NOAA FORM 76-35A

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

Data Acquisition & Processing Report

Type of Survey HYDROGRAPHIC

Field No OPR-O112-KR&L-04

Registery No. H11354

LOCALITY

State ALASKA

General Locality Approaches to Sitka, AK

Sublocality Sitka Sound

2004

CHIEF OF PARTY

DEAN MOYLES

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DATE ....

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Title Sheet

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A – Equipment

The R/V Quicksilver and the R/V Kvichak Surveyor 1 acquired all multibeam sounding data during the course of this project. The Quicksilver was utilized to collect multibeam data and sound velocity profiles in shallow to medium water depths (4 to 100 meters) while the Kvichak Surveyor 1 collected multibeam data and sound velocity profiles in medium to deep water depths (50 to 200 meters). The equipment list and vessel descriptions are included in Appendices A and B.

The Beechcraft King Air 90 (call sign N80Y) collected shallow water bathymetry (down to 15 meters), topographic (up to 100 meters) and imagery data during the course of this project. The aircraft was equipped with a SHOALS-1000T Bathymetric and Topographic LIDAR System. The equipment list along with technical specifications and plane descriptions are included in Appendices A and B.

SOUNDING EQUIPMENT

The R/V Quicksilver was equipped with a hull mounted Reson SeaBat 8101 multibeam system during the OPR-O112-KR&L-04 Approaches to Sitka survey. The Reson 8101 system operates at a frequency of 240 kHz, with 101 horizontal beams centered 1.5º apart (150º across-track beam width) and 1.5º along-track beam width. It transmits and receives a sonar signal to measure the relative water depth over the 150º swath. The range scale, gain, power level, ping rates, etc. were a function of water depth and data quality. Any changes to these parameters were noted on the survey line logs (see Separate 1).

The line orientation for the Quicksilver was normally parallel to the coastline and bathymetric contours in the area. The line spacing depended on the water depth and data quality, but never exceeded three times the water depth.

The Kvichak Surveyor 1 was equipped with pole mounted Reson SeaBat 8111 multibeam system during the OPR-O112-KR&L-04 Approaches to Sitka survey. The Reson 8111 system operates at a frequency of 100 kHz, with 101 horizontal beams centered 1.5º apart (150º across-track beam width) and 1.5º along-track beam width. It transmits and receives a sonar signal to measure the relative water depth over the 150º swath. The range scale, gain, power level, ping rates, etc. were a function of water depth and data quality. Any changes to these parameters were noted on the survey line logs (see Separate 1).

The line orientation for the Kvichak Surveyor 1 was normally parallel to the bathymetric contours in the area. The line spacing depended on the water depth and data quality, but never exceeded three times the water depth.

A 15 ft skiff, referred to as the DP Skiff, was used to perform item investigations. The skiff was equipped with a CSI GBX-PRO DGPS receiver, WinFrog v3.4.0 data acquisition system (operated on a Panasonic laptop) and a Sony digital camera. NOAA nautical charts were displayed as a layer in WINFROG for reference. Soundings on submerged features were conducted with a leadline, but to aid the hydrographer in locating the shoalest point of targets near the surf zone or areas of limited visibility, a Hummingbird Piranha Max15 fish finding sounder was used.

LIDAR EQUIPMENT

The Beechcraft King Air 90 (call sign N80Y) was equipped with a SHOALS-1000T Bathymetric and Topographic LIDAR System. The 1 kHz bathymetric laser (or hydro laser) was used to collect data over the entire survey area. The laser was operated to achieve 4m x 4m spot spacing flying at 400m altitudes at approximately 160 knots. The survey lines were planned with 20% overlap and flown twice – once at low water and once at high water in opposing directions to achieve 200% coverage.

In the LIDAR system, the laser outputs green and infrared beams. The infrared beam is used to detect the water surface and does not penetrate. The green beam penetrates the water and is used to detect the seafloor. The green beam also generates red energy when excited at the air/water interface. This is known as Raman backscatter and can also be used to detect the sea surface. Distances to the sea surface and seafloor are calculated from the times of the laser pulses, using the speed of light in air and water. Background theory on bathymetric LIDAR can be found in the paper, "*Meeting the Accuracy Challenge in Airborne LIDAR Bathymetry*" (Guenther, et al.[1]). This paper can be found in Appendix E.

The topographic data was also collected using the 1 kHz bathymetric laser and was operated to achieve 4m x 4m spot spacing flying at 400m altitude at approximately 160 knots. The survey lines were planned with 20% overlap and flown two times in opposing directions to achieve 200% coverage.

In addition to LIDAR data, a DuncanTech DT4000 digital camera was also used to acquire one 24-bit color photo per second. The camera, mounted in a bracket at the rear of the sensor, captures imagery of the area being flown. The data was then utilized during processing in the GCS and later by way of an orthomosaic for shoreline application.

SIDE SCAN SONAR

Towed Side Scan Sonar (SSS) operations were not required by this contract. Backscatter data output by the Reson 8101 & 8111 multibeam systems was logged but was only used to facilitate data cleaning.

[1] *"Meeting the Accuracy Challenge in Airborne LIDAR Bathymetry", Gary C. Guenther, A. Grant Cunningham, Paul E. LaRocque, David J. Reid*

POSITIONING EQUIPMENT

Multibeam Vessels

Each vessel was equipped with an Applanix Position and Orientation System for Marine Vessels (POS/MV) to measure and calculate each position. Position was determined in real time using a NovAtel GPS-502 L1/L2 antenna, which was connected to a NovAtel Millennium GPS card residing in the POS/MV. The POS/MV was configured to accept USCG differential corrections, which were output from a CSI MBX-3S Coast Guard beacon receiver. This unit also provided the position and velocity values to the POS/MV's Inertial Measurement Unit (IMU). The inertial navigation system, implemented by the POS/MV, computes a position by way of a complex form of dead reckoning using the GPS position, heading, and motion of the IMU.

An MBX-S differential receiver that used the U.S. Coast Guard (USCG) network of differential beacons was the source of RTCM (Radio Technical Commission for Maritime Services) corrections for real-time positioning.

To improve accuracy by implementing post-processed GPS, it was necessary to acquire dual frequency GPS data at known locations on the ground so that a Kinematic GPS (KGPS) solution could be used for final positioning. LCMF established two local control points: both on the Sitka Airport Property, adjacent to the runway. Refer to Appendix B of the OPR-O112-KR&L-04 "Horizontal and Vertical Control Report" for procedures and results.

The numerous real time displays of the POS/MV controller software were monitored throughout the survey to ensure that the positional accuracies specified in the NOS Hydrographic Surveys Specifications and Deliverables (version March 2003) were achieved. These include, but are not limited to the following: GPS Status, Position accuracy, Receiver Status (which included HDOP) and Satellite Status. During periods of high HDOP and/or low number of available satellites survey operations were suspended.

LIDAR

The aircraft was equipped with an Applanix Position and Orientation System for Airborne Surveys (POS/AV). The Applanix POS/AV 410 measured orientation (roll, pitch and heading) as well as position. The system consists of a POS/AV computer with a NovAtel Millennium GPS card, a NovAtel 512 airborne L1/L2 GPS antenna, and an Inertial Measuring Unit (IMU). The IMU is permanently mounted within the SHOALS-1000T sensor. It uses a series of linear accelerometers and angular rate sensors that work in tandem to determine orientation. The orientation information is used in post-processing to determine position of the laser spots. However, analog data from the POS/AV was also used during acquisition to maintain a consistent laser scan pattern.

Data received by the airborne system was continually monitored for data quality during acquisition operations. Display windows showed coverage and other information concerning the system status. In addition, center waveforms at 5Hz were shown. This information allowed the airborne operator to assess the general quality of all data being collected.

Positioning was determined in real time using a NavCom StarFire SF2050M DGPS receiver. The NavCom SF2050-M received both L1/L2 and L band corrections from the StarFire network. An AeroAntenna AT-3065-9 antenna was used to acquire the differential corrections. Two differential receivers were available: the NavCom StarFire SF2050M and a CSI MBX-3S Coast Guard beacon receiver. The NavCom StarFire SF2050M was the primary source of differential corrections for this project.

However, final positions were determined using a post-processed Kinematic GPS solution. For this purpose LCMF established two local control points on the Sitka Airport Property, adjacent to the runway. Refer to Appendix B of the OPR-O112-KR&L-04 “Horizontal and Vertical Control Report” for procedures and results.

SOFTWARE

Multibeam Acquisition

The primary data sets were collected with Triton Elics International's Isis Sonar V 6.5, which was upgraded to record the UTC time stamp from the POS/MV to a Raw Navigation Packet. Isis Sonar operated on an Athlon 2800 Dual Processor PC running Windows 2000 and logged data in the XTF file format. The XTF files contain all multibeam bathymetry, position, attitude, heading and UTC time stamp data required by CARIS to process the soundings. Delph Map was utilized on the same computer to assist with real time QC of the acquired data.

The following display windows are available in Isis and Delph Map for operators to monitor data quality:

1. Parameter Display: The display window shows navigation, attitude and heading information. It gives the user the ability to switch files during data acquisition and also displays information on ping counts and file sizes.
2. View 2-D and 3-D: The 2-D window displays the current multibeam profile. The 3-D window displays a 3-D mesh of the current line of profiles. The data in both windows have attitude data applied for quality control purposes.
3. Waterfall: The Waterfall displays backscatter data.
4. Graph Window: The user can display the sensor data in a graphical format, which aids in determining heave filter settings for the HDMS and POS M/V.
5. Delph Map: Delph Map displays binned soundings in plan view or 3-D. The bin size is user defined and can be filtered by beam number and quality. Normally used to verify coverage.

The Quicksilver and the Kvichak Surveyor 1 were both equipped with an additional computer running WinFrog (version 3.4.0). This computer contained a Novatel GPS card and was used for helms display, line tracking, and general navigation.

WinFrog offers the following display windows for operators to monitor data quality:

1. Devices: The Devices window shows the operator which hardware is attached to the PC. It also allows the operator to configure the devices, determine whether they are functioning properly, and view received data.
2. Graphic: The Graphic window shows navigation information in plan view. This includes vessel position, survey lines, background vector plots and raster charts.
3. Vehicle: The Vehicle window can be configured to show any tabular navigation information required. Typically, this window displays position, time, line name, heading, HDOP, speed over ground, distance to start of line, distance to end of line, and distance off line. Many other data items are available.
4. Calculation: The Calculation window is used to look at specific data items in tabular or graphical format. Operators look here to view the status of the GPS satellite constellation and position solutions.

In addition to monitoring position, attitude, and heading accuracies, the Applanix POS/MV controller software was used to log raw POSMV data—consisting of the POSPac groups and group 3 (Primary GPS Data), 102 (Sensor 1 Data) and 111 (True Heave). The controller logged data to an external hard drive that was connected directly to the POSMV by SCSI interface. These data were collected at an interval of 50 Hz and later post-processed and applied in Caris HIPS.

MBSurvey Tools was used to aid in file administration and reporting during data acquisition. This program created a daily file that contained survey line, SVP and static draft logs. These logs were stored digitally thus eliminating the constant printing and manual input of items such as start and end of line times, Reson settings, etc. on each log sheet.

LIDAR Acquisition

The primary data sets were collected with the SHOALS-1000T Airborne Bathymetric and Topographic LIDAR control and data acquisition system (SCADA) using the 1kHz bathymetric laser (or hydro laser). The Pilots utilize a heads up display (HUD) display connected to the operators rack and is located in the cockpit for line tracking.

The following eight System Monitor display windows are available in the SHOALS-1000T Bathymetric and Topographic Lidar control and data acquisition system (SCADA) for operators to monitor data quality:

1. Main Display: This display summarizes functional information from the other displays.

2. Flightline Display: This displays the settings for the current flightline, entered in the ground control system (GCS) before the mission.
3. Algorithm Display: This displays data for each laser shot from the real-time airborne depth extraction algorithm.
4. Dropout Statistics Display: This displays the dropout statistics for the current flightline. Dropouts are laser shots for which the depth algorithm cannot produce a valid depth. All values are reset to zero when a new line is selected.
5. Laser + Receiver Display: This displays vital information such as energy levels and surface channel status from the laser and receiver that is fundamental to SHOALS – 1000 operation.
6. POS/AV Display: This displays useful positioning and orientation statistics from the POS/AV and GPS.
7. Drives Display: This displays the amount of space on two hard drives that has been used to record SHOALS – 1000 data in survey state. Data is recorded onto both drives in parallel.
8. Power Supplies Display: This displays the voltages being output by the SHOALS – 1000 power supplies, and the temperatures on the power supply boards.

In addition to the system windows listed, the operator also has a Real Time Chart display, Waveform Display, and Video Image windows. The chart display shows color depth soundings and swath coverage. The depths are color-coded numbers representing the depth in meters according to the color scale set by the operator. The waveform display, updated at 5Hz, shows the quality of the depths being collected, and helps to confirm that all four channels are producing good waveforms. The video window shows the digital camera images of the area, and is updated every second.

Multibeam Processing

All Soundings were processed using CARIS (Computer Aided Resource Information System) HIPS (Hydrographic Information Processing System) 5.3 and CARIS HDCS (Hydrographic Data Cleaning System). CARIS HIPS 5.4 was used to merge the multibeam data with the LIDAR data. Preliminary Smooth Sheet soundings were exported from HIPS, suppressed using CARIS GIS 4.4, imported into Microstation SE (V05.07.01.14) and tagged as specified in the NOS Hydrographic Surveys Specifications and Deliverables (version March 2003).

AutoDesk Map R 5.0 and ArcMap 9.0 were utilized for general survey planning, reviewing coverage plots, creating fill-in lines, tielines, etc.

ESRI ArcMap 9.0 with the Shoreline Correlator add-on was utilized for processing the additional item investigations DPs.

Applanix POSPac 4.1 was utilized for post-processing the dual frequency GPS data sets acquired by the survey vessels and the base stations. For every survey day and vessel, a new project was setup in POSPac. The software then extracted the POS data collected on the survey vessel into the POSPac project, separating it into component data sets such as IMU, primary GPS, and secondary GPS.

Using POSGPS—part of the POSPac suite—dual frequency GPS data from the vessels and ground control base station were converted from their native formats (NovAtel and Ashtech, respectively), to the POS GPS .gpb format. The KGPS data sets were then post-processed using the LCMF antenna phase center positions given in Appendix B of the Horizontal and Vertical Control Report.

The POSPac module POSProc then used the post-processed KGPS positions to process the POSMV attitude data and refine the inertial solution. The final solution was exported to an sbet.out file, which was then used by an in-house converter program that extracted the KGPS positions to be used in the Caris Generic Data Parser (GDP) program.

A complete summary of the GPS post-processing accuracy estimates can be found in Appendix C of the Horizontal and Vertical Control Report.

Applanix POS Convert 1.4 was used to extract True Heave data from the raw POS data collected on the survey vessels. This text file was applied to the CARIS lines after being parsed to a format acceptable by the CARIS Generic Data Parser using MBSurvey Tools.

LIDAR Processing

All soundings were processed using SHOALS GCS (Ground Control System) 5.16 and converted to CARIS HIPS 5.4. Preliminary Smooth Sheet soundings were exported from HIPS, suppressed using CARIS GIS 4.4, imported into Microstation SE (V05.07.01.14) and tagged as specified in the NOS Hydrographic Surveys Specifications and Deliverables (version March 2003).

SHOALS GCS Management And Planning Software (MAPS) 5.15 and ESRI ArcMap 9.0 were utilized for general survey planning.

Applanix POSPac 4.1 was utilized for post-processing the dual frequency GPS data sets acquired by the aircraft and the base stations. For every flight mission, a new project was setup in POSPac. The software then extracted the POS data collected on the aircraft into the POSPac project, separating it into component data sets such as IMU, primary GPS, and secondary GPS.

Using POS GPS—part of the POSPac suite—dual frequency GPS data from the aircraft and ground control base station were converted from their native formats (NovAtel and Ashtech, respectively), to the POS GPS .gpb format. The KGPS data sets were then post-processed using the LCMF antenna phase center positions given in Appendix B of the Horizontal and Vertical Control Report.

The POSPac module POSProc then used the post-processed KGPS positions to post-process the POS/AV attitude data and refine the inertial solution. The final solution was exported to an sbet.out file, which was then used by SHOALS GCS.

Interactive Visualization Systems, Inc. (IVS) Fledermaus 6.1.2e was used to edit the data auto-processed in SHOALS GCS.

Sound Velocity Profiles

Sound velocity profile (SVP) data from the Applied Microsystems Ltd. (AML) Smart Probes were acquired using Window’s HyperTerminal. MBSurvey Tools was used to split the profile into its up and down components, decimate the data, and write a CARIS format that contained time and position. A complete list of software and versions used on this project is included in Appendix A.

Refer to the “2004-NOAAProcessing Procedures” document for a detailed processing routine with procedures used.

B –Quality Control

MULTIBEAM DATA

In order for the XTF files collected by ISIS to be used by CARIS, they must be converted to HDCS format using an XTF converter routine. Prior to the XTF files being converted using the XTF to HDCS function, vessel offsets, patch test calibration values, and static draft were entered into the vessel configuration file.

Once converted, the SVP, Dynamic Draft, True Heave and KGPS data were loaded into each line and then SVP corrected in CARIS HIPS. The attitude, navigation and bathymetry data for individual lines were all examined for noise, as well as ensuring the completeness and correctness of the data set. Filter setting files used during processing of the 8101 and 8111 lines were: 60_012.hft and 65_012.hft, which rejected beams greater than 60 and 65 degrees past nadir and all soundings with a quality flag other than 3 (a quality flag is assigned to each sounding by the multibeam system). Data quality determined which filter setting file was applied. Note: “Rejected” does not mean the sounding data was deleted, but that it was flagged as being bad. Data flagged as rejected due to the angle from nadir parameters did contained valid data, but the routine was conducted to flag noise and increase the processing flow. Valid data could have been reinserted into the data set during line and subset editing to fill data gaps. The filter setting used were noted on each corresponding line log (refer to Separate 1).

In high noise areas additional filters may have been applied to specific sections or entire lines. In these instances, the additional filters were noted on the line logs (refer to Separate 1).

After each individual line was examined and cleaned in CARIS HIPS the tide zone file was loaded and the lines merged. Subsets were then created in CARIS HDCS Subset Edit mode and adjacent lines of data were examined to identify any tidal busts, sound velocity errors, roll errors, and to clean any remaining noise in the data set.

After subset cleaning, color and gray scale sun illuminated Digital Terrain Models (DTM's) were created in HIPS to aid in confirming coverage and to help detect any errors in SVP, attitude, tides, etc. The DTM's were created at various grid sizes as specified by the NOS Hydrographic Surveys Specifications and Deliverables. The DTM's were exported to GeoTIFF format and imported into AutoDesk Map for a final review of coverage and systematic errors.

A statistical analysis of the sounding data was conducted via the CARIS Quality Control Report (QCR) routine. Tie lines were run in each sheet and were compared with lines acquired from the main-scheme lines where applicable. The Quality Control Reports are in Separate 4.

Sounding data that passed the required quality assurance checks were imported into a CARIS HIPS workfile and shoal biased. The data were then suppressed using a constant term of 4 and a sounding size of 1.8mm in CARIS GIS using the Suppress Soundings program. Contours were generated in CARIS GIS at intervals specified in Appendix 8 in the NOS Hydrographic Surveys Specifications and Deliverables and were edited in Microstation SE and Microstation 8.1. Final shoal biased soundings and contours were saved and plotted in Microstation SE. Refer to Fugro Pelagos Inc. Document titled "2004-NOAAProcessingProcedures".

Additional item investigations were conducted on objects that required further action in order to be proven or disproved. A 15 ft. skiff, referred to as DP Skiff, was used to perform item investigations. The skiff was owned by Kvichak Marine and piloted by Fugro Pelagos personnel. The DP skiff could generally safely navigate in any area where it could maintain 0.5 meters of under-keel clearance, except in locations of heavy swells near shore. The skiff was equipped with a CSI GBX-PRO DGPS receiver, WinFrog v3.4.0 data acquisition system (operated on a Panasonic laptop) and a Sony digital camera. The LIDAR Smooth Sheet data (if available) and NOAA charts were displayed as a layer in WINFROG for reference. The DP skiff was outfitted with a fish finding sounder to help locate submerged features. However, a lead line was used to take soundings. Detached Positions (DPs) and their corresponding hydrographer's remarks were digitally recorded in WINFROG and digital photographs were taken for features when feasible.

ArcMap v9.0 with the Shoreline Correlator add-on (written by the Fugro Pelagos Inc. GIS department) aided in the processing of the investigation results. The Correlator utilized the Winfrog Log files to create an individual DP form for all acquired DPs. The correlator was mapped to the Winfrog log, tide, photos, NOAA Chart (largest scale available), LIDAR data, smooth sheet soundings and multibeam coverage files to calculate and display the desired information for each DP. Figure 1 shows an example of a DP form produced from the Correlator.

DP ITEM NUMBER : **JD244_11** DP Form

Date:	31 August, 2004
Julian Day:	244
UTC Time:	17:03:10
Latitude:	56 56 25.09 N
Longitude:	135 25 59.72 W
North:	6310824.32
East:	473638.55
Raw (+Depth) or (-Height) (m):	-1.52
Draft Corrector (m):	N/A
SV Corrector (m):	N/A
Tide Corrector (m):	-0.41
Corrected to MLLW (m):	-1.11
Corrected to MLLW (fathoms):	-0.61
Corrected to MLLW (feet):	-3.64

DP Comment: LARGE_CHTD_rock PH9 11 YDS 340 MAG 5 FT HIGH

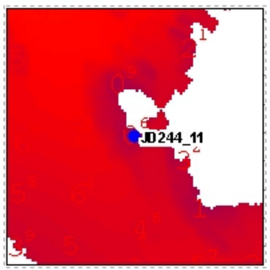
Correlating DP Item Numbers:

N/A	N/A
N/A	N/A

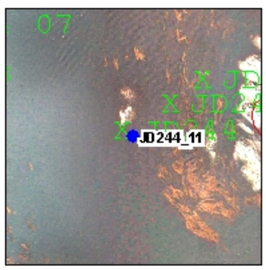
Correlating MB Least Depth:
None

Remarks/Recommendations:
None

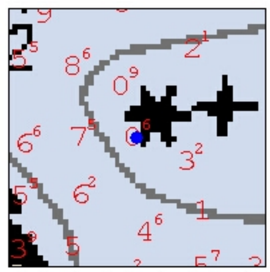
Chart: 17326_1 Topo: Carto Code: None



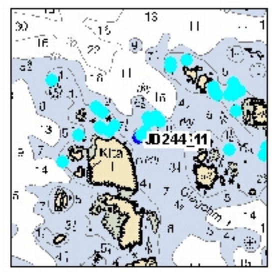
Multibeam Coverage & Smooth Sheet Soundings
200m x 200m



Ortho Mosaic
200m x 200m



NOAA Chart & Smooth Sheet Soundings
200m x 200m



NOAA Chart
2000m x 2000m

Figure 1 - DP Correlator Sheet

LIDAR DATA

Data were provisionally processed at the temporary office base in Sitka, Alaska, to determine data coverage. The remaining data were processed in Fugro Pelagos' San Diego office. An overall processing flow is given in Figure 2, below.

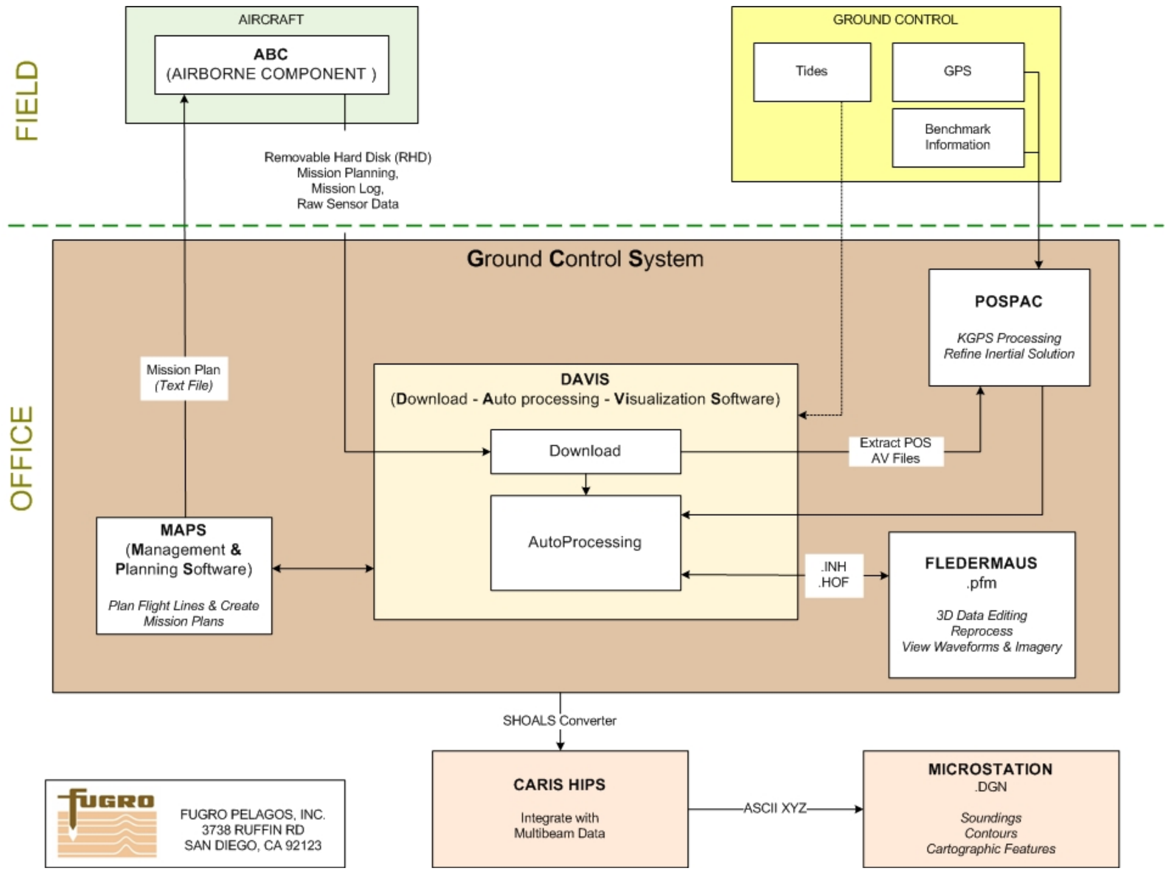


Figure 2 - Processing Data Flow

GROUND CONTROL

All data were processed using the Optech SHOALS-1000T Ground Control System (GCS) on Windows XP workstations. The GCS includes links to Applanix POSPac software for GPS and inertial processing, and IVS Fledermaus software for data visualization and 3D editing.

The GCS was used to process the KGPS and inertial solutions (via POSPac), apply environmental parameters, auto-process the LIDAR waveforms, apply the vertical datum offsets and tides, and edit data (via Fledermaus). The processed data was then converted to CARIS HIPS Version 5.4 and an ASCII file for MicroStation exported.

The LIDAR dataset was processed as two datasets, by splitting the data as Hydro data and Topo data. This was done since tides could not be applied to the Topo data. The Hydro data was processed using kinematic positioning (horizontal) and tide data (vertical) while the Topo data was processed using kinematic data for both horizontal and vertical datums. In order to apply kinematic data as the vertical datum, the Ellipsoid to MLLW relationship had to be determined.

LCMF established the Ellipsoid to MLLW relationship in Sitka to be -0.50m. Therefore if the survey area was only in the immediate vicinity of Sitka then any data referenced to the Ellipsoid could be corrected to MLLW by simply applying this straight offset.

To examine the relationship, two multibeam datasets were created: one with tides as the vertical datum and the other with the Ellipsoid as the vertical datum. A gridded surface was created for each dataset and a difference surface between the two was calculated. In this way it became apparent that the relationship is not constant over this sheet—the difference map made it evident that though the relationship is indeed -0.50m in Sitka it becomes zero at the southwest corner of the sheet.

The difference map was then used to zone the Ellipsoid – MLLW separation. The zone correctors (in 0.05m increments) were applied to the LIDAR Topo data. Since the MLLW to MHW separation was established the Topo elevations were then referenced to MHW. An image of the Ellipsoid to MLLW relationship is shown below.

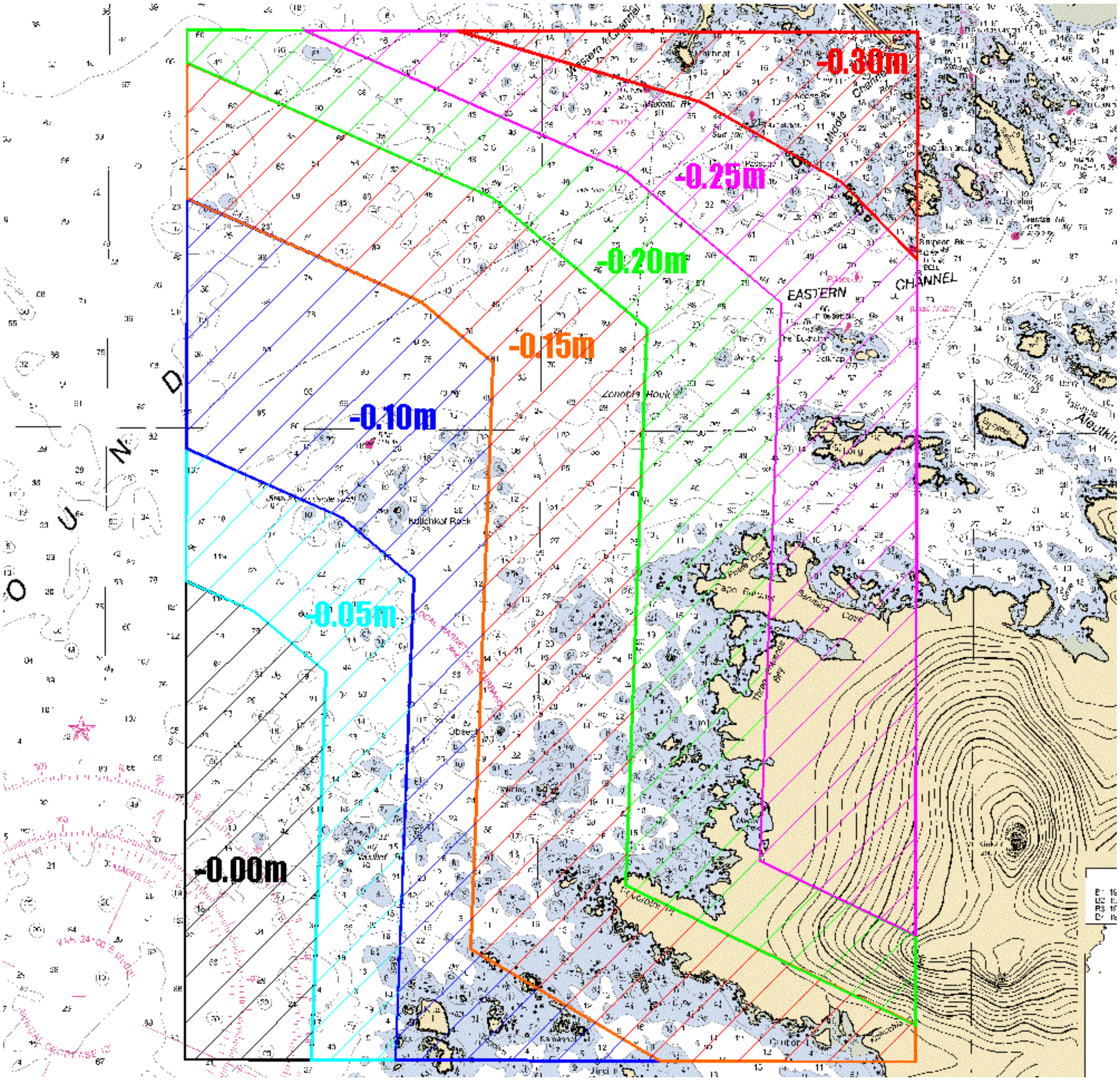


Figure 3 - MLLW - NAD83 Ellipsoid Relationship

For every flight mission, a project was set up in Applanix POSPac, version 4.1. POS/AV data downloaded from the air was extracted from DAViS (Download, Auto processing and Visualization Software) into the POSPac project. A copy of the native Ashtech GPS ground control files were also copied to the POSPac project directory. With POSGPS version 4.1, GPS data from the air and ground control base station were converted from the native NovAtel and Ashtech GPS formats respectively, to the POSGPS' .gpb format. The KGPS data was then post-processed using the LCMF antenna phase center positions (see Appendix B of the Horizontal and Vertical Control Report), as the master control coordinates. A summary of the GPS quality control processing results can be found in Appendix C of the Horizontal and Vertical Control Report.

The post-processed GPS positions were then used to process the POS orientation data and refine the inertial solution. The final solution was exported in a sbet.out file, which was then used by the GCS during LIDAR auto processing.

Once data had been downloaded to DAViS, hardware related calibration information was entered into the GCS. A list of the calibration values used can be found in Section C. In addition to the hardware values, some default environmental parameters were also set. Initially, the surface detection method was selected to use the Raman channel. If no Raman pick was found then the Infrared would be used, followed by the Green channel.

Before auto processing in the GCS, the tide zone file and tides (Hydro data) were imported into GCS and KGPS zones were also defined (for Topo data). Once calibration values were set, environmental parameters selected, tide and KGPS zones defined and KGPS data processed, the LIDAR data was auto processed using the GCS. The auto processing routine contains a waveform processor to select surface and bottom returns from the bathymetry data, and surfaces from the topographic data. In addition, it contains algorithms to determine position for each laser pulse.

The auto process algorithms obtained inputs from the raw data and calculated a height, position, and confidence for each laser pulse. This process, using the set environmental parameters, also performed a first cut at cleaning the data of poor land/seafloor detections. Questionable soundings were flagged as suspect, with attached warning information.

Data were then imported into a project PFM format file to allow data inspection and editing in Fledermaus.

Data visualization and editing was done using Fledermaus. Fledermaus was used to view a gridded surface of the entire dataset in 3D (Figure 4). Any areas with questionable soundings/elevations were then reviewed using the 3D area-based editor, which displayed each individual sounding in 3D (Figure 5). This was used on smaller subsets of the data. Gross fliers were rejected. Other data of uncertain quality requiring more examination were reviewed with the waveform window, showing shallow and deep channel bottom selections, and IR and Raman surface picks (Figure 6). Other metadata such as confidence and warnings are also incorporated into the viewer. In addition, the camera image associated with the laser pulse was displayed.

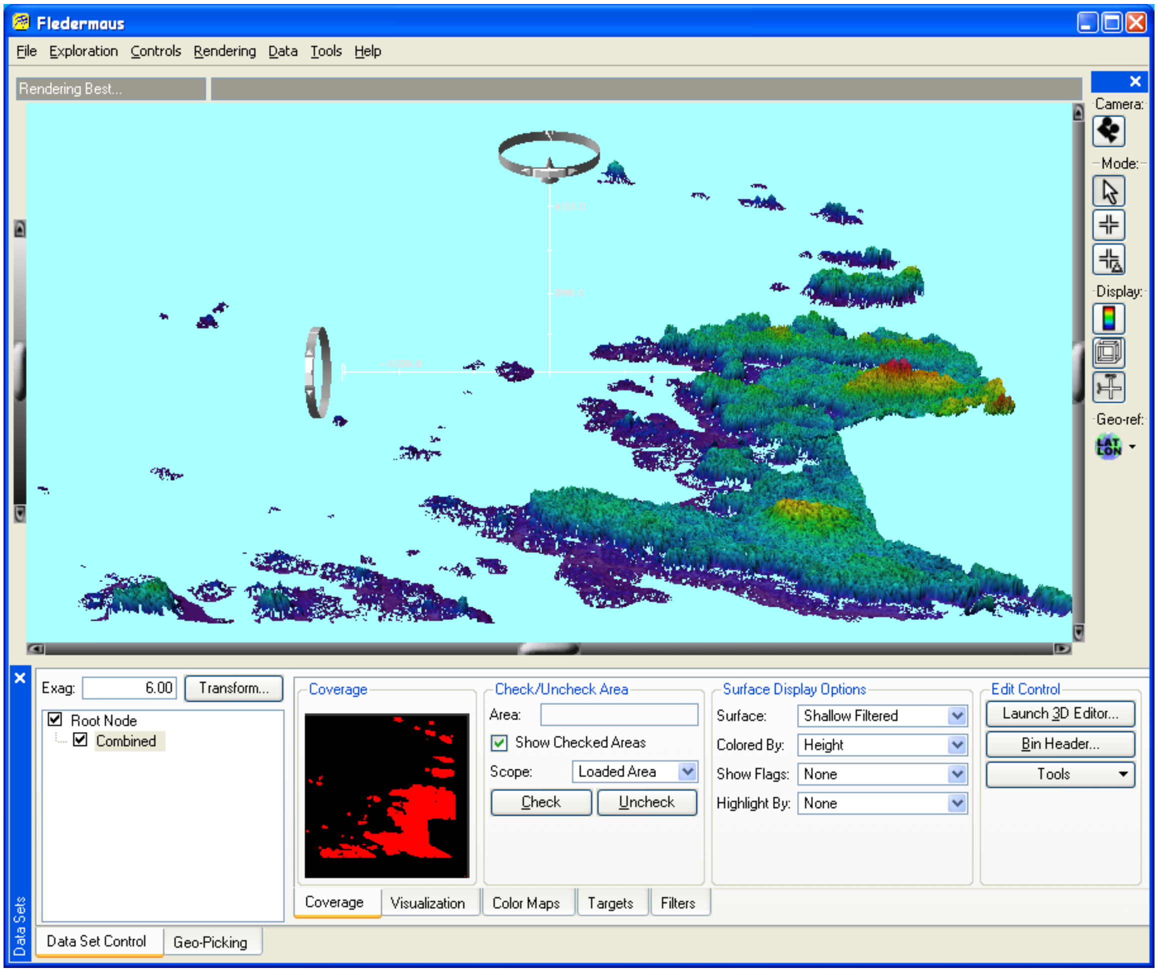


Figure 4 Viewing the Dataset Surface in Fledermaus

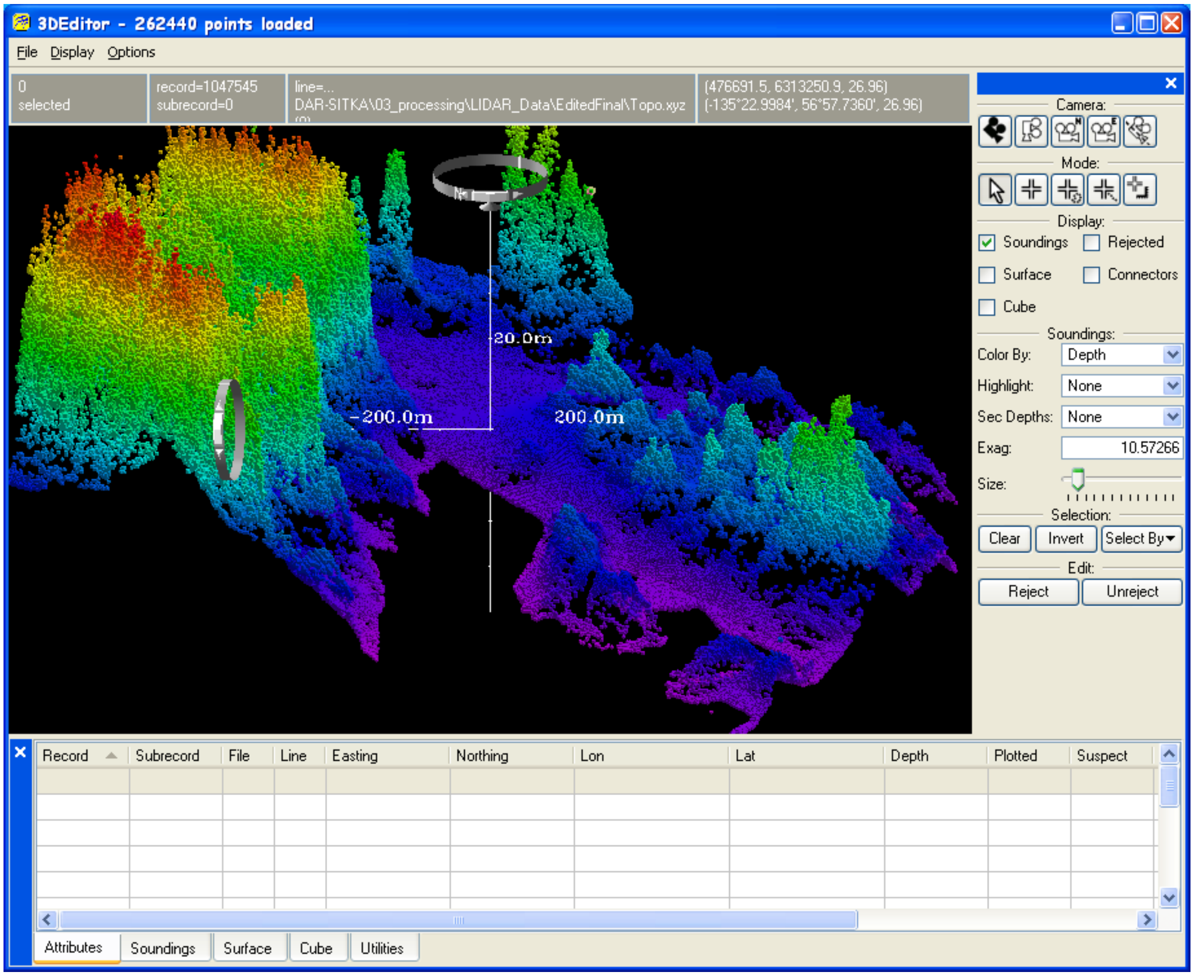


Figure 5 - Fledermaus 3D Editor

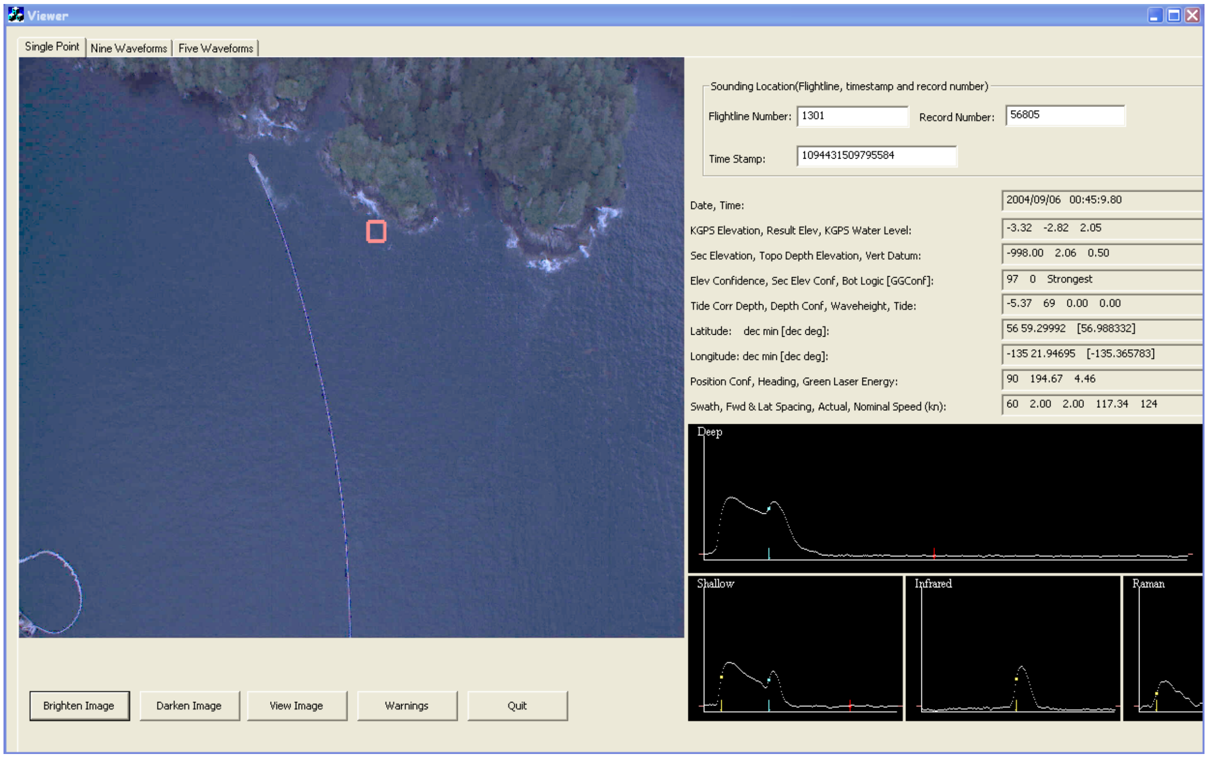


Figure 6 - Waveform Viewer

Other SHOALS specific tools, such as depth swapping (for handling second depth returns), were used inside Fledermaus.

Once all editing was completed in Fledermaus, the .HOF files were converted to CARIS HIPS Version 5.4 and exported to ASCII XYZ files. Exported data were in NAD83, with soundings and elevations relative to MLLW in fathoms. During the importing of this data into Microstation, elevations 2.25 feet above the MHW value were referenced to MHW. The data were transformed to the final charting datum, given in Table 1. Note that while these XYZ files are in meters the smooth sheet is in fathoms and feet.

Table 1 - Geodetic Parameters for Charting & Deliverables

Datum	North American Datum 1983
Projection	Geographic
Horizontal Units	N/A
Vertical Datum	Mean Lower Low Water (MLLW)
Vertical Units	Fathoms

A statistical analysis of the sounding data was conducted via the CARIS GIS QC Tool. Tie lines were run in the area and were compared with lines acquired from the main-scheme lines where applicable. The Quality Control Reports are in Separate 4.

Sounding data that passed the required quality assurance checks were imported into a CARIS HIPS workfile along with the multibeam soundings and shoal biased. The data were then suppressed using a constant term of 4 and a sounding size of 1.8mm in CARIS GIS using the Suppress Soundings program. Contours were generated in CARIS GIS at intervals specified in Appendix 8 in the NOS Hydrographic Surveys Specifications and Deliverables and were edited in Microstation SE and Microstation 8.1. Final shoal biased soundings and contours were saved and plotted in Microstation SE. Refer to Fugro Pelagos document titled "2004-NOAAProcessingProcedures".

Secchi Disk Readings

Secchi disc measurements were taken throughout the survey in various blocks in the survey area. A list of Secchi depth readings is provided in Table 2. Figure 7 shows what a typical disk measurement looks like. The Secchi disc is lowered slowly until it is just out of view. The depth is noted and the steps are repeated to assure accurate readings. As a rule of thumb, the SHOALS-1000T is capable of sensing the bottom to depths equal to three times the Secchi depth.

Secchi Disk clearly visible

Secchi Disk barley visible

Secchi Disk out of view

Figure 7 - Secchi Disk Measurement

Table 2 - Secchi Depth Readings

DATE	TIME	LATITUDE	LONGITUDE	SURVEY AREA	SECCHI DEPTH (m)
2004-234	0:36:17	56-59-59.37 N	135-28-07.08 W	BLOCK 1U08A	8.5
2004-234	16:45:52	56-59-40.27 N	135-24-49.83 W	BLOCK 1U08A	10.0
2004-234	18:55:16	56-59-30.96 N	135-24-50.43 W	BLOCK 1U08A	11.5
2004-234	21:05:09	56-59-18.46 N	135-26-03.09 W	1U08A / 1U06A	10.5
2004-234	22:50:05	56-59-19.12 N	135-26-00.12 W	BLOCK 1U06A	9.0
2004-235	0:55:09	56-57-44.51 N	135-28-27.78 W	BLOCK 1U06A	9.0
2004-235	16:35:09	56-57-25.01 N	135-27-57.04 W	BLOCK 1U06A	10.0
2004-235	18:37:39	56-57-26.65 N	135-27-59.08 W	BLOCK 1U06A	10.0

DATE	TIME	LATITUDE	LONGITUDE	SURVEY AREA	SECCHI DEPTH (m)
2004-235	21:33:48	56-57-41.54 N	135-25-58.52 W	BLOCK 1U06A	8.0
2004-236	1:28:08	56-56-52.86 N	135-27-10.65 W	BLOCK 1U06A	6.5
2004-236	16:22:41	56-57-31.20 N	135-25-37.05 W	BLOCK 1U06A	6.0
2004-236	20:25:26	56-56-12.19 N	135-27-06.06 W	BLOCK 1U06A	6.0
2004-236	23:52:32	56-56-52.99 N	135-35-32.28 W	BLOCK 1U06A	5.5
2004-237	2:10:11	57-00-10.57 N	135-22-58.11 W	BLOCK 1U04	7.0
2004-237	15:46:04	56-56-51.55 N	135-24-58.29 W	BLOCK 1U06A	4.0
2004-237	19:07:03	56-56-28.25 N	135-23-22.74 W	BLOCK 1U06A	3.5
2004-237	22:15:03	56-56-28.32 N	135-24-08.52 W	BLOCK 1U06A	4.5
2004-238	1:57:03	56-57-11.17 N	135-26-35.71 W	BLOCK 1U06A	4.5
2004-238	15:17:33	57-01-51.77 N	135-21-29.43 W	BLOCK 1U04	6.0
2004-238	15:30:19	57-00-28.05 N	135-23-38.33 W	BLOCK 1U04	6.0
2004-238	15:46:08	56-59-03.04 N	135-24-13.55 W	BLOCK 1U05	5.5
2004-238	17:31:06	56-57-19.76 N	135-25-02.83 W	BLOCK 1U05	5.5
2004-238	19:15:05	56-57-20.87 N	135-23-34.03 W	BLOCK 1U05	5.0
2004-238	21:10:05	56-57-28.05 N	135-23-31.39 W	BLOCK 1U05	4.5
2004-238	23:12:09	56-57-55-.88 N	135-23-48.47 W	BLOCK 1U05	6.0
2004-239	1:09:06	56-58-13.37 N	135-24-06.07 W	BLOCK 1U05	5.5
2004-239	15:12:56	57-01-51.67 N	135-21-32.00 W		7.5
2004-239	15:30:02	57-00-28.39 N	135-23-03.13 W		6.5
2004-239	15:44:32	56-59-01.28 N	135-24-12.65 W	BLOCK 1U05	7.0
2004-239	17:33:07	56-58-39.13 N	135-23-52.18 W	BLOCK 1U05	6.5
2004-239	19:14:43	56-58-50.13 N	135-23-30.14 W	BLOCK 1U05	4.5
2004-239	21:45:07	56-58-17.45 N	135-23-13.03 W	BLOCK 1U05	4.5
2004-239	23:50:05	56-58-59.57 N	135-24-56.83 W	BLOCK 1U05	7.0
2004-240	2:05:08	56-57-30.93 N	135-25-04.70 W	BLOCK 1U05	4.5
2004-240	15:25:32	57-00-28.10 N	135-23-05.79 W	BLOCK 1U02	4.5
2004-240	15:41:10	56-59-03.90 N	135-24-53.05 W	BLOCK 1U05	5.5
2004-240	17:27:06	56-58-44.39 N	135-24-40.54 W	BLOCK 1U05	7.0
2004-240	19:20:03	56-57-31.15 N	135-24-34.66 W	BLOCK 1U05	6.5
2004-240	21:05:13	56-59-35.17 N	135-24-04.51 W	BLOCK 1U05	6.5
2004-240	23:05:05	56-01-28.45 N	135-21-03.66 W	BLOCK 1U02	5.0
2004-241	0:06:11	56-01-20.80 N	135-21-54.58 W	BLOCK 1U02	6.0
2004-243	23:12:32	56-57-13.13 N	135-24-56.83 W	BLOCK 1U06	5.0
2004-244	0:56:04	56-56-26.67 N	135-25-11.80 W	BLOCK 1U06	6.5
2004-244	15:54:08	56-59-48.91 N	135-22-25.46 W	BLOCK 1U04	7.5
2004-244	16:39:58	57-01-16.08 N	135-24-02.54 W	BLOCK 1U03	8.5
2004-244	17:26:52	56-58-16.38 N	135-24-28.09 W	BLOCK 1U05	8.0
2004-244	18:35:10	56-57-55.31 N	135-27-37.11 W	BLOCK 1U06	8.0
2004-244	21:52:11	56-57-31.50 N	135-26-50.35 W	BLOCK 1U06A	7.5
2004-245	16:31:00	57-00-10.16 N	135-25-35.24 W	BLOCK 1U08	8.5
2004-245	18:00:41	56-59-43.43 N	135-26-25.48 W	BLOCK 1U08	10.5
2004-245	19:35:55	56-58-50.77 N	135-23-56.11 W	BLOCK 1U05	8.0
2004-245	21:03:54	56-57-24.17 N	135-23-48.73 W	BLOCK 1U05	7.5

C - Corrections to Soundings

SOUND VELOCITY PROFILES

To correct multibeam data for changes in sound velocity, sound velocity casts were performed nominally every two to three hours. The AML Smart Probes used to determine sound velocities for the surveys sampled at a rate of eight-velocity and pressure observation pairs a second. For each cast, the probes were held at the surface for two minutes to achieve temperature equilibrium. The probes were then lowered and raised slowly (no greater then 1 meter per second) to maintain equilibrium. Between casts, the sound velocity sensors were stored in a barrel of fresh water to minimize salt-water corrosion and to hold them at ambient water temperatures. Refer to Appendix C for Calibration Reports.

SETTLEMENT CURVE

The squat settlement tests for the R/V Quicksilver were conducted in Sand Point, AK on May 20, 2004 (Julian Day 141).

To perform the squat settlement test, the R/V Quicksilver logged dual frequency (L1/L2) data on the POS/MV. The squat settlement tests were performed by first establishing a 500 meter line in the direction of the current. The survey vessel occupied the south end of the line for two minutes while logging L1/L2 GPS data. The line was run heading north at an engine rate of 600 RPM, then south along the line at the same rate, stopping at the south end of the line to obtain an additional two minutes of ‘static’ L1/L2 GPS data. The scenario repeated at incrementing engine RPM’s until the full range of possible survey speeds was covered. The entire series was done twice on the R/V Quicksilver—with and without roll depressors deployed.

All measurements were corrected for pitch and roll and reduced to the vessel’s common reference point (CRP) during processing in Applanix POSPac V4.1. Heave was removed by averaging the altitude data for each RPM and static set. Static measurements observed at the end of lines were used to establish tidal correctors to apply to the squat settlement test data. A settlement curve for the Quicksilver, with the Reson 8101 installed, was then calculated from the corrected KGPS-derived altitude data in Excel.

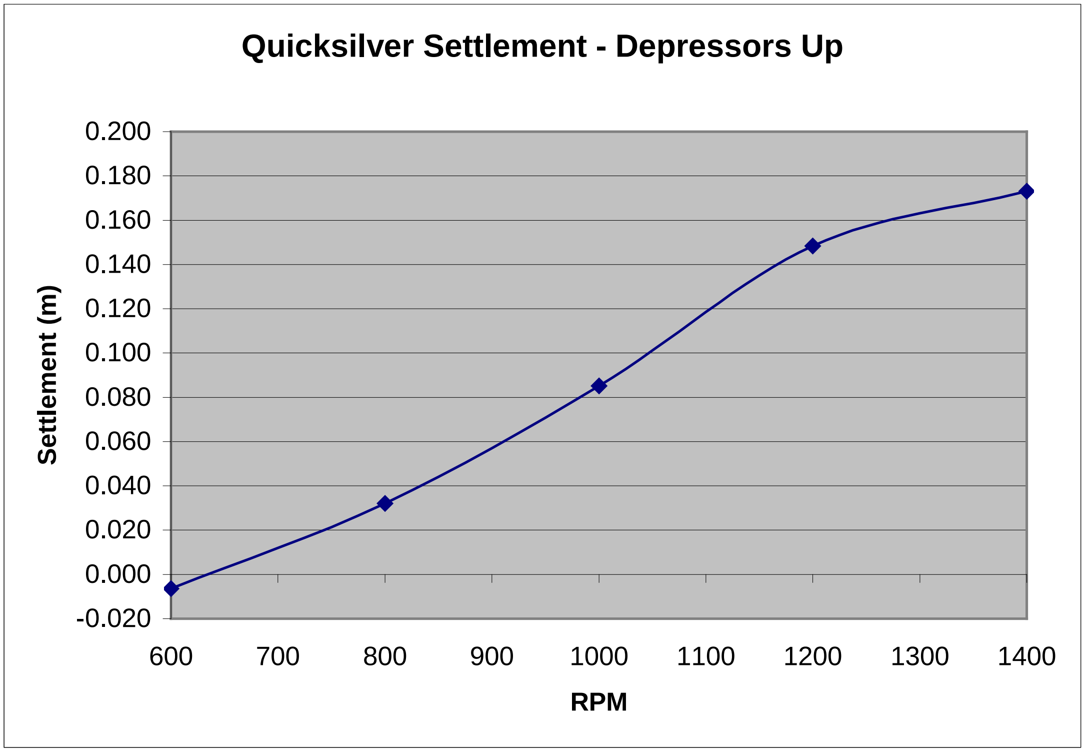


Figure 8 - R/V Quicksilver Settlement Curve (with Depressors Up)

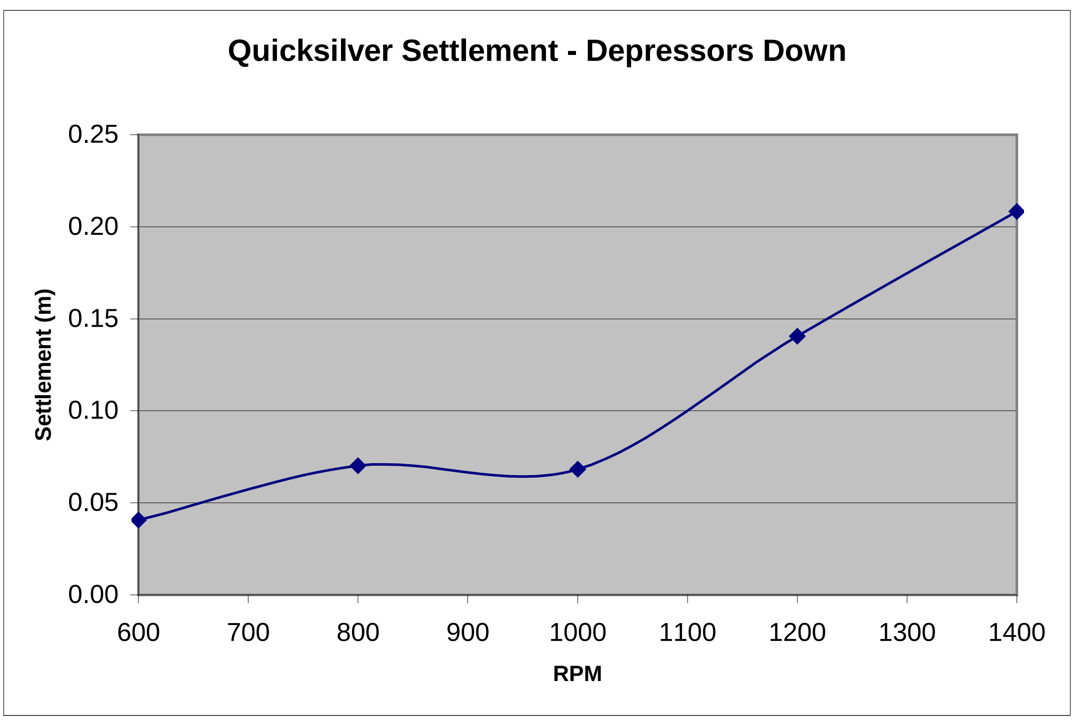


Figure 9 - R/V Quicksilver Settlement Curve (with Depressors Down)

The results of the squat settlement test for the Reson 8101 are shown below.

Table 3 - R/V Quicksilver Squat Settlement Results

QUICKSILVER-8101 CALCULATED SETTLEMENT		
RPM	DEPRESSORS UP	DEPRESSORS DOWN
600	-0.01	0.04
800	0.03	0.07
1000	0.09	0.07
1200	0.15	0.14
1400	0.17	0.21

Note: Vessel speed was noted on the survey line logs (refer to Separate 1).

The squat settlement test for the R/V Kvichak Surveyor 1 was conducted in Sand Point, AK on June 8, 2004 (Julian Day 160).

To perform the squat settlement test, the R/V Kvichak Surveyor 1 logged dual frequency data on the POS/MV. The squat settlement tests were performed by first establishing a 500 meter line in the direction of the current. The survey vessel occupied the south end of the line for two minutes while logging L1/L2 GPS data. The line was then run heading north at an engine rate of 700 RPM and then south at 700 RPM, stopping at the south end of the line to obtain an additional two minutes of ‘static’ L1/L2 GPS data. Again, the survey vessel occupied the south end of the line and the scenario repeated at incrementing engine RPM’s.

All measurements were corrected for pitch and roll and reduced to the vessel’s common reference point (CRP) during processing in Applanix POSPac V4.1. Heave was removed by averaging the altitude data for each RPM and static set. Static measurements observed at the end of lines were used to establish tidal correctors to apply to the squat settlement test data. A settlement curve for the Kvichak Surveyor I, with the Reson 8111 installed, was then calculated from the corrected KGPS-derived altitude data in Excel.

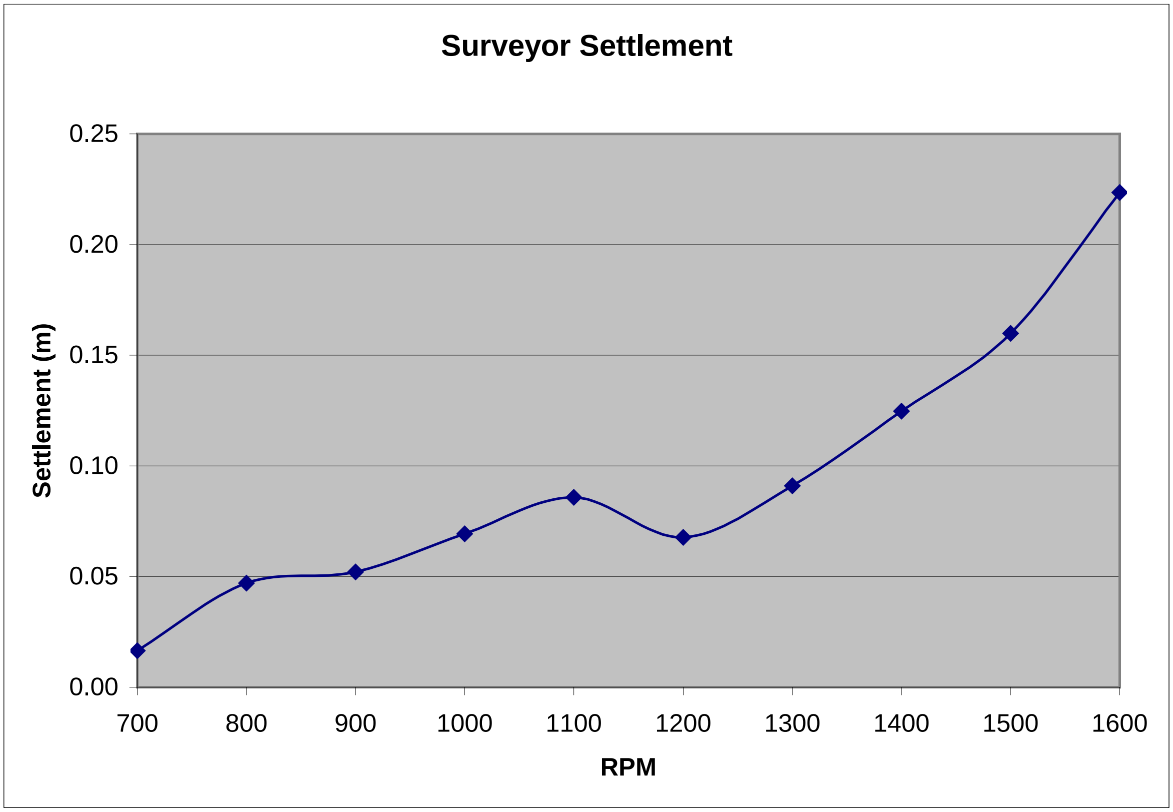


Figure 10 - R/V Kvichak Surveyor 1 Settlement Curve

The results of the squat settlement test for the Reson 8111 are shown bellow.

Table 4 - R/V Kvichak Surveyor 1 Squat Settlement Results

KVICHAK SURVEYOR 1-8111 CALCULATED SETTLEMENT	
RPM	
700	0.02
800	0.05
900	0.05
1000	0.07
1100	0.09
1200	0.07
1300	0.09
1400	0.12
1500	0.16
1600	0.22

Note: Vessel speed was noted on the survey line logs (refer to Separate 1).

STATIC DRAFT

Static draft was measured from tabs on both sides of the vessels, the average was taken, and then the correction to the common reference point was applied. The table below shows the draft values for the R/V Quicksilver used in data processing.

Table 5 - Draft Measurements for the R/V Quicksilver (8101)

DRAFT #	JULIAN DAY	TIME (UTC)	DEPTH (m)
1	2004-230	15:00	-0.42
2	2004-231	15:00	-0.41
3	2004-232	15:00	-0.42
4	2004-233	15:00	-0.39
5	2004-234	15:00	-0.39
6	2004-235	15:00	-0.39
7	2004-236	15:00	-0.38
8	2004-237	15:00	-0.39
9	2004-238	15:00	-0.43
10	2004-239	15:00	-0.43
11	2004-240	15:00	-0.42
12	2004-241	15:00	-0.43
13	2004-242	15:00	-0.41
14	2004-243	15:00	-0.41
15	2004-244	15:00	-0.395
16	2004-245	15:00	-0.38
17	2004-246	15:00	-0.38
18	2004-247	15:00	-0.415
19	2004-258	15:00	-0.42
20	2004-259	15:00	-0.42

The table below shows the draft values for the R/V Kvichak Surveyor 1 used in data processing.

Table 6 - Draft Measurements for the R/V Kvichak Surveyor 1 (8111)

DRAFT #	JULIAN DAY	TIME (UTC)	DEPTH (m)
1	2004-208	15:00	0.53
2	2004-209	15:00	0.53
3	2004-210	15:00	0.545

TIDES

All sounding data were reduced to MLLW initially using unverified tidal data from the NOAA tide station (ID# 9451600), located in Sitka, AK.

Smoothed tidal data for a twenty-four hour period, UTC (Alaska Standard Time to UTC was +8 hours), was assembled by LCMF and e-mailed to the Sitka office at the end of every Julian Day. A cumulative file for each gauge was updated each day by appending the new data.

On September 24, 2004, LCMF issued verified tidal data from the NOAA tide gauge for OPR-O112-KR&L-04. On September 25, 2004 all multibeam sounding data were re-merged using CARIS HIPS tide routine. On January 25, 2005, using the GCS, the tide zone file and tides were imported into GCS and all LIDAR sounding data were tide corrected. Verified tidal data was used for the Preliminary Smooth Sheet.

VESSEL ATTITUDE: HEADING, HEAVE, PITCH, AND ROLL

Vessel heading and dynamic motion were measured by the POS/MV for the OPR-O112-KR&L-04 survey. The system calculated heading by inversing between two NovAtel GPS generated antenna positions. An accelerometer block (the IMU), which measured vessel attitude, was mounted directly over the multibeam transducer on each vessel. The operational accuracy specifications for this system, as documented by the manufacturer, are as follows:

Table 7 - POS/MV Specifications

POS/MV Accuracy	
Pitch and Roll	0.035°
Heading	0.05°
Heave	5% or 5-cm over 20 seconds

AIRCRAFT ATTITUDE: HEADING, PITCH, AND ROLL

Aircraft heading and dynamic motion were measured by the POS/AV for the OPR-O112-KR&L-04 survey. An accelerometer block (the IMU), which measured aircraft attitude, was mounted directly inside the sensor unit within the SHOALS-1000T system. The operational accuracy specifications for this system, as documented by the manufacturer, are as follows:

Table 8 - POS/AV Specifications

POS/AV Accuracy	
Pitch and Roll	0.008°
Heading	0.015°

MULTIBEAM PATCH TEST

A patch test is conducted to identify alignment errors (timing, pitch, heading and roll) between the motion sensor and the multibeam transducer. Note: The patch tests that were conducted for the R/V Quicksilver and R/V Kvichak Surveyor 1 during OPR-P183-KR-04 (Shumagin Islands and Vicinity) to derive timing, pitch, heading, and roll errors was also used for OPR-O112-KR&L-04 (Approaches to Sitka). These values were then enter into the vessel configuration files for each vessel and utilized in the routine processing for OPR-O112-KR&L-04 (Approaches to Sitka).

Additional patch tests were conducted during the course of the survey for quality control and testing purposes, but the derived values did not change and were therefore not entered into the vessel configuration file and not used in processing. Patch test calibration values used to correct all soundings for the survey were as follows:

Table 9 - Patch Test Results for Quicksilver Reson 8101

Patch Test Results for Quicksilver Reson 8101 May 12th, 2004 (2004-133)		
Test	**CARIS Session**	**Mean Correction**
Navigation Timing Error	Patch_133_Nav	0.00 seconds
Pitch Offset	Patch_133_Pitch	0.25°
Azimuth Offset	Patch_133_Yaw	1.4°
Roll Offset	Patch_133_Roll	-0.78°

Table 10 - Patch Test Results for the Kvichak Surveyor 1 Reson 8111

Patch Test Results for Kvichak Surveyor 1 Reson 8111 May 29th, 2004 (2004-150)		
Test	**CARIS Session**	**Mean Correction**
Navigation Timing Error	Patch_150_Nav	0.00 seconds
Pitch Offset	Patch_150_Pitch	-0.60°
Azimuth Offset	Patch_150_Yaw	-1.10°
Roll Offset	Patch_150_Roll	-0.25°

LIDAR SYSTEM CALIBRATION

Careful alignment of the various Hydro subsystem components is performed in the laboratory prior to airborne use (Note: no documented report issued). However, there remain small residual angular offsets that are impossible to measure there with sufficient accuracy, so airborne data is collected for their determination.

The Hydro subsystem calibration is broken into the following groups

1. Angular Calibration
2. Vertical Accuracy
3. Horizontal Accuracy

4. Underwater Vertical Accuracy

The Angular calibrations are carried out by collecting data over a suitable water surface, preferably on a calm day. The data is then analyzed in SHOALS GCS to derive the Angular calibration values. This is done by analyzing small sections of data at a time, such that the applied Angular values cause the water surface to be flat and un-tilted.

The angular calibration values (as obtained above), when applied to the data creates a flat and un-tilted surface. Vertically, however, it could be offset from the absolute elevation. To remove this residual vertical error, the angular calibration is combined in an iterative method with comparisons between the LIDAR derived elevations over a previously surveyed land surface (an airport runway is often used as the land surface). The angular offsets and the vertical offsets of the system are fully determined when any altitude dependence of the elevation differences between the two data sources are removed.

The horizontal accuracy is checked by collecting data over a recognizable manmade feature, such as a large building with well-defined corners. The LIDAR points at the corners of the building are compared to the known coordinates to determine the horizontal accuracy. No horizontal offsets were required for to achieve horizontal position accuracy requirements—the angular calibration values were sufficient to satisfy the requirements.

Finally the underwater vertical offsets are determined by collecting data over a previously surveyed seafloor (derived from multibeam sonar). As with the land-based vertical offset comparisons, the LIDAR data is compared to the multibeam sonar derived surface. A vertical depth offset is then calculated to produce agreement between the LIDAR and the multibeam surfaces.

As with the Hydro subsystem, the down looking cameras internal parameters are determined through laboratory measurements (refer to Appendix C for calibration procedures and results). In addition to the laboratory measurements the camera needs to be bore sighted with the rest of the system. Collecting flightlines with camera imagery over a recognizable feature in four directions does this. A set of camera pointing angles is derived such that the recognizable feature is in the same location regardless of the flight direction.

The ERDAS Image V8.7 software was utilized to create the orthomosaic that was used for the mapping and verifying of shoreline features. The accuracy of the orthomosaic is apparent when viewing photos from reciprocal lines in the orthomosaic, the horizontal alignment of distinct features are well within IHO Order 1 (+5m). The positional accuracy of the orthomosaic was verified by a ground truth method via the Skiff. In areas where it was safe to navigate, the Skiff obtained horizontal positions on rocks that were clearly defined on the orthomosaic and the results were well within the IHO Order 1 specifications.

Table 11 - SHOALS-1000T Calibration Values

SHOALS-1000T (SYSTEM 3) CALIBRATION VALUES August 7th, 2004	
Angular Calibration (degrees)	
Rcvr_horiz_misalign_angle	-0.108
Rcvr_vert_misalign_angle	0.472
Imu_sensor_pitch_offset	-0.353
Scan_x_yaw_misalign_angle	-0.180
Vertical Offsets (meters)	
Bathy_topo_bias_200	-0.250
Bathy_topo_bias_300	-0.250
Bathy_topo_bias_400	-0.250
Underwater Vertical Offsets (meters)	
Deep_bias_left_200	0.270
Deep_bias_right_200	0.250
Deep_bias_left_300	0.230
Deep_bias_right_300	0.210
Deep_bias_left_400	0.220
Deep_bias_right_400	0.190
Apriori_depth_bias_shallow	-0.130
Apriori_depth_bias_deep	-0.130
Camera Calibration Values (degrees)	
Camera_boresight_roll	-0.200
Camera_boresight_pitch	11.300
Camera_boresight_heading	0.000

ADDITIONAL SOUNDING METHODS

Hand lead lines are simple, accurate and are not subject to breakdown. It is however, awkward to use and inconvenient in bad weather. Additionally, it is difficult to determine if the sounding obtained was the shoalest point of the feature, if the feature cannot be visually seen. The lead line was used on the project to conduct additional item investigations on LIDAR data that required further action to be proven or disproved. Also, to assist the hydrographer in locating targets near the surf zone or areas of limited visibility, a Hummingbird Piranha Max15 fish finding sounder was added as an aid.

The actual measurement tool utilized for this survey was not a traditional lead line with the standardized markings, but a strong cloth/vinyl tape measure on a winding reel. A round 3-pound lead ball was affixed to the end of the tape which was shortened so that the bottom of the ball was the zero point at touchdown. This was then checked and confirmed using a standard marked survey rod. Additional QC of the lead line measurements were conducted by comparison to actual swath bathymetry where applicable.

The maximum sounding depth taken was 10.8 fathoms but the majority of the confirmations were made in sub-fathom depths. Stretch of the actual lead line was not measurable and considered negligible.

The Hummingbird Sounder used could not be accurately compensated for draft or skiff motion. It was used primarily as a search tool to locate the shoalest point for the leadline sounding, no soundings from this sounder were used on the smooth sheet.. In areas that a leadline sounding could not be taken safely or accurately, the analog displayed depth on the sounder was recorded to allow trend comparison to Lidar survey data. Calibration of the sounder was conducted by comparison to leadline readings in flat benign areas in depths up to 3 fathoms.

Note: All lead line measurements were recorded directly to the water line and corrected for tide. Lead line soundings present on the smooth sheets are tagged in the digital files and can be differentiated from the multibeam sounding by the vessel name, which in this case is the DP Skiff.

Specifications of the Hummingbird Piranha Max 15 sounder are as follows:

Table 12 - Max 15 Sounder Specifications

Depth Capability:	600 feet/100 fathoms
Display Window Size:	3 7/8” Diagonal
Display Matrix:	160V x 132H
Display Type:	4 Level Grayscale High Contrast FSTN LCD
Power Output:	100 Watts (RMS) & 800 Watts (Peak to Peak)
Operating Frequency:	200kHz & 83 kHz
Sonar Coverage:	20° & 60° @ -10db
Transducer:	Transom Mount
Power Input Range:	10-20 VDC
Mounting:	Easy On, Easy Off Tilting Mount
Unit Size:	4 3/8” W x 6 1/8”H x 3 ¼”D

D - Approval Sheet

Approval Sheet

For

H11354

Standard field surveying and processing procedures were followed in producing this survey in accordance with the following documents:

> OPR-O112-KR&L-04 statement of work and hydrographic manual;
> Fugro Pelagos, Inc. Acquisition Procedures (2004- NOAAAcquisitionProcedures);
> Fugro Pelagos, Inc. Processing Procedures (2004-NOAAProcessingProcedures);

The data were reviewed daily during acquisition and processing.

This report has been reviewed and approved. All records are forwarded for final review and processing to the Chief, Pacific Hydrographic Branch.

Approved and forwarded,

Dean Moyles, Fugro Pelagos, Inc.
Lead Hydrographer
Fugro Pelagos, Inc. Survey Party

Appendix A – Equipment List and Software Versions

Equipment

Table A1 – Multibeam Equipment Used

System	Manufacturer	Model	Serial No.
Multibeam Sounder	Reson	SeaBat 8101 Processor	12945
		SeaBat 8101 Transducer	1600001
		8101 Firmware Dry: 8010-2-07-2D4D	
		Wet: 8101-1-06-2F6B	
Multibeam Sounder	Reson	SeaBat 8111 Processor	23279
		SeaBat 8111 Transducer Array	Transmit/Receive
			0100050/0700016
		8111 Firmware Dry: 8111-2.07-996C Wet: 8111-1.00CA00	
POS/MV	Applanix	Firmware Model 320: Ver 2.08	711
POS/MV	Applanix	IMU	078
POS/MV	Applanix	Firmware Model 320: Ver 2.08	692
POS/MV	Applanix	IMU	135
POS/MV	Applanix	Firmware Model 320: Ver 2.08	577
POS/MV	Applanix	IMU	241
GPS Receivers	Novatel	Novatel GPS Card, PC Series	450017
GPS Receivers	Novatel	Novatel GPS Card, PC Series	96230005
GPS Receivers	Novatel	Novatel GPS Card, PC Series	450024
GPS Antenna	Novatel	L1/L2	10080
GPS Antenna	Novatel	L1/L2	5029448
GPS Antenna	Novatel	L1/L2	5029447
GPS Antenna	Novatel	L1	14370531
GPS Antenna	Novatel	L1	17769531
GPS Antenna	Novatel	L1	13625531
Smart Sensor	Applied Microsystems Ltd.	Smart Sound Velocity and Pressure	4298-SV&P
Smart Sensor	Applied Microsystems Ltd.	Smart Sound Velocity and Pressure	4821-SV&P
Smart Sensor	Applied Microsystems Ltd.	Smart Sound Velocity and Pressure	4820-SV&P
Smart Sensor	Applied Microsystems Ltd.	Smart Sound Velocity and Pressure	4704-SV&P
Smart Sensor	Applied Microsystems Ltd.	Smart Sound Velocity and Pressure	4300-SV&P
Smart Sensor	Applied Microsystems Ltd.	Smart Sound Velocity and Pressure	4932-SV&P
CTD Profiler	Sea-Bird Electronics	SBE 19 Plus	290
RTCM	CSI Inc.	CSI MBX-3	9841-2496-0002
RTCM	CSI Inc.	CSI-MBX-3	9833-2166-0001
RTCM	CSI Inc.	CSI MBX-3	9932-4356-0001
RTCM	CSI Inc.	CSI-MBX-3	0042-7227-0001
RTCM	CSI Inc.	CSI MBX-3	9830-2023-0001
RTCM	CSI Inc.	CSI-MBX-3	9834-2211-0002
DGPS	CSI Inc.	GBX PRO	0031-6753-0001
Digital Camera	JVC	JVC	117J3562
Laptop	Panasonic	CF-72	CF-72TCJWZEM
Control Station	Ashtech	Z Surveyor	UZ01376
Control Station	Ashtech	Z Surveyor	UZ01605
Control Station	Ashtech	Z Surveyor	UZ01364
Control Station	Ashtech	L1/L2 GPS Antenna	MA15345
Control Station	Ashtech	L1/L2 GPS Antenna	MA15352
Control Station	Ashtech	L1/L2 GPS Antenna	MA15340

LIDAR Equipment

Table A2 – Lidar Equipment Used

System	Manufacturer	Model	Serial No.
SHOALS-1000T	Optech	SHOALS-1000T	System 3.0
Digital Camera	DuncanTech	DuncanTech DT4000	534
POS/AV	Applanix	Firmware Model 410	609
POS/AV	Applanix	IMU	404247
GPS Antenna	AeroAntenna	AT 2775	5070
AeroAntenna	Aero	AT-3065-9	5848
NavCom StarFire	NavCom Technology, Inc.	StarFire SF2050M	1000
Radio Beacon	CSI Inc.	CSI-MBX-3	0314-11467-0001

Multibeam Software

Triton Isis V 6.5
Delph Map V 2.9.0.21
Winfrog V 3.4.0
HPTools V 8.9.5
CARIS Hips/Sips V 5.3 (w/ Service Pack 3)
CARIS GIS V 4.4a (w/ Service Pack 4)
MapInfo Professional V 5.0
AutoDesk Map R 5.0
MBSurvey Tools V1.0
File Convert V 1.0
Chart-X V 2.6
Microstation SE V 05.07.01.14
Microstation V 08.01.02.15
POS/MV V3 Controller V1.4
ESRI Arc Map V9.0
Correlator V1.0
POSConv v1.4
POSPac 4.1

LIDAR Software

GCS V 5.16
IVS Fledermaus 6.1.2e
CARIS Hips/Sips V 5.4 (w/ Service Pack 1)
Microstation SE V 05.07.01.14
Microstation V 08.01.02.15
POSPac 4.1
ESRI Arc Map V9.0
ERDAS Image V8.7

Appendix B – Vessel Descriptions

R/V Quicksilver

The R/V Quicksilver (Figure B1) was modified to accommodate a survey crew and acquisition hardware. The keel was cut just aft of mid-ship and a Reson 8101 multibeam sonar was installed. A conical cowling protected the sonar head forward and aft by a crescent shaped skid (Figure B2). The accelerometer package for a POS/MV was mounted in the hull of the vessel just over the 8101 multibeam transducer head.

Three Novatel antennas were mounted above the 8101 and accelerometer for positioning and heading (Figure B3). The two POS/MV antennas were offset 0.6m either side of the central antenna. The port side antenna (L1/L2) functioned as the POS/MV master antenna; the starboard side antenna functioned as the POS/MV secondary. The central antenna was used in Winfrog for helmsman display only.

The AML Smart Probe SV&P sensors and the CTD were deployed from an A-Frame on the stern using a small hydraulic winch.

The Quicksilver was fitted with depressors. These devices are simply weighted, bird shaped pieces of steel that hang in the water on either side of the vessel. The depressors' primary function was to reduce vessel roll. The Quicksilver was operated with the depressors deployed or stowed depending on sea conditions. The status of the depressors was noted on all survey line logs, and appropriate corrections made for dynamic draft in CARIS.

Offset values were applied to the data in CARIS HIPS as specified in the vessel configuration file (VCF). Vessel offsets used are shown in the following table. Note that the VCF does not contain navigation offsets because the position provided by the POS/MV is already corrected to the CRP.

Table B1 - Vessel Offsets (Quicksilver)

Quicksilver Vessel Offsets				
From	**To**	**X**	**Y**	**Z**
CRP	IMU – POS/MV	0.00	0.00	0.00
CRP	Reson 8101 Transducer	0.03	-0.16	0.57
CRP	Navigation GPS Antenna	0.05	0.00	-4.77
CRP	GPS1 – Master Antenna	-0.55	0.00	-4.77
CRP	GPS3 – Slave Antenna	0.65	0.00	-4.76
CRP	Draft Measuring Point, Port	-2.35	0.15	-1.84
CRP	Draft Measuring Point, Starboard	2.35	0.15	-1.84

Note: All units are meters.
CRP is the top-center of the IMU.
Axis used: X positive toward Starboard
Y positive toward Bow
Z positive in to the water

Table B2 - Vessel Specifications (Quicksilver)

Survey Launch	F/V Quicksilver
Official Number	947419
Owner	Marcus Ballweber
Year Built	1989
Length	32 ft
Beam	15.5 ft
Draft	3 ft
Gross Ton	28
Net Ton	15
Mechanical Power	860 hp
Electrical	5kW

Figure B1 - R/V Quicksilver

Figure B2 - Hull Mounted Reson 8101 (Quicksilver)

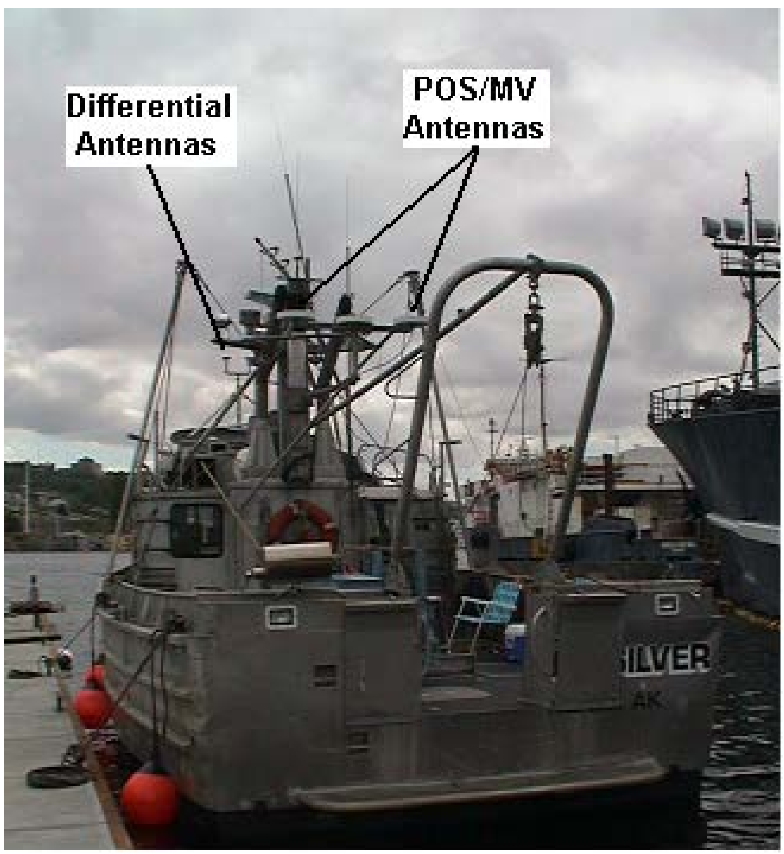


Figure B3 - Differential and POS/MV Antennas (Quicksilver)

R/V Kvichak Surveyor 1

The R/V Kvichak Surveyor 1 (Figure B4) accommodated survey crew and acquisition hardware. The vessel was reconfigured with a moon pool (Figure B5) and fitted with a survey strut and support configuration just aft of the main cabin. This housed the 8111 (Figure B6), POS/MV IMU and the POS/MV GPS antennas.

Two Novatel GPS antennas were mounted on a plate on the top of the survey strut above the 8111 and accelerometer for positioning and heading. The POS/MV master antenna was positioned on the port side of the mount and the secondary antenna was positioned on the starboard side of the mount (Figure B7). An additional GPS antenna was place on the starboard side of the wheelhouse and was used in Winfrog for helmsman display only (Figure B8). The POS/MV IMU was installed in a watertight compartment 3.033m above the Reson 8111 (Figure B9). The sonar mount was designed to house the Resons' 8101, 8111 and 8160.

During the design and fabrication of the survey strut and support tower (Figure B10), to ensure that the pole would not vibrate and could be deployed in the same position every time, a system of clamps and wedges were installed. The support tower had three levels above the deck, each with a clamping mechanism, which was held fixed on the starboard side and tightened from the port side to hold it in place (Figure B11). In the moon pool a rugged brace was fabricated to prevent vibration and to hold the sonar in the same position on every deployment (Figure B12). In addition to this, the marine engineers at Kvichak Marine designed vortex generates which were simply pieces of 1" X 12" angled aluminum, that were fabricated to the front of the survey strut. These were designed to interrupt the flow of water around the strut to prevent any oscillation.

The AML Smart Probe SV&P sensors and the CTD were deployed from an A-Frame on the stern using a hydraulic winch.

Offset values were applied to the data in CARIS HDCS as specified in the vessel configuration file (VCF). Vessel offsets used are shown in the following table. Note that the VCF does not contain navigation offsets because the position provided by the POS/MV is already corrected to the CRP.

Table B3 - Vessel Offsets (Kvichak Surveyor 1)

Kvichak Surveyor 1 Vessel Offsets				
From	**To**	**X**	**Y**	**Z**
CRP	IMU – POS/MV	0.000	0.000	0.000
CRP	Reson - 8111 Transducer	0.100	0.243	3.033
CRP	GPS 1 - Master Antenna	-0.812	-0.115	-3.745
CRP	GPS 3 - Slave Antenna	0.718	-0.176	N/A
CRP	GPS 2 - WinFrog	2.060	10.568	N/A
CRP	Draft Measuring Point, Port	-3.586	0.072	-1.695
CRP	Draft Measuring Point, Starboard	3.602	0.092	-1.695

Note: All units are meters.
CRP is the top-center of the IMU.
Axis used: X positive toward Starboard
Y positive toward Bow
Z positive in to the water

Table B4 - Vessel Specifications (Kvichak Surveyor 1)

Survey Launch	Kvichak Surveyor 1
Number	1154556
Owner	Kvichak Marine Industries
Year Built	2001
Length	66.7 ft
Beam	24.6 ft
Draft	5.5 ft
Engines	Cat 3196 (660 hp)
Electrical Power	32 kW

Figure B4 - R/V Kvichak Surveyor 1

Figure B5 - Moon Pool Trap Door

Figure B6 - Reson 8111 Mount

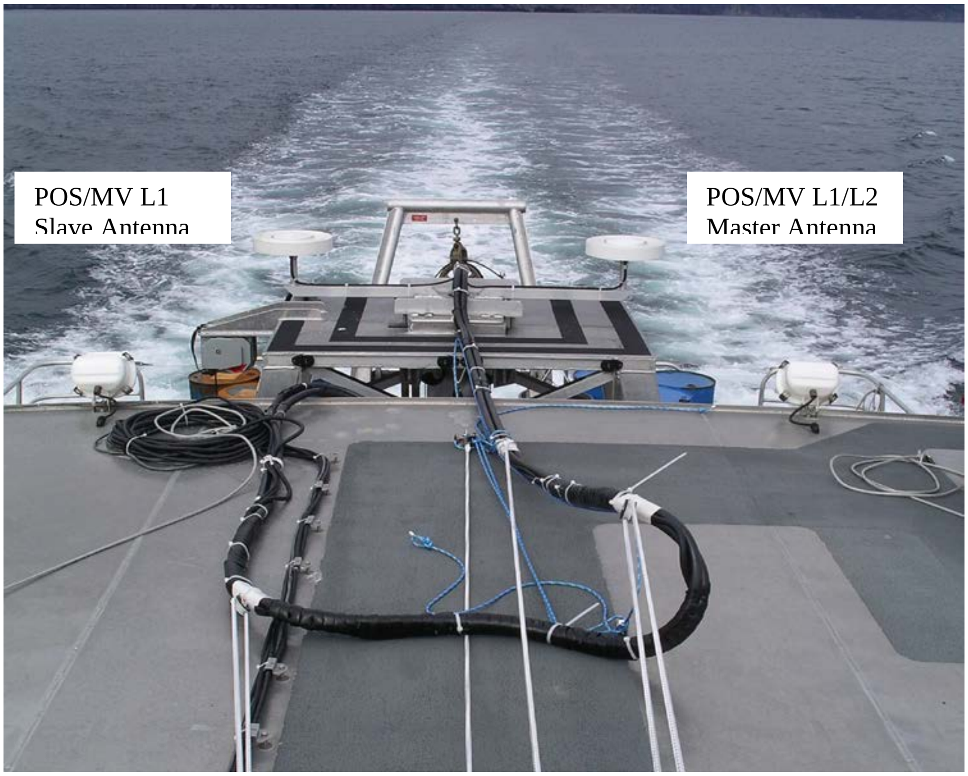


Figure B7 - POS/MV Antennas (Kvichak Surveyor 1)

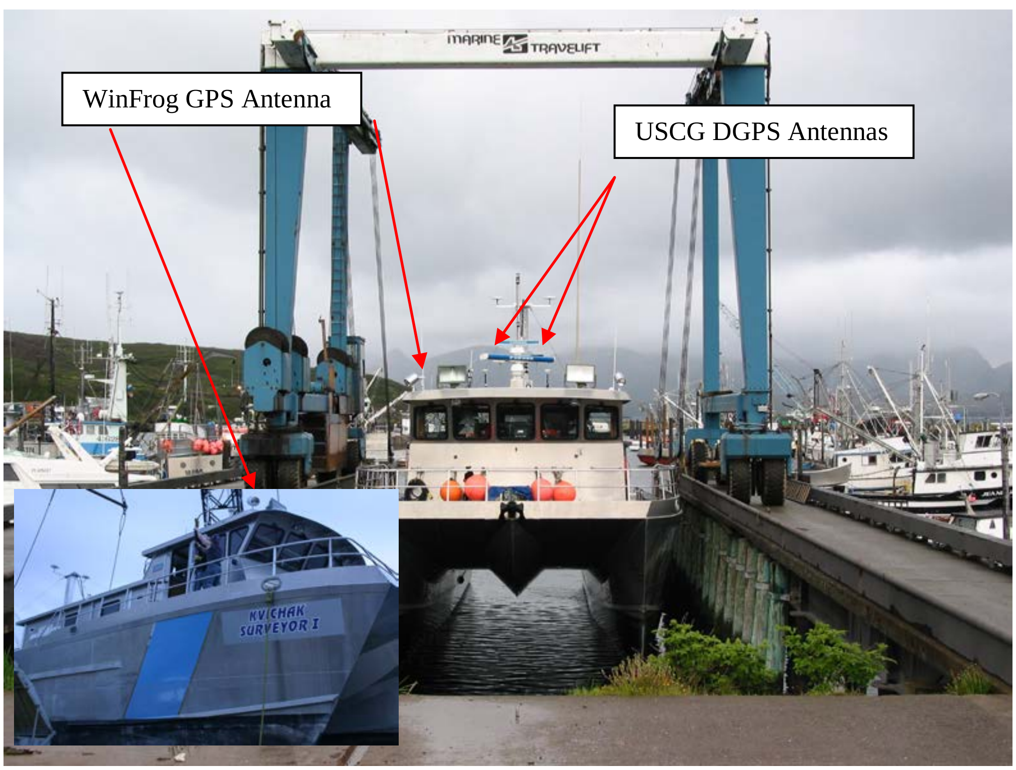


Figure B8 - Winfrog GPS Antenna

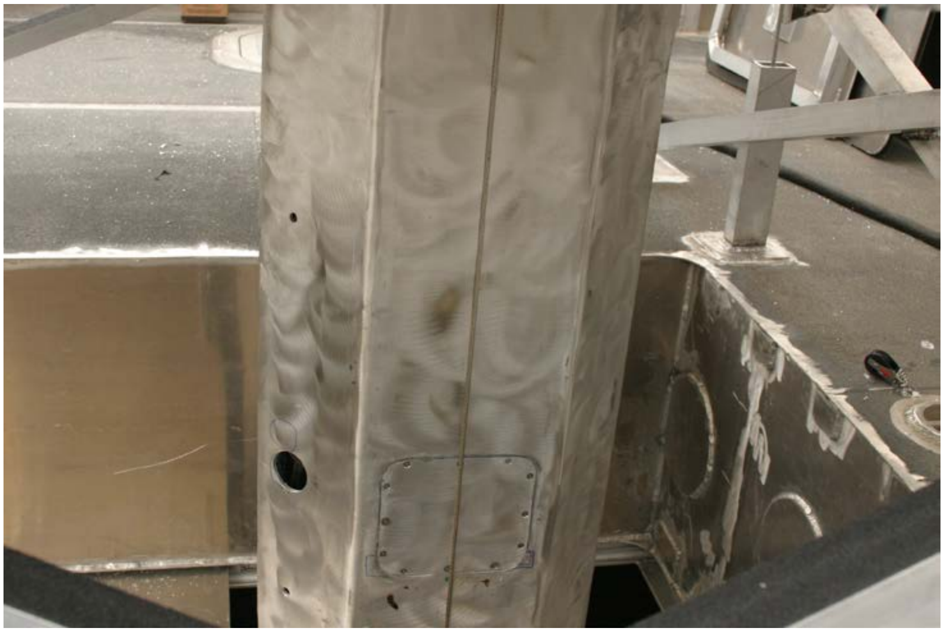


Figure B9 - POS/MV IMU Watertight Compartment

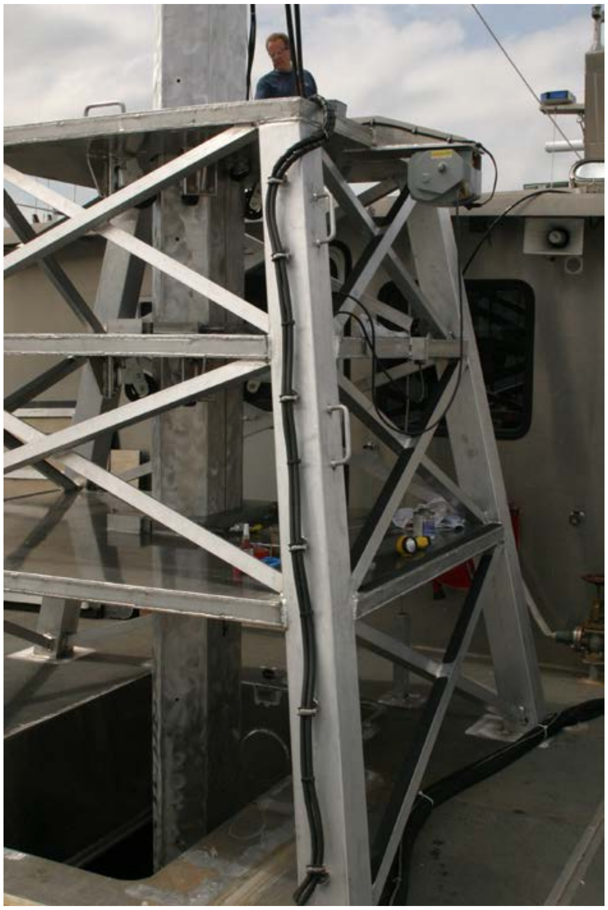


Figure B10 - Survey Strut, Support Tower and Winch

Figure B11 - Strut Clamp

Figure B12 - Moon Pool Clamp

LIDAR

The Beechcraft King Air 90 (Figure B13) was modified with a camera door in the AFT starboard side floor, in which the SHOALS-1000T Bathymetric and Topographic LIDAR System could be mounted. Technical specifications for the plane can be found in Table B5 below. The aircraft was mobilized at Buttonville Airport, Ontario, Canada with the assistance of Optech staff. The airborne component of the SHOALS-1000T consists of three separate modules. The lasers and camera are housed in a single package that was bolted to a flange above the aircraft camera door (Figure B14). An equipment rack, containing the system cooler and power supplies, was installed aft of the laser (Figure B15). The operators console was attached to the seat rails foreword of the power supply. The console was installed so the operator was facing forward (Figure B16). All hardware was located on the starboard side of the aircraft. Equipment installation required about 2 hours.

The only offset measurement required during system mobilization is from the POS AV Inertial Measurement Unit (IMU) to the POS AV GPS antenna. The IMU is completely enclosed within the laser housing. The offsets from the IMU to a common measuring point (CMP) on the outside of the housing are known.

Offsets were measured using a total station. An arbitrary base line was established along the port side of the aircraft. Ranges and bearings were measured from the total station to the CMP on the top of the laser housing (Figure B18). Additional measurements where made to the sides and top of the housing to determine its orientation. A final measurement was made to the center of the POSMV GPS antenna (Figure B17). The IMU to POS AV GPS offsets are calculated using the known IMU to CMP offsets. A summary of the offset measurements can be found in (Table 13) below.

Table B5 - Aircraft Offsets

OFFSET	X	Y	Z
IMU to CMP	0.073	-0.230	-0.415
CMP to POS AV GPS Antenna	-0.526	0.073	-0.953
IMU to POS AV GPS Antenna	-0.453	-0.157	-1.368

The offsets from the IMU to the POS AV GPS antenna are entered in to the POS AV console prior to survey.

Table B6 - Beechcraft King Air (N80Y)

Airplane	Beechcraft king air
Official Number	N80Y
Owner	Dynamic Aviation
Wing Span	47 ft 10.5 in
Length	35 ft 6 in
Gross Weight	9,650 lbs
Typical Empty Weight	5,150 lbs
Survey Mode Duration	~4-5 hours
Engine	PT6A-20 (Jet)

Figure B13 - Beechcraft King Air (N80Y) at Sitka Airport

Figure B14 - Lasers and camera

Figure B15 - System cooler and power supplies

Figure B16 - Operators console

Figure B17 - NovAtel GPS Antenna and Aero DGPS Antenna locations

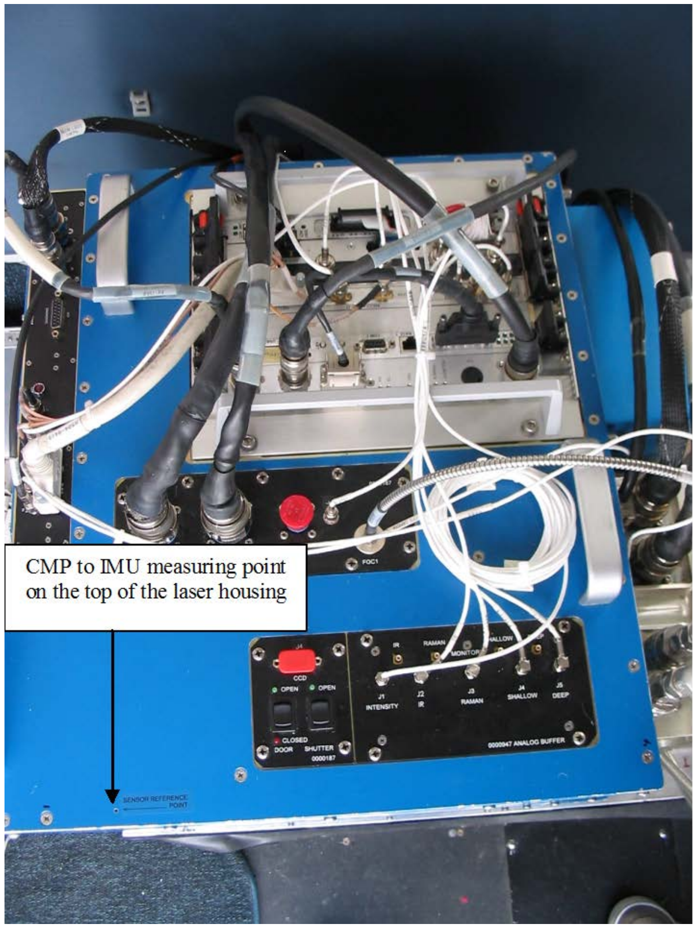


Figure B18 - CMP to IMU measuring point

Appendix C – Calibration Reports

Appendix D – Survey Strut Operation

A] Transiting with strut stowed

1) Strut must be in raised position, pinned and clamped in upper three locations
2) Strut head rope stays must be in place and tight
3) Hoisting winch cable must be snug but not tight, winch breaker off
4) Moon pool door must be closed, both lines winched tight and cleated off

B] Deploying strut

Maximum vessel speed while deploying strut is 2.0 knots

Deploy strut while vessel is oriented straight downwind if possible

1) Verify winch circuit breaker on, test winch momentarily in down and up directions
2) Check that transducer cables are free and clear
3) Loosen three upper strut clamps, pry clamps apart if necessary to avoid binding
4) Open moon pool door
5) Remove stainless steel safety pin through strut
6) Lower strut so that lower clamp settles into wedge support blocks
7) Partially close the moon pool door to provide access to the lower clamp assembly
8) Check alignment of lower clamp assembly into supports & loosen lower clamp bolts
9) Lower strut to fully deployed position
10) Ensure that lower clamp assembly is fully seated into lower supports with rubber coated mallet, tighten the lowest set of clamps
11) Remove rope stays & secure the strut head bracket atop the tower
12) Tighten the remaining three strut clamps, ensure that clamping bolts are tightened evenly
13) Open fully and secure the moon pool door
14) Slightly tension cable with winch to eliminate flow induced vibration

C] Operations with strut deployed

Maximum engine speed with strut deployed is 1300 RPM

Maximum vessel speed with strut deployed is 13.0 knots through the water

D] Retracting strut

Maximum vessel speed when retracting the strut is 2.0 knots

Retract strut while vessel is oriented straight downwind if possible

1) Shut down survey transducer
2) Check winch power, ensure breaker is switched on
3) Momentarily test winch in down direction, then tension cable
4) Loosen the clamp device at the strut head atop the tower
5) Partially close the moon pool door and secure
6) Loosen the upper three strut clamps, pry clams apart if necessary to avoid binding
7) Once the assembly is slightly free from lower supports, loosen the lowest strut clamp
8) Open the moon pool door completely
9) Attach rope stays
10) Raise strut until lowest clamp lightly contacts underside of lowest tower platform and tighten
11) Raise strut slightly to assist the release of the lower clamp from support blocks. It may be necessary to free lower assembly with rubber-coated mallet.
12) Install stainless steel safety pin through strut
13) Secure all four clamps on the strut, tighten bolts evenly to properly clamp strut
14) Close moon pool door, winch both lines tight and cleat off, tension all four strut rope stays

Appendix E – Background theory on bathymetric LIDAR