**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-K339-KR2-14

*Registry No.* H12714, H12715 & H12716

LOCALITY

*State* LOUISIANA

*General Locality* Barataria Bay

*Sublocality* Areas in and around Barataria Bay, Bastian Bay, and Southwest Pass

2014-2015

CHIEF OF PARTY

Dean Moyles

LIBRARY & ARCHIVES

**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<br><br>**HYDROGRAPHIC TITLE SHEET** | REGISTER NO.<br><br>H12714, H12715 & H12716 |
|---|---|
| **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 Louisiana

General Locality Barataria Bay

Locality Areas in and around Barataria Bay, Bastian Bay, and Southwest Pass

Scale 1:40,000 Date of Survey 11/27/2014 – 06/30/2015

Instructions dated May, 2013 Project No. OPR-K339-KR2-14

Vessel Geodetic Surveyor (556510), Go America (1120138)

Chief of party Dean Moyles

Surveyed by Moyles, Farley, Rokyta, Mount, Fairbank, Geiger, Klein et al.

Soundings taken by echo sounder, hand lead, pole Dual Reson SeaBat 7125 (Geodetic Surveyor, Over the Side Mount), Dual Reson SeaBat 7125 (Go America, Over the Side 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 survey is to update existing NOS nautical charts in a high commercial traffic area.

ALL TIMES ARE RECORDED IN UTC.


FUGRO PELAGOS INC.

3574 RUFFIN ROAD

SAN DIEGO, CA 92123

## A – Equipment

The Geodetic Surveyor and Go America acquired all sounding data for this project. The equipment list and vessel descriptions are included in Appendix I.

Sounding Equipment

The Geodetic Surveyor, 122 feet in length with a draft of 10 feet, was equipped with an over the side pole that housed an underwater IMU and dual Reson SeaBat 7125 multibeam sonars (dual meaning two independent systems). The Reson 7125 is a dual frequency system operating at 200 and 400 kHz. The system was operated Equi-Distant beam mode option; which forms 256 across track beams (in 200 kHz) and 512 across track beams (in 400 kHz), with maximum swath coverage of 140°. 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).

The Reson systems and IMU were installed on a special mounting plate, where each Reson 7125 were rotated approximately 15 degrees. The Reson systems were installed in their normal SV2 bracket which included an SV70 probe (located in the nose cone) and were simply attached to the mounting plate by a flange. Refer to Appendix I for more information and graphics.

All 7125 multibeam data files were logged in the s7k format using WFMB v3.10.4.9. The bathy data from each Reson 7125 (records 7004/7006) were stitched together in WFMB to create one s7k file with each ping containing 1024 beams.

Note: The Geodetic Surveyor was utilized November 26, 2014 through December 11, 2014 and February 23, 2015 through February 24, 2015. Due to scheduling conflicts and engine issues, the Geodetic Surveyor was demobilized in May 2015. The equipment and a work container were then mobilized on the Go America and work commenced May 17, 2015.

The Go America, 150 feet in length with a draft of 10 feet, was equipped with an over the side pole that housed an underwater IMU and dual Reson SeaBat 7125 multibeam sonars (dual meaning two independent systems). The Reson 7125 is a dual frequency system operating at 200 and 400 kHz. The system was operated Equi-Distant beam mode option; which forms 256 across track beams (in 200 kHz) and 512 across track beams (in 400 kHz), with maximum swath coverage of 140°. 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).

The Reson systems and IMU were installed on a special mounting plate, where each Reson 7125 were rotated approximately 15 degrees. The Reson systems were installed in their normal SV2 bracket which included an SV70 probe (located in the nose cone) and were simply attached to the mounting plate by a flange. Refer to Appendix I for more information and graphics.

All 7125 multibeam data files were logged in the s7k format using WFMB v3.10.4.9. The data from each Reson 7125 (records 7004/7006) were stitched together in WFMB to create one s7k file with each ping containing 1024 beams.

It should be noted that both vessels were equipped with dual Reson 7125 sonars, which were operated in the full rate dual head (FRDH) mode in the Reson topside. Also since we were logging the 7004/7006 records roll stabilization was not utilized.

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** | **Geodetic Surveyor** | **Go America** |
| **Mount Type** | Over the Side | Over the Side |
| **Sonar System** | Dual Reson 7125 | Dual Reson 7125 |

Backscatter Imagery

Towed SideScan 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

Geodetic Surveyor and Go America were equipped with an Underway CTD (UCTD) from Teledyne OceanScience for the acquisition of sound velocity profiles. Sound velocity casts were normally performed every two to three hours on both vessels. 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 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 |

**Figure 1: UCTD (Go America)**

The vessels were also 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 with a ±0.5 dbar accuracy for pressure. The instruments were mounted within a weighted cage and were hand deployed from the port or stbd sides of the vessel, depending on current and weather.

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 WFMB 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. The reference sound velocity was reset after each cast and when a cast was performed due to a significant deviation from the reference sound velocity.

## Positioning & Attitude Equipment

All vessels were equipped with an Applanix Position and Orientation System for Marine Vessels (POS MV) 320 V4 (underwater IMU) 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 Fugro's Marinestar corrections; Marinestar is a decimeter level, phase based service using satellite 'orbit and clock' data valid worldwide, based upon GPS L1 and L2 frequencies, it provides a horizontal accuracy of 10 cm and vertical accuracy of 15 cm.

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 (HSSD) were achieved. These include, but are not limited to, the following: GPS Status, Positional 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 the Geodetic Surveyor and Go America, 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 2: Port Radar Water Level Sensor (Go America)**

**Figure 3: Starboard Radar Water Level Sensor**

Bottom Sampling

The Geodetic Surveyor and Go America were equipped with a 2.4L Van Veen Grab bottom sampler and 100m of line. The sampler was hand deployed, and retrieved via a davit that was installed on the port side of the vessel. All samples were discarded after the sample information was recorded.

Software

Acquisition

All raw multibeam data were collected with WFMB v3.10.4.9. WFMB ran on a Windows 7 PC with a quad-core Intel processor. Data from the Reson 7125 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 tabular or graphical format. Operators look here to view the status of the GPS satellite constellation and position solutions, real-time SV, tidal values, etc.
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 procedure based on current 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 sidescan 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 PosPac MMS. Additionally, the True Heave data applied in post-processing was collected concurrently in the same file. The program also provided real-time QC and alarms for excessive HDOP, PDOP, and DGPS outages.

Fugro Pelagos' MB Survey Tools v3.1.5 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) v8.1.11  HIPS converted the s7k files to HIPS format, corrected soundings for sound velocity, motion, tide, and vessel offset, and were used to examine and reject noisy soundings.  HIPS also produced the final BASE (Bathymetry Associated with Statistical Error) surfaces.

CARIS Notebook v3.1.1 was used to generate the S-57 Feature Files.

ESRI ArcMap v10.3 was utilized for survey planning, reviewing coverage plots, creating infills & crosslines, and creating graphics.

Applanix POSPac MMS 6.2 was utilized for the post-processing of vessel dual frequency GPS data, along with the simultaneous base station data to calculate higher accuracy positions than those calculated in real-time.

MB Survey Tools v3.1.5 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 v3.1.5 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.

## 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. These measured values included true heave RMS from the raw POS MV files, positioning and attitude uncertainties from the Applanix POSPac MMS RMS 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 level for the horizontal and vertical components of 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 0.020 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 7125 processor, yielding timing accuracies on the order of 1 millisecond. Therefore 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 through 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 Tides and Water Levels Statement of Work; it stated the overall estimated tidal error for the survey area was 0.33m. In order to account for the measured and zoning uncertainty the following were used during TPU calculation; measured uncertainty was set to 0.10m and zoning uncertainty set to 0.23m.
- Sound Speed Values were determined in MB Survey Tools, 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 manufacturers specifications.
- MRU Align Standard Deviation for the Gyro and Roll/Pitch were set to 0.10° 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 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 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, 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 filtered using a swath angle filter and a RESON quality flag filter (**Table 4**). The swath angle filter rejected all soundings falling farther from a specified angle from nadir. The RESON quality flag filter rejected 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 processor 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 |
|---|---|---|
| Port_68_Stbd_68_01.hff | 68˚ | 0&1 |
| Port_65_Stbd_62_01.hff | 65˚& 62º | 0&1 |
| Port_64_Stbd_64_01.hff | 64˚ | 0&1 |

It should be noted that some areas were also subjected to a surface filter; this was conducted on a line by line basis, using various resolutions. Data that fell within the half a meter resolution were gridded at two meters and data within the two meter resolution we gridded at four meters. When the surface filter was applied, the applicable resolution was selected and standard deviation threshold type along with a threshold value of two was selected. The surface filter alleviated noise that was a result of the soft muddy bottom, fish, etc. The line was then re-examined in swath editor and any additional noise removed. During subset cleaning, areas where features exist, rejected soundings were displayed and if needed soundings marked rejected by the surface filter were re-accepted.

Raw POS MV data were processed in Applanix POSPac MMS 6.2 with a Single Base Station Solution using the Grand Isle (GRIS) CORs station dual frequency GPS data. A Smoothed Best Estimated Trajectory (SBET) file containing a Post Process Kinematic (PPK) 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 (NAD 83).

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 subtracting 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 CO-OPS.

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 HSSD April 2014. 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 |
| 0.5m | 0-20m | Order 1a | 4.00 | 0.50% | 0.354m | 1.96 | Density & Local | 2.00 | 2.50 | 1 pixel |
| 2m | 20-Maxm | Order 1a | 4.00 | 0.50% | 1.414m | 1.96 | Density & Local | 2.00 | 2.50 | 1 pixel |

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

Subsets Tiles (to track areas examined) were then 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 that soundings were carried through to the finalized BASE surface.

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 main-scheme 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 Geodetic Surveyor and Go America. 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 inside the lab or 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 WFMB 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. This reference sound velocity was determined by averaging 50 sound velocities produced at the head. The reference sound velocity was reset after each cast and also reset when a cast was performed due to a significant deviation from the reference sound velocity.

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 five minutes logging L1/L2 GPS data. The line was first run at lowest possible engine RPM, then rerun heading the opposite direction at the same RPM, stopping at the end of the line to obtain an additional five 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.

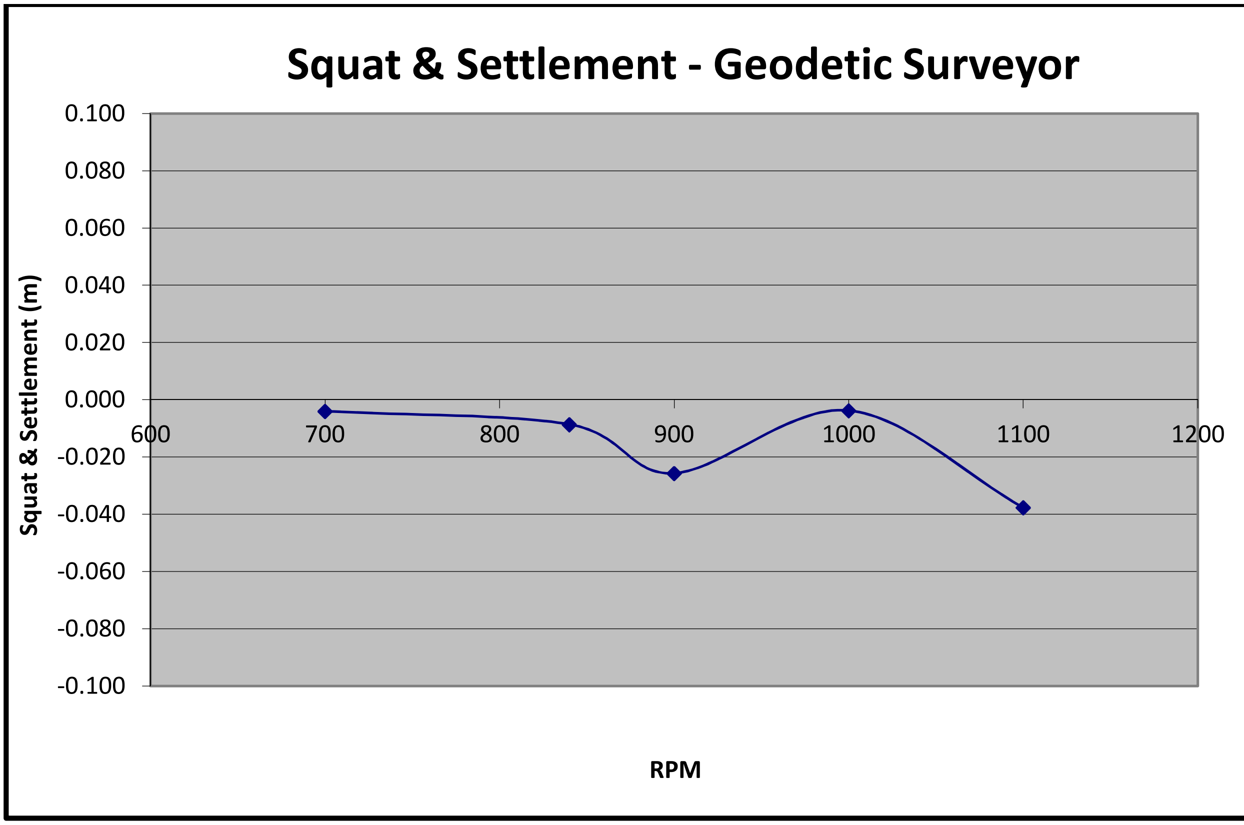



**Figure 4 Geodetic Surveyor Dynamic Draft**

**Table 7 Geodetic Surveyor Squat Settlement Results**

| Geodetic Surveyor DYNAMIC DRAFT CORRECTORS | | |
|---|---|---|
| Speed (kts) | RPM | Settlement |
| 3.9 | 700 | -0.002 |
| 4.7 | 840 | -0.009 |
| 5.0 | 900 | -0.026 |
| 5.5 | 1000 | -0.004 |
| 6.1 | 1000 | -0.038 |

The squat settlement test for the Geodetic Surveyor was conducted on November 29, 2014 (Julian Day 333).

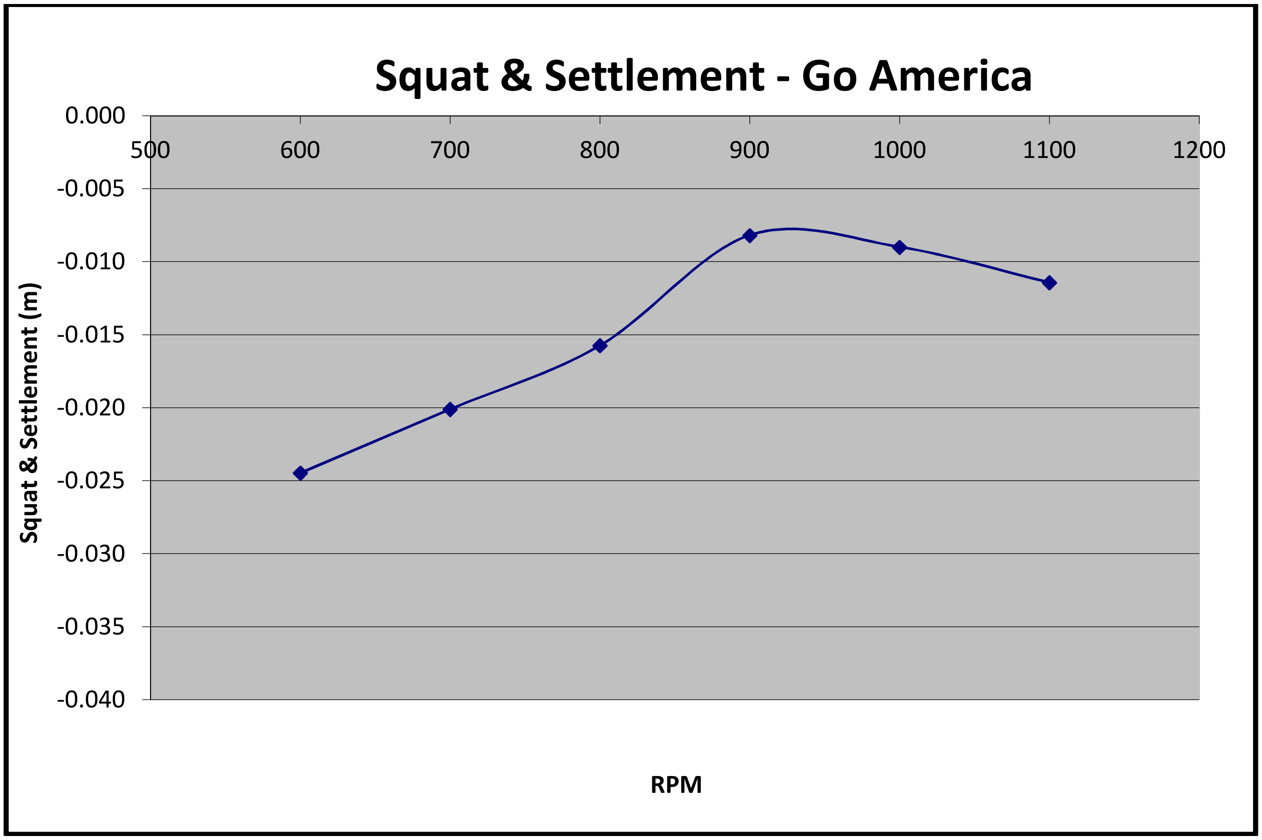



**Figure 5 Go America Dynamic Draft**

**Table 8 Go America Squat Settlement Results**

| Go America DYNAMIC DRAFT CORRECTORS | | |
|---|---|---|
| Speed (kts) | RPM | Settlement |
| 3.8 | 600 | 0.017 |
| 4.6 | 700 | 0.035 |
| 5.3 | 800 | 0.054 |
| 5.9 | 900 | 0.066 |
| 6.4 | 1000 | 0.079 |
| 7.5 | 1100 | 0.083 |

The squat settlement test for the Go America was conducted on May 20, 2015 (Julian Day 140).

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 9 Draft Measurements for the Geodetic Surveyor (Dual 7125)**

| DRAFT # | JULIAN DAY | DATE (UTC) | TIME (UTC) | DEPTH (m) |
|---|---|---|---|---|
| 1 | 328 | 11/24/2014 | 9:22:01 | -3.79 |
| 2 | 330 | 11/26/2014 | 11:32:21 | -3.8 |
| 3 | 332 | 11/28/2014 | 17:32:33 | -3.78 |
| 4 | 333 | 11/29/2014 | 13:08:50 | -3.77 |
| 5 | 333 | 11/29/2014 | 23:25:40 | -3.76 |
| 6 | 334 | 11/30/2014 | 11:41:22 | -3.75 |
| 7 | 335 | 12/1/2014 | 15:57:17 | -3.75 |
| 8 | 336 | 12/2/2014 | 13:33:43 | -3.73 |
| 9 | 336 | 12/2/2014 | 18:55:04 | -3.76 |
| 10 | 337 | 12/3/2014 | 11:08:23 | -3.74 |
| 11 | 337 | 12/3/2014 | 20:50:06 | -3.73 |
| 12 | 339 | 12/5/2014 | 14:16:27 | -3.74 |
| 13 | 340 | 12/6/2014 | 20:00:06 | -3.72 |
| 14 | 342 | 12/8/2014 | 14:19:16 | -3.7 |
| 15 | 343 | 12/9/2014 | 3:26:33 | -3.7 |
| 16 | 343 | 12/9/2014 | 12:03:21 | -3.7 |
| 17 | 344 | 12/10/2014 | 14:09:40 | -3.69 |
| 18 | 344 | 12/10/2014 | 20:25:52 | -3.68 |
| 19 | 345 | 12/11/2014 | 21:02:11 | -3.67 |
| 20 | 54 | 2/23/2015 | 16:30:00 | -3.8 |

**Table 10 Draft Measurements for the Go America (Dual 7125)**

| DRAFT # | JULIAN DAY | DATE (UTC) | TIME (UTC) | DEPTH (m) |
|---|---|---|---|---|
| 1 | 136 | 5/16/2015 | 19:53:37 | -3.43 |
| 2 | 137 | 5/17/2015 | 10:01:36 | -3.43 |
| 3 | 137 | 5/17/2015 | 18:58:00 | -3.4 |
| 4 | 138 | 5/18/2015 | 17:24:09 | -3.39 |
| 5 | 138 | 5/18/2015 | 21:31:13 | -3.37 |
| 6 | 139 | 5/19/2015 | 8:53:17 | -3.35 |
| 7 | 140 | 5/20/2015 | 15:32:59 | -3.35 |

| DRAFT # | JULIAN DAY | DATE (UTC) | TIME (UTC) | DEPTH (m) |
|---|---|---|---|---|
| 8 | 141 | 5/21/2015 | 0:54:26 | -3.35 |
| 9 | 141 | 5/21/2015 | 9:25:08 | -3.35 |
| 10 | 141 | 5/21/2015 | 19:37:14 | -3.34 |
| 11 | 143 | 5/23/2015 | 0:14:21 | -3.3 |
| 12 | 143 | 5/23/2015 | 8:52:22 | -3.3 |
| 13 | 143 | 5/23/2015 | 17:50:55 | -3.37 |
| 14 | 146 | 5/26/2015 | 22:04:20 | -3.35 |
| 15 | 148 | 5/28/2015 | 1:55:56 | -3.44 |
| 16 | 148 | 5/28/2015 | 9:54:36 | -3.41 |
| 17 | 148 | 5/28/2015 | 18:15:18 | -3.4 |
| 18 | 149 | 5/29/2015 | 12:52:55 | -3.39 |
| 19 | 149 | 5/29/2015 | 19:08:11 | -3.4 |
| 20 | 150 | 5/30/2015 | 13:59:26 | -3.38 |
| 21 | 150 | 5/30/2015 | 21:27:46 | -3.37 |
| 22 | 151 | 5/31/2015 | 6:32:29 | -3.37 |
| 23 | 152 | 6/1/2015 | 0:05:30 | -3.37 |
| 24 | 152 | 6/1/2015 | 10:20:52 | -3.38 |
| 25 | 152 | 6/1/2015 | 18:41:33 | -3.37 |
| 26 | 153 | 6/2/2015 | 16:53:22 | -3.36 |
| 27 | 154 | 6/3/2015 | 2:28:20 | -3.35 |
| 28 | 155 | 6/4/2015 | 1:14:45 | -3.35 |
| 29 | 155 | 6/4/2015 | 12:03:01 | -3.33 |
| 30 | 155 | 6/4/2015 | 19:26:11 | -3.33 |
| 31 | 156 | 6/5/2015 | 3:43:03 | -3.33 |
| 32 | 156 | 6/5/2015 | 23:27:10 | -3.33 |
| 33 | 157 | 6/6/2015 | 9:32:43 | -3.33 |
| 34 | 157 | 6/6/2015 | 17:57:18 | -3.32 |
| 35 | 158 | 6/7/2015 | 12:35:53 | -3.32 |
| 36 | 158 | 6/7/2015 | 21:45:46 | -3.3 |
| 37 | 159 | 6/8/2015 | 8:30:40 | -3.29 |
| 38 | 159 | 6/8/2015 | 23:07:40 | -3.29 |
| 39 | 160 | 6/9/2015 | 10:14:23 | -3.3 |
| 40 | 160 | 6/9/2015 | 12:47:49 | -3.34 |
| 41 | 161 | 6/10/2015 | 19:21:54 | -3.39 |
| 42 | 162 | 6/11/2015 | 14:42:21 | -3.35 |
| 43 | 164 | 6/13/2015 | 14:30:43 | -3.38 |
| 44 | 165 | 6/14/2015 | 1:40:08 | -3.37 |
| 45 | 165 | 6/14/2015 | 10:27:37 | -3.4 |
| 46 | 166 | 6/15/2015 | 3:59:41 | -3.4 |

| DRAFT # | JULIAN DAY | DATE (UTC) | TIME (UTC) | DEPTH (m) |
|---|---|---|---|---|
| 47 | 166 | 6/15/2015 | 12:52:51 | -3.39 |
| 48 | 168 | 6/17/2015 | 1:04:04 | -3.37 |
| 49 | 168 | 6/17/2015 | 19:22:53 | -3.35 |
| 50 | 169 | 6/18/2015 | 4:41:26 | -3.35 |
| 51 | 169 | 6/18/2015 | 13:59:04 | -3.32 |
| 52 | 169 | 6/18/2015 | 23:23:00 | -3.34 |
| 53 | 170 | 6/19/2015 | 8:35:45 | -3.33 |
| 54 | 170 | 6/19/2015 | 19:03:59 | -3.32 |
| 55 | 171 | 6/20/2015 | 1:31:18 | -3.32 |
| 56 | 171 | 6/20/2015 | 10:19:32 | -3.33 |
| 57 | 171 | 6/20/2015 | 19:15:06 | -3.31 |
| 58 | 172 | 6/21/2015 | 3:51:52 | -3.31 |
| 59 | 172 | 6/21/2015 | 13:02:06 | -3.29 |
| 60 | 172 | 6/21/2015 | 22:22:41 | -3.29 |
| 61 | 173 | 6/22/2015 | 7:55:57 | -3.27 |
| 62 | 173 | 6/22/2015 | 17:31:23 | -3.27 |
| 63 | 174 | 6/23/2015 | 1:49:45 | -3.27 |
| 64 | 174 | 6/23/2015 | 11:22:33 | -3.27 |
| 65 | 174 | 6/23/2015 | 21:51:50 | -3.26 |
| 66 | 175 | 6/24/2015 | 4:23:39 | -3.25 |
| 67 | 175 | 6/24/2015 | 14:19:55 | -3.25 |
| 68 | 175 | 6/24/2015 | 19:05:12 | -3.39 |
| 69 | 176 | 6/25/2015 | 5:39:41 | -3.38 |
| 70 | 177 | 6/26/2015 | 1:09:09 | -3.38 |
| 71 | 177 | 6/26/2015 | 10:48:22 | -3.35 |
| 72 | 177 | 6/26/2015 | 20:55:52 | -3.38 |
| 73 | 178 | 6/27/2015 | 5:42:30 | -3.39 |
| 74 | 179 | 6/28/2015 | 10:02:37 | -3.37 |
| 75 | 179 | 6/28/2015 | 20:09:28 | -3.34 |
| 76 | 180 | 6/29/2015 | 4:34:17 | -3.34 |
| 77 | 180 | 6/29/2015 | 8:43:59 | -3.34 |
| 78 | 181 | 6/30/2015 | 11:07:33 | -3.33 |

Tides

All sounding data were initially reduced to MLLW using preliminary tidal data from the tidal station located on Grand Isle, LA. This station is owned and operated by the NOAA's National Ocean Service through the Center for Operational Oceanographic Products and Services (CO-OPS).

Preliminary tidal data was assembled by CO-OPS and accessed through the NOAA tides and currents website (*http://tidesandcurrents.noaa.gov/*). A cumulative file for the gauge in use was updated daily by appending the new data as it became available. It should be noted that these unverified tides were used in the field for preliminary processing only.

On July 20, 2015, verified tide data was acquired from CO-OPS through the NOAA tides and currents website (*http://tidesandcurrents.noaa.gov/*). The verified data applied to all sounding data in CARIS HIPS using tidal zones provided by NOAA. All sounding data was then remerged. Verified tidal data were used for all final CUBE Surfaces, soundings, and S-57 Feature files.

For additional information, refer OPR-K339-KR2-14 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 11**.

**Table 11 Patch Test Results Summary**

| Patch Test Results | | | | | | |
|---|---|---|---|---|---|---|
| **Vessel** | **Patch Test Day[1]** | **MB Sonar** | **Timing Error** | **Pitch Offset** | **Roll Offset** | **Azimuth Offset** |
| Geodetic Surveyor | 2014-326 | Port 7125 400 kHz | 0.000 | 0.600 | 16.498 | -1.800 |
| | 2014-326 | Stbd 7125 400 kHz | 0.000 | 0.600 | -15.600 | -1.400 |
| | | | | | | |
| Go America | 2015-134 | Port 7125 400 kHz | 0.000 | -0.300 | 16.498 | -0.700 |
| | 2015-134 | Stbd 7125 400 kHz | 0.000 | 0.500 | -15.600 | -1.400 |

### Additional Sounding Techniques

None.

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

## D – Approval Sheet

**Approval Sheet**

For

# H12714, H12715 & H12716

As Chief of Party, Field operations for this hydrographic survey were conducted under my direct supervision, with frequent personal checks of progress and adequacy. I have reviewed the attached survey data and reports.

All field sheets, this Data Acquisition and Processing Report, and all accompanying records and data are approved. All records are forwarded for final review and processing to the Processing Branch.

The survey data meets or exceeds requirements as set forth in the NOS Hydrographic Surveys and Specifications Deliverables Manual, Standing and Letter Instructions, and all HSD Technical Directives. These data are adequate to supersede charted data in their common areas. This survey is complete and no additional work is required.

Approved and forwarded,

Dean Moyles, (ACSM Cert. No. 226)
Senior Hydrographer
Fugro Pelagos, Inc.
October 30, 2015

X Moyles, Dean

Digitally signed by Moyles, Dean
DN: dc=com, dc=fugro, l=america, ou=fpi, ou=people_fpi, 0.9.2342.19200300.100.1.1=moylesd, cn=Moyles, Dean, email=dmoyles@fugro.com
Date: 2015.11.26 10:01:28 -08'00'

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

## Appendix I – Vessel Reports

### Geodetic Surveyor

The Geodetic Surveyor **(Figure 6),** is a Fugro owned vessel that accommodated a survey crew, acquisition hardware. Dual Reson SeaBat 7125 multibeam sonars were installed on an over the side pole mount approximately amidships. The Reson systems and IMU were installed on a special mounting plate, where each Reson 7125 were rotated approximately 15 degrees. The Reson systems were installed in their normal SV2 bracket which included an SV70 probe (located in the nose cone) and were simply attached to the mounting plate by a flange. The inertial measurement unit (IMU) for the POS MV was an underwater unit that was installed directly above the Reson 7125's (**Figure 7**).

All 7125 multibeam data files were logged in the s7k format using WFMB v3.10.4.9. The bathy data from each Reson 7125 (records 7004/7006) were stitched together in WFMB to create one s7k file with each ping containing 1024 beams.

**Table 12 Vessel Specifications (Geodetic Surveyor)**

| SURVEY VESSEL<br>Geodetic Surveyor | |
|---|---|
| Owner | Fugro GeoServices, Inc. (FGSI) |
| Official Number | 556510 |
| Length | 122' 7" |
| Breadth | 30' |
| Depth | 10' 6" |
| Max Draft | 10' |
| BHP Main Engines | 5600 HP (Alco 12-251 x 2) |
| Gross Tonnage (US) | 97 |
| Fresh Water Capacity | 40,000 Gallons |
| Fuel Capacity | 21,300 Gallons |


**Figure 6 Geodetic Surveyor**

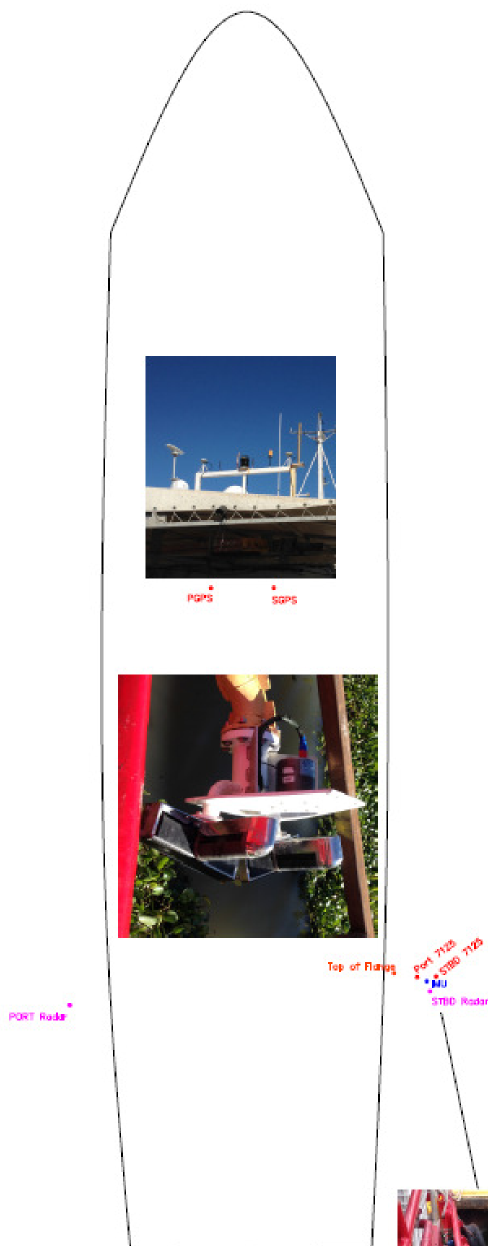
**Figure 7 Geodetic Surveyor Dual 7125 with Underwater IMU**

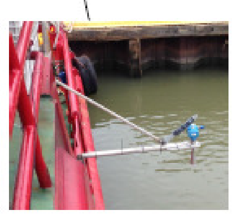
Two Trimble L1/L2 antennas were mounted above and forward from the sonar. Offset 1.985 meters port-starboard from each other, the L1/L2 antennas provided GPS data to the POS MV for position, attitude, and heading computations. The port side antenna functioned as the POS MV master antenna; the starboard side antenna functioned as the POS MV secondary.

The UCTD sensors were deployed from the stern using a unique deployment and re-spooling mechanism that allows the probes to be launched and recovered without the vessel 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, just forward of the CRP (IMU) and Reson 7125. WaterLOG H3611 (Radar Water Level Sensors) were installed on the port and starboard gunwales of Geodetic Surveyor 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 8**).



| Geodetic Surveyor | | | |
|---|---|---|---|
| Sensor | X | Y | Z |
| IMU (CRP) | 0.000 | 0.000 | 0.000 |
| Sonar Reference Point (Port) | -0.305 | 0.127 | -0.438 |
| Sonar Reference Point (STBD) | 0.295 | 0.149 | -0.447 |
| PGPS (Phase Center - Trimble) | -6.816 | 12.427 | 11.353 |
| SGPS (Phase Center - Trimble) | -4.831 | 12.433 | 11.364 |
| Port Static Draft | -11.279 | -0.756 | 5.419 |
| Stbd Static Draft | 0.103 | -0.320 | 5.271 |
| Top of Pole | -1.030 | 0.257 | 5.705 |
| | | | |
| | | | |
| | | | |

Notes:

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) | 12.427 | -6.816 | -11.353 |
| | | | |
| Note: | | | |
| X is positive to Bow | | | |
| Y is positive towards Stbd | | | |
| Z is negative above Ref | | | |

| CARIS Reference Frame | | | |
|---|---|---|---|
| Sensor | X | Y | Z |
| IMU | 0.000 | 0.000 | 0.000 |
| Sonar Reference Point (Port) | -0.305 | 0.127 | 0.438 |
| | P | R | Y |
| Port Patch Test Results | 0.600 | 16.498 | -1.800 |
| Sonar Reference Point (STBD) | 0.295 | 0.149 | 0.447 |
| | P | R | Y |
| Stbd Patch Test Results | 0.600 | -15.600 | -1.400 |
| Note: | | | |
| X is positive towards Stbd | | | |
| Y is positive to Bow | | | |
| Z is postive below Ref | | | |

| Geodetic Surveyor Vessel Outline | | |
|---|---|---|
| Sensor | X | Y |
| Pt 1 | -9.40 | -8.50 |
| Pt2 | -1.70 | -8.40 |
| Pt3 | -1.40 | -0.40 |
| Pt4 | -1.40 | 23.70 |
| Pt5 | -5.70 | 30.70 |
| Pt6 | -10.00 | 23.70 |
| Pt7 | -10.00 | -0.35 |

Notes:

All coordinates are on the IMU reference Frame.
X is positive to Stbd
Y is positive towards Bow

**Figure 8 Geodetic Surveyor Offset Diagram**

Go America

The Go America **(Figure 9),** is owned and operated by Guice Offshore, it accommodated a survey crew, acquisition hardware. An office space container was installed on the back deck; this housed all processing and acquisition hardware. Dual Reson SeaBat 7125 multibeam sonars were installed on an over the side pole mount approximately amidships. The Reson systems and IMU were installed on a special mounting plate, where each Reson 7125 were rotated approximately 15 degrees. The Reson systems were installed in their normal SV2 bracket which included an SV70 probe (located in the nose cone) and were simply attached to the mounting plate by a flange. The inertial measurement unit (IMU) for the POS MV was an underwater unit that was installed directly above the Reson 7125's (**Figure 10**).

All 7125 multibeam data files were logged in the s7k format using WFMB v3.10.4.9. The bathy data from each Reson 7125 (records 7004/7006) were stitched together in WFMB to create one s7k file with each ping containing 1024 beams.

**Table 13 Vessel Specifications (Go America)**

| SURVEY VESSEL<br>Go America | |
|---|---|
| Owner | Guice Offshore |
| Official Number | 1120138 |
| Length | 150' |
| Breadth | 36' |
| Depth | 11' 6" |
| Max Draft | 10' |
| BHP Main Engines | 2 X KTA 38MO |
| Gross Tonnage (US) | 86 |
| Fresh Water Capacity | 14,982 Gallons |
| Fuel Capacity | 31,497 Gallons |


**Figure 9 Go America**

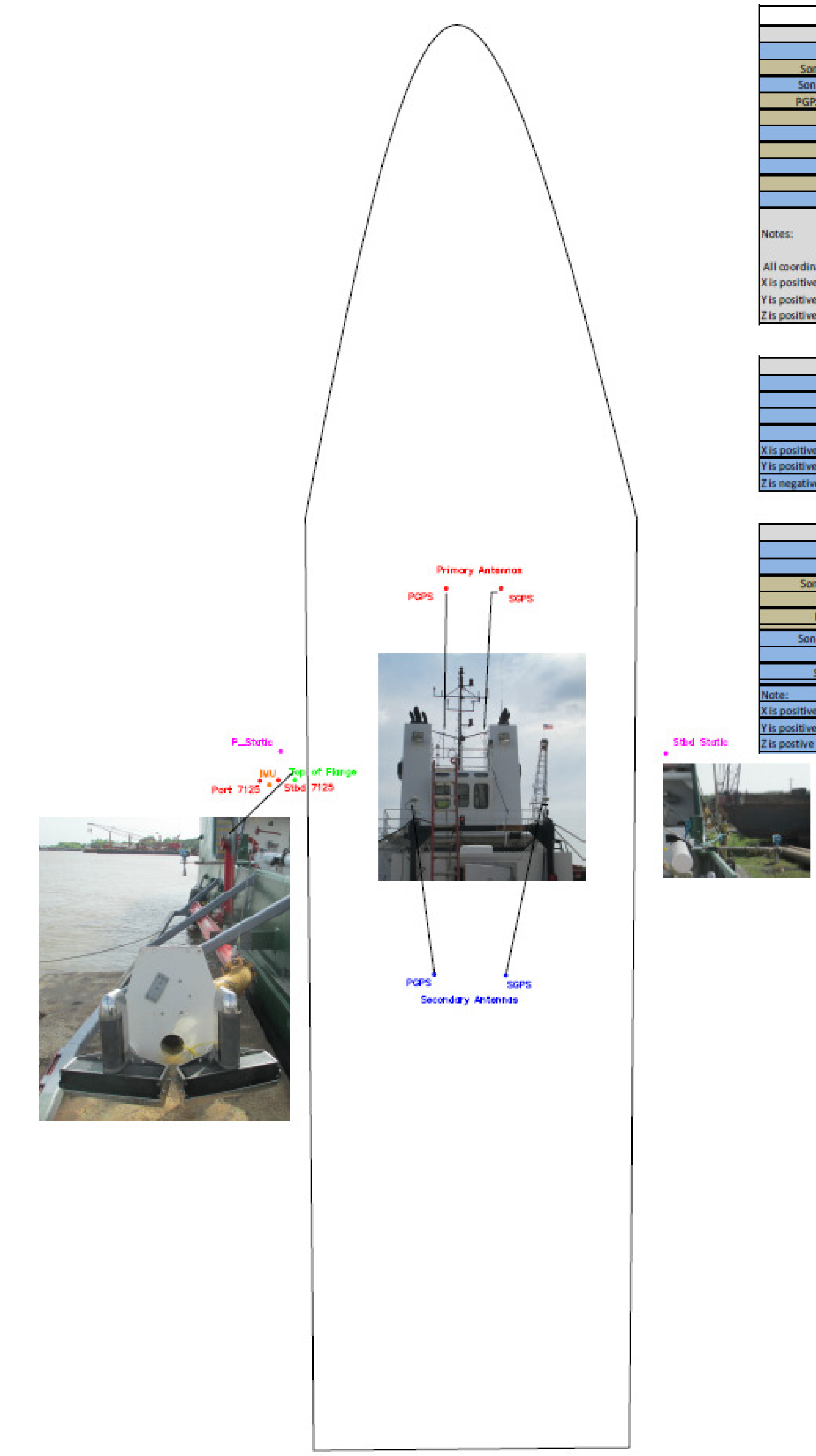
**Figure 10 Go America Dual 7125 with Underwater IMU**

Two Trimble L1/L2 antennas were mounted above and forward from the sonar. Offset 1.753 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 the stern using a unique deployment and re-spooling mechanism that allows the probes to be launched and recovered without the vessel 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, just forward of the CRP (IMU) and Reson 7125. WaterLOG H3611 (Radar Water Level Sensors) were installed on the port and starboard gunwales of Go America 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**).




| R/V Go America | | | |
|---|---|---|---|
| Sensor | X | Y | Z |
| IMU (CRP) | 0.000 | 0.000 | 0.000 |
| Sonar Reference Point (Port) | -0.305 | 0.127 | -0.438 |
| Sonar Reference Point (STBD) | 0.295 | 0.149 | -0.447 |
| PGPS (Phase Center - Trimble) | 5.315 | 6.297 | 13.740 |
| Port Static Draft | 0.365 | 1.072 | 5.205 |
| Stbd Static Draft | 12.701 | 1.000 | 5.270 |
| Top of Pole | 0.816 | 0.154 | 5.678 |
| | | | |
| | | | |
| | | | |

Notes:

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) | 6.297 | 5.315 | -13.740 |
| | | | |
| Note: | | | |
| X is positive to Bow | | | |
| Y is positive towards Stbd | | | |
| Z is negative above Ref | | | |

| CARIS Reference Frame | | | |
|---|---|---|---|
| Sensor | X | Y | Z |
| IMU | 0.000 | 0.000 | 0.000 |
| Sonar Reference Point (Port) | -0.305 | 0.127 | -0.438 |
| | P | R | Y |
| Port Patch Test Results | -0.300 | 16.498 | -0.700 |
| Sonar Reference Point (STBD) | 0.295 | 0.149 | -0.447 |
| | P | R | Y |
| Stbd Patch Test Results | 0.500 | -15.600 | -1.400 |
| Note: | | | |
| X is positive towards Stbd | | | |
| Y is positive to Bow | | | |
| Z is postive below Ref | | | |

**Figure 11 Go America Offset Diagram**

Equipment

**Table 14 Geodetic Surveyor and Go America Acquisition Equipment**

| Description | Serial Number |
| --- | --- |
| Applanix IMU LN200 | 64 |
| Applanix POS MV Processor L1/L2 (RTK) | 2161 |
| GPS Antenna L1/L2 (Primary) | 1441043288 |
| GPS Antenna L1/L2 (Secondary) | 1441028087 |
| RESON NAVISOUND SVP 70 (Primary) | 2007073 |
| RESON NAVISOUND SVP 70 (Spare) | 2711079 |
| RESON 71-P Processor-7125 SV2 (FP3) | 18340313024 |
| RESON 71-P Processor-7125 SV2 (FP3) | 18243512030 |
| Reson SeaBat 7125 400kHz/200Khz Projector | 1612100 |
| Reson SeaBat 7125 400kHz/200Khz Projector | 1012060 |
| Reson SeaBat 7125 Receive Array | 4107007 |
| Reson SeaBat 7125 Receive Array | 2507038 |
| Fugro Pelagos Acquisition PC | BGR 602604 |
| WinFrog Multibeam Dongle | 3100441U |
| WinFrog Multibeam Dongle | 3100442U |
| UCTD Sea-Bird Velocity Probe | 0132 |
| UCTD Sea-Bird Velocity Probe | 0134 |
| Starboard WaterLOG H3611 (Draft Measurement) | 1582 |
| Port WaterLOG H3611 (Draft Measurement) | 1581 |
| AML SV Plus Velocity Probe | 4703 |
| AML SV Plus Velocity Probe | 5354 |
| AML SV Plus Velocity Probe | 5353 |

Software

**Table 15 Software List (Geodetic Surveyor, Go America, & Processing Center)**

| Software Package | Version | Service Pack | Hotfix |
|---|---|---|---|
| Fugro Pelagos WinFrog Multibeam | 3.10.4.9 | N/A | N/A |
| Fugro Pelagos MB Survey Tools | 3.1.5 | N/A | N/A |
| Fugro Pelagos POSMVLogger | 1.2 | N/A | N/A |
| CARIS HIPS/SIPS | 8.1 | N/A | 11 |
| CARIS Notebook | 3.1 | 1 | 1-2 |
| CARIS Bathy DataBASE | 3.2 | 2 | 1-8 |
| ESRI ArcGIS | 10.3 | 10.3 | N/A |
| Applanix POS MV V4 Controller | 7.41 | 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 Motion Reference Unit (MRU).

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

No adjustment was required for 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 16 Patch Test Results for Each Vessel**

| Patch Test Results | | | | | | |
|---|---|---|---|---|---|---|
| **Vessel** | **Patch Test Day**[2] | **MB Sonar** | **Timing Error** | **Pitch Offset** | **Roll Offset** | **Azimuth Offset** |
| Geodetic Surveyor | 2014-326 | Port 7125 400 kHz | 0.000 | 0.600 | 16.498 | -1.800 |
| | 2014-326 | Stbd 7125 400 kHz | 0.000 | 0.600 | -15.600 | -1.400 |
| | | | | | | |
| Go America | 2015-134 | Port 7125 400 kHz | 0.000 | -0.300 | 16.498 | -0.700 |
| | 2015-134 | Stbd 7125 400 kHz | 0.000 | 0.500 | -15.600 | -1.400 |

**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 verifying 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 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 November 22, 2014, hydrographers onboard the Geodetic Surveyor performed bar check calibrations for the respective Reson 7125 multibeam sonar systems.

Prior to performing the bar check calibrations, accurate static draft measurements were performed. Then, a flat, metal plate was lowered to a specific depth below the waterline, using lowering lines of metal chain on both sides to have the plate horizontal at 5.0 meters of water

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

depth.

The Reson 7125 systems were energized and data were acquired to measure the plate's depth. During data acquisition, the vessels' navigation and motion sensors, a POS M/V 320 (v. 4) for the vessel, were also energized to record the vessels' attitude in the water at the time of measurement. Data were acquired for a period of 1-2 minutes to provide data samples large enough to calculate an average observed depth for each system.

An SVP cast was performed to create sound velocity profiles of the water column in the vicinity of the vessel.

The data were then processed in CARIS HIPS & SIPS 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. In general, the static draft measurement, the vessel equipment offsets, the vessel attitude data, and the sound velocity corrections were all applied to the raw depth observations.

The data were then further processed in the CARIS HIPS & SIPS 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.

Multibeam Bar Check Results

**Geodetic Surveyor Reson 7125 (5m Bar Depth)**

The image below shows a CARIS HIPS & SIPS Swath Editor display screen with the horizontal plate ensonified at a depth of 5.06 meters below the waterline (the value of 5.06 meters is the average depth calculated over a 1-minute period of data acquisition).

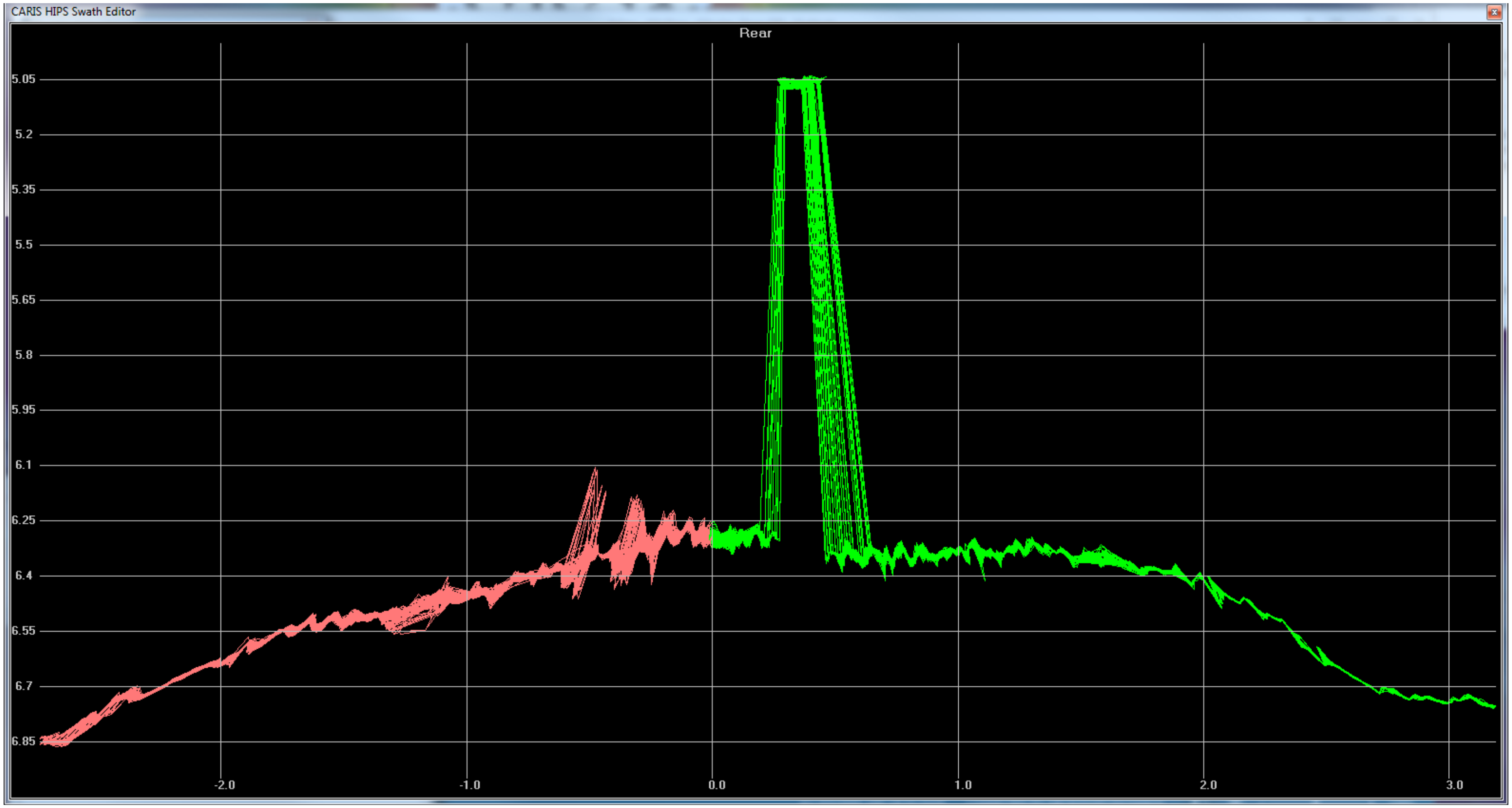



**Figure 12 Geodetic Surveyor 5m Bar Check Showing the Bar Relative to Seafloor**

**Note:** Due to the mob location of the Go America, the pole was not able to be lowered fully to conduct a bar check. It should also be noted that field conditions did not allow a bar check to be conducted either, a comparison was made by examining overlapping data from both vessels in numerous locations; refer to multibeam confidence checks below.

**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) |
|---|---|---|
| Area 1 GS vs. GA | -0.01 | 0.05 |
| Area 2 GS vs. GA | -0.01 | 0.06 |

**Note:** The above results were computed from difference surfaces that were created from overlapping data collected on the Geodetic Surveyor (GS) and the Go America (GA) during field operations. The same or better results were noticed in additional checks that were performed using 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 0.01°, 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.

The GAMS subsystem should be calibrated only one time at the start of the survey. An additional calibration should be completed and logged any time the IMU or antennas are moved.

<u>GAMS Calibration Results</u>

The calculations give the following results:

**Table 17: Vessel Heading Calibration (GAMS Calibration)**

| Vessel | Geodetic Surveyor | Go America |
|---|---|---|
| Two Antenna Separation (m) | 1.976 | 1.754 |
| Heading Calibration Threshold (deg) | 2.000 | 2.000 |
| Heading Correction (deg) | 0.000 | 0.000 |
| Baseline Vector X axis | 0.072 | 0.029 |
| Baseline Vector Y axis | 1.974 | 1.753 |
| Baseline Vector Z axis | 0.066 | -0.061 |

**Appendix IV – Sound Speed Sensor Report**

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