Cover Sheet (NOAA Form 76-35A)

NOAA FORM 76-35A

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

Data Acquisition and Processing Report

Type of Survey HYDROGRAPHIC

Field No OPR-Q191-KR-12

Registry No. H12439, H12440, H12441, H12442, H12443, H12444, & H12445

LOCALITY

State ALASKA

General Locality Krenitzin Islands

Sublocality Areas in and around Akun, Avatanak, and Tigalda Islands

2012

CHIEF OF PARTY

Dean Moyles

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DATE..

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Title Sheet (NOAA Form 77-28)

NOAA FORM 77-28 (11-72) U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION **HYDROGRAPHIC TITLE SHEET**	REGISTER NO. H12439, H12440, H12441, H12442, H12443, H12444, & H12445
INSTRUCTIONS – The Hydrographic Sheet should be accompanied by this form, filled in as completely as possible, when the sheet is forwarded to the Office	FIELD NO.

State ALASKA

General Locality Krenitzin Islands

Locality Areas in and around Akun, Avatanak, and Tigalda Islands

Scale 1:40,000 Date of Survey 06/16/2012 – 07/09/2012

Instructions dated June, 2012 Project No. OPR-Q191-KR-12

Vessel F/V PACIFIC STAR (556510), R/V R2 (623241), R/V D2 (647782)

Chief of party Dean Moyles

Surveyed by MOYLES, REYNOLDS, FARLEY, ROKYTA, LYDON, TIXIER, MOUNT, FAIRBANK, et al.

Soundings taken by echo sounder, hand lead, pole RESON SEABAT 7111 (PACIFIC STAR, HULL MOUNT), RESON SEABAT 7101 (R2 & D2, HULL MOUNT)

Graphic record scaled by FUGRO PELAGOS, INC. PERSONNEL

Graphic record checked by FUGRO PELAGOS, INC. PERSONNEL

Protracted by N/A Automated plot by N/A

Verification by

Soundings in METERS at MLLW

REMARKS: The purpose of this work is to provide NOAA with modern and accurate hydrographic survey data for the area extending from Tigalda Island to Rootok Island.

ALL TIMES ARE RECORDED IN UTC.

FUGRO PELAGOS INC.

3574 RUFFIN ROAD

SAN DIEGO, CA 92123

A – Equipment

The F/V Pacific Star (with launches R2 and D2) acquired all sounding data for this project. The equipment list and vessel descriptions are included in Appendices I and II.

Sounding Equipment

F/V Pacific Star, 162 feet in length with a draft of 16 feet, was equipped with a hull mounted Reson SeaBat 7111 multibeam echosounder system for the OPR-Q191-KR-12 project. The Reson 7111 system operates at a frequency of 100 kHz and forms 301 beams at a 1.5° spacing (across-track), with maximum swath coverage of 150°. Operating modes such as range scale, gain, power level, ping rates, etc. were a function of water depth and data quality and were noted on the survey line logs (see the Descriptive Report Separate 1). All 7111 multibeam data files were logged in the s7k format using WinFrog Multibeam v3.09.21.

R/V R2, a Pacific Star launch, is 29 feet in length with a draft of 3 feet. For this survey, R2 was equipped with a hull mounted Reson SeaBat 7101 multibeam echosounder. The Reson 7101 on R2 was fitted with a stick projector and operated at a frequency of 240 kHz. The system forms either 239 or 511 beams across a 150° swath width. All 7101 multibeam data files were logged in the s7k format using WinFrog Multibeam v3.09.21.

R/V D2, a Pacific Star launch, is 29 feet in length with a draft of 3 feet. For this survey, D2 was equipped with a hull mounted Reson SeaBat 7101 multibeam echosounder. The Reson 7101 on D2 was fitted with a stick projector and operated at a frequency of 240 kHz. The system forms either 239 or 511 beams across a 150° swath width. All 7101 multibeam data files were logged in the s7k format using WinFrog Multibeam v3.09.21.

The line orientation for all vessels was generally parallel to the coastline and bathymetric contours of the area. The line spacing was dependent on water depth and data quality, with an average line spacing of two to three times water depth.

The following table summarizes the sonar models and configurations used on each survey vessel.

Table 1 Vessel Sonar Summary

Vessel Sonar Summary			
Vessel	**Pacific Star**	**R2**	**D2**
Mount Type	Hull	Hull	Hull
Sonar System	Reson 7111	Reson 7101	Reson 7101

Backscatter Imagery

Towed Side Scan Sonar (SSS) operations were not required by this contract, but the backscatter and beam imagery snippet data from all multibeam systems were logged and are stored in the s7k files. All beam imagery snippet data was logged in the 7028 record of the s7k file for the project.

Sound Velocity Profilers

F/V Pacific Star was equipped with an Underway CTD (UCTD) from OCEANSCIENCE for the acquisition of sound velocity profiles. Sound velocity casts were normally performed every two to three hours on the Pacific Star. The UCTD uses a custom freefall CTD probe manufactured by industry leader Sea-Bird Electronics. Using field-proven and very accurate conductivity, temperature, and pressure sensors, the UCTD delivers very precise, high quality results. The internal electronics and exposed sensor components are carefully designed to withstand deployment and recovery at speeds up to 20 kts. Sampling at 16 Hz, overall depth resolution of below 25 cm is attained at a drop speed of approximately 4 m/s. The specifications of the CTD probe sensors are shown below.

Table 2 UCTD Specs

	Conductivity (S/m)	Temperature (C)	Depth (dbar)	Salinity (PSU)
Resolution	0.0005	0.002	0.5	0.005
Accuracy - Raw Data	0.03	0.01 - 0.02	4	0.3
Accuracy - Processed Data	0.002-0.005	0.004	1	0.02 - 0.05
Range	0 - 9	-5 - 43	0 - 2000	0 - 42

The R/Vs R2 and D2 were each equipped with two AML 1000 dbar Sound Velocity & Pressure (AML SV&P) Smart Sensors. The AML SV&P directly measures sound velocity through a time of flight calculation, and measures pressure with a temperature compensated semiconductor strain gauge at a 10Hz sample rate. The instrument has a 0.015m/s resolution with a ±0.05m/s accuracy for sound velocity measurements and a 0.01 dbar resolution and a ±0.5m dbar accuracy for pressure. The instruments were mounted within a weighted cage and deployed using a hydraulic winch that contained 350m of shielded Kevlar reinforced cable via a stern mounted A-Frame.

Fugro Pelagos' MB Survey Tools was used to check the SV profiles graphically for spikes or other anomalies, and to produce an SVP file compatible with CARIS (Computer Aided Resource Information System) HIPS (Hydrographic Information Processing System). The WinFrog Multibeam acquisition package also provided quality control (QC) for surface sound velocity.

This was accomplished by creating a real-time plot from the sound velocity probe at the Reson sonar head and notifying the user (via a flashing warning message) if the head sound velocity differed by more than 5m/s from a defined reference sound velocity. This message was used as an indication that the frequency of casts may need to be increased. The reference sound velocity was determined by averaging 50 sound velocities produced at the head. This reference sound velocity was reset when a cast was performed due to a significant deviation from the reference sound velocity, or normally, once a day.

Note: The Sea-Bird probes used with the UCTD system onboard the F/V Pacific were calibrated on (October 2011), which was seven months prior to the commencement of the project. The probes performed well and compared favorably with the other SV&P sensors on the two launches. On June 18, 2012, approval was given by the COTR to proceed with survey operations, with the agreement that both probes would need to be recalibrated after the completion of the survey and results compared with the existing calibration coefficients. Pre-survey and post-Survey calibrations documentation can be found in Appendix III, with the results showing minimal differences between the two calibration coefficients.

Positioning & Attitude Equipment

All vessels were equipped with an Applanix Position and Orientation System for Marine Vessels (POS MV) 320 V4 to calculate position and vessel attitude. Position was determined in real-time using a Trimble Zephyr L1/L2 GPS antenna, which was connected to a Trimble BD950 L1/L2 GPS card residing in the POS MV. An Inertial Measurement Unit (IMU) provided velocity values to the POS MV; allowing it to compute an inertial position, along with heading, and attitude. The POS MV was configured to accept differential corrections which were output from a CSI MBX-3 DGPS receiver that was tuned to the closest or strongest USCG DGPS station.
The operational accuracy specifications for this system, as documented by the manufacturer, are as follows:

Table 3 POS MV Specifications

POS MV Accuracy	
Pitch and Roll	0.02°
Heading	0.02°
Heave	5% or 5-cm over 20 seconds

The PosMvLogger and POS MV controller software's real-time QC displays were monitored throughout the survey to ensure that the positional accuracies specified in the NOS Hydrographic Surveys Specifications and Deliverables were achieved. These include, but are not limited to, the following: GPS Status, Position Accuracy, Receiver Status (which included HDOP & PDOP), and Satellite Status.

Static Draft Measurement

The WaterLOG H3611 (Radar Water Level Sensors) were installed on the port and starboard gunwales of F/V Pacific Star to obtain a more precise static draft measurement. The WaterLOG H3611 produced a sample distance to water surface every second with an accuracy of ±0.003m. Samples were taken over a 10 minute period and averaged to determine the vessel's static draft.

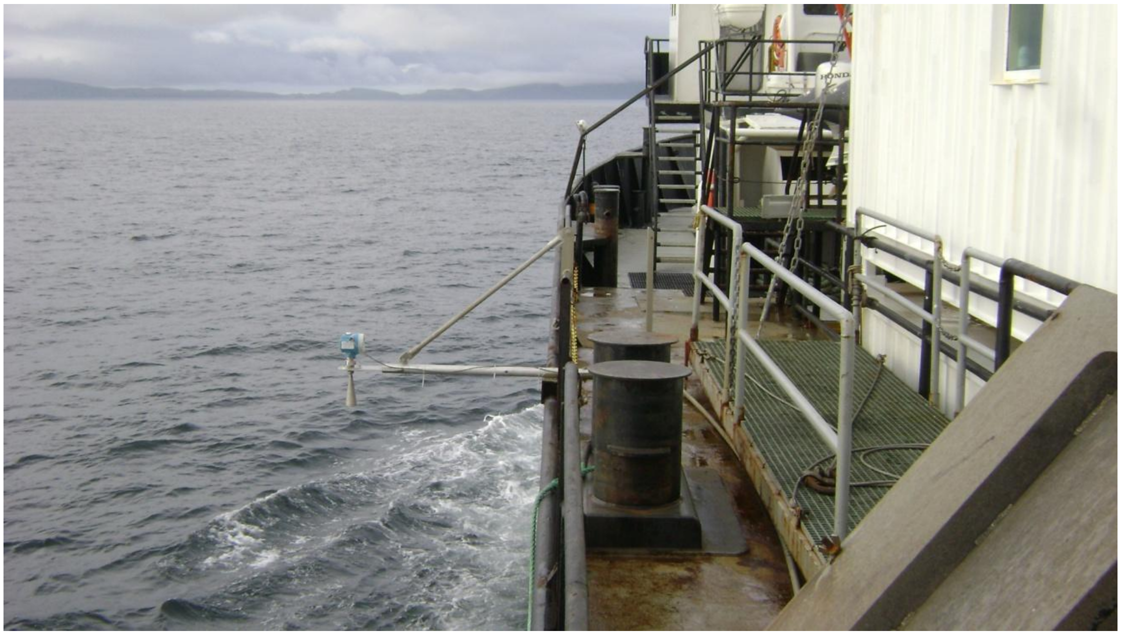


Figure 1: Port Radar Water Level Sensor

Figure 2: Starboard Radar Water Level Sensor

Bottom Sampling

The F/V Pacific Star was equipped with a 2.4L Van Veen Grab bottom sampler and 300m of line. The sampler was deployed and retrieved samples using a hydraulic capstan mounted on the stern deck. All samples were discarded after the sample information was recorded.

Software

Acquisition

All raw multibeam data were collected with WinFrog Multibeam v3.09.21 (WFMB). WFMB ran on a Windows 7 PC with a dual-core Intel processor. Data from the Reson 7111 and 7101 sonars were logged in the s7k file format. The s7k files contain all multibeam bathymetry, position, attitude, heading, and UTC time stamp data required by CARIS to process the soundings. A separate WFMB module (PosMVLogger) on the same PC logged all raw POS MV data for the post-processing of vessel positions in Applanix POSPac MMS software. WFMB also provided a coverage display for real-time QC and data coverage estimation.

WFMB 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 to view received data.
2. Graphic: The Graphics 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 selectable.
4. Calculation: The Calculations window is used to look at specific data items in a tabular or graphical format. Operators look here to view the status of the GPS satellite constellation and position solutions.
5. MBES Coverage Map: The Coverage Map provides a real-time graphical representation of the multibeam data. This allows the user to make judgments and corrections to the data collection process based on current operational conditions.
6. MBES QC View: The QC View contains four configurable windows for real-time display of any of the following: 2D or 3D multibeam data, snippets, pseudo side scan, or backscatter amplitude. In addition to this, it contains a surface sound speed utility that is configurable for real-time SV monitoring at the sonar head.

Applanix POS MV V4 controller software was used to monitor the POS MV system. The software has various displays that allow the operator to check real-time position, attitude and heading accuracies, and GPS status. POS MV configuration and calibration, when necessary, was also done using this program.

Fugro Pelagos' PosMvLogger v1.2 was used to provide uninterrupted logging of all Inertial Motion Unit (IMU), dual frequency GPS, and diagnostic data required to produce a Post Processed Kinematic (PPK) GPS solution using Applanix PosPacMMS. Additionally, the True Heave data, later applied in post-processing, was collected concurrently in the same file. The program also provided real-time QC and alarms for excessive HDOP and PDOP, and DGPS outages.

Fugro Pelagos' MB Survey Tools v2.00.31.00 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 records. These logs were stored digitally in a database format and later used to create the log sheets in PDF format located in the Descriptive Report Separate 1.

Processing

All Soundings were processed using CARIS (Computer Aided Resource Information System) HIPS (Hydrographic Information Processing System) v7.1. HIPS converted the s7k files to HIPS format, corrected soundings for sound velocity, motion, tide, and vessel offset, and was used to examine and reject noisy soundings. HIPS also produced the final BASE surfaces.

CARIS Notebook v3.1 was used to generate the S-57 Feature Files.

ESRI ArcMap v10.0 was utilized for survey planning, reviewing coverage plots, creating infill lines and crosslines, and graphics.

Applanix POSPac MMS v5.4 was utilized for post-processing the vessel dual frequency GPS data with simultaneous base station data to calculate higher accuracy positions than those calculated in real-time.

MB Survey Tools v2.00.31.00 was used to extract True Heave from POS files and put data into a text format acceptable to the CARIS Generic Data Parser. This was only utilized when the CARIS Load True Heave routine in HIPS failed to import.

MB Survey Tools v2.00.31.00 allowed processors to track changes and add comments while processing. MB Survey Tools was also used to process all sound velocity profiles and to convert them into a CARIS format.

A complete list of software and versions used on this project is included in Appendix I. Refer to the "2012-MBES_Processing_Procedures_April 2012 R0" document for a detailed processing routine with procedures used.

B – Quality Control

Error estimates for all survey sensors were entered in the CARIS Hips Vessel File (HVF). Additionally, measured uncertainty values were applied to the data where possible. This included positioning and attitude uncertainties from the Applanix POSPac MMS RMS files, True Heave RMS from the raw POS MV files, and calculated surface sound velocity values. These error estimates were used in CARIS to calculate the Total Propagated Uncertainty (TPU) at the 95% confidence interval for the horizontal and vertical components for each individual sounding.

The values that were entered in the CARIS HVF for the survey sensors are the specified manufacturer accuracy values and were downloaded from the CARIS website **http://www.caris.com/tpu/**. The following is a breakdown and explanation on the manufacturer and Fugro Pelagos-derived values used in the error model:

- Navigation – A value of 0.10 m was entered for the positional accuracy. This value was selected since all positions were post-processed, with X, Y, and standard deviation values better than 0.10 m.
- Gyro/Heading – Vessel was equipped with a (POS MV) 320 V4, and had a baseline < 4 m, therefore, a value of 0.020m was entered in the HVF as per manufacturer specifications.
- Heave – The heave percentage of amplitude was set to 5% and the Heave was set to 0.05 m, as per manufacturer specifications.
- Pitch and Roll - As per the manufacturer accuracy values, both were set to 0.02 degrees.
- Timing – All data were time stamped when created (not when logged) using a single clock/epoch (Pelagos Precise Timing method). Position, attitude (including True Heave), and heading were all time stamped in the POS MV. A ZDA+1 PPS string was also sent to the Reson 7111 processor, yielding timing accuracies on the order of 1 millisecond, and as a result a timing error of 0.001 seconds was entered for all sensors on all vessels.
- All vessel and sensor offsets were derived via conventional survey techniques (total station), while the vessel was dry docked. The results yielded standard deviations of 0.005 m to 0.010 m, vessel and survey dependent.
- Vessel speed – set to 0.10 m/s since a POS MV with a 50 Hz output rate was in use.
- Loading – estimated vessel loading error set to 0.05 m. This was the best estimate of how the measured static draft changed throughout the survey day.
- Draft – it was estimated that draft could be measured to within 0.01 m to 0.03 m; therefore, values in this range were entered.
- Tide error was set according to Hydrographic Surveys Specifications and Deliverables (HSSD) April 2011; measured uncertainty was set to 0.1m and zoning uncertainty set to 0.2m.
- Sound Speed Values were determined in MBTools, via the SVP Statistics utility. This utility calculated the Mean, Variance, Standard Deviation, and Min/Max values at a user specified depth interval. A separate value was also taken from the manufacturer's specifications.
- IMU Align StdDev for the Gyro and Roll/Pitch were set to 0.10 degrees since this is the estimated misalignment between the IMU and the vessel reference frame.

The calculated vertical and horizontal error or TPU values were then used to create finalized CUBE (Combined Uncertainty Bathymetry Estimator) surfaces; only soundings meeting or exceeding project accuracy specifications were included in this process.

An overview of the data processing flow follows:

In order for the s7k files collected by WFMB to be used by CARIS, they must first be converted to HDCS format using the CARIS ResonPDS converter routine. Prior to the files being converted, vessel offsets, patch test calibration values, TPU values, and static draft values were entered into the HVF.

Once converted, the Observed Tide and True Heave data were loaded into each line and the line was SVP corrected in CARIS HIPS. The TPU was then computed for each sounding, and the attitude, navigation, and bathymetry data for each individual line were examined for noise, as well as to ensure the completeness and correctness of the data set.

The data was then filtered using a swath angle filter and a RESON quality flag filter (**Table 4**). The swath angle filter rejects all soundings falling outside a specified angle from nadir. The RESON quality flag filter rejects soundings based on the colinearity and brightness of each ping. Note that “rejected” does not mean the sounding was deleted ; it was instead flagged as bad so that it would not be included in subsequent processing, such as surface creation. Data flagged as rejected did contain valid data, but were flagged to remove noise and to speed the processing flow. Valid data were manually reaccepted into the data set occasionally during line and subset editing as required.

Table 4 RESON Quality Flags

Quality Flag	Brightness	Colinearity
0	Failed	Failed
1	Pass	Failed
2	Failed	Pass
3	Pass	Pass

Several CARIS filter files were defined in project preplanning (**Table 5**). The processer selected the appropriate filter file based on a brief review of the data for environmental noise and bottom topography. Filter settings were sometimes modified based on data quality and sonar used, but all filter settings used were noted on each corresponding line log found in the Descriptive Report Separate 1.

Table 5 CARIS Filter File Definitions

File name	Angle from Nadir	Quality Flag
60_Q_0.hff	60˚	0
60_Q_01.hff	60˚	0&1

File name	Angle from Nadir	Quality Flag
65_Q_0.hff	65˚	0
65_Q_01.hff	65˚	0&1
70_Q_0.hff	70˚	0
70_Q_01.hff	70˚	0&1
Quality_0.hff	No Filter	0

Raw POS MV data were processed in Applanix POSPac MMS 5.4 with a Single Base Station Solution using the Fugro Pelagos Base Station's dual frequency GPS data. A Smoothed Best Estimated Trajectory (SBET) file containing a Post Process Kinematic Inertial Navigation Solution was created. Additionally, a POSPac MMS RMS file was created which contained uncertainty information specific to each position and attitude calculation. The SBET and RMS files were loaded into each line at a frequency of 10Hz for position records, 100 Hz for attitude records, and 1 Hz for RMS uncertainty data in CARIS HIPS. This operation replaced the real time navigation, pitch, roll, gyro, and GPS Height data with PPK navigation, attitude records, and uncertainty data. Note that all positioning data was processed to the North American Datum of 1983 (NAD83).

Processing of the POS MV data into a SBET file using a single base solution created highly accurate ellipsoid altitudes, normally better than 10cm, for all positioning data. Real-time ellipsoid altitude data was replaced with the SBET solution and a GPS tide was then calculated for each line. The GPS tide was generated by using the ellipsoid height and subtracted the heave, dynamic draft, and static draft specific to each line. This GPS tide value allowed the sounding data to be taken to the ellipsoid without modification to the vessel configuration file. Although the GPS tide values are stored within the CARIS line file, the GPS tide values were only applied to QC potential vertical busts. All final products were created using the Verified Smoothed Zone Tide data provided by John Oswald & Associates.

CUBE surfaces were then created at each required resolution for the Sheet or Block. Each CUBE resolution surface was then finalized using the depth thresholds for that specific resolution. The finalized CUBE surfaces were used for subset cleaning, so only the surface relating to the specific resolutions' depth range would be reviewed. CUBE parameters were derived from NOS Hydrographic Surveys Specifications and Deliverables (April, 2012). The following depth thresholds and CUBE parameter settings were used on this project.

Table 6 CUBE Surface Parameters

Surface Resolution	Depth Range	IHO S-44 Specification	Surface Creation				Disambiguation			
			Estimate Offset	Capture Distance Scale	Capture Distance Minimum	Horizontal Error Scalar	Method	Density Strength Limit	Locale Strength Maximum	Locale Search Radius
1m	0-20m	Order 1a	4.00	0.50%	0.707m	1.96	Density & Local	2.00	2.50	1 pixel
2m	18-40m	Order 1a	4.00	0.50%	1.414m	1.96	Density & Local	2.00	2.50	1 pixel

Surface Resolution	Depth Range	IHO S-44 Specification	Surface Creation				Disambiguation			
			Estimate Offset	Capture Distance Scale	Capture Distance Minimum	Horizontal Error Scalar	Method	Density Strength Limit	Locale Strength Maximum	Locale Search Radius
4m	36-80m	Order 1a	4.00	0.50%	2.828m	1.96	Density & Local	2.00	2.50	1 pixel
8m	72-160m	Order 1a	4.00	0.50%	5.657m	1.96	Density & Local	2.00	2.50	1 pixel
16m	144m-max	Order 1a	4.00	0.50%	11.314m	1.96	Density & Local	2.00	2.50	1 pixel

Deviations from these thresholds, if any, are detailed in the appropriate Descriptive Report.

Next, subsets tiles (to track areas examined), were created in CARIS HIPS. Adjacent lines of data were examined to identify tidal busts, sound velocity and roll errors, as well as to reject any remaining noise in the data set that adversely affected the CUBE surface.

While examining the data in subset mode, soundings were designated wherever the CUBE surface did not adequately depict the shoalest point of a feature. Soundings were designated when they met or exceeded the criteria for designation set forth in the Specifications and Deliverables. Designation ensured soundings were carried through to the finalized BASE surfaces.

A statistical analysis of the sounding data was conducted via the CARIS Quality Control Report (QCR) routine. Crosslines were run in each survey and compared with CUBE surfaces created from the mainscheme lines. The IHO S-44 criteria for an Order 1a survey, as specified in the Project Letter, were used in the CARIS Quality Control Report comparison on a beam by beam basis. Quality Control results are found in Separate 4 of each survey's Descriptive Report directory.

CARIS Notebook 3.1 was utilized to produce the S-57 final feature file (FFF). Seabed Area (SBDARE) polygon objects were picked from areas with obvious rocky bottom topography from the BASE surfaces. Meta-Coverage (M_COV) and Meta-Quality (M_QUAL) objects were defined as required using the extents of the multibeam BASE surfaces. All additional features that could not be depicted in the CARIS BASE surfaces, such as rocks and bottom samples, were logged in the S-57 assigned feature file (AFF).

C – Corrections to Soundings

Sound Velocity Profiles

Sound velocity casts were normally performed every two to three hours on the Pacific Star and on launches R2 and D2. For each cast (excluding the UCTD), the probes were held at the surface for one to two minutes to achieve temperature equilibrium. The probes were then lowered and raised at a rate of 1 m/s. Between casts, the sound velocity sensors were stored in fresh water to minimize salt-water corrosion and to hold them at ambient water temperature.

Fugro Pelagos' MB Survey Tools was used to check the profiles graphically for spikes or other anomalies, and to produce an SVP file compatible with CARIS HIPS. The WinFrog Multibeam acquisition package also provided QC for surface sound velocity. This was accomplished by creating a real-time plot from the sound velocity probe at the Reson sonar head and notifying the user (via a flashing warning message) if the head sound velocity differed by more than 5m/s from a defined reference sound velocity. This alarm was used as an indication that the frequency of casts may need to be increased. The reference sound velocity was determined by averaging 50 sound velocities produced at the head. The reference sound velocity was reset when a cast was performed due to a significant deviation from the reference sound velocity, or normally. once a day.

All sound velocity probes were calibrated just prior to the start of survey operations and no probe's calibration exceeded 6 months (the exception is the UCTD; refer to **Note** in Section A under Sound Velocity Profiles).

Refer to Appendix III for SVP Calibration Reports.

Settlement Curves

Squat-settlement tests were performed on all vessels to obtain dynamic draft correctors.

The squat-settlement tests were performed by first establishing a 1000 meter line in the direction of the current. The survey vessel sat static at one end of the line for three minutes logging L1/L2 GPS data. The line was first run heading north at lowest possible engine RPM, then rerun heading south at the same RPM, stopping at the south end of the line to obtain an additional three minutes of static L1/L2 GPS data. This pattern was repeated for additional lines at incrementing vessel RPMs.

All measurements were corrected for heave, pitch, roll, and reduced to the vessel's common reference point (CRP). Static measurements observed at the end of each line set were used to compute a tide curve for tidal corrections. After post-processing with base station data in Applanix POSPac, a settlement curve of dynamic draft correctors was computed via MB Survey Tools.

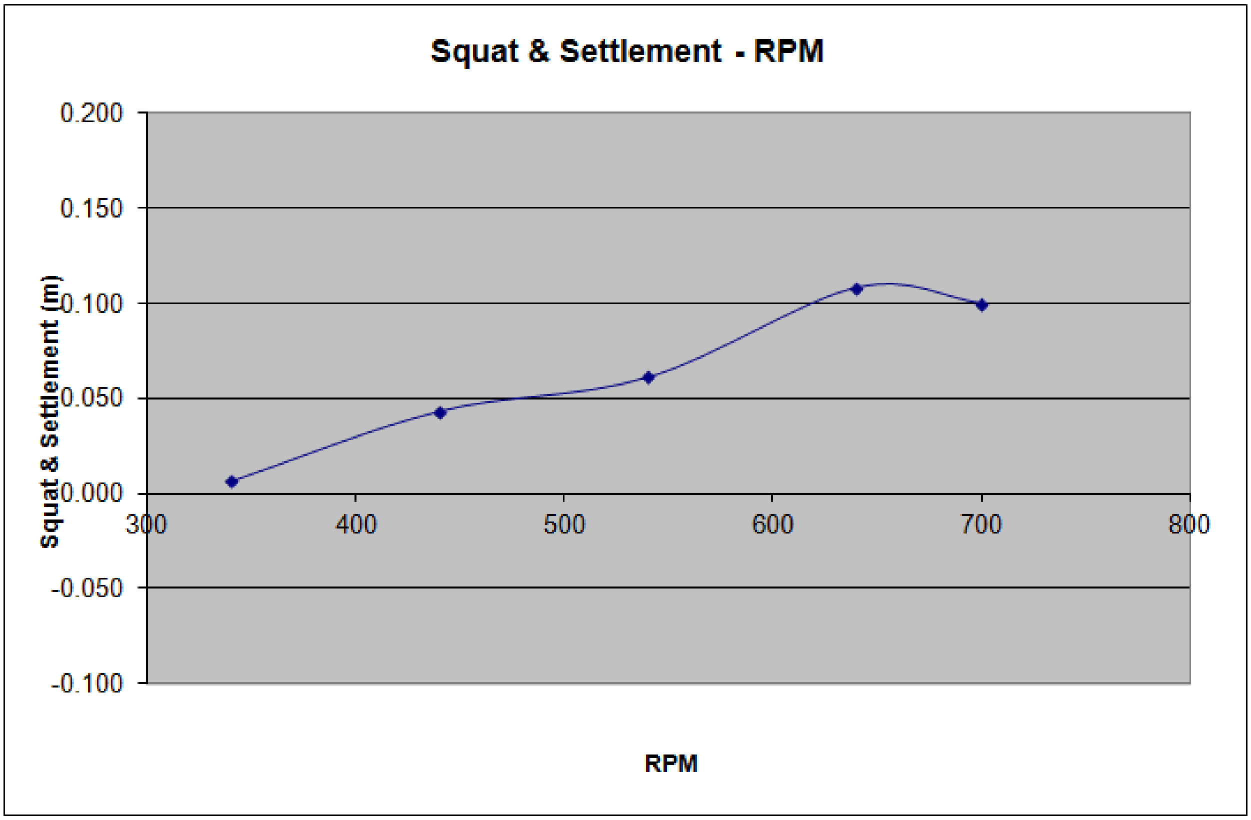


Figure 3-Pacific Star Dynamic Draft

Table 7 Pacific Star Squat Settlement Results

Pacific Star DYNAMIC DRAFT CORRECTORS		
Speed (kts.)	RPM	Settlement
5.1	340	0.006
5.8	390	0.025
6.5	440	0.043
7.3	490	0.052
8.1	540	0.061
8.8	590	0.084
9.5	640	0.108
10.3	690	0.101
10.4	700	0.100

The squat settlement test for the F/V Pacific Star was conducted in the vicinity of Avatanak Strait, AK on July 2, 2012 (Julian Day 184).

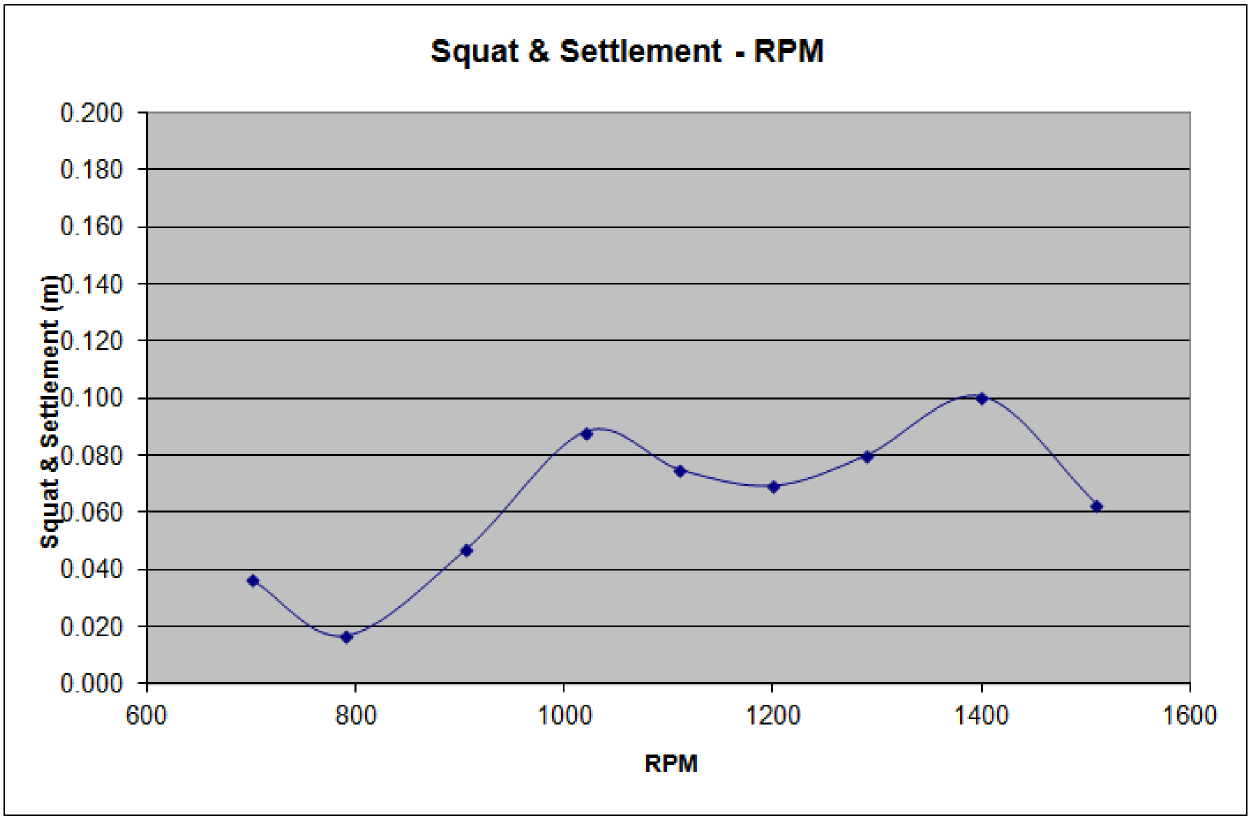


Figure 4-R2 Dynamic Draft

Table 8 R2 Squat Settlement Results

R2 DYNAMIC DRAFT CORRECTORS		
Speed (kts.)	RPM	Settlement
3.8	700	0.036
3.6	790	0.017
4.3	900	0.047
4.8	1020	0.088
5.1	1110	0.075
5.5	1200	0.069
5.9	1290	0.080
6.4	1400	0.010
6.6	1510	0.063

The squat settlement test for the R/V R2 was conducted in the vicinity of Avatanak Strait, AK on July 2, 2012 (Julian Day 184).

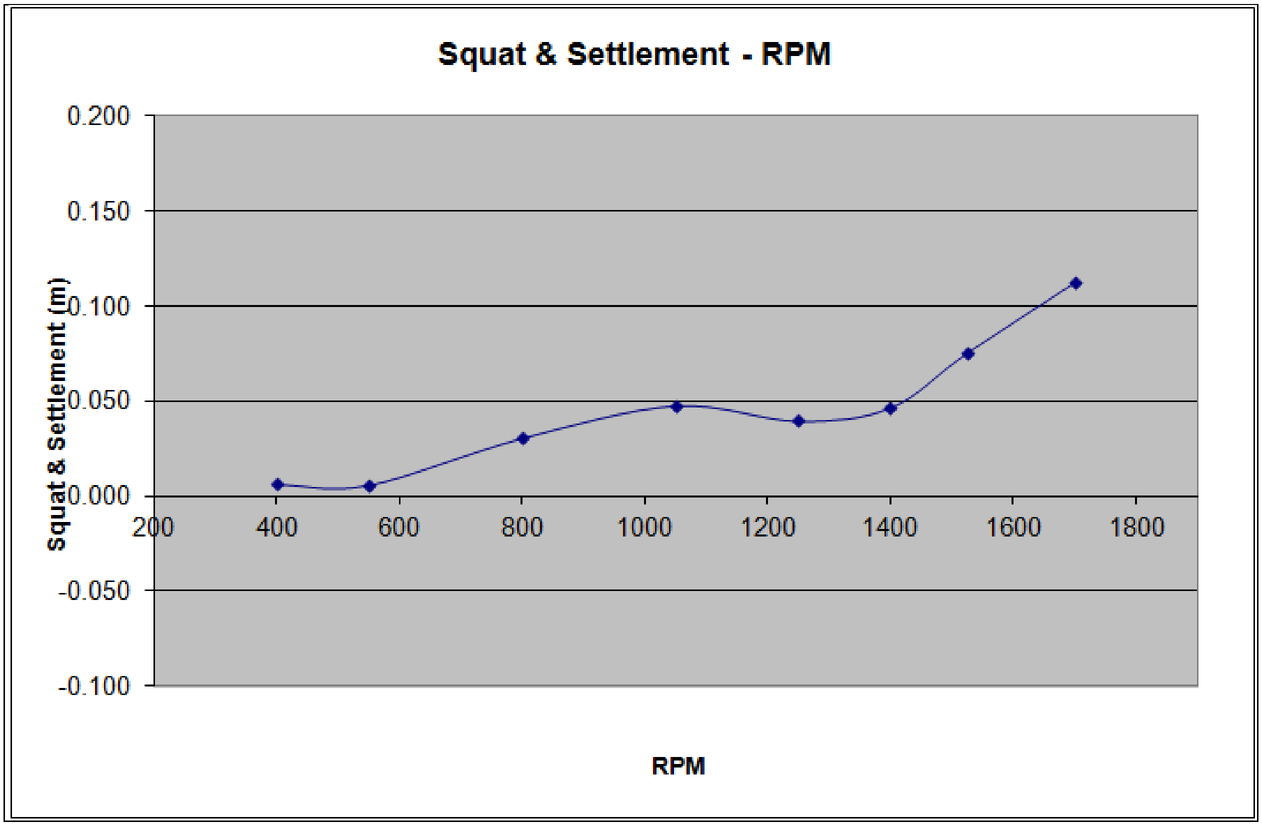


Figure 5-D2 Dynamic Draft

Table 9 D2 Squat Settlement Results

D2 DYNAMIC DRAFT CORRECTORS		
Speed (kts.)	RPM	Settlement
4.1	400	0.006
4.1	550	0.006
4.6	800	0.030
5.4	1050	0.048
6.2	1250	0.040
6.7	1400	0.046
6.9	1525	0.075
7.5	1700	0.112

The squat settlement test for the R/V D2 was conducted in the vicinity of Avatanak Strait, AK on July 2, 2012 (Julian Day 184).

Static Draft

Static draft was measured from tabs on both sides of the vessel, the average taken, and the correction to the common reference point applied. The tables below show the static draft values measured for all vessels.

Table 10 Draft Measurements for the F/V Pacific Star (7111)

DRAFT #	JULIAN DAY	DATE (UTC)	TIME (UTC)	DEPTH (m)
1	168	6/16/2012	22:22	-1.76
2	169	6/17/2012	15:03	-1.71
3	169	6/17/2012	8:41	-1.75
4	169	6/17/2012	2:35	-1.72
5	170	6/18/2012	8:15	-1.74
6	170	6/18/2012	2:05	-1.72
7	170	6/18/2012	14:33	-1.71
8	171	6/19/2012	8:19	-1.72
9	171	6/19/2012	2:56	-1.74
10	171	6/19/2012	14:21	-1.71
11	172	6/20/2012	14:35	-1.68
12	172	6/20/2012	8:16	-1.71
13	172	6/20/2012	2:18	-1.71
14	173	6/21/2012	15:12	-1.68
15	173	6/21/2012	8:30	-1.69
16	173	6/21/2012	2:22	-1.68
17	174	6/22/2012	14:56	-1.73
18	174	6/22/2012	8:11	-1.69
19	174	6/22/2012	2:23	-1.66
20	175	6/23/2012	14:33	-1.64
21	175	6/23/2012	8:25	-1.67
22	175	6/23/2012	2:20	-1.67
23	175	6/23/2012	1:35	-1.64
24	176	6/24/2012	14:30	-1.63
25	176	6/24/2012	8:24	-1.66
26	176	6/24/2012	2:17	-1.64
27	177	6/25/2012	8:04	-1.65
28	177	6/25/2012	14:34	-1.63
29	177	6/25/2012	5:50	-1.65
30	178	6/26/2012	15:40	-1.65
31	178	6/26/2012	8:17	-1.64

DRAFT #	JULIAN DAY	DATE (UTC)	TIME (UTC)	DEPTH (m)
32	178	6/26/2012	4:05	-1.67
33	179	6/27/2012	14:37	-1.6
34	179	6/27/2012	7:41	-1.62
35	179	6/27/2012	3:15	-1.61
36	180	6/28/2012	14:43	-1.57
37	180	6/28/2012	3:12	-1.59
38	180	6/28/2012	8:00	-1.61
39	181	6/29/2012	14:28	-1.57
40	181	6/29/2012	8:11	-1.6
41	181	6/29/2012	2:18	-1.59
42	182	6/30/2012	1:54	-1.59
43	182	6/30/2012	14:58	-1.57
44	184	7/2/2012	14:25	-1.66
45	184	7/2/2012	5:44	-1.7
46	185	7/3/2012	14:32	-1.65
47	185	7/3/2012	2:53	-1.69
48	186	7/4/2012	15:39	-1.63
49	186	7/4/2012	7:31	-1.67
50	187	7/5/2012	14:54	-1.63
51	187	7/5/2012	0:15	-1.66
52	188	7/6/2012	5:18	-1.64
53	191	7/9/2012	18:59	-1.59

Table 11 Draft Measurements for the R/V R2 (7101)

DRAFT #	JULIAN DAY	DATE (UTC)	TIME (UTC)	DEPTH (m)
1	169	6/17/2012	1:18	-0.25
2	170	6/18/2012	14:47	-0.27
3	170	6/18/2012	2:24	-0.27
4	171	6/19/2012	14:46	-0.25
5	172	6/20/2012	14:36	-0.25
6	172	6/20/2012	4:33	-0.26
7	173	6/21/2012	15:30	-0.26
8	174	6/22/2012	18:49	-0.25
9	175	6/23/2012	14:32	-0.27
10	176	6/24/2012	2:20	-0.27
11	176	6/24/2012	14:28	-0.26
12	176	6/24/2012	2:20	-0.27
13	177	6/25/2012	14:40	-0.25

DRAFT #	JULIAN DAY	DATE (UTC)	TIME (UTC)	DEPTH (m)
14	178	6/26/2012	15:01	-0.24
15	179	6/27/2012	3:54	-0.26
16	180	6/28/2012	14:41	-0.26
17	180	6/28/2012	3:40	-0.27
18	184	7/2/2012	14:39	-0.27
19	185	7/3/2012	14:30	-0.26
20	186	7/4/2012	6:48	0.1
21	186	7/4/2012	15:44	-0.24
22	187	7/5/2012	15:01	-0.25
23	188	7/6/2012	14:37	-0.27
24	189	7/7/2012	15:46	-0.25
25	190	7/8/2012	14:58	-0.23
26	191	7/9/2012	17:45	-0.24

Table 12 Draft Measurements for the R/V D2 (7101)

DRAFT #	JULIAN DAY	DATE (UTC)	TIME (UTC)	DEPTH (m)
1	169	6/17/2012	14:32	-0.18
2	170	6/18/2012	14:42	-0.2
3	171	6/19/2012	14:23	-0.19
4	172	6/20/2012	14:35	-0.19
5	173	6/21/2012	14:25	-0.19
6	174	6/22/2012	15:05	-0.19
7	175	6/23/2012	14:31	-0.19
8	176	6/24/2012	14:25	-0.19
9	178	6/26/2012	15:37	-0.19
10	178	6/26/2012	1:44	-0.17
11	180	6/28/2012	14:47	-0.19
12	180	6/28/2012	1:17	-0.19
13	181	6/29/2012	14:53	-0.19
14	182	6/30/2012	14:32	-0.18
15	184	7/2/2012	14:10	-0.19
16	185	7/3/2012	14:30	-0.19
17	186	7/4/2012	15:44	-0.21
18	187	7/5/2012	15:15	-0.2
19	188	7/6/2012	15:38	-0.18
20	189	7/7/2012	14:32	-0.2
21	190	7/8/2012	15:21	-0.18

Tides

All sounding data were initially reduced to MLLW based on Preliminary Zoning provided by CO-OPS and modified by John Oswald and Associates (JOA) to use gauges located in Trident Bay, Rootok Island, and Tigalda Bay. Tidal data for a twenty-four hour period UTC, (Alaska Daylight Time to UTC was +8 hours) was assembled by JOA and uploaded to their ftp site at the end of every Julian Day. A cumulative file for the gauges was updated each day by appending the new data. It should be noted that these unverified tides were used in the field for preliminary processing only.

Between June and August, Sea-Bird pressure data was collected at two locations around Derbin Strait. The Sea-Bird data, along with PPK derived vessel altitude data, was used in developing final tide zones. The tidal zoning was modified by JOA, providing a more elaborate zoning scheme from the preliminary NOAA CO-OPS zones issued in the Statement of Work.

On October 13, 2012, JOA issued verified tidal data and final zoning for OPR-Q191-KR-12. All sounding data was then re-merged using CARIS HIPS and SIPS tide routine. Verified tidal data were used for all final Navigation BASE surfaces and S-57 Feature files.

For additional information, refer to OPR-Q191-KR-12 Horizontal and Vertical Control Report.

Vessel Attitude: Heading, Heave, Pitch, and Roll

Vessel heading and dynamic motion were measured by the Applanix (POS MV) 320 V4 on all vessels. The system calculated heading by inversing between two Trimble GPS generated antenna positions. An accelerometer block (the IMU), which measured vessel attitude, was mounted directly above the multibeam transducer.

Calibrations

Multibeam

For all vessel and sonar configurations, patch tests were conducted to identify alignment errors (timing, pitch, heading, and roll) between the motion sensor and the multibeam transducer(s). Patch test calibration values used to correct all soundings for the survey are shown in **Table 13**.

Table 13 Patch Test Results Summary

Patch Test Results						
Vessel	**Patch Test Day**[1]	**MB Sonar**	**Timing Error**	**Pitch Offset**	**Roll Offset**	**Azimuth Offset**
Pacific Star	JD152	7111 100 kHz	0.000	-0.400	0.535	-0.600
	JD184	7111 400 kHz	0.000	-0.400	0.535	-0.600
	JD191	7111 400 kHz	0.000	-0.400	0.590	-0.600
R2	JD175	7101 240 kHz	0.000	-1.750	0.140	-1.880
D2	JD176	7101 240 kHz	0.000	-0.500	1.840	1.800
D2	JD188	7101 240 kHz	0.000	-0.600	1.900	1.800

Additional Sounding Techniques

None.

[1] Julian day the actual test was done is listed. May be pre-dated in CARIS HVF to cover lines run before patch test.

D – Approval Sheet

Approval Sheet

For

H12439, H12440, H12441, H12442, H12443, H12444, & H12445

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

OPR-Q191-KR-12 Statement of Work
NOS Hydrographic Surveys Specifications and Deliverables, April 2011 Edition
Fugro Pelagos, Inc. Acquisition Procedures (2012-MBES_Acquisition_Procedures_ April 2012 R0)
Fugro Pelagos, Inc. Processing Procedures (2012-MBES_Processing_Procedures_April 2012 R0)

The data were reviewed daily during acquisition and processing, and the survey is complete and adequate for its intended purpose.

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, (ACSM Cert. No. 226)
Senior Hydrographer
Fugro Pelagos, Inc.
February 1, 2013

X Dean Moyles

Digitally signed by Dean Moyles
DN: cn=Dean Moyles, o=Fugro Pelagos, Inc., ou, email=dmoyles@fugro.com, c=US
Date: 2013.01.31 14:59:39 -08'00'

Dean Moyles (ACSM Cert. No. 226)
Senior Hydrographer

Appendix I – Vessel Reports

F/V Pacific Star

The F/V Pacific Star **(Figure 6),** a former Bering Sea crab fishing vessel, was modified to accommodate a survey crew, acquisition hardware, and survey launches. Living quarters and office space containers were installed on the back deck. Davits previously used on the R/V Davidson were installed near the aft end of the vessel to lift and deploy the R2 and D2 survey launches. Access doors and infrastructure were built to facilitate access to the launches.

A Reson SeaBat 7111 multibeam sonar was hull mounted near the best estimate of the vessel's center of gravity, approximately amidships. A Drop Keel was installed on the vessel and the 7111 sonar with sound velocity probes was mounted within the keel. The Drop Keel provided the sonar protection from damage and limited interference (**Figure 9**). The inertial measurement unit (IMU) for the POS MV was installed inside the hull directly above the Reson 7111.

Table 14 Vessel Specifications (F/V Pacific Star)

SURVEY VESSEL F/V PACIFIC STAR	
Owner	Pacific Star Fisheries, LLC
Official Number	556510
Length	162'
Breadth	38'
Depth	14'
Max Draft	16'
BHP Main Engines	3,000 combined BHP (1500 ea) Two Electromotive Diesels
Gross Tonnage (US)	194
Fresh Water Capacity	24,399 Gallons
Fuel Capacity	90,112 Gallons

Figure 6 F/V Pacific Star

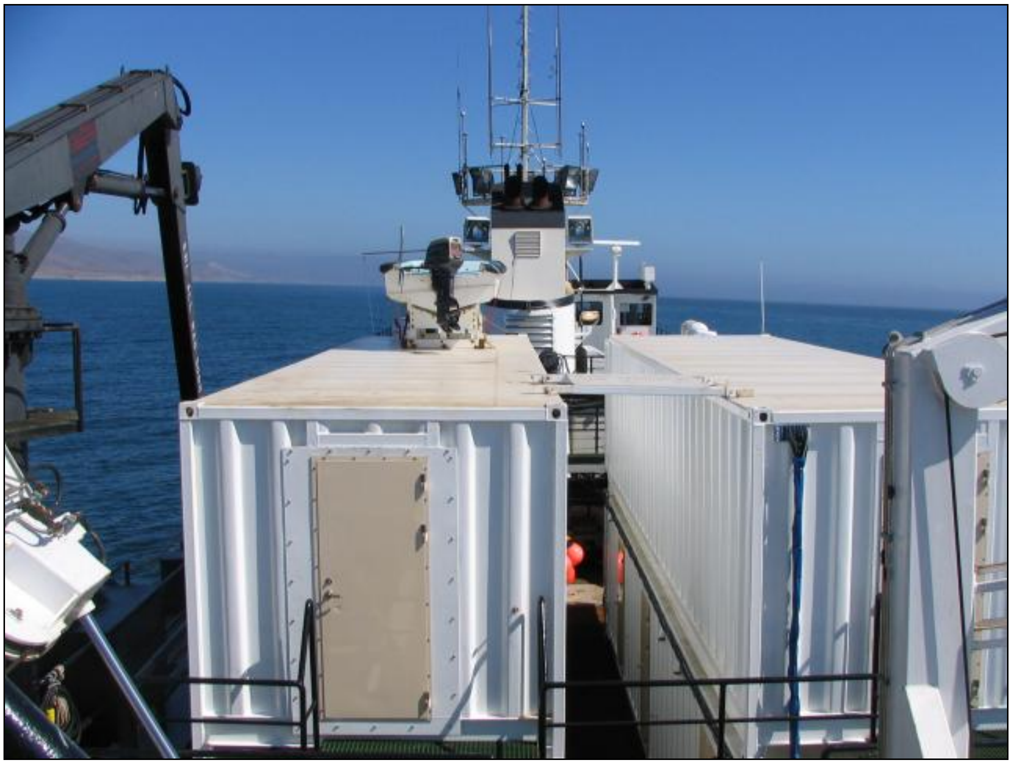


Figure 7 F/V Pacific Star Office Containers

Figure 8 F/V Pacific Star Davit Launch System

Figure 9 F/V Pacific Star Drop Keel with 7111

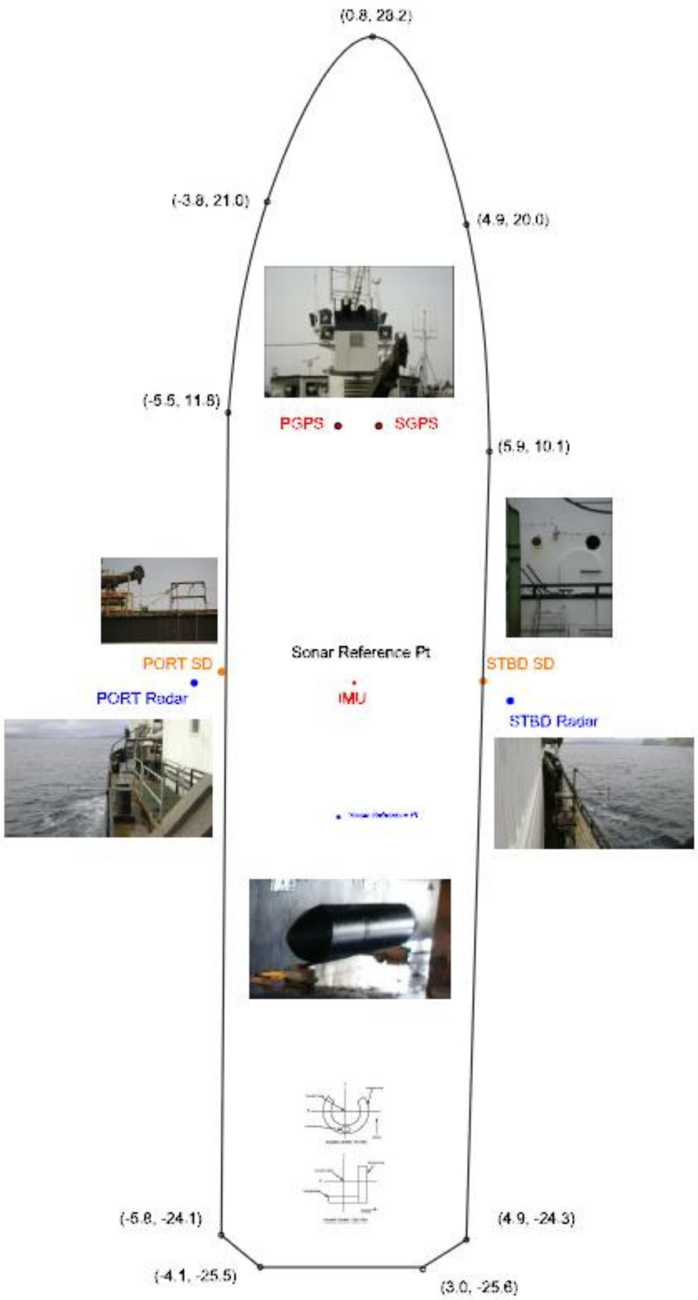
Two Trimble L1/L2 antennas were mounted above and forward from the sonar. Offset 1.8 meters port/starboard from each other, the L1/L2 antennas provided GPS data to the POS MV for position, attitude, and heading computations. The port side antenna functioned as the POS MV master antenna; the starboard side antenna functioned as the POS MV secondary.

The UCTD sensors were deployed from an A-Frame on the stern using a unique deployment and re-spooling mechanism that allows the probes to be launched and recovered time after time without ever needing to slow down or stop.

Draft measurement tabs were installed at convenient measurement stations on both the port and starboard sides of the vessel, in line with the CRP and Reson 7111. WaterLOG H3611 (Radar Water Level Sensors) were installed on the port and starboard gunwales of F/V Pacific Star to obtain a more precise static draft measurement.

Offset values for the CRP to the sonar and waterline were applied to the data in CARIS HIPS as specified in the HIPS vessel file (HVF). Offsets between the GPS antennas and the CRP were applied internally by the POS MV by entering a GPS lever arm offset. Note that the HVF does not contain navigation offsets, because the position provided by the POS MV is already corrected to the CRP. Vessel offsets used are shown in the offset diagram (**Figure 11**).

Figure 10 F/V Pacific Star



F/V Pacific Star

Sensor	X	Y	Z
IMU (CRP)	0.000	0.000	0.000
Sonar Reference Point	-0.157	-4.186	-2.082
PGPS (Phase Center - High Gain Ant)	-0.709	11.216	13.329
PGPS (Phase Center - Trimble)	-0.709	11.216	13.303
SGPS (Phase Center - Trimble)	1.067	11.218	13.293
Port Static Draft	-5.798	0.486	5.971
Stbd Static Draft	5.625	0.076	5.914
Port Radar Draft Device (SN 1581)	-6.983	-0.002	6.143
Stbd Radar Draft Device	6.807	-0.786	5.974

Notes:
Z value for the Radars have been adjusted to their Acoustic Center.
All coordinates are on the IMU reference Frame.
X is positive to Stbd
Y is positive towards Bow
Z is positive Up

POS M/V Reference Frame

Sensor	X	Y	Z
PGPS (Phase Center)	11.216	-0.709	-13.329

Note:
X is positive to Bow
Y is positive towards Stbd
Z is negative above Ref

Figure 11 F/V Pacific Star Offset Diagram

R/V R2

The R/V R2 **(Figure 12),** a Pacific Star launch, was modified to accommodate a survey crew and acquisition hardware. The keel was cut just aft of mid-ship and a Reson 7101 multibeam sonar was installed. A conical cowling protected the sonar head forward and aft by way of a crescent shaped skid. The accelerometer package for a POS MV was mounted in the hull of the vessel just over the 7101 multibeam transducer head.

Two Trimble L1/L2 antennas were mounted above the 7101 for positioning and heading. The two POS MV antennas were offset 2.0m port/starboard from each other. The port side antenna (L1/L2) functioned as the POS MV master antenna; the starboard side antenna functioned as the POS MV secondary.

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

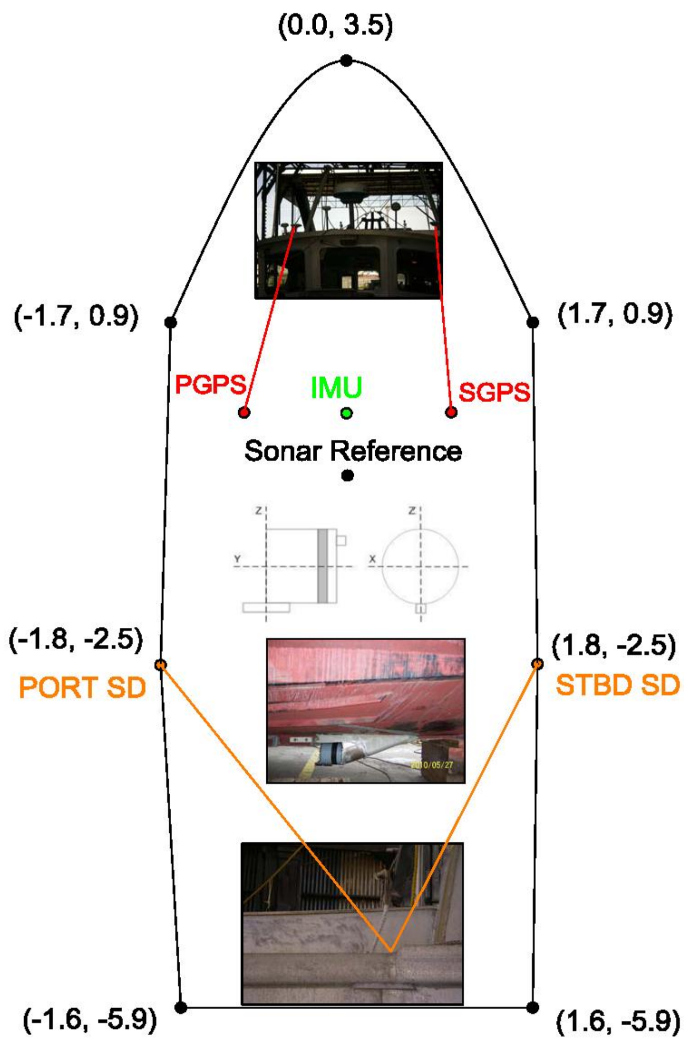
Draft measurement points were indentified at convenient measurement stations on both the port and starboard sides of the vessel, aft of the CRP and Reson 7101.

Offset values for the CRP to the sonar and waterline were applied to the data in CARIS HIPS as specified in the HIPS vessel file (HVF). Offsets between the GPS antennas and the CRP were applied internally by the POS MV by entering a GPS lever arm offset. Note that the HVF does not contain navigation offsets, because the position provided by the POS MV is already corrected to the CRP. Vessel offsets used are shown in the offset diagram **(Figure 13)**.

Figure 12 R/V R2

Table 15 Vessel Specifications (R2)

SURVEY LAUNCH R/V R2	
Owner	Stabbert Maritime Yacht & Ship
Official Number	623241
Year Built	1980/1982
Length	28.9’
Beam	12’
Draft	3’
Gross Tonnage	15
Net Tonnage	13
Mechanical Power	Caterpillar 3208
Electrical	Northern Lights



R/V R2

Sensor	X	Y	Z
IMU (CRP)	0.000	0.000	0.000
Sonar Reference Point	0.010	-0.618	-0.641
PGPS (Phase Center)	-0.990	0.007	3.053
SGPS (Phase Center)	1.013	0.009	3.032
Port Static Draft	-1.797	-2.500	1.424
Stbd Static Draft	1.846	-2.489	1.379

Note:
X is positive to Stbd
Y is positive towards Bow
Z is positive Up

POS M/V Reference Frame

Sensor	X	Y	Z
PGPS (Phase Center)	0.007	-0.990	-3.053

Note:
X is positive to Bow
Y is positive towards Stbd
Z is negative above Ref

Figure 13 R/V R2 Offset Diagram

R/V D2

The R/V D2 **(Figure 14)**, a Pacific Star launch, was modified to accommodate a survey crew and acquisition hardware. The keel was cut just aft of mid-ship and a Reson 7101 multibeam sonar was installed. A conical cowling protected the sonar head forward and aft by way of a crescent shaped skid. The accelerometer package for a POS MV was mounted in the hull of the vessel just over the 7101 multibeam transducer head.

Two Trimble L1/L2 antennas were mounted above the 7101 and accelerometer for positioning and heading. The two POS MV antennas were offset 2.0m port/starboard from each other. The port side antenna (L1/L2) functioned as the POS MV master antenna; the starboard side antenna functioned as the POS MV secondary.

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

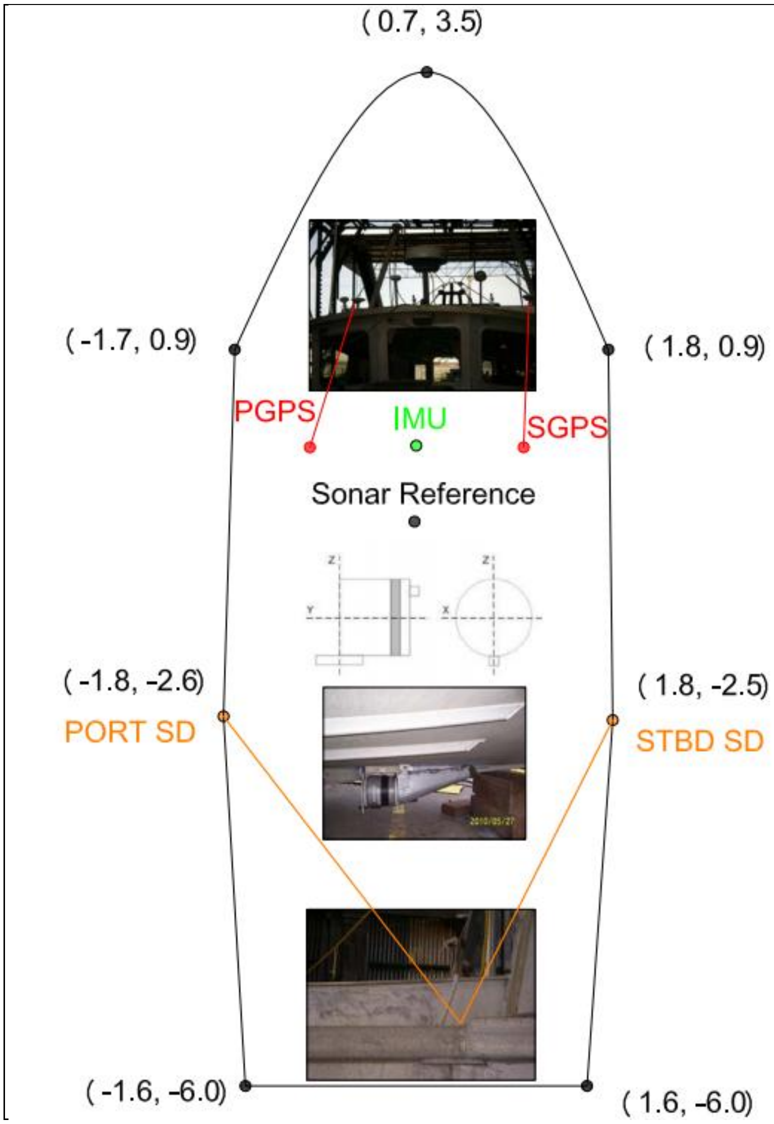
Draft measurement points were indentified at convenient measurement stations on both the port and starboard sides of the vessel, aft of the CRP and Reson 7101.

Offset values for the CRP to the sonar and waterline were applied to the data in CARIS HIPS as specified in the HIPS vessel file (HVF). Offsets between the GPS antennas and the CRP were applied internally by the POS MV by entering a GPS lever arm offset. Note that the HVF does not contain navigation offsets, because the position provided by the POS MV is already corrected to the CRP. Vessel offsets used are shown in the offset diagram (**Figure 15**).

Figure 14 R/V D2

Table 16 Vessel Specifications (D2)

SURVEY LAUNCH R/V D2	
Owner	Stabbert Maritime Yacht & Ship
Official Number	647782
Year Built	1980/1982
Length	28.9’
Beam	12’
Draft	3’
Gross Tonnage	15
Net Tonnage	13
Mechanical Power	Caterpillar 3208
Electrical	Northern Lights



R/V D2			
Sensor	X	Y	Z
IMU (CRP)	0.000	0.000	0.000
Sonar Reference Point	-0.016	-0.712	-0.674
PGPS (Phase Center)	-0.996	-0.016	3.029
SGPS (Phase Center)	1.007	-0.015	3.001
Port Static Draft	-1.805	-2.536	1.354
Stbd Static Draft	1.841	-2.572	1.294

Note:
X is positive to Stbd
Y is positive towards Bow
Z is positive Up

POS M/V Reference Frame			
Sensor	X	Y	Z
PGPS (Phase Center)	-0.016	-0.996	-3.029

Note:
X is positive to Bow
Y is positive towards Stbd
Z is negative above Ref

Figure 15 R/V D2 Offset Diagram

Equipment

Table 17 Pacific Star Acquisition Equipment

Description	Serial Number
Applanix IMU LN200	49
Applanix POS MV Processor L1/L2 (RTK)	2354
GPS Antenna L1/L2 (Primary)	1441036287
GPS Antenna L1/L2 (Secondary)	1441028087
GPS RECEIVER CSI GBX PRO	0214-8517-0001
GPS Beacon Antenna AT300	5701
RESON NAVISOUND SVP 70 (Primary)	4506001
RESON NAVISOUND SVP 70 (Spare)	1008130
RESON 71-P Processor-7111 SV	18231411003
Reson 7111 Receive Array	1409090
Reson 7111 Transmit Array	4608501
Fugro Pelagos Acquisition PC	BGR 602607
WinFrog Multibeam Dongle	BGR602947
UHF Radio Modem (Boat to Boat)	075004326
UCTD Sea-Bird Velocity Probe	0054
UCTD Sea-Bird Velocity Probe	0059
Starboard WaterLOG H3611 (Draft Measurement)	1618
Port WaterLOG H3611 (Draft Measurement)	1581

Table 18 Launch R2 Acquisition Equipment

Description	Serial Number
Applanix IMU LN200	241
Applanix POS MV Processor L1/L2 (RTK)	2161
GPS Antenna L1/L2 (Primary)	1441043381
GPS Antenna L1/L2(Secondary)	1440941086
GPS CSI MBX-3 Coastguard Receiver	9833-2166-0001
GPS Beacon Antenna AT300	5701
RESON NAVISOUND SVP 71	2008033
RESON 7-1-P Processor-7101	4409002
RESON 7101 Transducer	2600002
Fugro Pelagos Acquisition PC	BGR 602837
WinFrog Multibeam Dongle	BGR602948
AML SV Plus Velocity Probe 1000 dbar (SV1)	5353
AML SV Plus Velocity Probe 1000 dbar (SV2)	4703
UHF Radio Modem (Boat to Boat)	075004322

Table 19 Launch D2 Acquisition Equipment

Description	Serial Number
Applanix IMU LN200	730
Applanix POS MV Processor L1/L2 (RTK)	2151
GPS Antenna L1/L2 (Primary)	1441043383
GPS Antenna L1/L2(Secondary)	1440941132
GPS RECEIVER CSI GBX PRO	0031-6753-0001
GPS Beacon Antenna AT300	5703
RESON NAVISOUND SVP 71	2008042
RESON 7-1-P Processor-7101	3409002
RESON 7101 Transducer	0210025
Fugro Pelagos Acquisition PC	BGR 602498
WinFrog Multibeam Dongle	BGR602949
AML SV Plus Velocity Probe 1000 dbar (SV1)	5282
AML SV Plus Velocity Probe 1000 dbar (SV2)	5283
UHF Radio Modem (Boat to Boat)	075004327

Software

Table 20 Software List (Pacific Star, R2, D2, & Processing Center)

Software Package	Version	Service Pack	Hotfix
Fugro Pelagos WinFrog Multibeam	3.09.21	N/A	N/A
Fugro Pelagos MBSurvey Tools	2.00.31.00	N/A	N/A
Fugro Pelagos POSMVLogger	1.2	N/A	N/A
CARIS HIPS/SIPS	7.1	2	1-2
CARIS Notebook	3.1	1	1
CARIS Bathy DataBASE	3.2	2	1-7
ESRI ArcGIS	10.0.0	2	N/A
Applanix POS MV V4 Controller	6.28	N/A	N/A
Applanix POSPac MMS	5.4	2	N/A
Nobeltec Tides and Currents	3.5.107	N/A	N/A
Microsoft Office	2007 Professional	N/A	N/A
Microsoft Windows (64-bit)	7 Enterprise	1	N/A
Helios Software Solutions TextPad	5.2.0	N/A	N/A
IrfanView	4.25	N/A	N/A

Appendix II – Echosounder Reports

Multibeam Echosounder Calibration

A patch test was completed for the MBES using seafloor topology for data to be corrected for navigation timing, pitch, azimuth, and roll offsets, which may exist between the MBES transducer and the Inertial Measurement Unit (IMU).

The patch test was run at various stages of survey operations to calibrate the MBES and IMU for different vessel configurations.

No adjustment was required for the navigation timing error. Fugro Pelagos has implemented a specific timing protocol for multibeam data acquisition. In this method, UTC time tags generated within the POS MV are applied to all position, heading, and attitude data. The POS MV ZDA+1 PPS (pulse per second) string is also sent to the Reson SeaBat sonar system, where the ping data are tagged. The architecture of the POS MV ensures that there is zero latency between the position, heading, and attitude strings. The only latency possible is in the ping time. In addition, the navigation-to-ping latency will be identical to the attitude-to-ping and heading-to-ping latencies.

Navigation latency is generally difficult to measure using standard timing and patch testing techniques. However, using Fugro Pelagos' timing protocol, the navigation latency will be the same as the roll latency. Fortunately, roll latencies are very easy to identify. Data with a roll timing latency will have a rippled appearance along the edge of the swath. During patch test analysis, the roll latency is adjusted until the ripple is gone. This latency value is then applied to the ping time, synchronizing it with the position, attitude, and heading data.

The pitch error adjustment was performed on sets of two coincident lines, run at the same velocity, over a conspicuous object, in opposite directions. The nadir beams from each line were compared and brought into alignment, by adjusting the pitch error value.

The azimuth error adjustment was performed on sets of two lines, run over a conspicuous topographic feature. Lines were run in opposite directions, at the same velocity with the same outer beams crossing the feature. Since the pitch error has already been identified, data from the same outer beams for each line were compared and brought into alignment, by adjusting the azimuth error value.

The roll error adjustment was performed on sets of two coincident lines, run over flat terrain, at the same velocity, in opposite directions. The pitch error and azimuth error were already identified. Data across a swath were compared for each line and brought into agreement by adjusting the roll error value.

Patch test data were then corrected using the identified values, and the process repeated to check their validity.
Patch test values were obtained in CARIS HIPS calibration mode. Calculated values were then entered in to the HVF so that data could be corrected during routine processing.

Multibeam Echosounder Calibration Results

Table 21 Patch Test Results for Each Vessel

Patch Test Results						
Vessel	**Patch Test Day**[2]	**MB Sonar**	**Timing Error**	**Pitch Offset**	**Roll Offset**	**Azimuth Offset**
Pacific Star	JD152	7111 100 kHz	0.000	-0.400	0.535	-0.600
	JD184	7111 100 kHz	0.000	-0.400	0.535	-0.600
	JD191	7111 100 kHz	0.000	-0.400	0.590	-0.600
R2	JD175	7101 240 kHz	0.000	-1.750	0.140	-1.880
D2	JD176	7101 240 kHz	0.000	-0.500	1.840	1.800
D2	JD188	7101 240 kHz	0.000	-0.600	1.900	1.800

Multibeam Bar Check

A bar check calibration of multibeam sonar systems is performed to accurately relate observed (recorded) depths to the true depth of water. Therefore, the calibration determines any error in the system's raw depth readings (as well as verifies the accuracy of the vessel offset survey).

A bar check calibration is performed by lowering a horizontal metal plate to a known depth below the waterline. Then, data at that known depth is acquired using the multibeam sonar system and processed using the CARIS HIPS and SIPS (v. 7.1) Swath Editor routine.

By processing the data in CARIS's Swath Editor routine, the vessel's equipment offsets measured during the offset survey, the sound velocity profile taken at the time of the bar check, the survey's static draft measurement procedure, and the data cleaning routine used during the survey are all applied to the data to calculate the difference between the sonar's measurement of the horizontal bar and the actual, known depth below the waterline.

Any difference in the measured depth versus the known depth can be attributed to error in the sound velocity profile, the static draft measurement procedure, the vessel offset survey, and/or the sonar system's internal capabilities.

On July 9, 2012, hydrographers onboard both R/V R2 and R/V D2 performed bar check calibrations for the respective Reson 7101 multibeam sonar systems.

[2] Julian day the actual test was done is listed. May be pre-dated in CARIS HVF to cover lines run before patch test.

Prior to performing the bar check calibrations, accurate static draft measurements were taken in calm water. Then, for each vessel, a flat, metal plate was lowered to a depth of 4.0 meters below the waterline, secured by lowering lines of steel rope on both sides of the plate to ensure the plate was horizontal at the 4.0 meter water depth.

The Reson 7101 systems were energized and data were acquired to measure the plate's depth. During the data acquisition, the vessels' navigation and motion sensors, a POS M/V 320 (v. 4) on each vessel, were also energized to record the vessels' attitude in the water at the time of measurement. Data were acquired for a period of 2 minutes to provide data samples large enough to calculate an average observed depth for each system.

SVP casts were performed to create sound velocity profiles of the water column in the vicinity of each vessel.

The data were then processed in CARIS HIPS & SIPS (v. 7.1) to reduce the observed depths to the waterline and compare them to the known depths of the horizontal plate. The processing procedure that was followed parallels the standard data processing procedures as detailed in the report of survey, with all static draft measurements, vessel equipment offsets, vessel attitude data, and sound velocity corrections applied to the raw depth observations.

The data were then further processed in the CARIS HIPS & SIPS (v. 7.1) Swath Editor routine.

The acquired observed plate's depths were exported from CARIS to Microsoft Excel to calculate an average observed depth over a 1-minute period for each system. The results of the bar check calibrations are detailed below.

<u>Multibeam Bar Check Results</u>

R/V R2's Reson 7101 (4m Bar Depth)

The images below shows a CARIS HIPS & SIPS (v. 7.1) Swath Editor display screen with the horizontal plate ensonified at a depth of 4.06 meters below the waterline (the value of 4.06 meters is the average depth calculated over a 1-minute period of data acquisition).

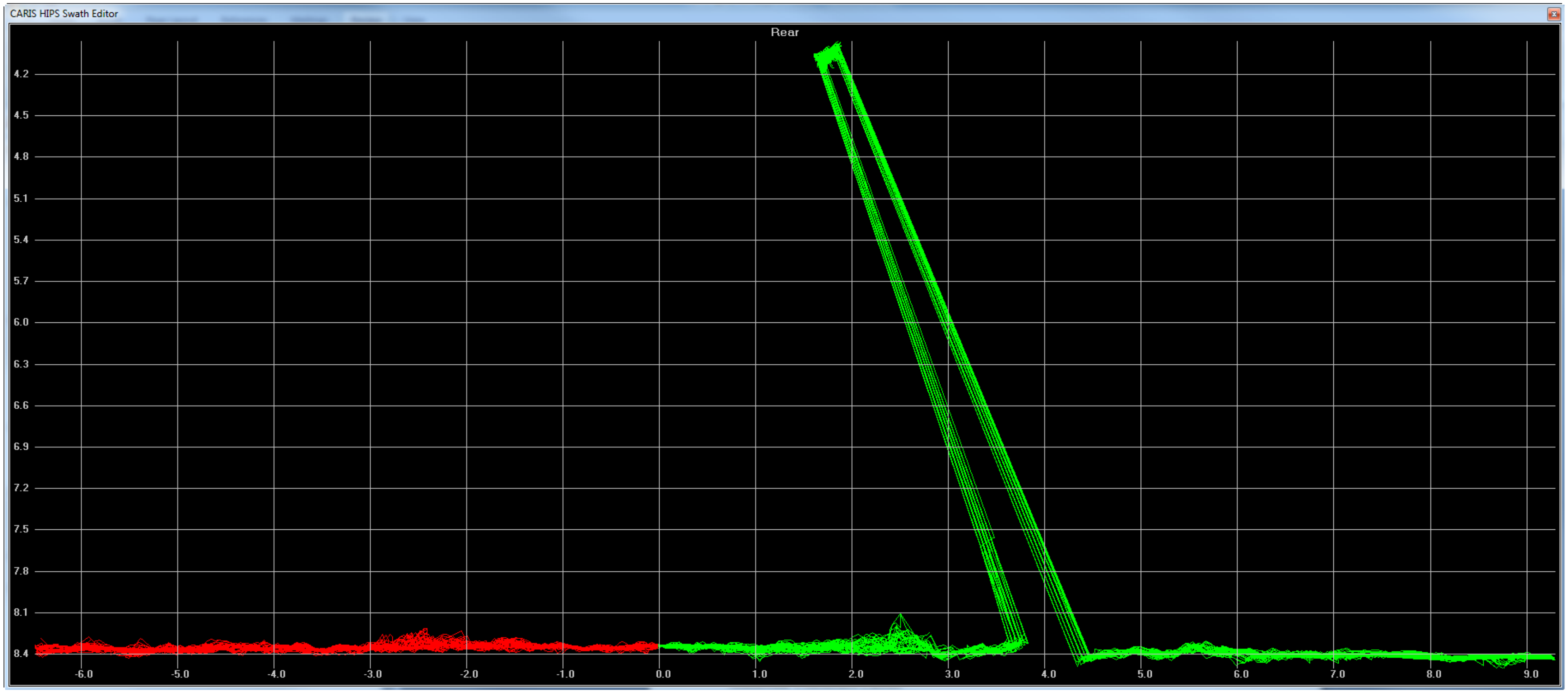


Figure 16 R/V R2 4m Bar Check Showing the Bar Relative to Seafloor

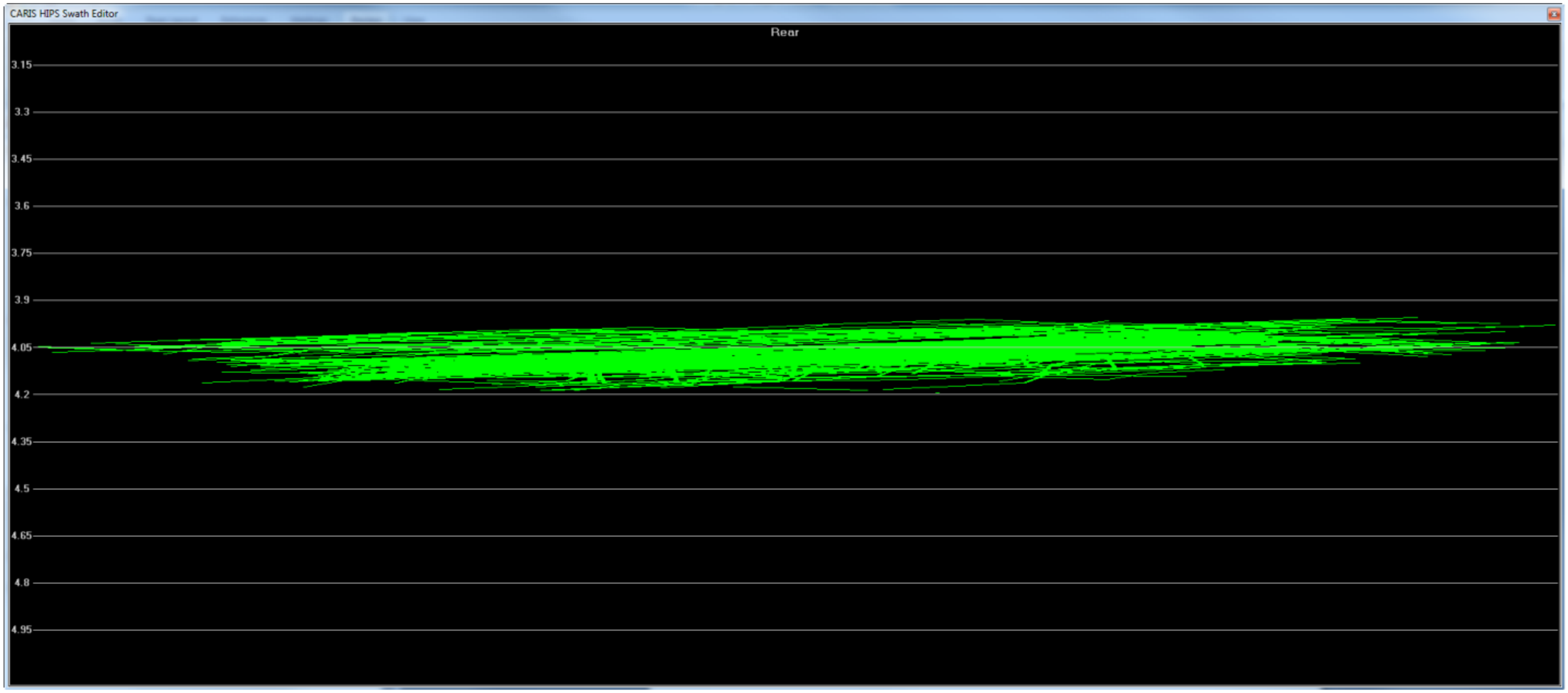


Figure 17 R/V R2 4m Bar Check Showing the Bar (Seafloor Deleted)

R/V D2's Reson 7101 (4m Bar Depth)

The images below shows a CARIS HIPS & SIPS (v. 7.1) Swath Editor display screen with the horizontal plate ensonified at a depth of 4.05 meters below the waterline (the value of 4.05 meters is the average depth calculated over a 1-minute period of data acquisition).

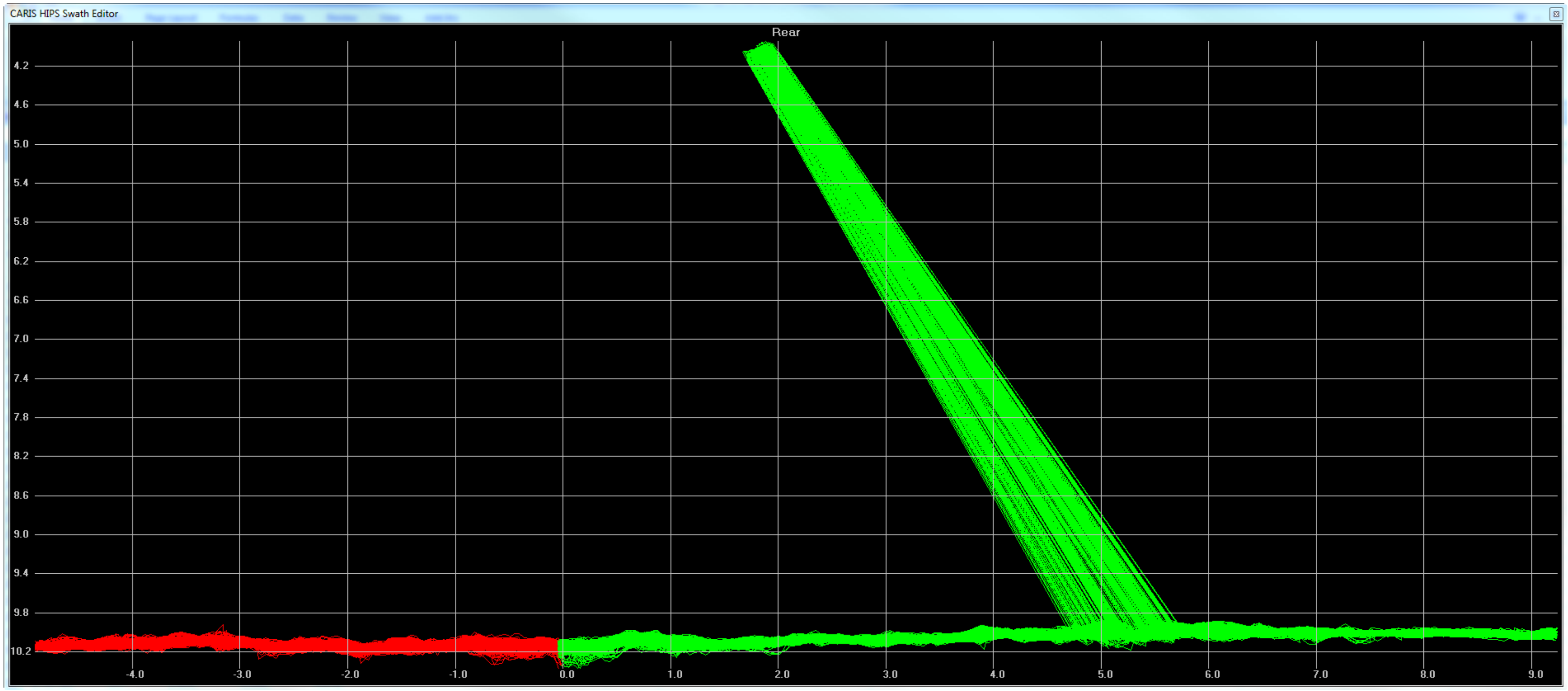


Figure 18 R/V D2 4m Bar Check Showing the Bar Relative to Seafloor

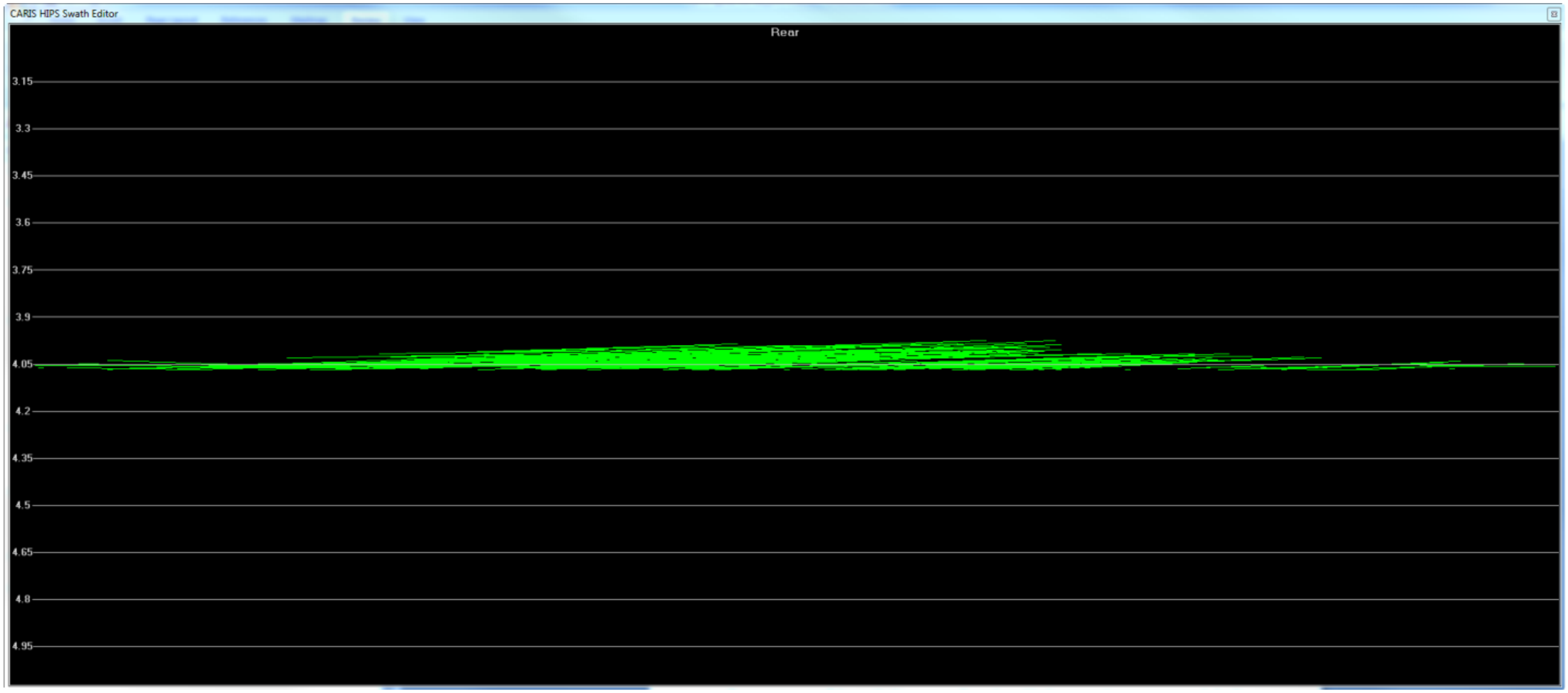


Figure 19 R/V D2 4m Bar Check Showing the Bar (Seafloor Deleted)

Multibeam Confidence Checks

Sonar system confidence checks, as outlined in Section 5.2.3.1 of the HSSD, were performed by comparing post processed depth information collected over a common area by each vessel. The confidence check results are outlined in the table below. In addition to this, checks were performed on overlapping mainscheme and crossline data collected from different vessels on different days.

Multibeam Confidence Check Results

Surface Vessels	Mean Difference (m)	Standard Deviation (m)
Pacific_Star vs. R2	-0.15	0.1
Pacific_Star vs. D2	-0.09	0.1
R2 vs. D2	0.05	0.04

Note: The above results were computed from difference surfaces that were created from data collected during a confidence check conducted during field operations. The same or better results were noticed in additional checks that were performed using overlapping mainscheme and crossline data.

Appendix III – Positioning and Attitude System Reports

GAMS Calibration

Vessel headings are measured by the Applanix POS MV 320 V4, by way of a GPS Azimuth Measurement Subsystem (GAMS). GAMS computes a carrier phase differential GPS position solution of a Slave antenna with respect to a Master antenna position, thereby computing the heading between the two. In order for this subsystem to provide a heading accuracy of 0.01º, the system needs to know and resolve the spatial relationship between the two antennas. During the GAMS calibration, since the offset from the IMU to the Master antenna is known (from the vessel offset survey), the location of the Slave antenna is calculated by computing the baseline between the two antennas with respect to the IMU axes.

To calibrate the heading data received from the POS MV GAMS subsystem, the POS Viewer software is used to run the GAMS Calibration routine. First, an accurate and precise separation distance between the two GNSS antennas is entered into the POS Viewer's GAMS Parameter Setup window. Once this known offset is entered into the system, the vessel begins maneuvering with turns to port and starboard (preferably figure-eight maneuvers) to allow the system to refine its heading accuracy.

Once the heading data falls to within an allowable accuracy, the vessel ends the figure-eight maneuvers and maintains a steady course and speed. The GAMS Calibration routine is started, and the POS MV completes the calibration. The results can be viewed in the GAMS Parameter Setup window of the POS Viewer software.

Note: The GAMS subsystem should be calibrated only once; at the start of the survey. Additional calibrations should only be conducted when the IMU or antennas are moved or replaced. The R/V D2 required an additional GAMS calibration on Julian Day 2012-188 to rectify an IMU failure.

GAMS Calibration Results

The calculations give the following results:

Table 22: Vessel Heading Calibration (GAMS Calibration)

Vessel	F/V Pacific Star	R/V R2	R/V D2 (Start of Survey to JD188)	R/V D2 (JD188 to End of Survey)
Two Antenna Separation (m)	1.770	1.998	2.001	1.998
Heading Calibration Threshold (deg)	0.500	0.500	0.500	0.500
Heading Correction (deg)	0.000	0.000	0.000	0.000
Baseline Vector:				
X Component (m) (+ fwd)	0.069	0.044	-0.069	-0.066
Y Component (m) (+ stbd)	1.768	1.997	2.000	1.997
Z Component (m) (+ down)	-0.009	0.025	0.034	0.024

Appendix IV – Sound Speed Sensor Report

All SVP Calibration Reports can be found under the Appendix_III_(SVP_Calibrations) directory.