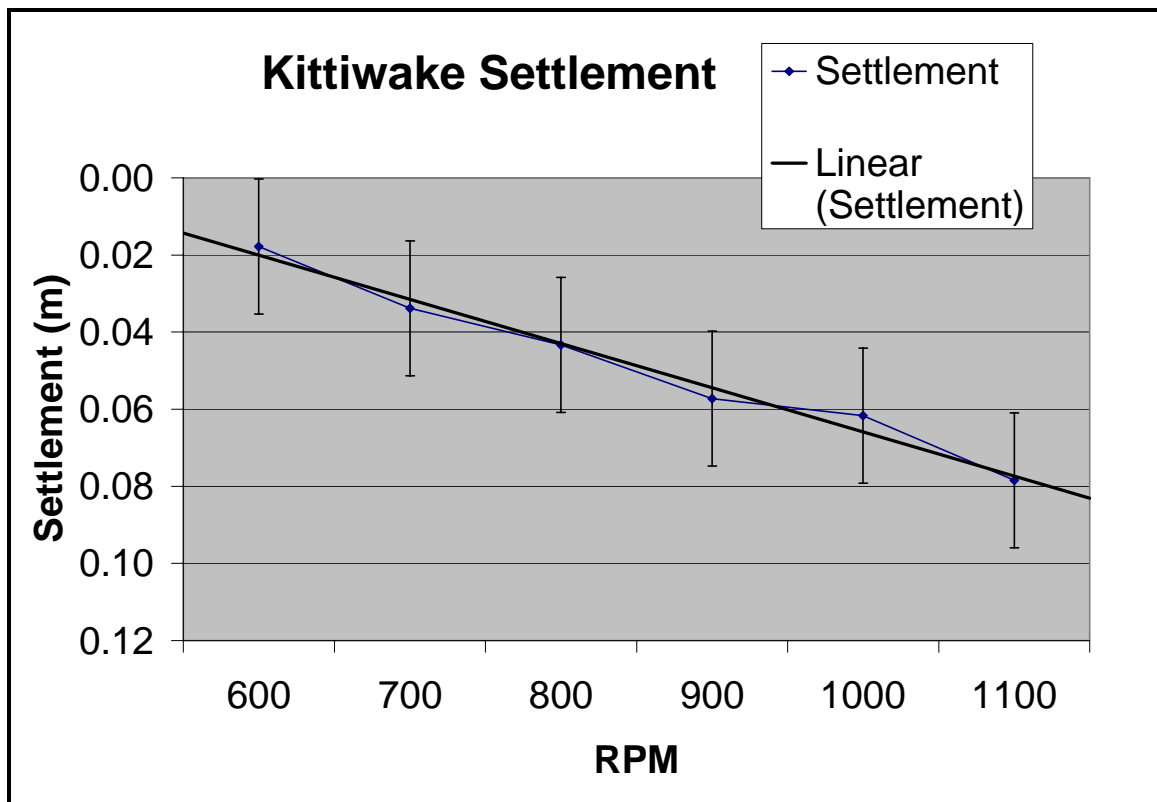


Figure 5 - R/V Kittiwake Settlement & Squat Measurements.

Table 13 – R/V Kittiwake Engine RPM vs. settlement measured during Settlement & Squat survey on JD 2007-148.

| RPM | Settlement (m) |
|------------|-----------------------|
| 600 | -0.02 |
| 700 | -0.03 |
| 800 | -0.04 |
| 900 | -0.06 |
| 1000 | -0.06 |
| 1100 | -0.08 |

A Kinematic base station (Trimble 4000 SSE), was set up on beach 5 km from the survey vessel. The base station used telemetry (Pacific Crest radios) to transmit Real Time Carrier Phase corrections to the Seapath 200 installed on *R/V Kittiwake*. The Seapath used the carrier phase corrections to determine the position of the navigation antenna on the *R/V Kittiwake* 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 Seapath 200 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 speed. Once the vessel was at the desired speed, 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 speed range. A graph was then constructed to illustrate settlement changes as a function of vessel speed.

Irish Ayes

Settlement and squat measurements for *Irish Ayes* were conducted on May 28, 2007 using On The Fly Real Time Kinematic (OTF-RTK) GPS Survey Procedures in Kachemak Bay near Homer, Alaska. All measurements were made with the multibeam transducer deployed in it's survey configuration.

Measurements were made using a Trimble 4000 SSE GPS receiver, Pacific Crest radio modems and a Coda Octopus F-180 attitude and positioning sensor and were recorded in 200 RPM increments from 1200 RPM to 3200 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 4000 SSE), was set up on beach 5 km from the survey vessel. The base station used telemetry (Pacific Crest radios) to transmit Real Time Carrier Phase corrections to the Coda Octopus F-180 installed on *Irish Ayes*. The F-180 used the carrier phase corrections to determine the position of the navigation antenna on the *Irish Ayes* 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 F-180 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, 3200 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.

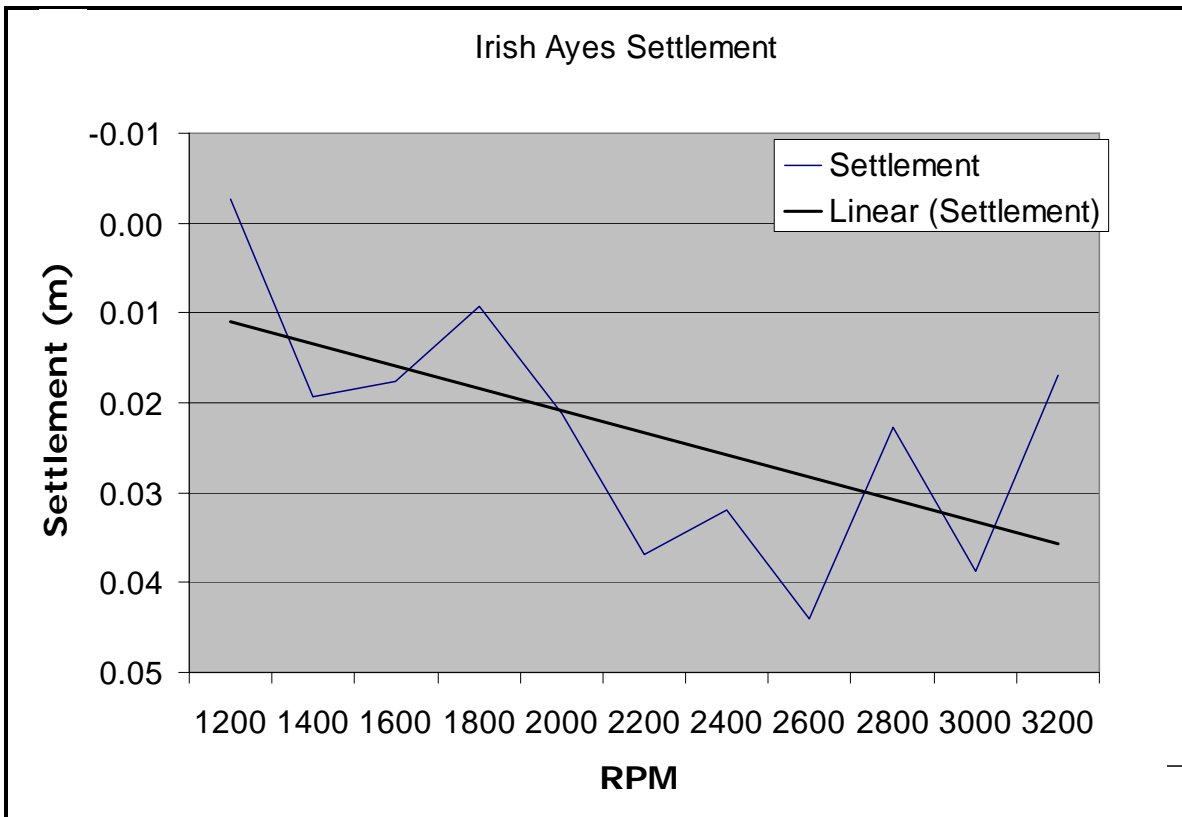


Figure 6 – Irish Ayes Settlement & Squat Measurements.

Table 14 – Irish Ayes average speed vs. settlement measured during Settlement & Squat survey on JD 2007-148.

| Engine RPM | Settlement (m) |
|-------------------|-----------------------|
| 1200 | 0.00 |
| 1400 | -0.02 |
| 1600 | -0.02 |
| 1800 | -0.01 |
| 2000 | -0.02 |
| 2200 | -0.04 |
| 2400 | -0.03 |
| 2600 | -0.04 |
| 2800 | -0.02 |
| 3000 | -0.04 |
| 3200 | -0.02 |

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 vessel speed.

C.5. Tide Correctors

Three Sea-Bird SBE 26 Sea Gauge Wave and Tide Recorders deployed approximately 5 km north of the historical tide station at Cape Sarichef (946-2787) in 30 meters of water served as datum control for this survey. The tidal datum for the survey was Chart Datum, Mean Lower Low Water (MLLW). The National Water Level Observation Network (NWLON) station at Unalaska, AK (946-2620) 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 & SIPS during the merge step of initial data processing.

The Sea-Bird tide recorders were downloaded weekly using a LinkQuest acoustic modem as a quality control check. Raw tide data was downloaded from the gauges upon retrieval at the end of the project. The data was then analyzed and final tides determined by John Oswald and Associates, LLC. Final tides were merged with the sounding data during the final stages of data processing.

C.6. Project Wide Tide Correction Methodology

The tidal zoning scheme was provided in the statement of work. The historic water level station at Cape Sarichef (946-2787) was used as the reference station for the zoning scheme. Refer to the Vertical and Horizontal Control Report for tide zone methods and operations.

LETTER OF APPROVAL

REGISTRY Numbers: H11643 and H11644

This report and the accompanying digital data are respectfully submitted.

Field operations contributing to the accomplishment of surveys H11643 and H11644 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-KR-07 include the Descriptive Reports and the Horizontal and Vertical Control Report.

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



Raj Bhangu, Hydrographer
TerraSond Ltd.

Date December 6, 2007