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A. EQUIPMENT

A.1. MAJOR OPERATIONAL SYSTEMS

The major operational systems used to acquire hydrographic data were a dual head Kongsberg EM3002 multibeam echo sounder (MBES) system and an Edgetech 4200 Side Scan Sonar (SSS). A list of the survey equipment is shown in Table 1.

Table 1. Survey Equipment

System	Manufacturer	Model	Serial Number
Multibeam Echo Sounder (Port)	Kongsberg	EM3002	Transducer: 225 Topside: 1076
Multibeam Echo Sounder (Starboard)	Kongsberg	EM3002	Transducer: 112 Topside: 1076
Side Scan Sonar (Primary)	Edgetech	4200 P	Side Scan Fish: 38216 Topside: 38213
Side Scan Sonar (Back –up)	Edgetech	4200 P	Side Scan Fish: 38186 Topside:38162
Single Beam Echo Sounder	ODOM	Echotrac MK III	Transducer: no serial number Topside:003477
Attitude and Positioning System (Primary)	CodaOctopus	F180	F0904015
Attitude and Positioning System (Back-up)	Coda Octopus	F180	F0907076
Positioning System	C -Nav	3050	C-Nav Receiver:15000
Positioning System	C-Nav	3050	C-Nav Receiver: 14323
Sound Speed at Transducer	YSI Electronics	600R-BCR-C-T	06L1372, 05G1488
CTD	Sea-Bird Electronics, Inc	SBE 19 Plus	5221
CTD	Sea-Bird Electronics, Inc	SBE 19 Plus	5222
Cable Payout Indicator	Subsea Systems	PI-5600	232
Grab Sampler	Wildco®	Petite Ponar®	N/A

A.2. SURVEY VESSEL

Survey operations were conducted aboard the R/V *Shearwater*, sub-contracted from Alpine Ocean Seismic Survey, Inc., and mobilized with equipment owned by C & C Technologies. The R/V *Shearwater* is a 110 foot (33.528 meter) catamaran survey vessel based out of New York, New York. Vessel profile and vessel specification information is shown in Table 2. A vessel diagram with all measured offsets from the central reference point is shown in Appendix 1: Vessel Reports – Vessel Offset Reports.

Table 2. Vessel Profile and Specifications.

Owner/Operator	Alpine Ocean Seismic Survey
Home Port / Flag	New York, New York/ USA
United States Coast Guard Official Number	641188
Year Built	1981/2011
Builder	Ben Halter
Intended Service	Coast Guard /Research
Operational Area	East Coast, USA
Length	110
Beam	39'
Draft	7'
Freeboard	10'

A.3. MULTIBEAM ECHOSOUNDER OPERATIONS

As outlined in the Project Instructions, either two hundred percent (200%) side scan sonar coverage with concurrent set line spacing MBES coverage or Object Detection coverage with backscatter was acquired within 4 to 20 meters water depth and complete (100%) MBES coverage was acquired in water depths greater than 20 meters. Any modifications to this data collection scheme are outlined in the Descriptive Reports of individual Sheets. Multibeam crossline data were acquired along transects perpendicular to the mainscheme lines. Crossline mileage consisted of at least 8% of the mainscheme mileage for set line spacing MBES coverage, and 4% of mainscheme mileage for complete bathymetric coverage, in accordance with Section 5.2.4.3 of the HSSD (2013). Refer to section B.1.3.1 for details on crossline comparisons.

Multibeam survey operations were conducted using a dual head configuration comprised of two Kongsberg EM3002 multibeam echo sounders. Both transducers were mounted on the same ram that extended through the port hull of the vessel. Each transducer was mounted with a 30 degree angular offset. The ram operates such that the transducers could be lowered and raised as needed for survey operations and transit. Pertinent operational specifications of the EM3002 multibeam systems are shown in Table 3. These specifications were obtained from the EM3002 product specification documentation.

Table 3. EM3002 Operational Specifications

Frequencies	292, 300, 307 kHz
Number of soundings per ping Dual Sonar Heads	Max 508
Maximum Ping Rate	40 Hz
Maximum Angular Coverage Dual Sonar Heads	200 degrees
Pitch and Roll stabilization	Yes
Heave compensation	Yes
Pulse Length	150 µs

The port transducer (serial number 225) was operated at a frequency of 293 kHz and the starboard transducer (serial number 112) was operated at a frequency of 300 kHz. The multibeam sonars were operated in high-density equidistant beam spacing mode. The high density mode increased the number of soundings to 254 per ping per head, for a total of 508 soundings per ping.

The angular coverage of the sonars was typically set at 64 degrees from nadir on the outer sector and approximately 30 degrees on the inner, provided there was sufficient water depth for overlapping beams; in shallow water the inner angular sector could be increased. This configuration can provide up to 5x times water depth bottom coverage depending on water depth.

The ping rate was monitored and generally kept between 10-20 pings/sec. When settings were changed they were noted in the logs but more commonly the vessel speed was adjusted to maintain a ping rate that would provide 3 pings/meter.

Object Detection coverage was obtained over all potentially significant features, in accordance with section 5.2.2.2 and 5.2.2.3 of the HSSD (2013). In addition, continuous along-track coverage was obtained, with no gaps greater than 3 nodes long. Fill-in lines were conducted when gaps were found to be more than 3 nodes long.

Full bathymetric coverage was also obtained over all AWOIS (Automated Wreck and Obstruction Information System) items assigned for full investigation in the Project Reference File (PRF).

A.4. SIDE SCAN SONAR OPERATIONS

The Edgetech 4200-P is a dual frequency side scan sonar that can operate at 300 or 600 kHz with two operating modes, high-speed or high definition; refer to Table 4 for additional specifications. For this survey, high frequency, high definition options were chosen. High definition mode (HDM) provided optimal along track resolution. The Edgetech 4200-P side scan sonar was operated in a towed configuration. A hanging sheave mounted to a retractable A-frame at the stern of the vessel was used as the tow point for the side scan sonar. Refer to Section C.2: Vessel Offset Measurements and Configuration and Appendix I: Vessel Reports – Vessel Layback Report for additional side scan sonar offset and layback information. The side scan sonar range scale did not exceed 100 m, in accordance with Section 6.1.2.4 of the HSSD (2013). The product specifications state that the fish can be towed at 4.8 knots in HDM. The data were continuously monitored during acquisition to ensure coverage.

Table 4. Edgetech 4200-P Product Specifications for High Definition Mode (HDM)

Frequency	300/600 kHz
Resolution (along track)	300 kHz 1.0m @ 200 meter range 600 kHz 0.45m @ 100 meter range
Resolution (across track)	300 kHz 3cm 600 kHz 1.5 cm
Operating Speed Envelope	4.8 kts in HDM, 9.6 kts in HSM

Line spacing was generally set to 40 meters in water depths of 0 to 25 feet (7.62 m), 60 meters in depths between 25 and 35 feet (7.62 – 10.67 m), and 90 meters in depths greater than 35 feet (10.67 m). The side scan sonar was operated at range scales of 50, 75, or 100 meters for line spacing of 40, 60, and 90 m respectively. The criteria of acquiring 200% SSS coverage for object detection was accomplished using the aforementioned parameters and Technique 1 as set forth in Section 6.1 of the HSSD (2013). In this technique a single survey was conducted with the tracklines separated by about half the distance required for 100-

percent coverage. Coverage mosaics were developed using a north/south system to ensure that 200% coverage was obtained.

A Subsea Systems Cable Payout Indicator was used to digitally record the tow cable length from the sheave. The cable out values were recorded in the side scan .xtf files, and later used for layback calculations. Cabling in and out was also noted in the acquisition logs. The side scan sonar was generally towed at heights in accordance with the required 8 to 20 percent of the range scale, although due to factors such as water depth and data quality, the side scan sonar was occasionally towed at heights of less than the required range scale. Confidence checks were observed and recorded in the logs.

A.5. ADDITIONAL SURVEY OPERATIONS

A.5.1. SINGLEBEAM OPERATIONS

An Odom Echotrac MK III was used to collect single beam data. This data was continuously recorded and monitored in real-time as an independent check of the nadir beam (bottom-detect) of the multibeam sonar system.

A.5.2. SOUND SPEED OPERATIONS

Sea Bird Electronics SBE19 Plus CTDs were used to calculate the speed of sound through the water column. Casts were performed at least twice daily and more often as needed. In general, two CTDs were simultaneously lowered within a cage structure during each cast. Dual Endeco YSI 600R sondes were used to calculate the sound speed at the transducer. Refer to Section C.7 for additional information.

A.5.3. BOTTOM SAMPLES

Bottom samples were acquired with a Wildco® Petite Ponat® grab sampler deployed from a winch aboard the vessel. The samples were described and photographed in the field; the samples were not retained. The bottom samples are fully attributed in the S-57 Final Feature File.

A.6. ACQUISITION AND PROCESSING SOFTWARE

A list of data acquisition and processing software systems are shown in Table 5. All systems on the network are synced using 1PPS strings from GPS. Processing software updates are shown in Table 6.

Table 5. Data Acquisition and Processing Software

Purpose	Software	Version	Date of Installation
Multibeam data recording and monitoring	Hydromap	n/a	05/19/2013
Multibeam control Software	Seafloor Information System (SIS)	3.4.3	09/10/2013
Side Scan Collection	SonarWiz5	V5.06.0031	09/09/2013
Side Scan Processing	SonarWiz5	V.5.06.0031	09/09/2013
Multibeam Processing	CARIS HIPS/SIPS	8.1	09/09/2013
Multibeam Processing	Notebook	3.1 with SP1	09/09/2013
CTD Conversion Tool	Seabird Electronics Sea Term	1.59	09-09-2013
CTD Conversion Tool	Seabird Electronics Data Conversion	7.22.5	09-09-2013
CTD Conversion Tool	SVTool	1.2	09-09-2013
IMU control software	F180 Series	3.04.0004	09-13-2013

Table 6. Data Processing Software Updates

Purpose	Software	Version	Date of Installation
Side Scan Processing (Field)	SonarWiz5	V.5.06.0031	09-09-2013
Side Scan Processing (Office)	SonarWiz5	V.5.06.0032	09/05/2013
Side Scan Processing (Office)	SonarWiz5	V.5.06.0037	11/01/2013
Side Scan Processing (Office)	SonarWiz5	V.5.06.0040	12/04/2013
Multibeam Processing (Field)	CARIS HIPS/SIPS	8.1	09/09/2013
Multibeam Processing (Office)	CARIS HIPS/SIPS	8.1.2	11/19/2013
Multibeam Processing (Office)	CARIS HIPS/SIPS	8.1.4	01/13/2014
Multibeam Processing (Office)	CARIS HIPS/SIPS	8.1.7	03/10/2014

Simrad's Seafloor Information System (SIS) software version 3.4.3 was used as the control software for the multibeam. This software allowed sound speed, attitude and position to be applied to the data in real time. Data were sent from SIS to C & C Technologies' proprietary software, Hydromap, to be recorded. Hydromap software was used for multibeam data collection, quality assurance, and quality control. The Hydromap display includes a coverage map, bathymetric and backscatter display waterfalls, and other parameter displays. These tools allow the operator to monitor coverage, compare between single beam and multibeam depths, monitor the various positioning systems, and identify any ray-bending effects in real time. Corrective measures were made whenever necessary, ensuring that only high-quality data were collected. In cases where re-runs were necessary due to degraded quality of data or due to lack of coverage, this was logged and additional data collected. Hydromap software was also used to monitor the survey line plan and maintain on-line control.

Multibeam data processing was conducted using CARIS HIPS and SIPS 8.1. CARIS Notebook 3.1 was used for contact correlation purposes and feature verification using the Composite Source File (CSF). All features in this file were updated based on the results of the survey and submitted as the Final Feature File. The NOAA Extended Attribute File V5_3_2 was used. The multibeam processing workflow is detailed in Section B.1.3.

Chesapeake Technologies SonarWiz Map5 V5.06.0031 software was used for side scan sonar data collection. The side scan sonar data were processed, evaluated and contacts identified using SonarWiz. Details on the side scan sonar processing workflow are outlined in section B.2.

B. QUALITY CONTROL

B.1. MULTIBEAM

All multibeam data collected for OPR-C319-KR-13 was processed using CARIS HIPS. One CARIS project was created for each sheet. CARIS project directory structures were created according to the format required by CARIS. Prior to importing any sounding data into CARIS, a HIPS vessel file (.hvf) was created. This vessel file includes uncertainty estimate values for all major equipment integral data collection. Uncertainty estimates assigned are further described in the following sections. The vessel file used for this project is included in the Data\Processed\HDCS\VesselConfig folder for each sheet.

CARIS HIPS was used to apply tides, merge, compute TPU and create BASE surfaces. CARIS HIPS was also used for multibeam data cleaning, quality control, crossline comparison, chart comparisons and side scan sonar contact correlation. These steps are described in following sections.

B.1.1. CARIS VESSEL FILES

The dual head vessel file contains the following active sensors: Transducer 1, Transducer 2, Navigation, Gyro, Heave, Pitch, Roll, Draft, TPU, SVP1, SVP2 and Waterline Height.

<u>Transducers 1 and 2</u>: The X/Y/Z fields (the location of the transducer from the reference point) are zero (0) for Transducer 1 and 2 because the locations of the transducers are entered in the SIS control software prior to data acquisition. The Roll/Pitch/Yaw fields (mounting misalignments resolved with the patch test) are zero (0) for Transducer 1 and 2 because the data is corrected for these during data acquisition using the SIS control software.

<u>Navigation</u>: The Navigation X/Y/Z fields (location of the navigation source from the reference point) are set to zero (0) because the locations of the navigation sources are entered in the SIS control software during data acquisition.

<u>Gyro</u>: No Gryo fields are edited because no offset was applied and the F180 IMU is aligned to the ship coordinate reference frame.

<u>Heave/Pitch/Roll</u>: Heave, Pitch, and Roll are compensated for by the F180 IMU and the respective X/Y/Z fields are set to zero (0) and the Apply switches are set to ‘No’ because the dynamic values are applied during data acquisition.

Draft: A squat and settlement test was performed in order to correct for the dynamic draft of the vessel. The values input into the CARIS vessel file are shown in Table 7. Refer to Section C.3: Static and Dynamic Draft Corrections for additional information.

Table 7. Vertical displacement of R/V *Shearwater* with speed.

Vertical Correction (m)	Speed (m/s)
0.00	0.45
-0.01	1.76
-0.03	2.31
-0.05	2.84
-0.08	3.34

SVP: An incorrect draft calculation was used from September 19 through September 24, 2013. In order to correct the waterline to CRP values, SVP 1 and 2 were added to the vessel file. The transducer offsets were added, as well as the pitch, roll and azimuth, because the transducers have large mounting offsets. Only the lines that needed to be re-processed were selected and processed with the CARIS Sound Velocity Correction (SVC) tool.

Waterline Height: The correct waterline height values were calculated and added to the vessel file for September 19 through September 24, 2013. Although the apply flag is set to 'No', the SVC (Sound Velocity Correction) uses the value for processing Kongsberg data.
TPU Offsets: The offsets were calculated from known locations of the equipment from CRP (refer to Appendix 1: Vessel Reports – Vessel Offsets Report for additional information).

TPU Offsets:

The offsets (Tables 8 and 9) were calculated from known locations of the equipment from CRP (refer to Appendix 1: Vessel Reports – Vessel Offsets Report for additional information).

Table 8. MRU to Transducer offsets.

MRU to Trans X (m)	MRU to Trans2 X (m)	MRU to Trans Y (m)	MRU to Trans2 Y (m)	MRU to Trans Z (m)	MRU to Trans2 Z (m)
-4.205	-3.778	-0.437	-0.437	6.446	6.446

Table 9. NAV to Transducer offsets

NAV to Trans X (m)	NAV to Trans2 X (m)	NAV to Trans Y (m)	NAV to Trans2 Y (m)	NAV to Trans Z (m)	NAV to Trans2 Z (m)
-2.977	-2.55	0.651	0.651	11.711	11.711

According to CARIS correspondence (refer to Project Reports\Project Correspondence), the Transducer Roll is the mounting angle of the Receive Array + Roll Calibration. The transducers aboard the R/V *Shearwater* are mounted at a 30 degree offset. The patch test values were either added to or subtracted from the 30 degrees; therefore the values entered in the Trans Roll and Trans Roll 2 fields are equal to the offset angles entered in the SIS control software (Table 10).

Table 10. Values entered in the Transducer Roll fields of the TPU Offsets section.

Trans Roll (deg)	Trans Roll 2 (deg)
31.5876	-28.9439

TPU Standard Deviation:

The values entered for the Standard Deviation are shown in Table 11. Explanation and reasoning are further explained in the following text.

Table 11. Values entered for the TPU Standard Deviation section of the HVF.

Field	Value
Motion Gyro:	0.025°
Heave % Amplitude:	5%
Heave (m):	0.05 m
Roll:	0.025°
Pitch:	0.025°
Position Nav:	0.05 m
Timing Trans:	0.01 s
Nav Timing:	0.01 s
Gyro Timing:	0.01 s
Heave Timing:	0.01 s
Pitch Timing:	0.01 s
Roll Timing:	0.01 s
Offset X:	0.001 m
Offset Y:	0.001 m
Offset Z:	0.003m
Vessel Speed:	0.8 m/s
Loading:	0.16 m
Draft:	0.037 m
Delta Draft:	0.02 m
MRU Align StdDev Gyro:	0.2°
MRU Align StdDev Roll/Pitch:	0.1°

The motion Gyro, Heave % Amplitude, Heave (m), Roll (deg) and Pitch (deg) values are based upon manufacturers' specifications as listed within the TPU resource link provided on the CARIS web page http://www.caris.com/tpu/navigation_tbl.cfm, which match the specifications in the F180 user's manual.

The Position NAV (m) was 0.05 m for survey operations conducted using the C-Nav 3050 as the primary navigation.

The Timing Trans and Nav, Gyro, Heave, Pitch and Roll Timing values were set to 0.01 s as they are serial connections, and 0.01 s is an appropriate value according to the Chapter 4 Appendix – CARIS HVF Uncertainty Values of the 2013 NOAA Field Procedures Manual.

The X/Y/Z Offset values: The survey of the equipment offsets on the R/V *Shearwater* were carried out using differential leveling for vertical measurements and a tape measure for horizontal measurements. Each level loop was closed and the misclosure calculated; if greater than 3 mm, the loop was repeated. This was used as the Z offset value. Each horizontal measurement conducted with a tape measure was read multiple times by multiple people. The standard deviation of a sample of measurements was calculated and averaged together to obtain the X and Y offset values.

Vessel Speed: According to according to the Chapter 4 Appendix – CARIS HVF Uncertainty Values of the 2013 NOAA Field Procedures Manual, this value is 0.03 plus the average current in the area; a value of 1.5 knot (0.77 m/s) was used for the average current.

Loading: Difference between the maximum and minimum draft measured for the duration of the survey.

Draft: The standard deviation was calculated for the draft measurements taken for the duration of survey operations.

Delta Draft: The dynamic draft data consists of 5 sets of lines run at varying speeds and the squat of the vessel at each speed. The standard deviation of the set of squat values for a specific speed setting was calculated and then averaged together for a final value.

According to the 2013 Field Procedures Manual, both the MRU Align. StdDev gyro and MRU Align StdDev Roll/Pitch can be estimated by calculating the standard deviation of a large sample of angular bias values resolved with a patch test.

B.1.2. TOTAL PROPAGATED UNCERTAINTY (TPU)

CARIS HIPS was used to compute the Total Propagated Uncertainty (TPU) for each sounding using the parameters shown in Figure 1.

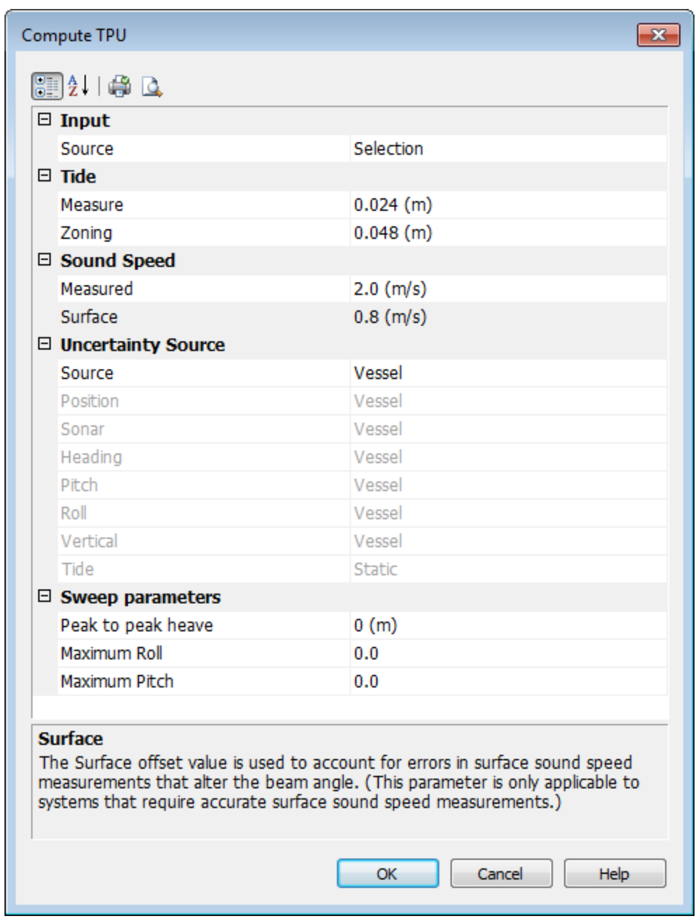


Figure 1. Total Propagated Uncertainty (TPU) values.

B.1.2.1. TIDE COMPONENT

According to section 1.3.3 of the Tides and Water Levels Statement of Work for this project (OPR-C319-KR-13), the estimated tidal error contribution to the survey area is 0.14 meters at the 95% confidence level. This estimate includes the estimated gauge measurement error, tidal datum computation error, and tidal zoning error. According to section 4.1.6 of the HSSD (2013) the typical tidal zoning error is 0.2 m at 95% confidence level and the measurement/processing error is typically 0.1 m at 95% confidence level. This indicates that the typical tidal zoning error is twice that of the typical measurement/processing error. Although the provided estimated of 0.14 m is less than the tidal and measurement errors as suggested by the HSSD, the provided 0.14 m value was split into a zoning component and measurement component, keeping the proportions as close to that of the HSSD as possible. 0.0934 m of the 0.14 m was attributed to the zoning error and 0.0466 m was attributed to the measurement/processing error. All error values entered in CARIS for the TPU calculation are assumed to be at the 1 sigma level and the 0.0934 m zoning error value and 0.0466 m measurement error were divided by 1.96, according to the Field Procedures Manual Section 4.2.3.8. Therefore, a final value of 0.048 m was entered as the zoning tide value and 0.024 m was entered for the measured tide value for the CARIS TPU calculation.

B.1.2.2. SOUND SPEED COMPONENT

The measured sound speed value TPU value is 2 m/s. The sound speed calculated at the transducer is compared to the sound speed calculated by the previous CTD cast. If the difference is 2 m/s or greater, it is necessary to obtain a new sound speed cast.

The surface sound speed value was set at 0.8 m/s with the following reasoning. The YSI 600R sonde is used to calculate the sound speed at the multibeam transducer. The resultant sound speed is a function of temperature and salinity (ignoring the effects of depth/pressure because the sensor is near the sea surface). The Law of the Propagation of Variances states that the uncertainty associated with an unknown (sound speed) can be calculated if the variance associated with a series of known variables (salinity and temperature) are known. The specifications for the 600R (http://www.ysi.com/productsdetail.php?600R-9) are shown in Table No. 12 and the known amount by which a certain change in salinity and temperature affect sound speed are shown in Table No. 13.

Table 12. Accuracies associated with salinity and temperature measured by the YSI 600R sonde.

Parameter	Accuracy
Salinity	± 1% of reading or 0.1 ppt (whichever is greater)
Temperature	± 0.15 °C

Table 13. The amount that sound speed changes with changes in salinity and temperature.

Parameter	Change in parameter	Change in Sound Speed
Salinity	1 ppt	1.3 m/s
Temperature	1 °C	4.5 m/s

A value of 30 ppt is used as a general surface salinity value. The uncertainty surrounding this measurement (using values in Table 16) is: 30 * .01 = ± 0.30 ppt; this value is used in the following calculations because it is greater than 0.1 ppt. The amount that 0.3 ppt salinity would change sound speed is:

$$0.3\ ppt * \left(\frac{1.3\frac{m}{s}}{1ppt}\right) = 0.39\frac{m}{s}$$

The accuracy associated with the temperature measurement is ± 0.15 °C (Table No. 16) and the amount that this value would change the sound speed is:

$$0.15°C * \left(\frac{4.5\frac{m}{s}}{1°C}\right) = 0.675\frac{m}{s}$$

The total uncertainty of the sound speed measurement is determined by calculating the square root of the quadratic sum of the individual uncertainty sources.

$$\sigma_{ss}^2 = \sigma_{sal}^2 + \sigma_{temp}^2$$
$$\sigma_{ss}^2 = (0.39\frac{m}{s})^2 + (0.675\frac{m}{s})^2$$
$$\sigma_{ss}^2 = (0.607735\frac{m}{s})^2$$
$$\sigma_{ss} = 0.7795\frac{m}{s}$$

This value of approximately $0.8\frac{m}{s}$ is within the range of values provided in the CARIS HVF Uncertainty Values document in Appendix 4 of the Field Procedures Manual, which is 0.2 to 2 m/s.

B.1.2.3. HORIZONTAL AND VERTICAL UNCERTAINTY COMPONENTS

The CARIS TPU command applies both a horizontal TPU (HzTPU) and depth TPU (DpTPU). According to section 3.1.1 of the HSSD (2013), the Total Horizontal Uncertainty (THU) in the position of the soundings will not exceed 5 m + 5 % of the depth. According to section 5.1.3 of the HSSD (2013) the Total Vertical (or depth) Uncertainty (TVU) is calculated using the following formula:

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

For IHO Order 1 surveys, in depths less than 100 meters, a = 0.5 m and b = 0.013. Several values are shown in Table 14.

Table 14. Maximum IHO Order 1 TVU values for water depths of 1 – 35 m in increments of 5 m.

a	b	Water Depth (m)	Maximum (TVU)
0.5	0.013	1	0.500
		5	0.504
		10	0.517
		15	0.537
		20	0.564
		25	0.596
		30	0.652
		35	0.707

The TPU was evaluated to ensure that the values are within the specifications above. In accordance with section 5.1.2 of the HSSD (2013), all depths reported in the deliverables are accompanied by the estimate of TPU.

B.1.3. MULTIBEAM PROCESSING

Upon commencement data acquisition for a Sheet, a CARIS project was created for the Sheet and multibeam lines converted by the processor on shift. All lines converted were assigned a project, vessel, and day. Preliminary tidal data from the Sandy Hook, NJ gauge (Station 8531680) was downloaded from the CO-OPS website: http://opendap.co-ops.nos.noaa.gov/axis//text.html and applied to all data in CARIS using the tidal zoning file supplied by CO-OPS (Refer to Section C.6 for detailed tide correction information). The lines were merged, TPU was computed and a BASE surface created. Due to processing limitations in the field, BASE surfaces were created based on location or day for evaluation purposes, with resolution depending on the requirement for that location.

Multibeam data were reviewed using the CARIS HIPS swath editor with the BASE surface and pertinent background data open. Background data included the chart(s) and the line files. For areas where both multibeam and side scan sonar data are collected, the preferred multibeam review method involves the ability to simultaneously review the side scan sonar data. When this was not possible, potential contacts were noted in multibeam processing log for future review of the side scan sonar data. In swath editor, erroneous and noisy data was rejected from the project. When the .PRF and .CSF files became available, these were also used during review.

For areas where both multibeam and side scan sonar data are collected, the preferred multibeam review method involved simultaneously reviewing the side scan sonar data. When this was not possible, potential contacts were noted in multibeam processing log and were subsequently reviewed in the side scan sonar data. In swath editor, erroneous and noisy data were rejected from the project.

In addition, if applicable, a contact S-57 file (Refer to section B.2.4 for additional information) was evaluated in the CARIS map window with BASE surfaces of the mainscheme lines and completed investigations to ensure complete coverage over significant targets. Object Detection Coverage (investigation data) was obtained over all potentially significant features. All contact investigation data were incorporated into BASE surfaces and then cleaned in swath editor and subset editor. The BASE surfaces were created as uncertainty surfaces with a single resolution of 0.5 m to ensure that a 1 x 1 x 1 m object would appear in the grid. The investigation data were reviewed with respect to mainscheme multibeam lines, charted data and, if available, side scan sonar contact information. If necessary, a designated sounding was assigned to the least depth sounding of an identified contact and the contact submitted in a Danger to Navigation Report.

Once all multibeam data had been cleaned and incorporated into a BASE surface, the surface underwent additional quality control. The standard deviation layer of the BASE surfaces was evaluated and areas of high standard deviation were investigated by all means appropriate, including subset editor, swath editor, comparison to charts, side scan sonar and backscatter data and side scan sonar contacts imported from SonarWiz. If data were found to misrepresent the seafloor, it was rejected. In addition, the BASE surface was evaluated using the CARIS 3D window with increased vertical exaggeration that can highlight outliers as well as potential contacts.

BASE surfaces were named as <Survey registry number>_<Sounding Type>_units of resolution_<Vertical Datum>, as specified in section 8.4.2 of the HSSD (2013). All BASE surfaces were created as uncertainty surfaces based upon IHO Order 1a standards. BASE surface resolution varied depending on depth and acquisition method, and is detailed in each descriptive report.

Crossline comparisons were generated on a regular basis as a quality control tool, which is explained further in the following section.

B.1.3.1. CROSSLINE COMPARISONS

B.1.3.1.1 HYDROMAP STATISTICAL COMPARISONS

Crossline statistical comparisons are performed for every line of multibeam data. Hydromap contains a tool that compares data from a main line with data from crosslines. The comparison calculates the mean difference and noise level as a function of cross-track position. The measurements are used for quantitative quality assurance of system accuracy and ray-bending analysis. In general, crosslines are used to produce reference data. The reference data is considered to be an accurate representation of the bottom. Since the data is taken from an orthogonal direction, the errors should at least be independent.

The crosslines are processed to produce the best possible data. Sound velocity profiles are taken to minimize any possible ray bending, and the multibeam swath angle is filtered to five degrees, which ensures that there are no measurable ray bending or roll errors. The data is binned and thinned using a median filter. The crossline swath data is then merged into a single file, and edited to ensure that there are no remaining outliers.

The line to be evaluated is processed to produce a trace file. Trace files are binned soundings that have not been thinned. The files contain x, y, and z data, as well as information on ping and beam numbers that is used for analysis. Processing parameters are set to use all beams with no filtering, and tidal affects are removed using predicted tides generated from Micronautics world tide software.

The effects of ray-bending can be measured by observing the values of the mean difference curve. Ray-bending produces a mean difference which curves upward or downward at the outer edges of the swath in a symmetric pattern around nadir. The value of the difference at a given across-track distance indicates the amount of vertical error being introduced by incorrect ray-bending corrections.

The accumulated statistics of all main line soundings compared to all crosslines is processed to produce four across-track profiles. The profiles represent the mean difference, standard deviation, root-mean-square difference, and percentile confidence interval. The data is provided in graphical form in a separate pdf document for each main line. These pdf’s are found in Separates II of the reports.

B.1.3.1.2 CARIS COMPARISONS

Crosslines were run perpendicular to mainscheme survey lines and comprised at least 8% of mainscheme line mileage for set line spacing coverage and at least 4% of mainscheme line for objection detection and complete MB coverage, in accordance with Section 5.2.4.3 of the HSSD (2013). Crossline comparisons were performed as a quality control tool to identify systematic errors and blunders in the survey data.

Crossline comparisons were performed in CARIS HIPS 8.1 using the surface difference tool. Separate BASE surfaces were generated for the mainscheme lines and crosslines and a difference surface between the mainscheme and crossline BASE surfaces computed. The difference surface was used as a data cleaning tool as well as a quality control tool. It was noted if the depth difference values differed by more than the maximum allowable Total Vertical Uncertainty (TVU), as outline in Section 5.2.4.3 of the HSSD (2013); refer to section B.1.2.3 for sample TVU values for certain depths. Areas were further evaluated where the depth values for the two datasets differed by more than the maximum allowable TVU and the source of error identified and explained.

Crossline comparisons were also generated using the CARIS QC report utility. Each crossline was compared to the depth layer of the BASE surface of the mainscheme lines (the reference surface). The crossline sounding data were grouped by beam number (1 – 508 in increments of 1). Survey statistic outputs include the total soundings in the range, the maximum distance of soundings above the reference surface, the maximum distance of soundings below the reference surface, the mean of the differences between the crossline soundings and the surface, the standard deviation of the mean differences, and the percentage of soundings that fall within the depth standards for a selected IHO Order. Although statistics were generated for all IHO Orders (Special Order, Order 1a, Order 1b and Order2), the percentage of crossline soundings that are within Order 1a specification is of primary interest for this project. The quality control statistics were evaluated for extreme values and are shown in Separates II: Digital Data.

The crossline and mainline BASE surfaces have been retained and submitted in the Fieldsheet directory.

B.1.3.2. REPORTING PRODUCTS AND FINALIZATION

Junction analysis was conducted using the CARIS differencing tool. Difference surfaces were generated with the survey of interest as Surface 1 and the adjoining survey as Surface 2.

Chart comparisons were performed in CARIS HIPS using cleaned BASE surfaces of mainscheme and investigation lines, colored depth ranges, and sounding layers. The data were compared to the largest scale charts in this area, summarized in Table No. 15 and 16.

Table 15. Raster Nautical Charts

Chart Number	Scale	Edition Number	Edition Date	LNM Date	NM Date
12326	80000	52	06/2013	04/15/2014	04/26/2014
12324	40000	35	03/2012	04/15/2014	04/26/2014
12327	40000	106	03/2014	04/15/2014	04/26/2014
12325	15000	4	10/2008	04/15/2014	04/26/2014

Table 16. Electronic Nautical Charts

ENC Name	Scale	Edition	Update Application Date	Issue Date	Preliminary
US5NY18M	15000	31	12/13/2013	04/03/2014	NO
US5NY1BM	40000	23	11/30/2012	01/29/0214	NO
US5NJ30M	40000	17	12/31/2013	02/12/2014	NO
US4NY1AM	80000	27	09/19/2013	03/18/2014	NO

The sounding layer to which charted soundings were compared was generated from the BASE surface created for each Sheet. The shoal biased radius option was always selected and the radius was selected as distance on the ground (in m). A single-defined radius was chosen that generated a sufficient amount of soundings, which potentially varied from sheet to sheet and is detailed in each Descriptive Report.

After all data had been cleaned, and all least depths on significant contacts had been designated, the BASE surfaces were finalized for submission. The final BASE surfaces were generated from the higher of the standard deviation or uncertainty values in order to preserve a conservative uncertainty estimate. The designated soundings were applied in order to maintain the shallowest soundings within the final BASE surface (Figure 2). Any depth threshold applied is detailed in the Descriptive Reports.

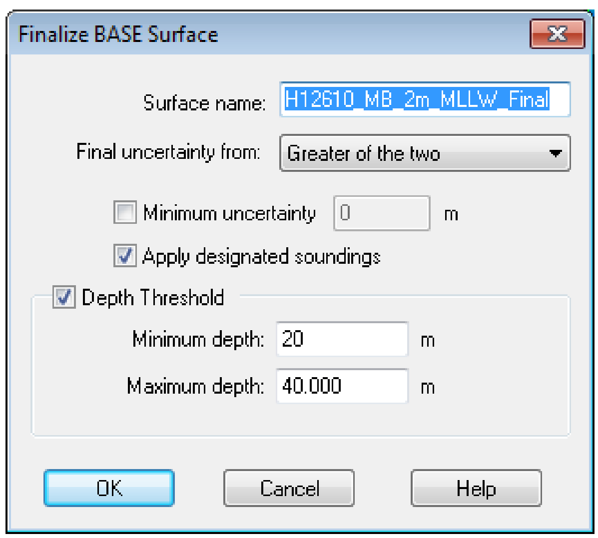


Figure 2. Sample BASE surface finalization parameters.

B.2. SIDE SCAN SONAR

B.2.1. IMAGE PROCESSING

Side scan sonar data were processed using Chesapeake Technologies' SonarWiz5. The water column was auto tracked in the field and the data slant range corrected after the data was imported into SonarWiz5. The bottom track was also evaluated during post-processing. The side scan sonar files were subsequently layback corrected and gains applied when necessary. The side scan sonar data were evaluated and contacts identified, always selected from slant-range corrected data. Bottom tracked and layback corrected files were exported from SonarWiz for the final deliverables.

B.2.2. REVIEW PROCESS AND PROOF OF COVERAGE

The side scan operator reviewed all data during data acquisition and noted in the survey logs any significant features or surface/water column effects. All side scan data were also reviewed at least twice post-collection. Any lines or portions of lines that did not meet quality standards due to noise, thermals, etc. were re-run. During review, a coverage map was produced. Any gaps in coverage were noted, logged in the re-run log, and brought to the attention of the party chief and the operators on shift.

A mosaic for each 100% coverage of the Sheet or section of a Sheet was created and submitted for the requirement of the interim and final deliverables. The coverage mosaics were generated from lines that were run south to north and those that were run north to south. These mosaics served as an additional quality control tool and were not only used for coverage but were used to correlate contacts seen on adjacent lines.

B.2.3. CONTACT SELECTION

Sonar contacts were identified and recorded as each line was reviewed. All contacts with shadows were recorded. All existing infrastructure, such as pipelines, wells, platforms, and buoys was also documented.

In addition to measuring the dimensions of each contact in SonarWiz, each contact was assigned two attributes to aid in the processing workflow. The first attribute (UserClass1) was related to the direction and coverage from which the contact was identified. The second attribute (UserClass2) was related to the nature of the contact and one of ten descriptors was chosen for each contact. These were: insignificant contact (INSCON), significant contact (SIGCON), offshore platform (OFSPLF), submerged pipeline (PIPSOL), submerged cable (CBLSUB), fish contact (FSHGRD), obstruction (OBSTRN), seabed area (SBAREA), unknown contacts (UNKCON) and buoys (BUOY).

All contacts that displayed a height of 1 meter or greater, calculated from the shadow length in SonarWiz, were considered significant within water depths of 20 meters or less, in accordance with Section 6.1.3.2 of the HSSD (2013). These contacts were always given the attribute ‘SIGCON’. Other contacts may have been deemed significant based on their characteristics (dimensions, strength of return, location etc.). Significant contacts had the potential to become obstructions (OBSTRN). All contacts not labeled as significant, but had some height off the bottom, were identified as insignificant (INSCON).

Large schools of fish were identified by shape, detached shadows and observations recorded in the acquisition logs. These contacts were noted as FSHGRD; however, fish were not generally picked as contacts. The second 100% SSS was evaluated to confirm the fish contact and to make sure no other contacts were obscured. The label seabed area (SBAREA) was used to include seabed change and features such as canholes and drag scars. The unknown (UNKCON) label was used only if no shadow could be measured. The majority of the UNKCON are picked generally because of possible correlation to either a significant or insignificant feature found on an adjacent line based factors such as proximity, shape and size.

B.2.4. CONTACT CORRELATION

Once all contacts were recorded and assigned the aforementioned attributes and dimensions, the contacts were exported from SonarWiz as a Comma Delimited File. Contacts were brought into Notebook 3.1 using the Object Import Utility as points under the LNDMRK class with several attributes assigned. The contacts were exported as an S-57 file and opened in CARIS.

The S-57 file of contacts was evaluated in the CARIS map window with BASE surfaces of the mainscheme lines and completed investigations to ensure complete coverage over significant targets. All significant contacts not fully developed with multibeam data were investigated further. If necessary, Danger to Navigation Reports were submitted for uncharted significant contacts and structures.

Once the multibeam BASE surfaces had been reviewed for anomalous data points in conjunction with charts and the side scan sonar contacts, the contacts were systematically reviewed in the CARIS HIPS map window with respect to BASE surfaces and charted features. The attributes of each contact were examined in the CARIS selection window and the Description field updated in SonarWiz, which would become the ‘Remarks’ field in the final .000 deliverable.

An S-57 file of all the contacts was generated in accordance with section 8.3.2 of the HSSD (2013). The contacts were imported into CARIS Notebook 3.1 as points under the $CSYMB class and exported as an S-57 file.

B.3. DATA DIRECTORY STRUCTURE

During data processing separate directories were created for CARIS projects, CARIS Notebook files, SonarWiz projects and Report Deliverables. Upon submission, these were combined into a directory structure that was generated to closely match the structure specified in Appendix 12 of the 2013 HSSD (Figure 3).

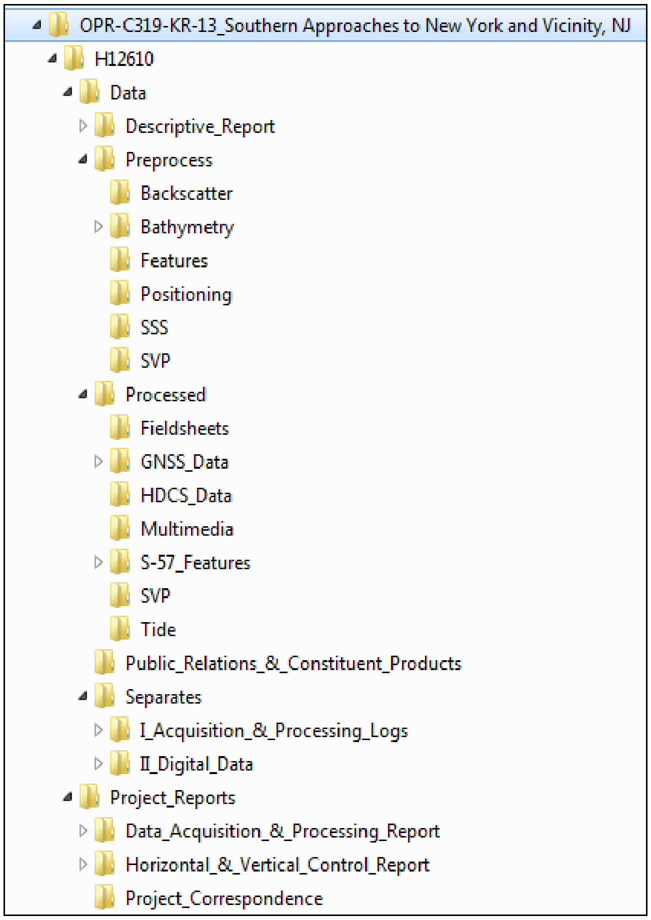


Figure 3. Overview of data directory structure.

A FieldSheets folder and an HDCS Data folder were added to the directory structure to remain consistent with the CARIS processing directories. No folders were removed from the directory structure as listed in Appendix 12; if no data exists for that particular folder, a text file explanation is included.

C. CORRECTIONS TO ECHOSOUNDINGS

C.1. INSTRUMENT CORRECTIONS

In order to ensure that the multibeam system was functioning properly, the single beam (Odom Echotrack MKIII) was monitored in real-time as an independent check of the nadir beam of the multibeam sonar system.

C.2. VESSEL OFFSET MEASUREMENTS AND CONFIGURATION

C.2.1. VESSEL CONFIGURATION PARAMETERS AND OFFSETS

The survey of the equipment offsets on the R/V *Shearwater* were carried out using differential leveling for vertical measurements and a tape measure for horizontal measurements. Each level loop was closed and the misclosure calculated; if the misclosure was greater than 3 mm, the loop was repeated. Each horizontal measurement conducted with a tape measure was read multiple times by multiple people. Figure 4 shows a picture of the R/V *Shearwater* and a vessel diagram with all measured offsets from the central reference point is shown in Appendix 1: Vessel Reports – Vessel Offset Reports.

Figure 4. R/V *Shearwater*.

C.2.2. LAYBACK

Layback was applied to all sidescan XTF files using SonarWiz5. Refer to Appendix I: Vessel Reports – Vessel Layback Report for additional information.

C.3. STATIC AND DYNAMIC DRAFT

Static draft measurements were read at least once daily during survey operations. The R/V *Shearwater* is equipped with a draft tube in the port hull of the vessel. The draft tube is mounted with a ruler where 0.00 is positioned at the waterline of the vessel. The distance from CRP (IMU) to the waterline (when the vessel is full of fuel and water) is 3.602 m. To calculate the water line to CRP measurement needed in SIS, the draft value observed from the draft tube is subtracted from the distance from the IMU to the waterline. Figure 5 shows static draft offsets.

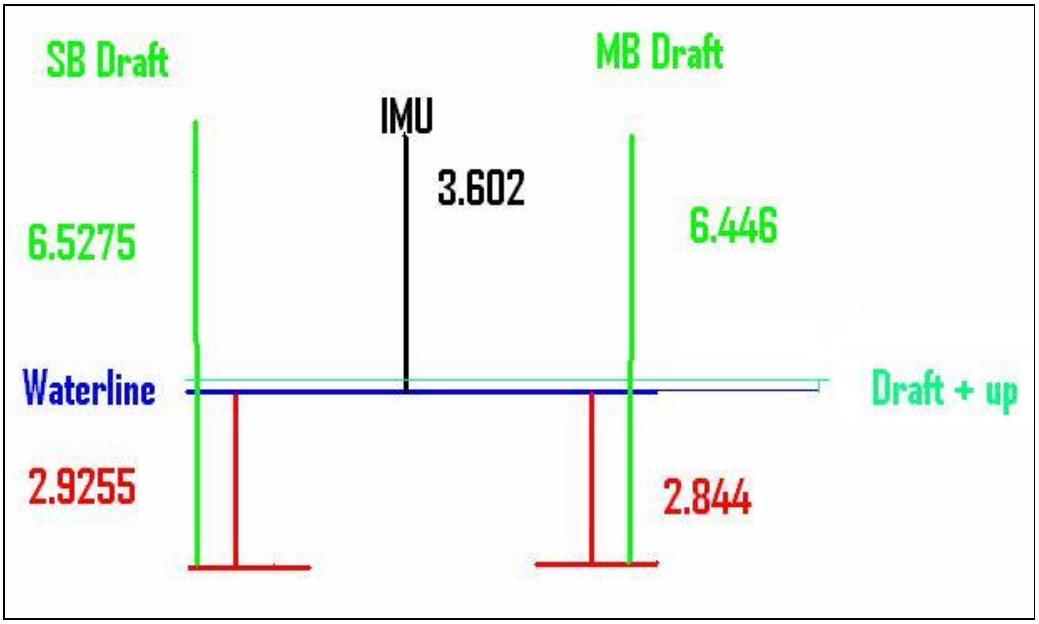


Figure 5. Static draft offsets.

In order to correct for the dynamic draft of the vessel, a squat and settlement test was performed in Sandy Hook Bay, NJ on September 15, 2013. Refer to Table 7 in Section B.1.1 and Appendix I: Vessel Reports – Dynamic Draft Report for additional information.

C.4. POSITIONING AND ATTITUDE SYSTEMS

The R/V *Shearwater* is equipped with three (3) GPS systems: two (2) C-Nav 3050 receivers and one (1) CodaOctopus F180 attitude and positioning system. All three GPS systems feed their position strings via serial interface to a serial splitter box. The position strings are then sent to multiple systems for logging and use. The F180 GPS is used for the serial and 1PPS strings that are used to sync all systems on the network.

The C-Nav 3050 receivers use the C-Nav Subscription Services, which can achieve 5 cm horizontal accuracy and 10 cm vertical accuracy. These systems are controlled and monitored with a C-Navigator system.

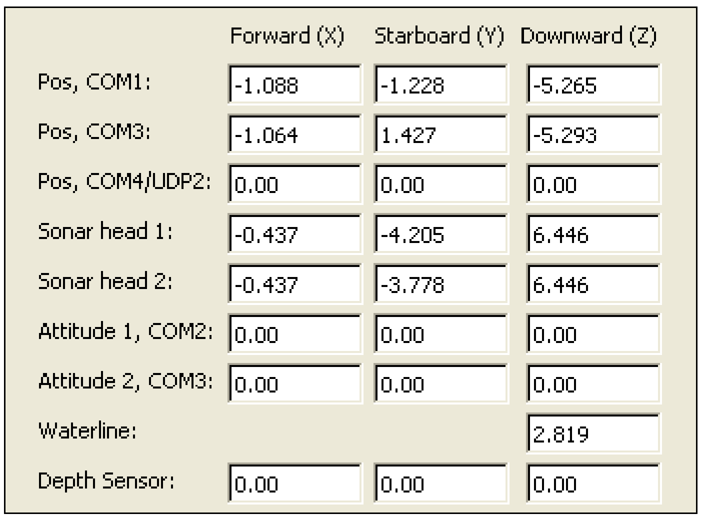
One (1) of the C-Nav receivers provides a DGPS correction via serial connection to the F180 system. The F180 is controlled and monitored using PC software via a network connection to the system. The F180 attitude and positioning system is integrated with the multibeam echo sounder to provide real-time heave, pitch, and roll corrections; heading is also obtained from the F180. The antenna baseline for the F180 is 3.379. Manufacturer accuracies are shown in Table 17.

Table 17. Manufacturer accuracies for the CodaOctopus F180 attitude and positioning system with an antenna baseline distance of 4 m.

Heading	Roll	Pitch	Heave
0.025º	0.025º	0.025º	The greater of 5% of heave amplitude or 5 cm

C.5. EQUIPMENT OFFSETS

The CRP for this survey was the IMU. Equipment offsets from the CRP were entered directly into the Simrad SIS software (Figure 6). The Primary C-Nav 3050 GPS offsets were entered into POS, COM1 and the Secondary C-Nav offsets were entered into POS, COM3. The multibeam transducer offsets were entered in Sonar Head 1 and Sonar Head 2 for the port (serial number 225) and starboard (serial number 112) transducers, respectively. The F180 offsets were entered in POS, COM4, Attitude 1, COM2 and Attitude 2, COM 3.



	Forward (X)	Starboard (Y)	Downward (Z)
Pos, COM1:	-1.088	-1.228	-5.265
Pos, COM3:	-1.064	1.427	-5.293
Pos, COM4/UDP2:	0.00	0.00	0.00
Sonar head 1:	-0.437	-4.205	6.446
Sonar head 2:	-0.437	-3.778	6.446
Attitude 1, COM2:	0.00	0.00	0.00
Attitude 2, COM3:	0.00	0.00	0.00
Waterline:			2.819
Depth Sensor:	0.00	0.00	0.00

Figure 6. Equipment offsets entered into the SIS software.

C.6. MULTIBEAM CALIBRATION

Prior to commencement of survey operations, a standard patch test was performed on September 19, 2013, south of Sandy Hook Bay, NJ to determine corrections for pitch, roll, and heading. C & C Technologies' proprietary software Hydromap was used in the field to determine results from the patch tests (Table 18).

Table 18. Patch Test Results (R/V *Shearwater* –September 19, 2013)

	Roll*	Pitch	Heading
Port Head	-1.5873	-3.90	-4.737
Starboard Head	1.0561	-4.16	-6.618

*Note that the dual head mounting bracket was constructed with a 30 degree angle; the roll values are added to or subtracted from the 30 degree offset.

The angular offsets from the patch tests were entered directly into the Simrad SIS software under Sensor Setup → Angular Offsets for correction of data in real-time (Figure 7).

	Roll	Pitch	Heading
Sonar head 1:	31.5876	-3.90	355.263
Sonar head 2:	-28.9439	-4.16	353.382
Attitude 1, COM2:	0.00	0.00	0.00
Attitude 2, COM3:	0.00	0.00	0.00
Stand-alone Heading:			0.00

Figure 7. Location and patch test results entered in SIS on September 19, 2013.

C.7. SOUND SPEED CORRECTIONS

The simultaneous sound speed profiles acquired with the Seabird Electronics SBE19 Plus CTDs were reviewed together as a quality control check. One profile was chosen which would be entered into the SIS control software and the multibeam data were corrected for the water column sound speed in real-time. Prior to importation into SIS, the chosen sound speed cast was extended by at least 50 feet beyond the deepest reading of the CTD. The intent of the extended data is strictly to avoid error messages associated with bad multibeam pings that were deeper than the sound speed cast. Extending the profile was accomplished by averaging the last ten to twenty data points in the profile. The onboard processor of the cast determined how many points to average in order to create an extension that accurately reflected the downward trend of the data. If water depths began to exceed the depth of the cast, another sound speed cast was taken. The mean water column sound speed generated from the chosen sound speed profile was applied to the singlebeam echo sounder data.

The difference between the sound speed measured by the SBE19 CTD and the sound speed calculated at the transducer by the Dual Endeco YSI 600R sondes was monitored in the SIS software. A difference of more than 2 m/s required a new cast to be taken.

The digital sound speed data and confidence checks can be found in: \Separates \II_Digital_Data\Sound_Speed_Data_Summary. In addition, a summary (.csv file) of the sound speed data acquired can be found in the Sound_Speed_List folder. This file was imported into Notebook 3.1 and exported as an S-57 file to be easily brought into CARIS. The .hob and .000 files along with a ReadMe.txt file of the attribute mapping used are also located in the Sound_Speed_List folder.

C.8. TIDES AND WATER LEVEL CORRECTIONS

The operating National Water Level Observation Network (NWLON) station at Sandy Hook, NJ (Station ID: 8531680) provided water level reducers for this project.

During survey operations, preliminary 6-minute tidal data from the Sandy Hook, NJ (Station 8531680) was downloaded from the NOAA Tides and Currents website and incorporated into a .tid (ASCII) file consisting of date, time and tide values. These tide values were applied to all multibeam data in CARIS using the tidal zoning definition file supplied by NOAA/CO-OPS; Table 19 shows the tide zones and correctors.

Table 19. Sandy Hook, NJ (8531680) Tide Zones and Correctors.

Tide Zone	Reference Station	Time Corrector	Range Ratio
SA1	8531680	-18	x100
SA2	8531680	-24	x0.96
SA14	8531680	-36	x0.91

Tidal zoning correctors were applied to verified data of the Sandy Hook, NJ tide station for final processing, as outlined in section 1.5 of the Tides and Water Levels Statement of Work. The verified tidal data was downloaded from the NOAA Tides and Currents website.

D. LETTER OF APPROVAL

Data Acquisition and Processing Report

OPR-C319-KR-13

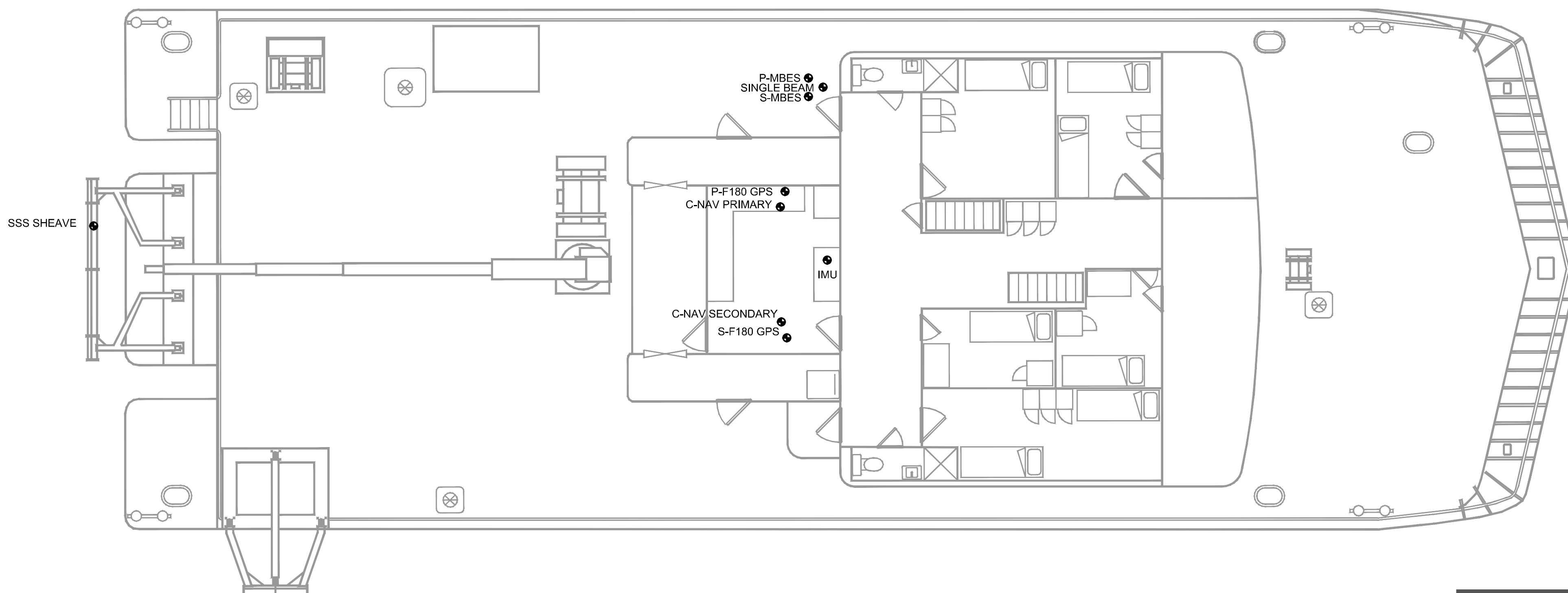
This report is respectfully submitted.

Field operations contributing to the accomplishment of this survey were conducted under my direct supervision with frequent personal checks of progress and adequacy. This report has been closely reviewed and is considered complete and adequate as per the Statement of Work.

Tara Levy
Chief of Party
C & C Technologies
May 2014

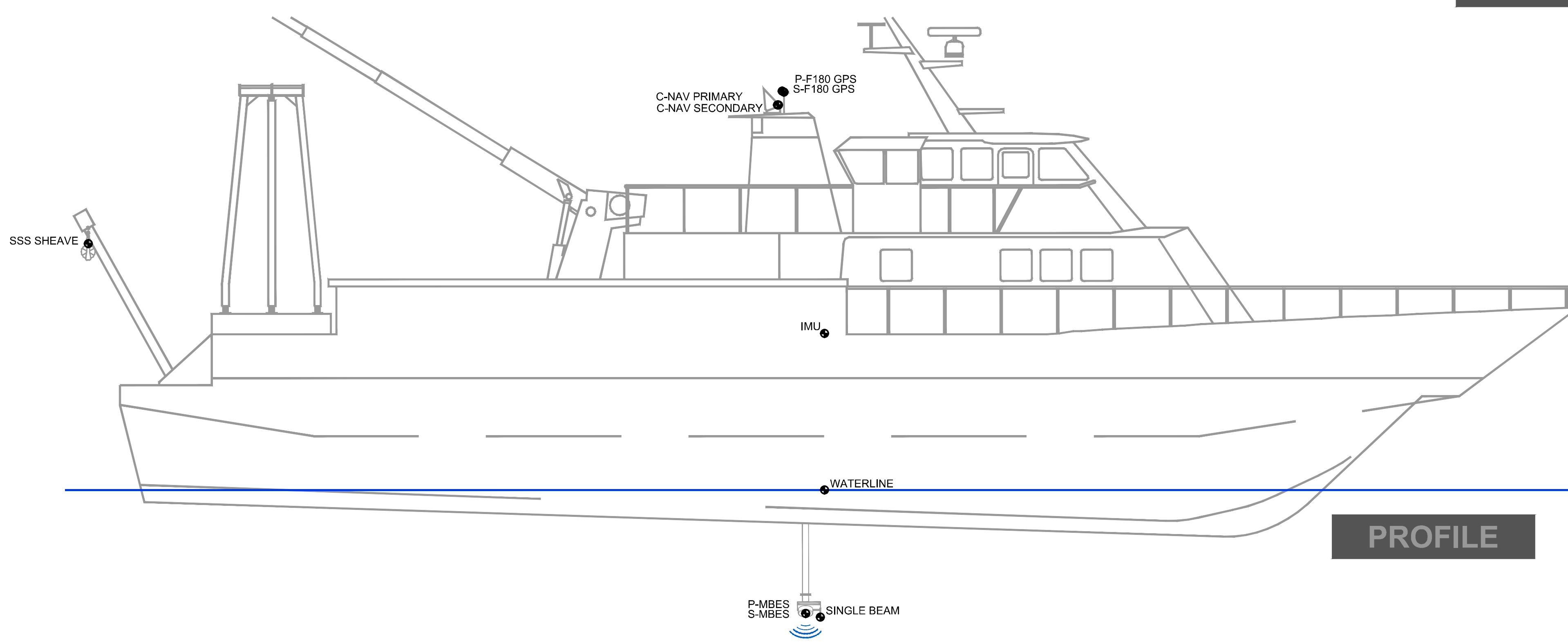
APPENDIX I

Vessel Reports

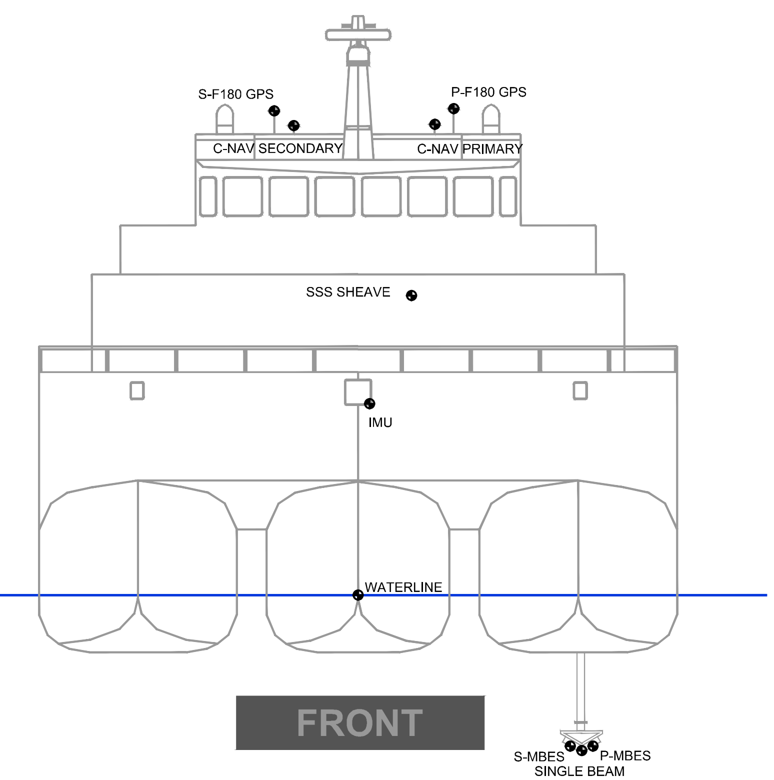


MAIN DECK

R/V SHEARWATER OFFSETS			
	PORT	STERN	KEEL
	X	Y	Z
IMU	0.0000	0.0000	0.0000
P-GPS (F180)	-1.5830	-0.9780	5.5810
S-GPS(F180)	1.7960	-0.9390	5.5580
MBES (PORT)	-4.2050	-0.4370	-6.4460
MBES (STBD)	-3.7780	-0.4370	-6.4460
SINGLE BEAM	-3.9920	-0.0970	-6.5720
C-NAV PRIMARY	-1.2280	-1.0880	5.2650
C-NAV SECONDARY	1.4270	-1.0640	5.2930
SSS SHEAVE	-0.7870	-16.9610	2.0680
DRAFT TUBE ZERO	---	---	-3.6020
WATERLINE			-3.6020



PROFILE



FRONT

R/V SHEARWATER

C&C Technologies
SURVEY SERVICES

Dynamic Draft Report – R/V *Shearwater*

General:

The draft of a vessel can change with varying speeds and cause the vessel to settle down in the water. The stern will squat, causing the relationship of the transducers to the water surface to change. In order to correct for the dynamic draft of the R/V *Shearwater*, a squat and settlement test was performed in Sandy Hook Bay, NJ on September 15, 2013.

The resultant corrections are added to the raw soundings to refer them back to a static state, as though the boat is stationary. Squat corrections are therefore considered positive quantities as the transducer depresses (squats) deeper into the water at increased speeds. In this case, a positive squat is added to the raw observed/recorded depth. A negative squat may occur with high-speed planning, surface effect, or hovering type vessels.

Definitions:

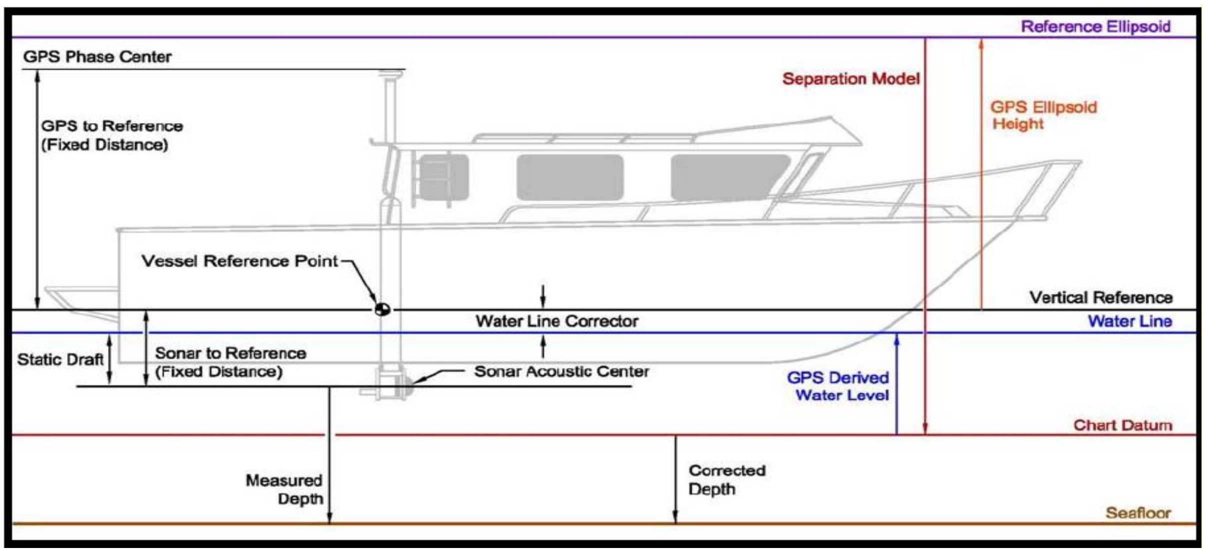


Figure 1. General definitions

Procedure:

An RTK base station was set up on land as close to the test area as possible and a static self-survey of at least one hour over a temporary point was conducted. The vessel communicates with the base station via radio connection. The C-Navigator displays "RTK-I" denoting a RTK fixed position (highest accuracy) when there is a connection with the base station; when the radio connection is lost this will change to "RTK-F" (a lower accuracy for position). In addition, the Rx light on the radio should continue to blink once per second until the connection is lost. The survey crew is responsible to observe this connection carefully and only record when “RTK-I” is displayed.

A number of vessel speeds were determined for the squat test. General surveying speeds start at approximately 3.0 kts and increase up to 6.5 kts, which was the top speed for the R/V *Shearwater* is 6.5 kts. Additionally, a baseline must be set to compare all subsequent speeds from. The final values that were determined for this squat and settlement test were idle (0 kts), 3.5 kts, 4.5 kts, 5.5 kts and 6.5 kts.

An arbitrary line was created in the navigational software (Hydromap) that was within the radio limits for the vessel to follow. Starting at one end of the survey line the vessel ran at each predetermined speed, sequentially and in the same direction, towards the other end of the line. The survey crew recorded each speed separately for a minimum of one minute. Survey crew also closely monitored the radio connection to ensure good data is being recorded (RTK-I). This procedure was repeated six (6) times, three (3) times in each direction.

Processing:

The GGA strings were extracted from each of the GPS files and all records without the ‘RTK-I’ level of accuracy (denoted by a ‘4’ in the raw data) removed. Each recording, once properly formatted, were brought into Microsoft Excel where the majority of the processing took place. The average Ellipsoid Height was calculated for each run. The data was normalized for ellipsoid height by subtracting the average of the ellipsoid heights at idle. The normalized ellipsoid heights were also normalized for tide, using tidal values from Sandy Hook, NJ station 8531680. The average ellipsoid height was then calculated for each speed.

Results:

The result of this normalization process is the average elevation differences of the vessel at different speeds. Although six (6) runs were conducted, labeled A through F, run D was removed due to anomalous data. The final vertical displacement of the R/V *Shearwater* with speed is shown in Table 1 and Figure 2. All values were applied to the data in CARIS during post-processing. Note that the values are negative, indicating that the vessel is lower in the water. Because the z-direction is positive down in the reference frame used for CARIS, these values are positive in the vessel file.

Table 1. Vertical displacement of the R/V *Shearwater* with speed.

Vertical Correction (m)	Speed (m/s)
0.00	0.45
-0.01	1.76
-0.03	2.31
-0.05	2.84
-0.08	3.34

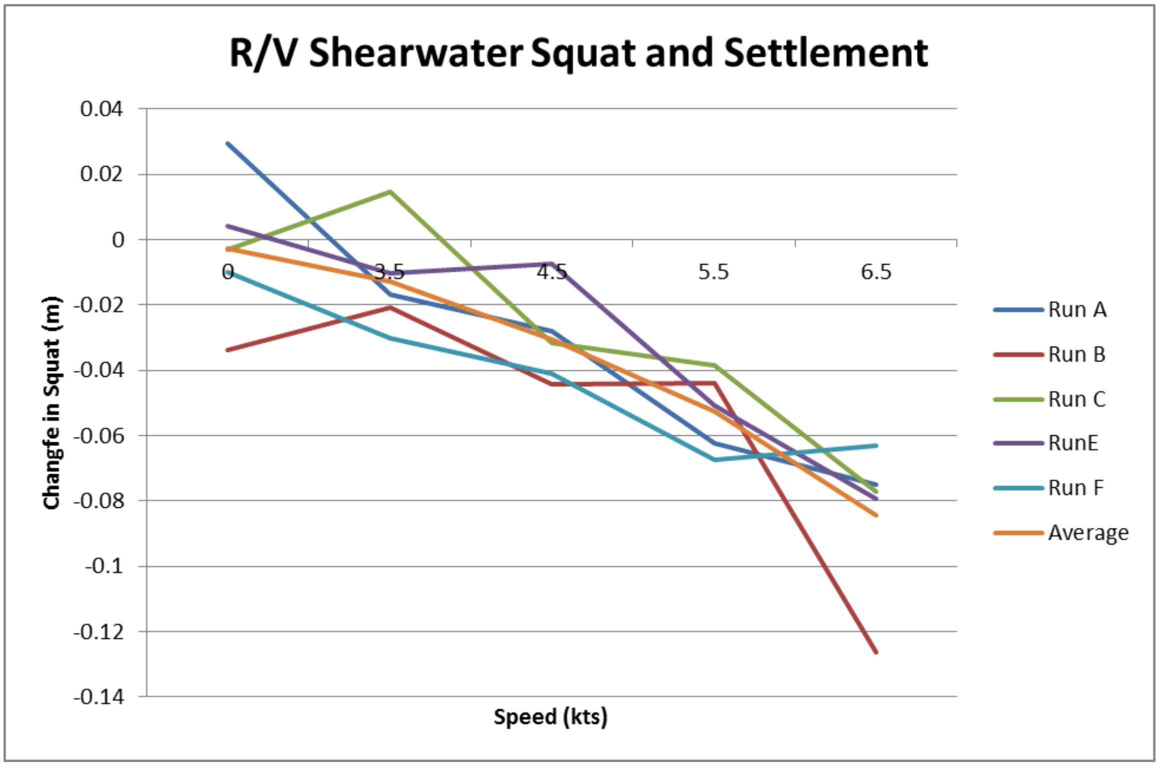


Figure 2. R/V *Shearwater* squat test results.

Project Log

C&C Technologies SURVEY SERVICES	**Project Number:**	**OPR-C319-KR-13**	**Page #:**	**001**
	Registry Number:	**H12608**	**Date** (YY/MM/DD):	**13/09/10**
	Vessel Name:	**Shearwater**	**Julian Day:**	**253**
	General Locality:	**East of Sandy Hook**		

Time (UTC)	Line Name	Fix	HDG	Speed (kts)	HDOP	Depth (m)	Remarks
1100							Crew boards R/V Shearwater, begin
							Mobilization
							Crew: J Baker, J Carlsen, A Drake
							J Wade, J Richard
							Tasks completed: set up antennas,
							Leveled antenna offsets, set up
							SSS system, begin setting up lab
0000							New day: 13/09/11 JD:254
1730							Additional crew arrives: T Levy,
							A, Cousson, V Hawkins
							Tasks completed: continued leveling
							Offsets, installed EM3002 heads,
							Set up seabirds, lead line, software
							Set up and configuration
							Unloaded groceries throughout day
0000							New day: 13/09/12 JD 255
							Continued mobilization of vessel
							Completed tasks: draft tube
							Construction and leveling, set up
							Base station and rover for squat
							Test, measured mulitbeam offsets
							Fastened SSS cradle to deck,
							Inventory and clean up
2200							Began F180 calibration in Hudson
							River
0000							New Day: 13/09/13 JD: 256
0000							F180 Calibration restarted with new
							Antenna separation value: 3.395m
0800							Return to dock, finished with
0945							F180 Calibrations
							Arrive back at dock
							Changing out cable on Port MB
							Head, checking values in F180

Project Log

Project Number:	OPR-C319-KR-13	Page #:	002
Registry Number:	H12608	Date (YY/MM/DD):	13/09/14
Vessel Name:	Shearwater	Julian Day:	257
General Locality:	East of Sandy Hook		

Time (UTC)	Line Name	Fix	HDG	Speed (kts)	HDOP	Depth (m)	Remarks
1330							Changed out F180 antennas +
							Raised them ~ 39 cm, changed out
							F180 box. Restarted calibration
							Setup new rack incase needed
							Tested SSS fish, troubleshooted
1800							Departed dock to wet test
							Side Scan.
							Issues with MB, Troubleshooting
							MB
2000							Fish on deck, F180 calibration
							While transiting to dock
2100							Continuing to Calibrate F180
0000							New Day 13/09/15 JD 258
1000							Headed to dock to work on
							MB Heads, Measurements + Squat
							Test prep
1130							MB head #225 replaced port side
							head
1200							BIST test heads checked fine
1230							Levelled new antenna rack
1330							Jim Wade and Jeff Richard depart
							Vessel for squat test base station
							Location
1347							Depart dock for squat test area
1545							Arrive in area, wait for base station
1650							On land to log data for an hour
							Cnav receiving RTK-1, transit to
							Start squat test
1704	SquatA-0	-	190	1.4	0.7	7.6	SOL
1705	SquatA-0	-	187	1.4	0.7	8.7	EOL
1711	SquatA-3	-	136	3.5	0.6	8.5	SOL RPM 280 noye:3.5kts
1712	SquatA-3	-	136	3.5	0.6	8.4	EOL
1714	SquatA-5	-	150	4.5	0.6	8.3	SOL

Project Log

	Project Number:	OPR-C319-KR-13	Page #:	003
	Registry Number:	H12608	Date (YY/MM/DD):	13/09/15
	Vessel Name:	R/V Shearwater	Julian Day:	258
	General Locality:	East of Sandy Hook		

Time (UTC)	Line Name	Fix	HDG	Speed (kts)	HDOP	Depth (m)	Remarks
1715	SquatA-45	-	152	4.5	0.6	8.3	EOL RPM 415
1717	SquatA-55	-	144	5.5	0.7	8.5	SOL RPM 443
1718	SquatA-55	-	151	5.6	0.6	8.6	EOL
1719	SquatA-65	-	144	6.6	0.6	8.8	SOL RPM 645
1720	SquatA-65	-	146	6.5	0.6	9.0	EOL RPM 627
1722	SquatB-00	-	340	1.2	0.6	9.2	SOL
1723	SquatB-00	-	355	1.0	0.7	9.3	EOL
1726	SquatB-35	-	330	3.5	0.6	9.2	SOL RPM 385
1727	SquatB-35	-	325	3.1	0.6	9.1	EOL note:line speed was 0.4 kts slow
1729	SquatB-45	-	325	4.5	0.7	8.7	SOL RPM 500
1730	SquatB-45	-	320	4.4	0.6	8.6	EOL
1731	SquatB-55	-	328	5.6	0.6	8.5	SOL RPM 640
1732	SquatB-55	-	321	5.5	0.6	8.4	EOL
1734	SquatB-65	-	323	6.4	0.6	8.7	SOL RPM 760
1735	SquatB-65	-	329	6.2	0.6	8.8	EOL
1741	SquatB-35b	-	321	3.4	0.7	8.6	SOL RPM 396
1742	SquatB-35b	-	325	3.2	0.6	8.7	EOL
1744	SquatC-00	-	186	1.1	0.6	8.8	SOL
1747	SquatC-00	-	300	1.1	0.7	8.7	Abort line: RTK float
1752	SquatC-00a	-	327	0.6	0.6	9.1	SOL
1753	SquatC-00a	-	327	0.5	0.6	9.2	EOL
1756	SquatC-35	-	148	3.4	0.7	8.8	SOL RPM:285
1757	SquatC-35	-	147	3.5	0.7	8.7	EOL
1759	SquatC-45	-	146	4.5	0.7	8.6	SOL RPM 420
1800	SquatC-45	-	164	4.3	0.7	8.6	EOL
1801	SquatC-55	-	155	5.4	0.7	8.8	SOL RPM 490
1802	SquatC-55	-	147	5.2	0.7	8.9	EOL
1803	SquatC-65	-	148	6.5	0.7	8.9	SOL RPM 630
1804	SquatC-65	-	145	6.6	0.7	9.2	EOL
1807	SquatD-00	-	336	0.7	0.7	9.3	SOL
1808	SquatD-00	-	333	0.8	0.8	9.3	EOL
1809	SquatD-35	-	339	3.4	0.8	9.4	SOL RPM 410
1810	SquatD-35	-	327	3.5	0.8	9.3	EOL

Project Log

Project Number:	OPR-C319-KR-13	Page #:	004
Registry Number:	H12608	Date (YY/MM/DD):	13/09/15
Vessel Name:	R/V Shearwater	Julian Day:	258
General Locality:	East of Sandy Hook		

Time (UTC)	Line Name	Fix	HDG	Speed (kts)	HDOP	Depth (m)	Remarks
1811	SquatD-45	-	327	4.5	0.7	9.1	SOL RPM: 510
1812	SquatD-45	-	328	4.5	0.8	9.0	EOL
1813	SquatD-55	-	328	5.6	0.8	9.0	SOL RPM: 623
1814	SquatD-55	-	328	5.6	0.8	8.7	EOL
1815	SquatD-65	-	330	6.5	0.7	8.8	SOL RPM: 755
1816	SquatD-65	-	327	6.5	0.7	8.7	EOL
1819	SquatE-00	-	118	0.8	0.7	8.9	SOL
1820	SquatE-00	-	110	0.9	0.8	8.9	EOL
1823	SquatE-35	-	150	3.4	0.9	9.1	SOL RPM: 305
1824	SquatE-35	-	150	3.2	0.8	8.9	EOL
1825	SquatE-45	-	155	4.8	0.8	9.1	SOL RPM: 490
1826	SquatE-45	-	151	4.3	0.8	9.1	EOL
1827	SquatE-55	-	157	5.6	0.8	9.2	SOL RPM: 535
1828	SquatE-55	-	147	5.5	0.8	9.3	EOL
1829	SquatE-65	-	149	6.4	0.8	9.5	SOL RPM: 645
1830	SquatE-65	-	148	6.6	0.9	9.6	EOL
1833	SquatF-00	-	312	0.7	0.8	9.8	SOL
1833	SquatF-00	-	300	0.4	0.8	9.8	Abort line: RTK-F
1834	SquatF-00a	-	276	0.1	0.8	9.7	SOL
1836	SquatF-00a	-	253	0.2	0.7	9.7	EOL
1837	SquatF-35	-	333	3.6	0.8	9.6	SOL RPM: 433
1838	SquatF-35	-	335	3.5	0.7	9.7	EOL
1839	SquatF-45	-	342	4.6	0.6	9.4	SOL RPM: 505
1840	SquatF-45	-	333	4.6	0.6	9.3	EOL
1841	SquatF-55	-	332	5.6	0.6	9.2	SOL RPM: 590
1842	SquatF-55	-	327	5.6	0.6	9.0	EOL
1843	SquatF-65	-	327	6.5	0.6	8.9	SOL RPM: 710
1844	SquatF-65	-	329	6.6	0.6	8.9	EOL
1845							Squat Test Complete, transit back to
							Dock for crew change
2115							Arrive at dock
							New crew arrive. J. Maslak, R. Ledford
							L. Weidner

Vessel Layback Report – R/V *Shearwater*

Side scan sonar data was collected with an Edgetech 4200-P series sonar, operated in a towed configuration. A hanging sheave mounted to a retractable A-frame at the stern of the vessel was used as the tow point for the side scan sonar.

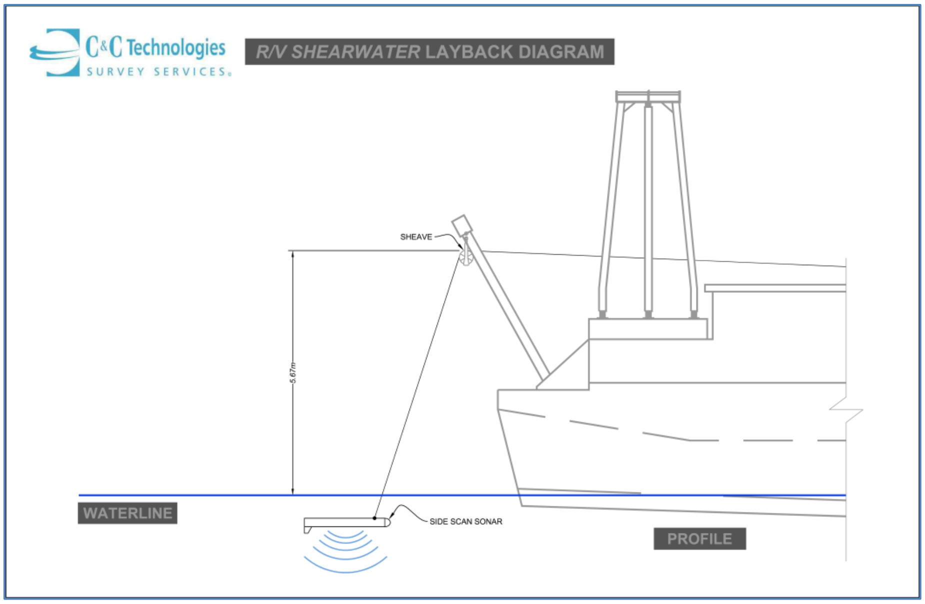


Figure 1. Side scan sonar towed configuration on the R/V *Shearwater*

Chesapeake Technologies' SonarWiz5 was used to process the side scan sonar files (versions of SonarWiz are noted in the main body of the DAPR). The raw XTF files were imported into SonarWiz and offsets applied. The sheave offsets were applied to the side scan sonar files to correct for the offset from the primary C-Nav GPS antenna to the towpoint (Table 1), and an offset applied to correct for the distance from the waterline to the sheave (Table 2). Positive X indicates that the sheave is starboard of the GPS, negative Y indicates that the sheave is aft of the GPS antenna and SonarWiz requires the sheave height to be positive.

Table 1. Sheave offsets from GPS

Sheave Offset from GPS (meters)	X	Y
	0.441	-15.873

Table 2. Sheave Height

Sheave Height Above Waterline (meters)	Z
	5.670

Layback was applied to all side scan sonar XTF files using SonarWiz, which allows the user to choose one of two layback algorithms, either Cable – Percent, which is used when only cable out was recorded, or Cable – Sensor Depth, which is used if the towfish has a depth sensor. The user also chooses the percentage of cable out to apply as an along-track offset. Bottom tracked and layback corrected files were exported from SonarWiz for the final deliverables.

APPENDIX II

Echosounder Reports

C&C Technologies
SURVEY SERVICES

NOAA

System Accuracy Test – R/V - *Shearwater*

An Odom Echotrac MKIII was used to collect single beam data. This data was continuously recorded and monitored in real-time as an independent check of the nadir beam (bottom-detect) of the EM3002D multibeam sonar system.

Hydromap, C & C Technologies' propriety software, was used to extract the single beam depths from the Echotrac files that are collected along with the multibeam data. The process outputs an .echotrac.xyz.txt and an .EM3002.xyz.txt. Lines were chosen at least once weekly throughout the surveys to compare. Table 1 below shows these lines in chronological order. No comparisons were made for the days of October 7 – 14, during which the vessel was waiting on weather.

Table 1. Dates, line name and Sheet for each singlebeam to multibeam comparison

Date	Line Name	Sheet
09/26/2013	1127-1	H12608
09/26/2013	H12610-TIE-305-1	H12610
10/03/2013	1321-1	H12608
10/15/2013	1355-1	H12608
10/17/2013	1464-1	H12608
10/22/2013	1417-3	H12608
10/22/2013	3039-1	H12610
10/23/2013	2030-1	H12609
10/29/2013	2001-1	H12609
11/6/2013	2230-2	H12609
11/14/2013	3041-2	H12610

The .xyz.txt files were imported into Fledermaus DMagic and separate grids for each line (singlebeam and multibeam) were generated. Fledermaus was used to compute difference surfaces with the multibeam surface as the reference surface and the singlebeam surface as the surface of interest.

It is evident that the singlebeam depths are consistently deeper than the multibeam depths, but the surfaces generally show good agreement; the mean of the differences between the lines does not exceed -0.21 meters. The more extreme minimum and maximum values were found to be small in number and generally associated with areas of sloping seafloor and bathymetric change. Statistics of the difference surfaces are shown in Table 2.

Table 2. Statistics of Difference Surfaces

Line Name	Mean	Standard Deviation	Min	Max	Median
1127-1	-0.14	0.04	-0.345	0.141	-0.14
H12610-TIE-305-1	-0.10	0.06	-0.385	0.105	-0.09
1321-1	-0.15	0.07	-0.506	0.544	-0.15
1355-1	-0.12	0.10	-0.313	0.463	-0.14
1464-1	-0.13	0.03	-0.175	-0.041	-0.14
1417-3	-0.18	0.03	-0.266	-0.032	-0.18
3039-1	-0.16	0.06	-0.433	0.263	-0.16
2030-1	-0.13	0.17	-0.558	0.463	-0.14
2001-1	-0.21	0.03	-0.255	-0.138	-0.21
2230-2	-0.16	-0.16	-0.380	-0.007	-0.16
3041-2	-019	-0.04	-0.361	-0.013	-0.19

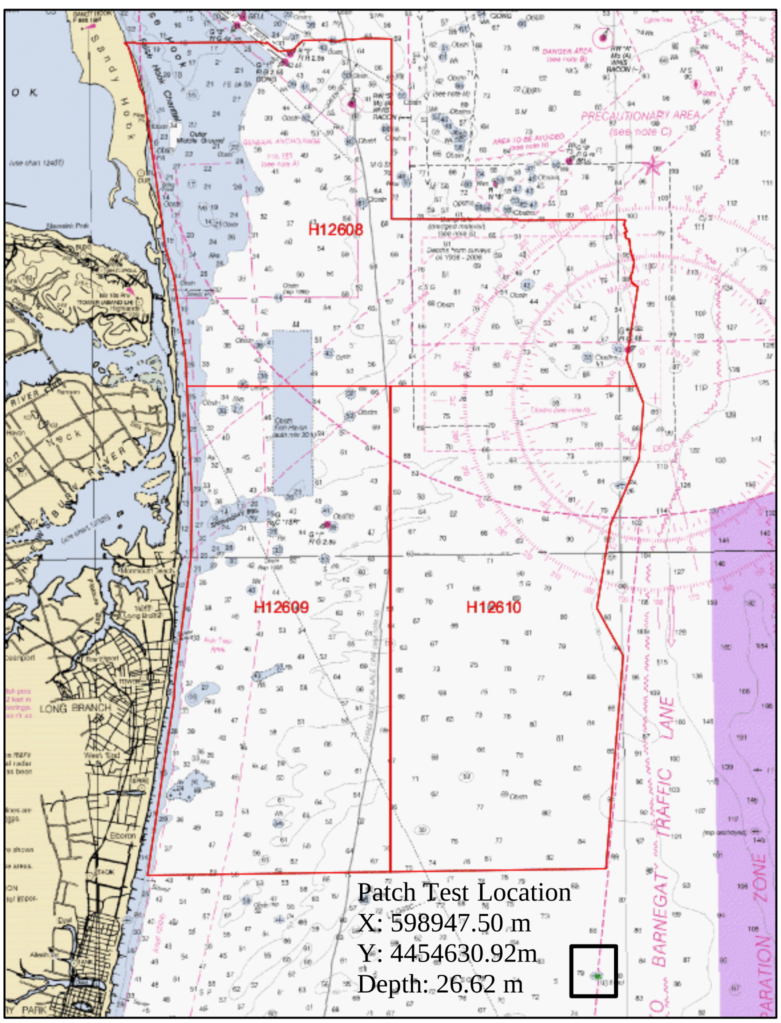
System Alignment Test (Patch Test) Report

Purpose:

The patch tests are performed in order to calculate the mounting angles of the multibeam transducers in the vessel reference frame. The angular offsets are applied in the topside transducer control software to ensure accurate depth calculations.

The R/V *Shearwater* was mounted with a dual head EM3002 configuration. The port head (SH1) has serial number 225 and starboard head (SH2) has serial number 112. Patch tests were conducted separately for each head. The initial roll values were set to **–30**° for Sonar Head 1 and **+30**° for Sonar Head 2. These values reflect the approximate mounting angles of each head and provided a baseline for roll calculations.

The patch test was conducted on September 19, 2013. Below is a map showing the location.



Patch test data for C & C Technologies' surveys have been historically processed using the proprietary software Hydromap.

Patch Test Processing Hydromap Procedure

Pitch: Two reciprocal lines run over a significant bottom feature.

$$\tan^{-1}\left(\frac{\Delta dx}{(\Delta \mathrm{wd} - \Delta \mathrm{dr}) * 2}\right)$$

Δdx = difference in along-track positions
$\Delta \mathrm{wd}$ = water depth
$\Delta \mathrm{dr}$ = distance from the transducer to the surface of the water

Transducer	Angle Offset
SH1	-3.90°
SH2	-4.16°

Roll : Two reciprocal lines run over a relatively flat surface (no features present).

$$\tan^{-1}\left(\frac{\Delta ms}{2}\right)$$

Δms = mean slope calculated in the beam analysis tool in Hydromap (regression analysis)

Transducer	Angle Offset
SH1	+31.5873°
SH2	-28.9439°

Yaw: Two parallel lines run in the same direction with 10% to 20% overlap over a significant bottom feature. The overlapping areas must contain the feature.

$$\tan^{-1}\left(\frac{\Delta dx}{\Delta \mathrm{n}}\right)$$

Δdx = difference in along-track positions
$\Delta \mathrm{n}$ = distance from the feature to nadir

Transducer	Angle Offset
SH1	-4.737°
SH2	-6.618°

Note: The values obtained are neither positive nor negative in Hydromap. The sign of the values is determined after.

Table 1. September 19, 2013 Patch Test results.

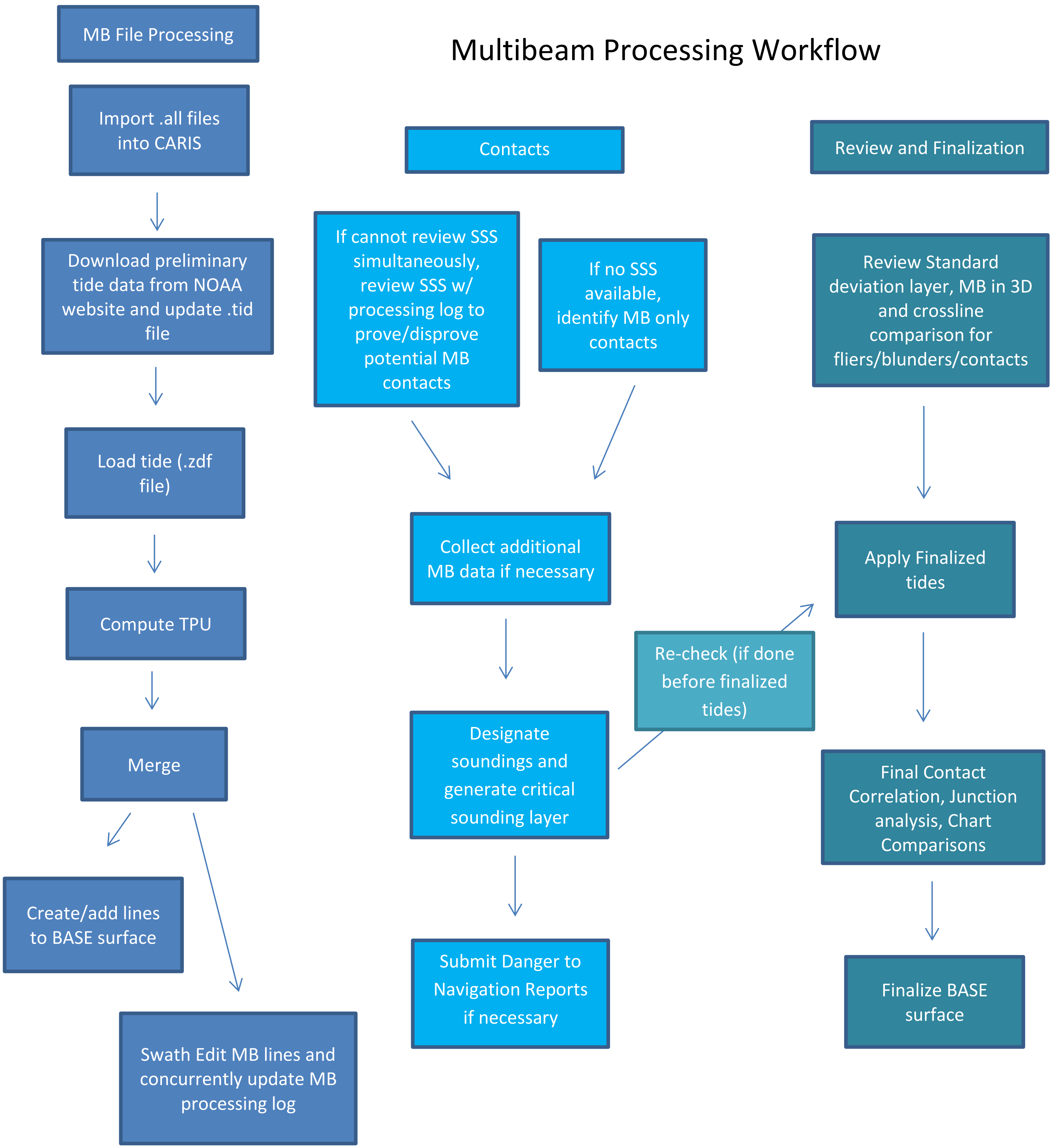
	Sonar Head 1- 225	Sonar Head 2- 112
Pitch	-3.90°	-4.16°
Roll	1.5873°	1.0561°
Yaw	-4.737°	-6.618°

Verification and Conclusions

During post processing, an attempt was made to process the patch test in CARIS using the calibration tool. However, the field methodology for conducting the patch test, incrementally correcting the patch test values in Hydromap and updating the patch test values in SIS, was not conducive to processing the patch test in CARIS. Correspondence with CARIS indicates that it is best if there are no values in the installation parameters in order to process the data. This has been noted and C & C Technologies' has plans to update the patch test collection procedures in the future.

Historically, and in this survey, the offset values are obtained from Hydromap and immediately input into the SIS control software. During processing of the data for this survey, no significant offsets were observed within the data and for this reason the original patch test values obtained from Hydromap are retained. No additional post-processing occurred other than what is specified the Data Acquisition and Processing Report and in respective Descriptive Reports.

Multibeam Processing Workflow



Side Scan Sonar Processing Workflow

C&C Technologies
SURVEY SERVICES
730 E. KALISTE SALOOM ROAD, LAFAYETTE, LA (337) 261-0660

APPENDIX III

Positioning and Attitude Sensor Reports

Calibration settings for F180 Series - R/V Shearwater
9/17/2013 4:41:44 AM

Calibration status is: Complete

Attitude Accuracy: 0.040 degrees.
Heading Accuracy: 0.092 degrees.

Calibration Configuration Parameters

X GPS Offset: -1.285 metres.
X GPS Accuracy: 0.011 metres.

Y GPS Offset: -2.163 metres.
Y GPS Accuracy: 0.011 metres.

Z GPS Offset: -5.497 metres.

Z GPS Accuracy: 0.185 metres.

GPS Rotation: 89.71 degrees.
GPS Rotation Accuracy: 0.08 degrees.

GPS Elevation: -0.18 degrees.
GPS Elevation Accuracy: 0.02 degrees.

Other Configuration Parameters

GPS Antenna Separation: 3.378 metres.
GPS Correction Type: DGPS.
Heading Offset: 0.00 degrees.
Pitch Offset: 0.00 degrees.
Roll Offset: 0.00 degrees.
X Remote Lever Arm: 0.000 metres.
Y Remote Lever Arm: 0.000 metres.
Z Remote Lever Arm: 0.000 metres.
Heave coupling: AC.
Altitude compensation to mean sea level datum: No.

Serial 1 Output Parameters

Serial 1 string: .
Serial 1 baud: 19200.
Serial 1 data bits: 8.
Serial 1 stop bits: 1.
Serial 1 parity: None.
Serial 1 update rate: 5 Hz.

Serial 2 Output Parameters

Serial 2 string: .
Serial 2 baud: 19200.
Serial 2 data bits: 8.
Serial 2 stop bits: 1.
Serial 2 parity: None.
Serial 2 update rate: 100 Hz.

C&C Technologies
SURVEY SERVICES
730 E. KALISTE SALOOM ROAD, LAFAYETTE, LA (337) 261-0660

APPENDIX IV

Sound Speed Sensor Reports

5221

Sea-Bird Electronics, Inc.

13431 NE 20th Street, Bellevue, WA 98005-2010 USA
Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 5221
CALIBRATION DATE: 28-Jun-13

SBE19plus TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS

a0 = 1.238148e-003
a1 = 2.531476e-004
a2 = 7.304508e-007
a3 = 1.093739e-007

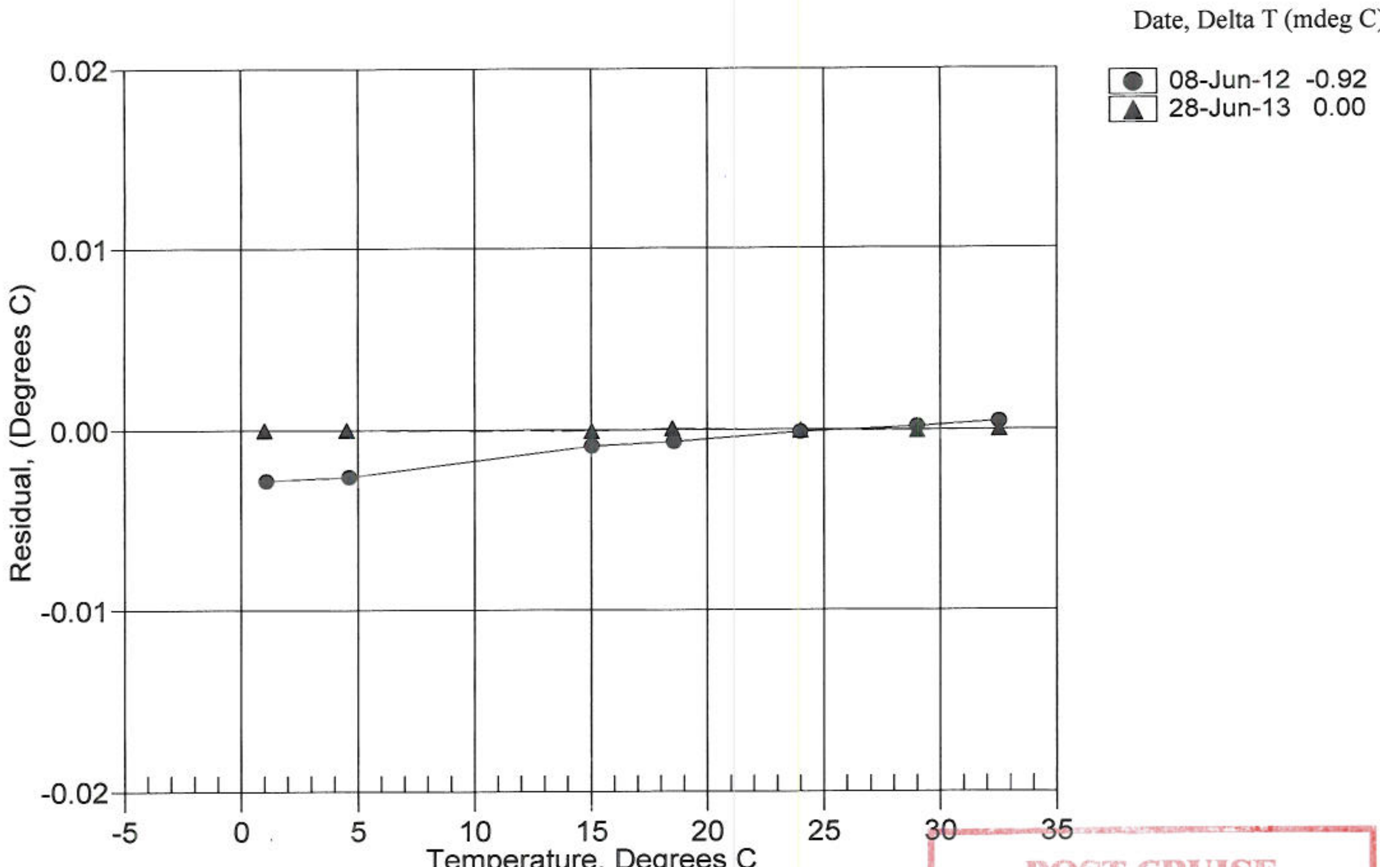
BATH TEMP (ITS-90)	INSTRUMENT OUTPUT(n)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
0.9999	735875.831	0.9999	-0.0000
4.5000	658667.780	4.5000	0.0000
15.0000	462152.831	15.0000	-0.0000
18.4999	408212.576	18.5000	0.0001
24.0001	334209.237	24.0001	-0.0000
29.0001	277301.576	29.0001	-0.0000
32.5001	242695.915	32.5001	0.0000

MV = (n - 524288) / 1.6e+007

R = (MV * 2.900e+009 + 1.024e+008) / (2.048e+004 - MV * 2.0e+005)

Temperature ITS-90 = $1/\{a0 + a1[ln(R)] + a2[ln^2(R)] + a3[ln^3(R)]\} - 273.15$ (°C)

Residual = instrument temperature - bath temperature



POST CRUISE CALIBRATION

SBE SEA-BIRD ELECTRONICS, INC.
13431 NE 20th St. Bellevue, Washington 98005 USA
Phone: (425) 643-9866 Fax: (425) 643-9954 www.seabird.com

Temperature Calibration Report

Customer:	C&C Technologies		
Job Number:	74576	**Date of Report:**	6/28/2013
Model Number	SBE 19Plus	**Serial Number:**	19P47719-5221

Temperature sensors are normally calibrated 'as received', without adjustments, allowing a determination sensor drift. If the calibration identifies a problem, then a second calibration is performed after work is completed. The 'as received' calibration is not performed if the sensor is damaged or non-functional, or by customer request.

An 'as received' calibration certificate is provided, listing coefficients to convert sensor frequency to temperature. Users must choose whether the 'as received' calibration or the previous calibration better represents the sensor condition during deployment. In SEASOFT enter the chosen coefficients. The coefficient 'offset' allows a small correction for drift between calibrations (consult the SEASOFT manual). Calibration coefficients obtained after a repair apply only to subsequent data.

'AS RECEIVED CALIBRATION' ☑ Performed ☐ Not Performed

Date: 6/28/2013 Drift since last cal: +0.00087 Degrees Celsius/year

Comments:

'CALIBRATION AFTER REPAIR' ☐ Performed ☑ Not Performed

Date: Drift since Last cal: Degrees Celsius/year

Comments:

Sea-Bird Electronics, Inc.

13431 NE 20th Street, Bellevue, WA 98005-2010 USA

Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 5221
CALIBRATION DATE: 28-Jun-13

SBE19plus CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

```
g = -1.035027e+000
h =  1.600348e-001
i = -5.014262e-004
j =  6.457895e-005
```

```
CPcor = -9.5700e-008
CTcor =  3.2500e-006
```

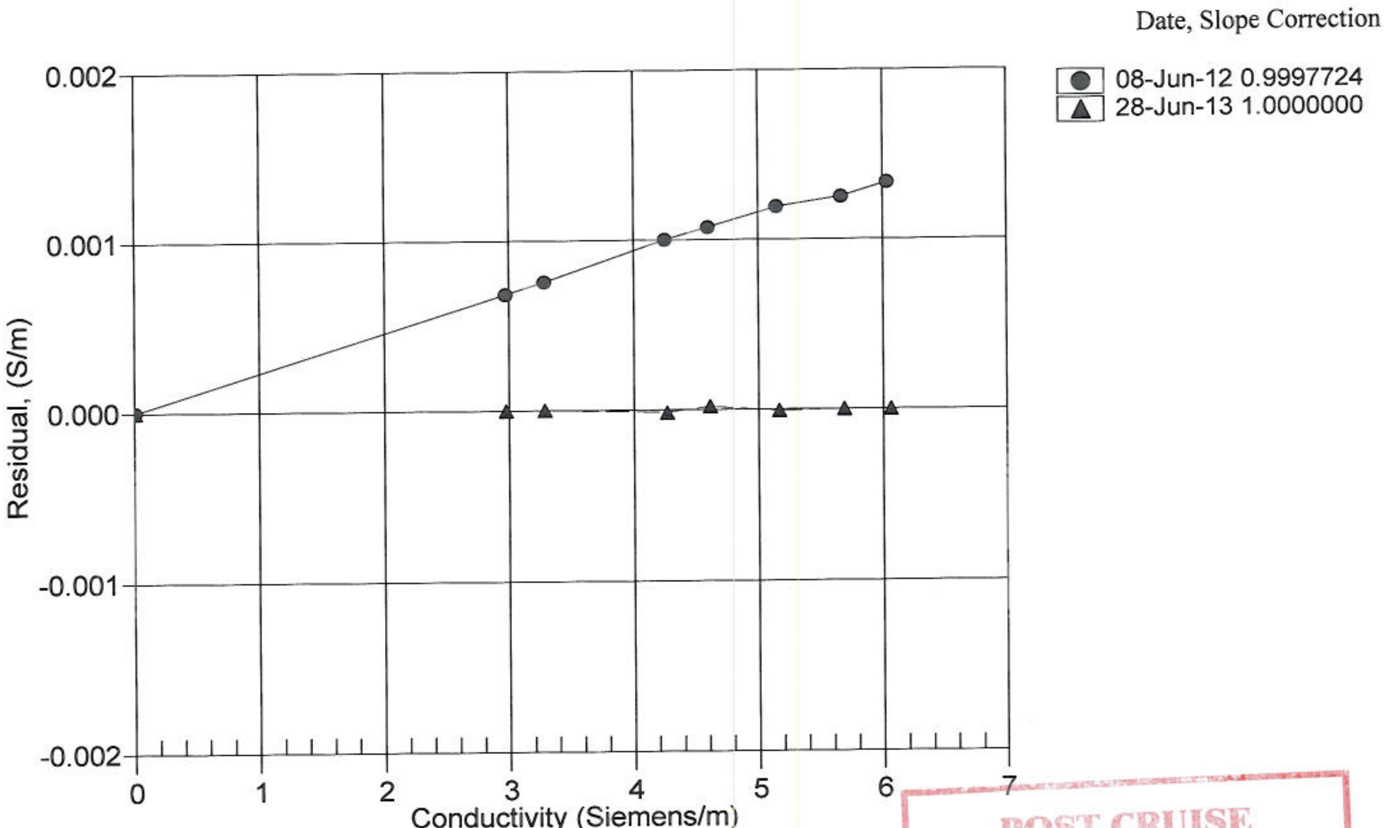
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (Hz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
22.0000	0.0000	0.00000	2549.98	0.0000	0.00000
0.9999	34.7813	2.97325	5018.60	2.9732	-0.00000
4.5000	34.7612	3.28004	5206.66	3.2800	0.00000
15.0000	34.7174	4.26076	5766.05	4.2607	-0.00001
18.4999	34.7081	4.60555	5949.96	4.6056	0.00002
24.0001	34.6979	5.16297	6235.47	5.1630	-0.00001
29.0001	34.6925	5.68433	6490.82	5.6843	-0.00000
32.5001	34.6899	6.05645	6666.88	6.0564	0.00000

f = INST FREQ / 1000.0

Conductivity = $(g + hf^2 + if^3 + jf^4) / (1 + \delta t + \varepsilon p)$ Siemens/meter

t = temperature[°C)]; p = pressure[decibars]; δ = CTcor; ε = CPcor;

Residual = instrument conductivity - bath conductivity



POST CRUISE CALIBRATION

SBE SEA-BIRD ELECTRONICS, INC.
13431 NE 20th Street Bellevue, Washington 98005 USA
Phone: (425) 643-9866 Fax: (425) 643-9954 www.seabird.com

Conductivity Calibration Report

Customer:	C&C Technologies		
Job Number:	74576	Date of Report:	6/28/2013
Model Number	SBE 19Plus	Serial Number:	19P47719-5221

Conductivity sensors are normally calibrated 'as received', without cleaning or adjustments, allowing a determination of sensor drift. If the calibration identifies a problem or indicates cell cleaning is necessary, then a second calibration is performed after work is completed. The 'as received' calibration is not performed if the sensor is damaged or non-functional, or by customer request.

An 'as received' calibration certificate is provided, listing the coefficients used to convert sensor frequency to conductivity. Users must choose whether the 'as received' calibration or the previous calibration better represents the sensor condition during deployment. In SEASOFT enter the chosen coefficients. The coefficient 'slope' allows small corrections for drift between calibrations (consult the SEASOFT manual). Calibration coefficients obtained after a repair or cleaning apply only to subsequent data.

'AS RECEIVED CALIBRATION' ☑ Performed ☐ Not Performed

Date: 6/28/2013 Drift since last cal: -0.00050 PSU/month*

Comments:

'CALIBRATION AFTER CLEANING & REPLATINIZING' ☐ Performed ☑ Not Performed

Date: Drift since Last cal: PSU/month*

Comments:

**Measured at 3.0 S/m*

Cell cleaning and electrode replatinizing tend to 'reset' the conductivity sensor to its original condition. Lack of drift in post-cleaning-calibration indicates geometric stability of the cell and electrical stability of the sensor circuit.

Sea-Bird Electronics, Inc.

13431 NE 20th Street, Bellevue, WA 98005-2010 USA

Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 5221
CALIBRATION DATE: 27-Jun-13

SBE19plus PRESSURE CALIBRATION DATA
870 psia S/N 2494572

COEFFICIENTS:

PA0 = -1.007417e+000
PA1 = 2.642563e-003
PA2 = 1.884526e-011
PTEMPA0 = -6.427899e+001
PTEMPA1 = 5.184738e+001
PTEMPA2 = -3.251193e-001

PTCA0 = 5.251871e+005
PTCA1 = -2.651889e+001
PTCA2 = 4.372853e-001
PTCB0 = 2.556488e+001
PTCB1 = 5.750000e-004
PTCB2 = 0.000000e+000

PRESSURE SPAN CALIBRATION

PRESSURE PSIA	INST OUTPUT	THERMISTOR OUTPUT	COMPUTED PRESSURE	ERROR %FSR
14.67	530745.0	1.7	14.67	0.00
179.94	593288.0	1.7	179.95	0.00
359.94	661339.0	1.7	359.95	0.00
539.96	729330.0	1.7	539.96	0.00
719.98	797263.0	1.7	720.00	0.00
874.97	855680.0	1.7	874.95	-0.00
720.00	797269.0	1.7	720.01	0.00
540.01	729346.0	1.7	540.01	-0.00
360.00	661351.0	1.7	359.98	-0.00
179.98	593291.0	1.7	179.96	-0.00
14.67	530745.0	1.7	14.68	0.00

THERMAL CORRECTION

TEMP ITS90	THERMISTOR OUTPUT	INST OUTPUT
32.50	1.89	530826.00
29.00	1.82	530836.32
24.00	1.72	530853.65
18.50	1.61	530891.00
15.00	1.54	530928.18
4.50	1.34	531117.20
1.00	1.27	531210.85

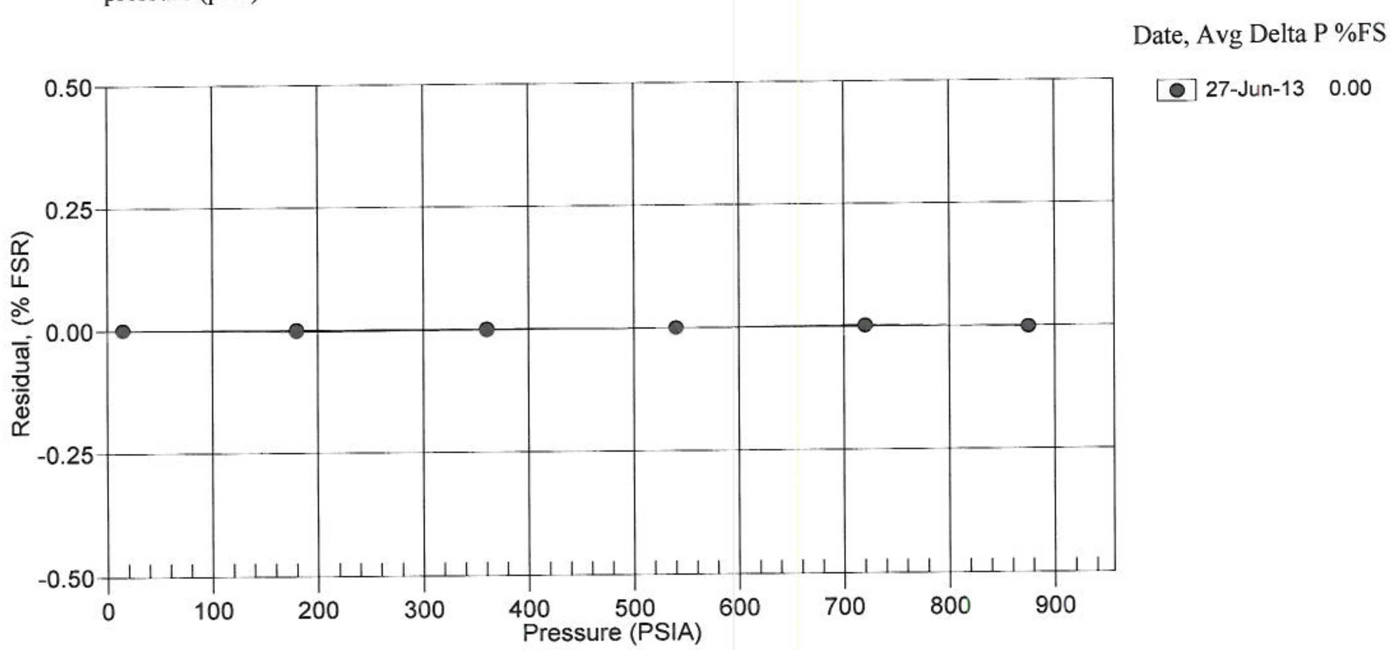
TEMP(ITS90)	SPAN(mV)
-5.00	25.56
35.00	25.59

y = thermistor output; $t = PTEMPA0 + PTEMPA1 * y + PTEMPA2 * y^2$

$x = \text{pressure output} - PTCA0 - PTCA1 * t - PTCA2 * t^2$

$n = x * PTCB0 / (PTCB0 + PTCB1 * t + PTCB2 * t^2)$

$\text{pressure (psia)} = PA0 + PA1 * n + PA2 * n^2$



Sea-Bird Electronics, Inc.

13431 NE 20th Street, Bellevue, WA 98005-2010 USA

Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 5222
CALIBRATION DATE: 05-Jun-13

SBE19plus TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS

a0 = 1.264759e-003
a1 = 2.629244e-004
a2 = -2.033500e-007
a3 = 1.538617e-007

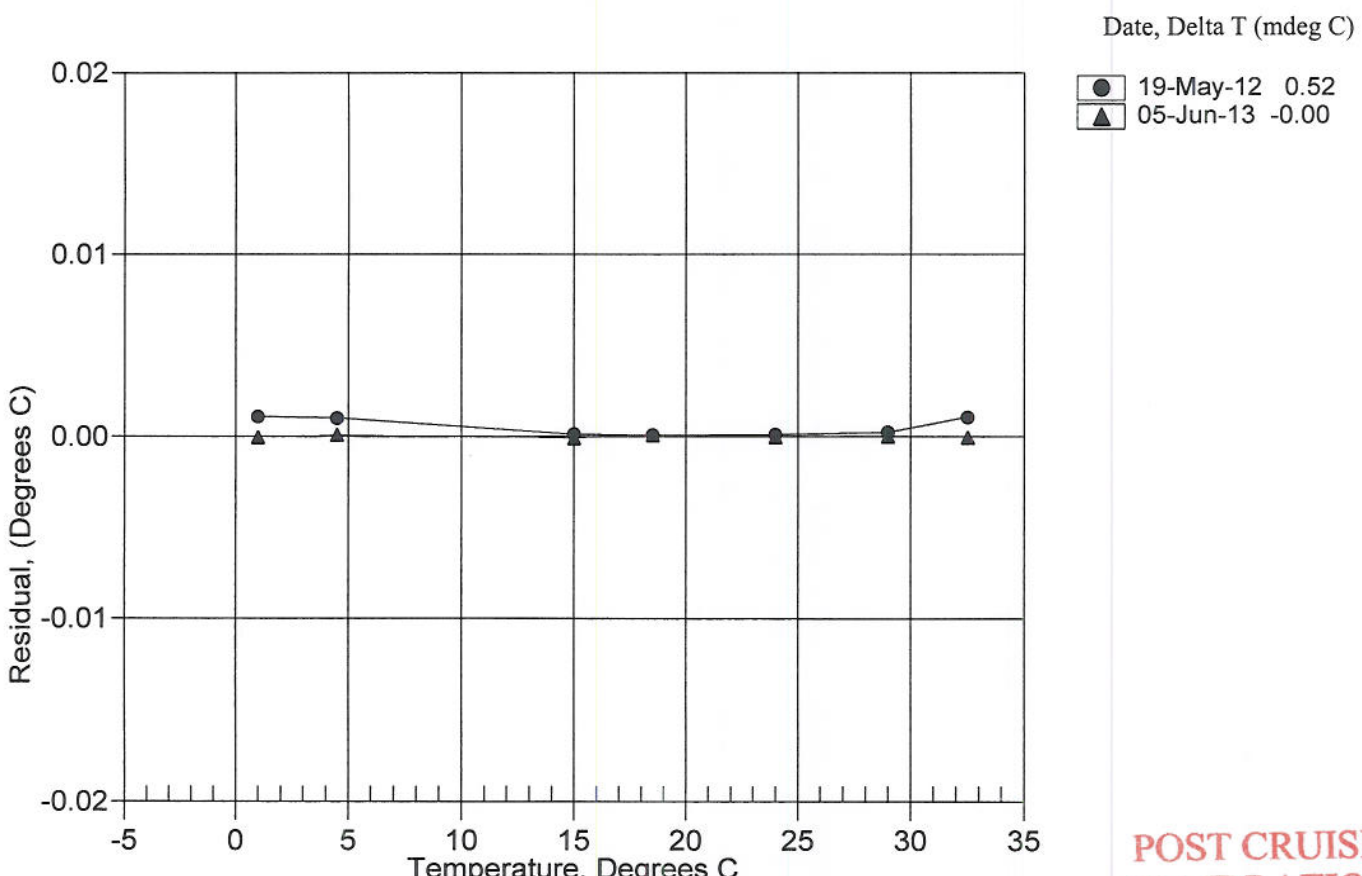
BATH TEMP (ITS-90)	INSTRUMENT OUTPUT(n)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
1.0000	619266.034	1.0000	-0.0000
4.5000	549294.559	4.5001	0.0001
15.0000	375970.458	14.9999	-0.0001
18.5000	329535.068	18.5001	0.0001
24.0000	266593.881	24.0000	-0.0000
29.0000	218769.288	29.0000	0.0000
32.5000	189926.186	32.5000	-0.0000

MV = (n - 524288) / 1.6e+007

R = (MV * 2.900e+009 + 1.024e+008) / (2.048e+004 - MV * 2.0e+005)

Temperature ITS-90 = $1/\{a0 + a1[ln(R)] + a2[ln^2(R)] + a3[ln^3(R)]\} - 273.15$ (°C)

Residual = instrument temperature - bath temperature



POST CRUISE CALIBRATION

SBE SEA-BIRD ELECTRONICS, INC.
13431 NE 20th St. Bellevue, Washington 98005 USA
Phone: (425) 643-9866 Fax: (425) 643-9954 www.seabird.com

Temperature Calibration Report

Customer:	C&C Technologies		
Job Number:	74312	**Date of Report:**	6/5/2013
Model Number	SBE 19Plus	**Serial Number:**	19P47719-5222

Temperature sensors are normally calibrated 'as received', without adjustments, allowing a determination sensor drift. If the calibration identifies a problem, then a second calibration is performed after work is completed. The 'as received' calibration is not performed if the sensor is damaged or non-functional, or by customer request.

An 'as received' calibration certificate is provided, listing coefficients to convert sensor frequency to temperature. Users must choose whether the 'as received' calibration or the previous calibration better represents the sensor condition during deployment. In SEASOFT enter the chosen coefficients. The coefficient 'offset' allows a small correction for drift between calibrations (consult the SEASOFT manual). Calibration coefficients obtained after a repair apply only to subsequent data.

'AS RECEIVED CALIBRATION' ☑ Performed ☐ Not Performed

Date: 6/5/2013 Drift since last cal: -0.00049 Degrees Celsius/year

Comments:

'CALIBRATION AFTER REPAIR' ☐ Performed ☑ Not Performed

Date: Drift since Last cal: Degrees Celsius/year

Comments:

Sea-Bird Electronics, Inc.

13431 NE 20th Street, Bellevue, WA 98005-2010 USA
Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 5222
CALIBRATION DATE: 05-Jun-13

SBE19plus CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

g = -1.001914e+000
h = 1.565880e-001
i = -5.372106e-004
j = 6.702204e-005

CPcor = -9.5700e-008
CTcor = 3.2500e-006

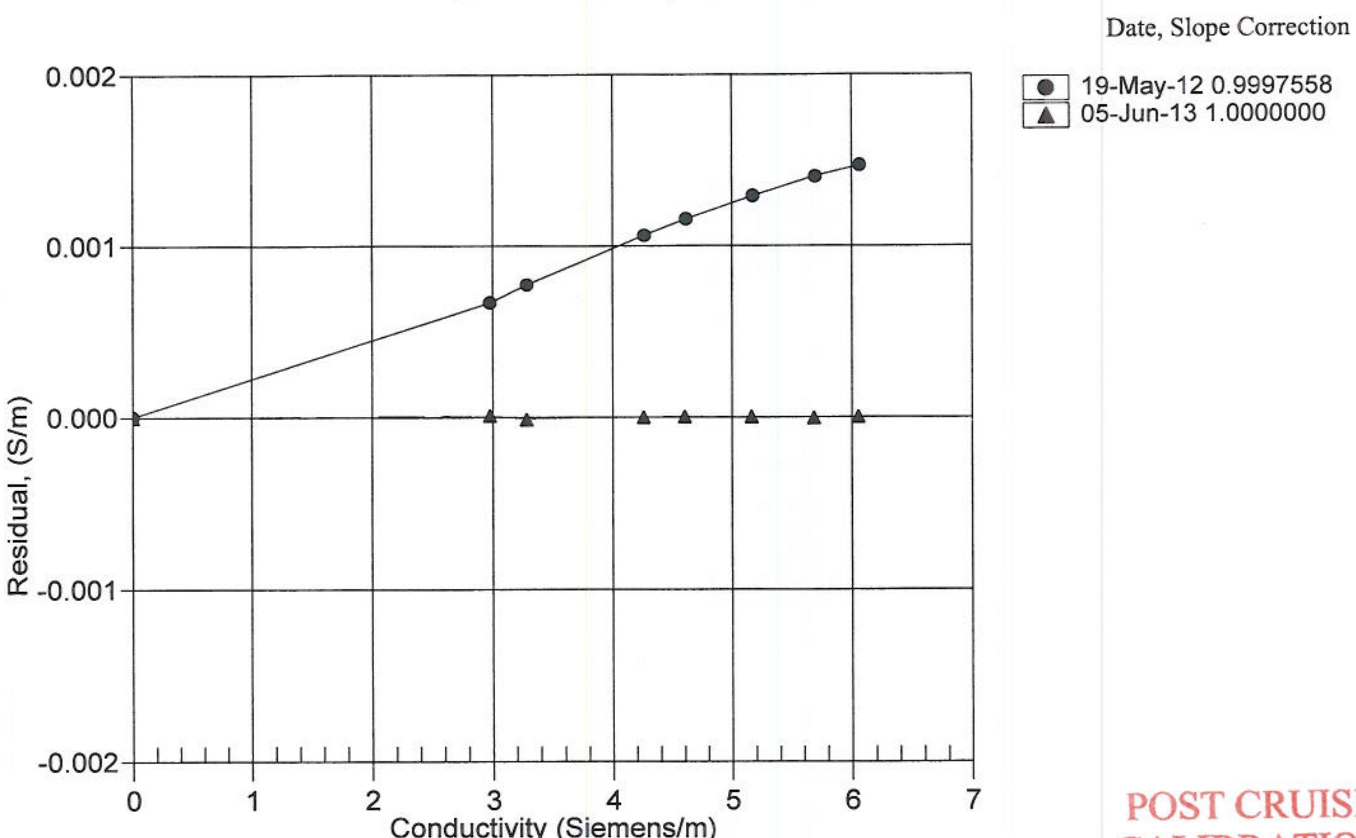
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (Hz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
22.0000	0.0000	0.00000	2537.07	0.0000	0.00000
1.0000	34.7608	2.97167	5053.69	2.9717	0.00001
4.5000	34.7411	3.27833	5244.59	3.2783	-0.00001
15.0000	34.6985	4.25869	5812.20	4.2587	-0.00000
18.5000	34.6893	4.60334	5998.69	4.6033	0.00000
24.0000	34.6791	5.16047	6288.13	5.1605	0.00000
29.0000	34.6733	5.68153	6546.87	5.6815	-0.00000
32.5000	34.6697	6.05331	6725.18	6.0533	0.00000

f = INST FREQ / 1000.0

Conductivity = $(g + hf^2 + if^3 + jf^4) / (1 + \delta t + \varepsilon p)$ Siemens/meter

t = temperature[°C)]; p = pressure[decibars]; δ = CTcor; ε = CPcor;

Residual = instrument conductivity - bath conductivity



POST CRUISE CALIBRATION

SBE SEA-BIRD ELECTRONICS, INC.
13431 NE 20th Street Bellevue, Washington 98005 USA
Phone: (425) 643-9866 Fax: (425) 643-9954 www.seabird.com

Conductivity Calibration Report

Customer:	C&C Technologies		
Job Number:	74312	Date of Report:	6/5/2013
Model Number	SBE 19Plus	Serial Number:	19P47719-5222

Conductivity sensors are normally calibrated 'as received', without cleaning or adjustments, allowing a determination of sensor drift. If the calibration identifies a problem or indicates cell cleaning is necessary, then a second calibration is performed after work is completed. The 'as received' calibration is not performed if the sensor is damaged or non-functional, or by customer request.

An 'as received' calibration certificate is provided, listing the coefficients used to convert sensor frequency to conductivity. Users must choose whether the 'as received' calibration or the previous calibration better represents the sensor condition during deployment. In SEASOFT enter the chosen coefficients. The coefficient 'slope' allows small corrections for drift between calibrations (consult the SEASOFT manual). Calibration coefficients obtained after a repair or cleaning apply only to subsequent data.

'AS RECEIVED CALIBRATION' ☑ Performed ☐ Not Performed

Date: 6/5/2013 Drift since last cal: -0.00060 PSU/month

Comments:

'CALIBRATION AFTER CLEANING & REPLATINIZING' ☐ Performed ☑ Not Performed

Date: Drift since Last cal: PSU/month

Comments:

**Measured at 3.0 S/m*

Cell cleaning and electrode replatinizing tend to 'reset' the conductivity sensor to its original condition. Lack of drift in post-cleaning-calibration indicates geometric stability of the cell and electrical stability of the sensor circuit.

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Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 5222
CALIBRATION DATE: 03-Jun-13

SBE19plus PRESSURE CALIBRATION DATA
870 psia S/N 2494573

COEFFICIENTS:

PA0 = -6.685777e-001
PA1 = 2.649095e-003
PA2 = 2.191241e-011
PTEMPA0 = -6.522660e+001
PTEMPA1 = 5.336769e+001
PTEMPA2 = -4.741150e-001

PTCA0 = 5.244232e+005
PTCA1 = -1.604035e+001
PTCA2 = 2.180958e-001
PTCB0 = 2.549788e+001
PTCB1 = 1.375000e-003
PTCB2 = 0.000000e+000

PRESSURE SPAN CALIBRATION

PRESSURE PSIA	INST OUTPUT	THERMISTOR OUTPUT	COMPUTED PRESSURE	ERROR %FSR
14.67	529978.0	1.7	14.68	0.00
179.91	592384.0	1.7	179.91	0.00
359.92	660298.0	1.7	359.91	-0.00
539.94	728144.0	1.7	539.93	-0.00
719.96	795913.0	1.7	719.95	-0.00
874.95	854200.0	1.7	874.94	-0.00
719.97	795938.0	1.7	720.01	0.00
539.98	728169.0	1.7	540.00	0.00
359.97	660319.0	1.7	359.96	-0.00
179.95	592398.0	1.7	179.95	-0.00
14.66	529962.0	1.7	14.65	-0.00

THERMAL CORRECTION

TEMP ITS90	THERMISTOR OUTPUT	INST OUTPUT
32.50	1.86	530025.68
29.00	1.79	530030.60
24.00	1.70	530052.70
18.50	1.59	530089.23
15.00	1.52	530121.85
4.50	1.32	530258.37
1.00	1.25	530289.04

TEMP(ITS90)	SPAN(mV)
-5.00	25.49
35.00	25.55

y = thermistor output; $t = PTEMPA0 + PTEMPA1 * y + PTEMPA2 * y^2$

$x = \text{pressure output} - PTCA0 - PTCA1 * t - PTCA2 * t^2$

$n = x * PTCB0 / (PTCB0 + PTCB1 * t + PTCB2 * t^2)$

$\text{pressure (psia)} = PA0 + PA1 * n + PA2 * n^2$