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Data Acquisition & Processing Report

Type of Survey Navigable Area

Project Number OPR-K379-KR-15

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LOCALITY

State Louisiana

General Locality Lousiana Coast, LA

2016

CHIEFS OF PARTY
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A. EQUIPMENT

A.1. MAJOR OPERATIONAL SYSTEMS

The major operational systems used to acquire hydrographic data were Kongsberg EM 2040C and EM3002 multibeam echo sounders (MBES) and Klein 5000 V2 and Edgetech 4200 side scan sonars (SSS). Lists of the survey equipment are shown in Tables 1, 2 and 3 for each vessel used in operations.

Table 1. Survey equipment aboard the R/V *Sea Scout*

System	Manufacturer	Model	Serial Number
Multibeam Echo Sounder (Port)	Kongsberg	EM2040C	Transducer: 0131 Topside: 20017
Multibeam Echo Sounder (Starboard)	Kongsberg	EM2040C	Transducer: 0133 Topside: 20017
Side Scan Sonar (Primary)	Klein	5000 V2	Side Scan: 376 Topside: 792
Side Scan Sonar (Back –up)	Klein	5000 V2	Side Scan: 410 Topside: 790
Single Beam Echo Sounder (Port)	Odom	Echotrac MK III	Transducer: TR7212 Topside:21646
Single Beam Echo Sounder (Starboard)	Odom	Echotrac MK III	Transducer: TR7211 Topside: 21646
Attitude and Positioning System	CodaOctopus	F180	F0907069
Positioning System	CNAV	3050	CNAV Receiver: 13769
Positioning System	CNAV	3050	CNAV Receiver: 15006
Sound Speed at Transducer	YSI Electronics	600R-BCR-C-T	99B0559, 04M1615
Sound Speed at Transducer	AML	SV•Xchange Calibrated Sensor	204374
CTD	Sea-Bird Electronics, Inc	SBE 19	2791,1174, 2645
CTD	Sea-Bird Electronics, Inc	SBE 19 Plus	5221, 5222, 7515,7516
SVP	Valeport	RapidSVT	31847
Cable Payout Indicator	Subsea Systems	PI-5600	234, 235

Table 2. Survey equipment aboard the R/V *C-Wolf*

System	Manufacturer	Model	Serial Number
Multibeam Echo Sounder (Port)	Kongsberg	EM3002	Transducer: 561 Topside: 1076
Side Scan Sonar (Primary)	EdgeTech 4200	300/600 kHz Portable	Side Scan: 38186 Topside: 38162
Single Beam Echo Sounder	Odom	CV100	Transducer: Topside: 10617
Attitude and Positioning System	CodaOctopus	F180	F0104012
Positioning System	CNAV	3050	CNAV Receiver: 22179
Positioning System	CNAV	3050	CNAV Receiver: 23107
Sound Speed at Transducer	YSI Electronics	600R-BCR-C-T	13H101931
CTD	Sea-Bird Electronics, Inc	SBE 19 Plus	5221, 5221

Table 3. Survey equipment aboard the R/V *C-Ghost.*

System	Manufacturer	Model	Serial Number
Multibeam Echo Sounder (Port)	Kongsberg	EM3002	Transducer: 605 Topside: 1010
Side Scan Sonar (Primary)	EdgeTech 4200	300/600kHz Portable	Side Scan: 38213 Topside: 38216
Single Beam Echo Sounder	Odom	Hydrotrac	Transducer: Topside: 20634
Attitude and Positioning System	CodaOctopus	F180	F0907076
Positioning System	CNAV	3050	CNAV Receiver: 22960
Positioning System	CNAV	3050	CNAV Receiver: 14323
Sound Speed at Transducer	YSI Electronics	600R-BCR-C-T	13L100270
CTD	Sea-Bird Electronics, Inc	SBE 19 Plus	5221, 5222

A.2. SURVEY VESSELS

Several vessels were used to conduct survey operations. The R/V *Sea Scout* is a 134 foot (40.842 meter) catamaran survey vessel based out of New Iberia, Louisiana, owned and operated by C & C Technologies. Vessel profile and vessel specification information is shown in Table 4. The R/V *C-Wolf* and R/V *C-Ghost* are two 30 foot (9.144 meter) aluminum vessels owned and operated by C & C Technologies. Vessel profile and vessel specification information is shown in Tables 5 and 6. Vessel diagrams with all measured offsets from the central reference point (CRP) of each vessel are shown in Appendix 1: Vessel Reports – Vessel Offset Reports.

Table 4. R/V *Sea Scout* Vessel Profile and Specifications

Owner/Operator	C & C Technologies, Inc.
Home Port / Flag	New Iberia, Louisiana / USA
United States Coast Guard Official Number	1237094
Year Built	2011
Place Built	Bellingham, Washington
Builder	All American Marine
Intended Service	Oceanographic Research
Operational Area	Gulf of Mexico
Length	134 Feet
Beam	37’ 4”
Draft	6’ 6”
Freeboard	7’ 7.5”

Table 5. R/V *C-Wolf* Vessel Profile and Specifications

Owner/Operator	C & C Technologies, Inc.
Home Port / Flag	Lafayette, Louisiana / USA
Hull ID	JQN00027J708
LA Registration Number	LA-2935-FS
Year Built	2008
Builder	Razerhead Boats Inc.
Intended Service	Oceanographic Research Vessel
Operational Area	Shallow Water, USA
Length	30’
Beam	8.5’
Draft	2.5’

Freeboard	2.5’

Table 6. R/V *C-Ghost* Vessel Profile Specifications

Owner/Operator	C & C Technologies, Inc.
Home Port / Flag	Lafayette, Louisiana / USA
Hull ID	JQN00023E707
LA Registration Number	LA-4402-FR
Year Built	2007
Builder	Razerhead Boats Inc.
Intended Service	Oceanographic Research Vessel
Operational Area	Shallow Water, USA
Length	30’
Beam	8.5’
Draft	2.5’
Freeboard	2.5’

A.3. MULTIBEAM ECHOSOUNDER OPERATIONS

One hundred percent (100%) side scan sonar coverage with concurrent set line spacing MBES coverage was acquired, as outlined in the Project Instructions. Multibeam crossline data was acquired along transects perpendicular to the main scheme lines. Crossline mileage consisted of at least 4% of the main scheme mileage, in accordance with Section 5.2.4.3 of the HSSD (2015). Refer to section B.1.3.1 for details on crossline comparisons. Operations specific to each vessel are outlined in the following sections.

A.3.1. R/V *Sea Scout*

The R/V *Sea Scout* is equipped with a Kongsberg EM2040C multibeam system with two transducers. The Transducers are not mounted with any intended angular offsets. Each transducer is mounted on a retractable ram in either hull of the vessel. The rams operate such that the transducers can be lowered and raised as needed for survey operations and transit.

Multibeam survey operations aboard the R/V *Sea Scout* were conducted using one of the two transducers; the transducer in use is detailed in the project logs. The port transducer (serial number 0131) was operated at a frequency of 310 kHz. The starboard transducer (serial number 0133) was operated at a frequency of 300 kHz. The multibeam sonars were operated in normal detection mode and equidistant beam spacing.

Pertinent operational specifications of the EM2040C multibeam system are shown in Table 7. These specifications were obtained from the EM2040C product specification documentation.

Table 7. EM2040C Operational Specifications

Frequencies	200-400 kHz in steps of 10 kHz
No. of soundings per ping Single Head, Single Swath	400
No. of soundings per ping Single Head, Dual Swath	800
No. of soundings per ping Dual Head, Dual Swath	1600
Maximum Ping Rate	50 Hz
Maximum Angular Coverage Single Sonar Head	130 degrees
Maximum Angular Coverage Dual Sonar Heads	200 degrees
Pitch and Roll stabilization	Yes
Heave compensation	Yes

Pulse Length	25 µs to 12 µs

A.3.2. R/V *C-Wolf* and R/V *C-Ghost*

Multibeam survey operations aboard the R/V *C-Wolf* and R/V *C-Ghost* were conducted with single transducer Kongsberg EM3002 multibeam echo sounders. The transducers on each vessel are mounted on rams that extend through a moon pool in the center of the vessel. The rams can be raised and lowered as needed for transit and survey operations.

The transducer on the R/V *C-Wolf* (serial number 561) was operated at a frequency of 300 kHz and the angular coverage of the sonar was typically set at 64 degrees from nadir. The multibeam sonar was operated in high-density equidistant beam spacing mode. The high density mode increased the number of soundings to 254 per ping.

The transducer on the R/V *C-Ghost* (serial number 605) was operated at a frequency of 300 kHz and the angular coverage of the sonar was typically set at 60 degrees from nadir. The multibeam sonar was operated in high-density equidistant beam spacing mode. The high density mode increased the number of soundings to 254 per ping.

Pertinent operational specifications of the EM3002 multibeam system are shown in Table 8. These specifications were obtained from the EM3002 product specification documentation.

Table 8. EM3002 Operational Specifications

Frequencies	292, 300, 307 kHz
Number of soundings per ping Single Sonar Head	Max 254
Maximum Ping Rate	40 Hz
Maximum Angular Coverage Single Sonar Head	65 degrees
Pitch and Roll stabilization	Yes
Heave compensation	Yes
Pulse Length	150 µs

A.4. SIDE SCAN SONAR OPERATIONS

Aboard the R/V *Sea Scout*, 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. On the R/V *C-Wolf* and R/V *C-Ghost*, a hanging sheave mounted to a fixed A-frame at the stern of the vessel was used as the tow point for the side scan sonar.

Line spacing was set to 80 meters for the entire survey. Split lines were also run when the effective range of the side scan sonar was reduced, mainly due to environmental conditions. 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.

Refer to the following sections, section C.2: Vessel Offset Measurements and Configuration and Appendix I: Vessel Reports – Vessel Layback Report for additional side scan sonar offset, layback information and vessel-specific operations.

A.4.1. R/V *Sea Scout*

A Klein 5000 V2 side scan sonar was operated in a towed configuration and a hanging sheave mounted to a retractable A-frame at the stern of the vessel was used as the tow point. 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 acquisition logs and also digitally in the side scan XTF files, and later used for layback calculations. In general, the survey speed of the towed side scan sonar would be limited by the range scale. However, according to the Klein 5000 V2 product specifications, the sonar fish can be towed at higher speeds with no loss of bottom coverage. The survey speed did not reach the limits as stated in the product specifications (Table 9), and survey operations were generally conducted at speeds between 4 and 8.5 knots. The side scan sonar data was continuously monitored during acquisition to ensure quality and coverage.

Table 9. Klein 5000 V2 Product Specifications

Number of Beams	5 port and 5 starboard
Frequency	455 kHz
Resolution (along track)	10 cm at 50 m, 20 cm at 75 m, 36 cm at 150 m
Resolution (across track)	3.75 cm at all pulse lengths
Operating Speed Envelope	2 to 10 knots at 150 m, 200 m and 250 m reconnaissance mode

A.4.2. R/V *C-Wolf* and R/V *C-Ghost*

Edgetech 4200 side scan sonars were operated in a towed configuration aboard each vessel. A hanging sheave mounted to a fixed A-frame at the stern of the vessel was used as the tow point. The cable out values were recorded in the acquisition logs and later used for layback calculations. In general, the survey speed of the towed side scan sonar would be limited by the range scale. However, according to the Edgetech 4200 product specifications, the sonar fish can be towed at higher speeds with no loss of bottom coverage when operating in the High Speed Mode. The survey speed did not reach the limits as stated in the product specifications (Table 10) and survey operations were conducted at speeds between 4 and 8.5 knots. The side scan sonar data was continuously monitored during acquisition to ensure quality and coverage.

Table 10. Edgetech 4200 Product Specifications

Frequency	300/600 kHz
Resolution (along track)	600 kHz: 0.6m @ 100m
Resolution (across track)	1.5 cm at 600 kHz
Operating Speed Envelope	4 to 12kts @ 150m

A.5. ADDITIONAL SURVEY OPERATIONS

A.5.1. Singlebeam Operations

An Odom Echotrac MK III was used to collect single beam data aboard the R/V *Sea Scout*; an Odom CV100 used aboard the R/V *C-Ghost;* and a Hydrotrac was used aboard the R/V *C-Wolf*. 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, SBE19 Plus CTDs and Valeport underway SVP's were used to calculate the speed of sound through the water column. Casts were performed at least twice daily aboard the R/V *Sea Scout* and more often as needed. In general, two CTDs were simultaneously lowered within a cage structure during each cast. Endeco YSI 600R sondes and an AML SV•Xchange were used to calculate the sound speed at the transducer. Casts were performed at least once daily aboard the R/V *C-Wolf* and R/V *C-Ghost* and more often as needed. Endeco YSI 600R sondes were used to calculate the sound speed at the transducer.

A.5.3. **Bottom Samples**

Bottom samples were acquired with a Wildco® Standard Ponar® grab sampler deployed from a winch aboard the R/V *Sea Scout*; no grab sample operations were conducted from the R/V *C-Wolf* or R/V *C-Ghost*. The samples were described and photographed in the field; the bottom samples are fully attributed in the S-57 Final Feature File.

A.5.4. **Backscatter**

Backscatter was acquired and logged within each raw MB file. EM2040C .all files were recorded aboard the R/V *Sea Scout*, EM3002 .all files were recorded aboard the R/V *C-Wolf* and R/V *C-Ghost.* The backscatter from the .all files was imported during CARIS conversion and reviewed when necessary. The data was also imported into FMGT for verification and review.

A.6. **ACQUISITION AND PROCESSING SOFTWARE**

A list of data acquisition and processing software systems is shown in Tables 11, 12 and 13. All systems on the network are synced using 1PPS strings from GPS. Processing software updates are shown in Table 14.

Table 11. Data Acquisition and Processing Software – R/V *Sea Scout*

Purpose	Software	Version	Date of Installation
Multibeam Data Recording and Monitoring	Hydromap	n/a	11-20-2013
Multibeam Control Software	Seafloor Information System (SIS)	4.1.5	05-05-2015
Side Scan Collection	SonarWiz5	V.5.06.0039	07-01-2014
Side Scan Processing	SonarWiz5	V.5.06.0039	07-01-2014
Side Scan Processing	SonarWiz5	V.5.06.0039	02-19-2016
Multibeam Processing	CARIS HIPS/SIPS	9.0	07-10-2015
CTD Conversion Tool	Seabird Electronics Sea Term	1.5.9	07-01-2014
CTD Conversion Tool	Seabird Electronics Data Conversion	7.22.2	07-01-2014
CTD Conversion Tool	SVTool	1.2	07-01-2014
IMU control software	F180 Series	3.04.0004	07-01-2014

Table 12. Data Acquisition and Processing Software – R/V *C-Wolf*

Purpose	Software	Version	Date of Installation
Multibeam Data Recording and Monitoring	Hydromap	n/a	08-27-2014
Multibeam Control Software	Seafloor Information System (SIS)	3.4.3	04-24-2014
Side Scan Collection	SonarWiz5	V.5.06.0039	05-25-2014
Side Scan Processing	SonarWiz5	V.5.08.0012	07-10-2015
Multibeam Processing	CARIS HIPS/SIPS	9.0	07-10-2015
CTD Conversion Tool	Seabird Electronics Sea Term	1.59	04-25-2014
CTD Conversion Tool	Seabird Electronics Data Conversion	7.23.1	04-25-2014
CTD Conversion Tool	SVTool	1.2	04-25-2014
IMU control software	F180 Series	3.04.0004	04-25-2014

Table 13. Data Acquisition and Processing Software - R/V *C-Ghost*

Purpose	Software	Version	Date of Installation
Multibeam Data Recording and Monitoring	Hydromap	n/a	05-25-2014
Multibeam Control Software	Seafloor Information System (SIS)	3.4.3	05-25-2014
Side Scan Collection	SonarWiz5	V.5.08.0012	09-05-2015
Side Scan Processing	SonarWiz5	V.5.08.0012	07-10-2015
Multibeam Processing	CARIS HIPS/SIPS	9.0	07-10-2015
CTD Conversion Tool	Seabird Electronics Sea Term	1.59	05-25-2014
CTD Conversion Tool	Seabird Electronics Data Conversion	7.23.1	05-25-2014
CTD Conversion Tool	SVTool	1.2	05-25-2014
IMU control software	F180 Series	3.04.004	05-25-2014

Table 14. Data Processing Software Updates

Purpose	Software	Version	Date of Installation
Side Scan Processing (Office)	SonarWiz5	V.5.08.0012	07/10/2015
Multibeam Processing (Office)	CARIS HIPS/SIPS	9.0.16	07/10/2015
Multibeam Processing (Office)	CARIS HIPS/SIPS	9.0.17	09/22/2015
Multibeam Processing (Office)	CARIS HIPS/SIPS	9.0.19	09/28/2015
Multibeam Processing (Office)	CARIS HIPS/SIPS	9.0.22	03/02/2016

A.6.1. **Multibeam Acquisition Software**

Kongsberg’s Seafloor Information System (SIS) software was used as the control software for the multibeam sonars. This software allowed sound speed, attitude, and position to be applied to the data in real time. Data was directed 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 was collected. In cases where re-runs were necessary due to degraded quality of data during acquisition or due to lack of coverage, the aforementioned difficulties were logged in the field. Additional data was collected for quality assurance. Hydromap software was used to monitor the survey line plan and also allow the boat operator(s) to maintain on-line control for all vessels in the field.

A.6.2. **Processing Software**

Multibeam data processing for the Kongsberg EM .all files was conducted using CARIS HIPS and SIPS 9.0. CARIS 9.0 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 in 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.

Side scan sonar (SSS) data was collected in XTF format aboard the R/V *Sea Scout*, R/V *C-Wolf* and R/V *C-Ghost* using Chesapeake Technologies' SonarWiz software. Sonarwiz software was used to process and evaluate all SSS data. 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-K379-KR-15 was processed using CARIS HIPS and SIPS 9.0. 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 multibeam data into CARIS, a HIPS vessel file (.hvf) was created. This vessel file includes uncertainty estimate values for all major equipment integral to data collection. Uncertainty estimates assigned are further described in the following sections. The vessel files used for this project are included in the Data\Processed\HDCS\VesselConfig folder for each sheet.

CARIS HIPS was used to apply tides, merge, compute TPU, apply SVC if necessary, and create surfaces. CARIS HIPS was also used for: multibeam data cleaning, quality control, crossline comparison, chart comparisons and side scan sonar contact correlation.

B.1.1. **CARIS Vessel Files**

B.1.1.1. R/V *Sea Scout*

The vessel files used for the R/V *Sea Scout* are named according to the transducer used (SeaScout_Starboard_Head, SeaScout_Port_Head, SeaScout_Dual). The vessel file contains the following active sensors: Transducer 1, Transducer2, Navigation, Gyro, Heave, Pitch, Roll, Draft, and TPU.

Transducer 1/Transducer 2: The X/Y/Z fields (the location of the transducer from the reference point) are zero (0) because the location of the transducer is 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) because the data is corrected for these during data acquisition using the SIS control software.

Navigation: 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.

Gyro: No Gyro fields are edited because no offset was applied and the F180 IMU is aligned to the ship's coordinate reference frame.

Heave/Pitch/Roll: 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 in real-time 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 15. All values were applied to the data in CARIS during post-processing. Negative values indicate that the vessel is lower in the water. Because the z-direction is positive down in the reference frame used for CARIS, the signs are opposite in the vessel file. Refer to Section C.3: Static and Dynamic Draft Corrections for additional information.

Table 15. Vertical displacement of R/V *Sea Scout* with speed

Vertical Correction (m)	Speed (m/s)
0.00	0.00
-0.01	1.70
-0.01	2.13
-0.03	3.07
-0.06	3.95
-0.10	4.82

TPU Offsets: The offsets (Tables 16 and 17) were calculated from known locations of the equipment from the CRP (refer to Appendix 1: Vessel Reports – Vessel Offsets Report for additional information).

Table 16. R/V *Sea Scout* MRU to Transducer offsets

Transducer	MRU to Trans X (m)	MRU to Trans Y (m)	MRU to Trans Z (m)
Transducer 1	-2.897	-1.527	7.192
Transducer 2	3.537	-1.523	7.220

Table 17. R/V *Sea Scout* NAV to Transducer offsets

Transducer	NAV to Trans X (m)	NAV to Trans Y (m)	NAV to Trans Z (m)
Transducer 1	-3.041	3.861	12.574
Transducer 2	3.393	3.865	12.602

According to CARIS correspondence, the Transducer Roll is the mounting angle of the Receive Array + Roll Calibration. The transducers aboard the R/V *Sea Scout* are mounted flat; therefore, the Transducer Roll (deg) is equal to the offset angle entered in the SIS control software (Table 18).

Table 18. Values entered in the Transducer Roll fields of the TPU Offsets section for the R/V *Sea Scout*.

Date	Transducer 1 Roll (deg)	Transducer 2 Roll (deg)
April 29, 2015	-1.05	-0.90

TPU Standard Deviation:

The values entered for the Standard Deviation are shown in Tables 19 and 20. Explanation and reasoning are further explained in the following text.

Table 19. Values entered for the TPU Standard Deviation section of the HVF for the R/V *Sea Scout.*

Field	Value
Motion Gyro:	0.05°
Heave % Amplitude:	5%
Heave (m):	0.05 m
Roll:	0.025°
Pitch:	0.025°
Position Nav:	0.08 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:	0.0017 m
Offset Y:	0.0037 m
Offset Z:	0.0009 m
Vessel Speed:	0.73 m/s
Delta Draft:	0.02 m
MRU Align StdDev Gyro:	0.108°
MRU Align StdDev Roll/Pitch:	0.06°

Table 20. Values entered for the Loading and Draft within the TPU Standard Deviation section of each Vessel File for the R/V *Sea Scout.*

	Port	Starboard	Dual
Loading:	0.025 m	0.008 m	0.020 m
Draft:	0.020 m	0.030 m	0.031 m

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 0.08 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 2014 NOAA Field Procedures Manual.

The survey of the vessel was carried out with a Leica TPS 1200+ total station. This instrument has a 1” (1-second) angular accuracy and a range accuracy of 1mm + 1.5ppm. The errors of the measured vessel offsets were estimated by comparing the relative geometry of the offsets measured during nine (9) independent total station setups (Table 21).

Table 21. Errors of measured R/V *Sea Scout* offsets.

No of reference points	47
Smallest misclosure	0 mm
Largest misclosure	9 mm
Standard deviation (X-offsets)	1.7 mm
Standard deviation (Y-offsets)	3.7 mm
Standard deviation (Z-offsets)	0.9 mm

Vessel Speed: According to the Chapter 4 Appendix – CARIS HVF Uncertainty Values of the 2014 NOAA Field Procedures Manual, this value is 0.03 plus the average current in the area; a value of 1.36 knots (0.7 m/s) was used for the average current (Johnson, 2008).

Loading: Historically, the loading uncertainty has been calculated as the difference between the maximum and minimum draft measured for the duration of the survey. Correspondence with CARIS (refer to Project_Reports\Project_Correspondence) indicates that this is high if the draft is measured every day and an updated method was established. First, the difference between the minimum and maximum draft measured during a day was calculated. CARIS correspondence indicated that this value could be halved, but was not in order to provide a more conservative estimate. The differences for all the days were then averaged together for an estimate of the loading uncertainty.

Draft: The standard deviation of the draft measurements taken for the duration of survey operations. This includes the port and starboard heads, as well as a combined value representing a dual head configuration.

Delta Draft: The dynamic draft data consists of 6 sets of lines run at varying speeds and the squat of the vessel at each speed. The standard deviation for each set of squat values for a specified speed setting was calculated and then averaged together for a final value.

According to the 2014 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. Several processors resolved the patch test several times in CARIS to calculate the standard deviations. Refer to Appendix 2: Patch Tests for additional information.

B.1.1.2. R/V *C-Wolf*

The R/V *C-Wolf* vessel file contains the following active sensors: Transducer 1, Navigation, Gyro, Heave, Pitch, Roll, Draft and TPU. Note that the SVP section may still show up in the vessel file as it was unable to be removed although no lines were sound velocity corrected.

Transducer 1: The X/Y/Z fields (the location of the transducer from the reference point) are zero (0) for Transducer 1 because the location of the transducer is 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) because the data is corrected for these during data acquisition using the SIS control software.

Navigation: 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.

Gyro: No Gyro fields are edited because no offset was applied and the F180 IMU is aligned to the ship's coordinate reference frame.

Heave/Pitch/Roll: 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 in real-time 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 22. All values were applied to the data in CARIS during post-processing. Negative values indicate that the vessel is lower in the water. Because the z-direction is positive down in the reference frame used for CARIS, the signs are opposite in the vessel file. Refer to Section C.3: Static and Dynamic Draft Corrections for additional information.

Table 22. Vertical displacement of the R/V *C-Wolf* with speed.

Vertical Correction (m)	Speed (m/s)
0.00	0
-0.0061	1.543
-0.0135	2.418
-0.0258	3.086
-0.0501	3.961

TPU Offsets: The offsets (Tables 23 and 24) were calculated from known locations of the equipment from CRP (refer to Appendix 1: Vessel Reports – Vessel Offsets Report for additional information).

Table 23. MRU to EM3002 Transducer offsets for the R/V *C-Wolf*.

MRU to Trans X (m)	MRU to Trans Y (m)	MRU to Trans Z (m)
0.000	-4.275	0.640

Table 24. NAV to EM3002 Transducer offsets for the R/V *C-Wolf*

NAV to Trans X (m)	NAV to Trans Y (m)	NAV to Trans Z (m)
0.435	-1.158	3.110

According to CARIS correspondence, the Transducer Roll is the mounting angle of the Receive Array + Roll Calibration. The transducer aboard the R/V *C-Wolf* is mounted flat; therefore the value entered in the Transducer Roll is equal to the offset angle entered in the SIS control software (Table 25).

Table 25. Transducer Roll for the R/V *C-Wolf*

Date	Trans Roll (deg)
Sep. 6, 2015	-0.19

TPU Standard Deviation:

The values entered for the Standard Deviation are shown in Table 26. Explanation and reasoning are further detailed in the following text.

Table 26. Values entered for the TPU Standard Deviation section of the HVF for the R/V *C-Wolf*.

Field	Value
Motion Gyro:	0.1°
Heave % Amplitude:	5%
Heave (m):	0.05 m
Roll:	0.025°
Pitch:	0.025°
Position Nav:	0.08 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:	0.02 m
Offset Y:	0.02 m
Offset Z:	0.02 m
Vessel Speed:	0.73 m/s
Loading:	0.080 m
Draft:	0.025 m
Delta Draft:	0.007 m
MRU Align StdDev Gyro:	0.04°
MRU Align StdDev Roll/Pitch:	0.05°

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 0.08 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 2014 NOAA Field Procedures Manual.

The X/Y/Z Offset values: The survey of the equipment offsets on the R/V *C-Wolf* was carried out using a total station. Typical accuracies are between 2 and 3 cm.

Vessel Speed: According to the Chapter 4 Appendix – CARIS HVF Uncertainty Values of the 2014 NOAA Field Procedures Manual, this value is 0.03 plus the average current in the area; a value of 1.36 knots (0.7 m/s) was used for the average current (Johnson, 2008).

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

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

Delta Draft: The dynamic draft data consists of 6 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 2014 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. Several processors resolved the patch test several times in CARIS to calculate the standard deviations. Refer to Appendix 2: Patch Tests for additional information.

B.1.1.3. R/V *C-Ghost*

The R/V *C-Ghost* vessel file contains the following active sensors: Transducer 1, Navigation, Gyro, Heave, Pitch, Roll, Draft, TPU. Note that the SVP section may still show up in the vessel file as it was not able to be removed although no lines were sound velocity corrected.

<u>Transducer 1</u>: The X/Y/Z fields (the location of the transducer from the reference point) are zero (0) for Transducer 1 because the location of the transducer is 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) 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 Gyro fields are edited because no offset was applied and the F180 IMU is aligned to the ship's 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). The 'Apply' switches are set to 'No' because the dynamic values are applied during data acquisition.

<u>Draft</u>: 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 27. All values were applied to the data in CARIS during post-processing. Negative values indicate that the

vessel is lower in the water. Because the z-direction is positive down in the reference frame used for CARIS, the signs are opposite in the vessel file. Refer to Section C.3: Static and Dynamic Draft Corrections for additional information.

Table 27. Vertical displacement of the R/V *C-Ghost* with speed.

Vertical Correction (m)	Speed (m/s)
0.00	0.00
-0.01	1.54
-0.02	2.06
-0.03	2.83
-0.05	3.34
-0.08	4.12
-0.08	5.14

TPU Offsets: The offsets (Tables 28 and 29) were calculated from known locations of the equipment from CRP (refer to Appendix 1: Vessel Reports – Vessel Offsets Report for additional information).

Table 28. MRU to EM3002 Transducer offsets for the R/V *C-Ghost*.

MRU to Trans X (m)	MRU to Trans Y (m)	MRU to Trans Z (m)
-0.016	-4.714	0.945

Table 29. NAV to EM3002 Transducer offsets for the R/V *C-Ghost*.

NAV to Trans X (m)	NAV to Trans Y (m)	NAV to Trans Z (m)
0.361	-1.350	3.128

According to CARIS correspondence, the Transducer Roll is the mounting angle of the Receive Array + Roll Calibration. The transducer aboard the R/V *C-Ghost* is mounted flat; therefore the value entered in the Transducer Roll is equal to the offset angle entered in the SIS control software (Table 30).

Table 30. Values entered in the Transducer Roll field of the TPU Offsets section for the R/V *C-Ghost*.

Date	Trans Roll (deg)
Sep. 3, 2015	0.08

TPU Standard Deviation:

The values entered for the Standard Deviation are shown in Table 31. Explanation and reasoning are further detailed in the following text.

Table 31. Values entered for the TPU Standard Deviation section of the HVF for the R/V *C-Ghost*.

Field	Value
Motion Gyro:	0.1°
Heave % Amplitude:	5%
Heave (m):	0.05 m
Roll:	0.025°
Pitch:	0.025°
Position Nav:	0.08 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:	0.02 m
Offset Y:	0.02 m
Offset Z:	0.02 m
Vessel Speed:	0.73 m/s
Loading:	0.035 m
Draft:	0.007 m
Delta Draft:	0.011 m
MRU Align StdDev Gyro:	0.04°
MRU Align StdDev Roll/Pitch:	0.07°

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 0.08 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 2014 NOAA Field Procedures Manual.

The X/Y/Z Offset values: The survey of the equipment offsets on the R/V *C-Ghost* was carried out using a total station. Typical accuracies are between 2 and 3 cm.

Vessel Speed: According to the Chapter 4 Appendix – CARIS HVF Uncertainty Values of the 2014 NOAA Field Procedures Manual, this value is 0.03 plus the average current in the area; a value of 1.36 knots (0.7 m/s) was used for the average current (Johnson, 2008).

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

Draft: The standard deviation of 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 2014 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. Several processors resolved the patch test several times in CARIS to calculate the standard deviations. Refer to Appendix 2: Patch Tests for additional information.

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.

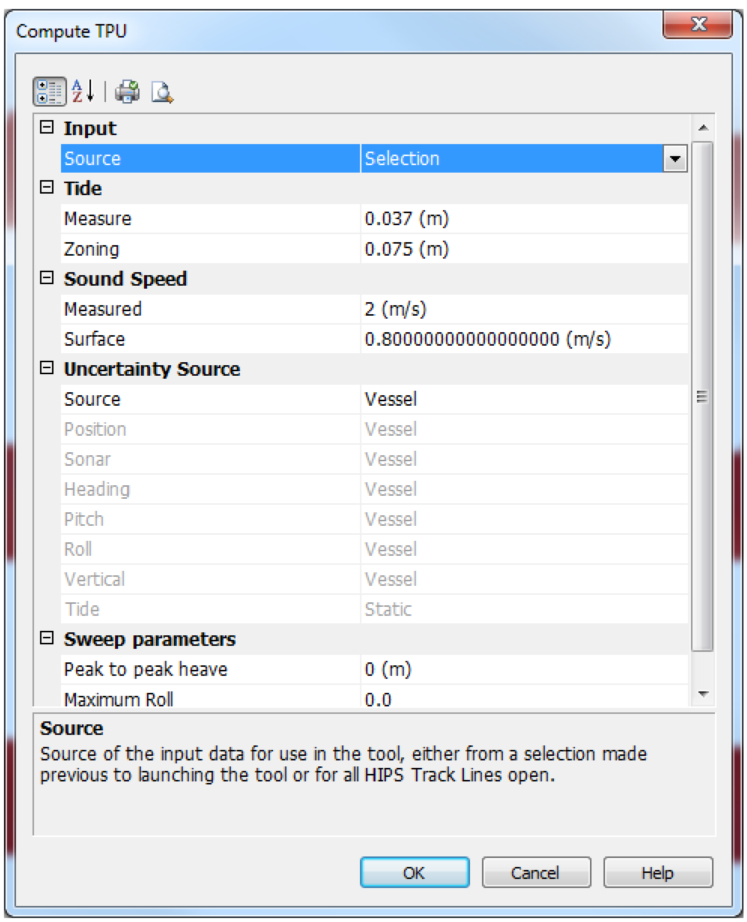

Figure 1. Total Propagated Uncertainty (TPU) values.

B.1.2.1. Tide Component

According to section 1.3.3 of the Tides and Water Levels Statement of Work for this project, the estimated tidal error contribution to the survey area is 0.22 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 (2015) the typical measurement error is 0.10 m at the 95% confidence level and the tidal zoning error is 0.2 m at the 95% confidence level. This indicates that the typical tidal zoning error is twice that of the typical measurement error. Although the provided estimate of 0.22 m is less than the tidal and measurement errors suggested in the HSSD (2015), the estimate was divided into a zoning component and a measurement component, keeping the proportions as close to that of the values of the HSSD (2015) as possible. A value of 0.147 m of the 0.22 m was attributed to the zoning error and 0.073 m was attributed to the measurement error. All error values entered in CARIS for the TPU calculation are assumed to be at the 1 sigma level, according to the Field Procedures Manual Section 4.2.3.8 and both the zoning and measurement errors were further divided by 1.96. Therefore, a final value of 0.075 m was entered as the zoning tide value and 0.037 m was entered as the measurement error. The estimated tidal error contribution provided by CO-OPs includes the datum error, which is typically 0.11 m for the Gulf coast at the 95% confidence level, according to section 4.1.6 of the HSSD (2015). No datum error was subtracted out of the provided estimated tidal error to provide more conservative values for the measurement and zoning errors.

B.1.2.2. Sound Speed Component

The measured sound speed 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. 32 and the known amount by which a certain change in salinity and temperature affect sound speed are shown in Table No. 33.

Table 32. 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 33. 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 32) 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. 32) and the amount that this value would change the sound speed is:

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

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 (2015), 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 (2015) 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 34.

Table 34. Maximum IHO Order 1 TVU values for water depths of 1 – 25 m in increments of 5 m.

a	b	d (Water Depth (m))	Maximum (TVU)
0.5	0.013	1	0.500
		5	0.504
		10	0.517
		15	0.538
		20	0.568
		25	0.606

The TPU was evaluated to ensure that the values are within the specifications above. In accordance with section 5.1.2 of the HSSD (2015), all depths reported in the deliverables are accompanied by the estimate of TPU.

B.1.3. **Multibeam Processing**

Upon commencement of 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 8764227 (LAWMA, LA) water level station was downloaded from the CO-OPS website: http://opendap.co-ops.nos.noaa.gov/axis//text.html or the NOAA Tides and Currents website. This tide data was applied to all MB data in CARIS using the tidal zoning file supplied by CO-OPS. Refer to Section C.8 for detailed tide correction information. The lines were merged, TPU was computed and a surface created. Data collected aboard the R/V *C-Wolf* and R/V *C-Ghost* were integrated with an existing project, if applicable, as soon as possible post-data collection.

CARIS HIPS swath editor was used to review the multibeam data with the surface and pertinent background data open. Background data included the chart(s) and the line files, as well as the PRF and CSF provided by NOAA. The preferred multibeam review method involves the ability to simultaneously review the side scan sonar data. When this was not possible, potential contacts were designated and noted in the multibeam processing log for future review with 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 surfaces of the main scheme lines and completed investigations to ensure complete coverage over all significant targets. The investigation data were reviewed with respect to main scheme multibeam lines, charted data, and 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 surface, the surface underwent additional quality control. The standard deviation layer of the surface was evaluated and areas of high standard deviation were investigated by all means appropriate, including: subset editor and swath editor, as well as comparison to charts, side scan sonar, backscatter data and side scan sonar contacts imported from SonarWiz. If data were found to misrepresent the seafloor, it was rejected. In addition, the surface was evaluated using the

CARIS 3D window with increased vertical exaggeration that highlights outliers as well as potential contacts. All examined soundings on the surface were reviewed and were either changed to designated or retained as examined using the criteria 5.2.1.2 Feature Detection and Designated Soundings.

The HydroOffice SARScan utility, downloaded curtesy of NOAA and UNH CCOM/JHC, was used as additional quality control check to search the surfaces for fliers. The surface was exported to ASCII format and the 'flier finder' utility used to check for fliers at 1 m and 0.5 m.

Surfaces were named as follows: <Survey registry number>_<Sounding Type>_<units of resolution>_<Vertical Datum>, as specified in section 8.4.2 of the HSSD (2015). All surfaces were created as uncertainty surfaces based upon IHO Order 1a standards. The surfaces were created as uncertainty surfaces with a single resolution of 1.0 m.

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

Crosslines were run perpendicular to the main scheme survey lines. Crossline mileage consisted of at least 4% of the main scheme mileage, in accordance with Section 5.2.4.3 of the HSSD (2015). Crossline comparisons were performed as a quality control tool to identify systematic errors and blunders in the survey data.

B.1.3.1.1 Hydromap Statistical Comparisons

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 are used for analysis. Processing parameters are set to use all beams with no filtering, and tidal effects 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. Select data is provided in graphical form in a separate PDF document for each main line. A selection of these PDF's can be found in Separates II of the reports.

B.1.3.1.2 CARIS Comparisons

Crossline comparisons were performed in CARIS HIPS 9.0 using the surface difference tool. Separate surfaces were generated for the main scheme lines and crosslines and a difference surface between the main scheme and crossline 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 outlined in Section 5.2.4.3 of the HSSD (2015); 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 surface of the main scheme lines (the reference surface). The crossline data were grouped by beam number. 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 standards for a selected IHO Order. Although statistics were generated for all IHO Orders (Special Order, Order 1a, Order 1b and Order 2), 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 surfaces have been retained and submitted in the Surfaces directory.

B.1.3.2. Reporting, Products and Finalization

Junction analysis was performed between adjoining contemporary and historical surveys using the CARIS differencing tool. Difference surfaces were generated with the current surveys as Surface 1 and the adjoining surveys as Surface 2.

Chart comparisons were performed in CARIS HIPS using clean surfaces of main scheme and investigation lines, colored depth ranges, and sounding layers. The data was compared to the most recent, largest scale nautical charts in this area, specified in each Descriptive Report.

A sounding layer was generated from the surface created for each Sheet and compared to charted depths. The shoal biased radius option was always selected and the radius was selected as distance on the ground (in meters). 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.

The surfaces were finalized for submission after all data had been cleaned and all least depths on the contacts either examined or designated. The final 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 surface (Figure 2). Any depth threshold applied is detailed in the Descriptive Reports.

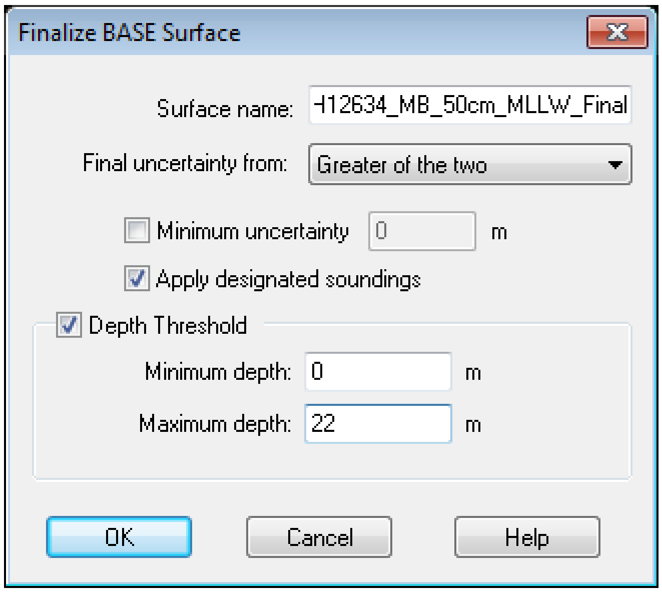

Figure 2. Sample BASE surface finalization parameters.

B.2. SIDE SCAN SONAR

B.2.1. Image Processing

Chesapeake Technologies' SonarWiz5 was used to process side scan sonar data. The water column was auto tracked in the field, if applicable, and the data slant range corrected after the data was imported into SonarWiz5. The bottom track was also reviewed during post-processing and corrected as necessary. The side scan sonar files were layback corrected in SonarWiz and gains applied when necessary. Each side scan sonar file was evaluated and contacts identified. Contacts were always selected from slant-range corrected data. Bottom tracked and layback corrected files were exported from SonarWiz for the final deliverables. The processed SSS investigations were imported into CARIS for verification purposes.

B.2.2. Data Review 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 sonar files were also reviewed at least twice during post processing. Any lines or portions of lines that did not meet quality standards due to noise, thermoclines, biologic interference, 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; gaps were filled when possible.

A mosaic of all the lines was created for the requirement of the final deliverables. In addition, separate side scan sonar mosaics of the original 100% side scan sonar coverage, rerun lines, platform/feature disprovals and investigations were generated for each Sheet. This allowed for the ability to overlay the various mosaics and verify that that noise observed on mainline data did not obscure any contacts. The mosaics can be found in the Data\Processed\Surfaces directory.

B.2.3. **Contact Selection**

Sonar contacts were identified and recorded as each line was reviewed. All contacts with shadows were recorded when possible. In areas where a high density of contacts exists in close proximity, the hydrographer retained the ability to select the area as a region, ensuring that the contact with the greatest height off bottom was selected and/or the least depth examined in the bathymetry. All existing infrastructure, such as pipelines, wells, platforms, and buoys were also documented.

In addition to measuring the dimensions of each contact in SonarWiz, contacts were assigned two attributes to aid in the processing workflow. The first attribute is related to the nature of the contact and one of several descriptors was chosen for each contact. These included, but may not be limited to: insignificant contact (INSCON), significant contact (SIGCON), linear contact not clearly a pipeline (LINEAR), offshore platform (OFSPLF), submerged pipeline (PIPSOL), jetty or groin (JETTY), submerged cable (CBLSUB), fish contact (FSHGRD), seabed area (SBAREA), unknown contacts (UNKCON) and buoys (BUOY). Most of these descriptors fulfill the requirement of updating the NINFOM for the customized attributes of the side scan sonar list as outlined in 8.2 of the HSSD (2015). However, the hydrographer may elect to retain LINEAR, INSCON and SIGCON if unsure of the exact nature of the feature. The second attribute is related to the significance of the contact and might include descriptors such as INSCON, SIGCON, OBSTRN and DTON.

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 (2015). These contacts were always given the attribute 'SIGCON' during processing. Other contacts may have been deemed significant based on their characteristics (dimensions, strength of return, location etc.).

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 label seabed area (SBAREA) was used to include seabed change and features such drag scars. The unknown (UNKCON) label was used only if no shadow could be measured and no other descriptor could be used to identify the feature. The majority of the UNKCON contacts are picked generally because of possible correlation to either a significant or insignificant feature found on an adjacent line based on 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 (csv). Contacts were brought into CARIS 9.0 using the Object Import Utility as points under the LNDMRK class with several attributes assigned.

The S-57 file of contacts was evaluated in the CARIS map window with the surfaces of the main scheme lines and completed investigations to ensure complete coverage over significant targets. All significant contacts not fully developed with multibeam data were further investigated. Danger to Navigation (DtoN) reports were submitted for uncharted significant contacts and structures.

After the multibeam 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 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 S-57 deliverable. This final S-57 file of all the contacts was generated in accordance with section 8.2 of the HSSD (2015).

B.3. **DATA DIRECTORY STRUCTURE**

During data processing separate directories were created for CARIS projects, 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 J of the 2015 HSSD (Figure 3).

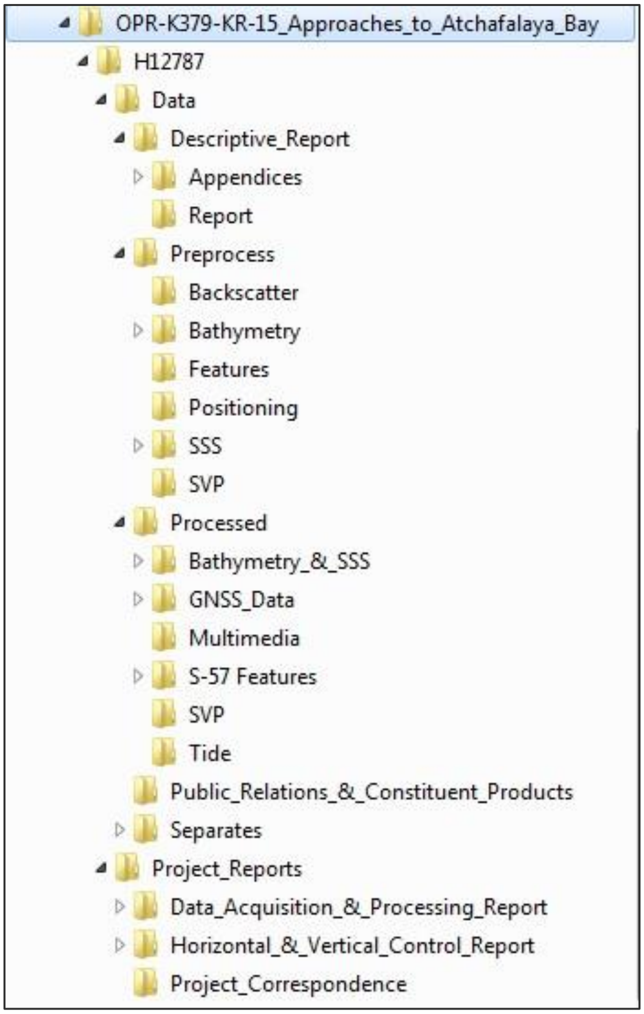

Figure 3. Overview of data directory structure.

Within the Processed\Bathymetry_&_SSS folder, three additional folders were generated: s <Surfaces> folder and an <HDCS Data> folder were added to the directory structure to remain consistent with the CARIS processing directories. An additional <SSS> folder in the was added and populated with fully corrected SSS files exported from SonarWiz. No folders were removed from the directory structure as listed in Appendix J; 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, a single beam sonar was monitored in real-time as an independent check of the nadir beam of the multibeam sonar system aboard the R/V *Sea Scout*, R/V *C-Wolf*, and R/V *C-Ghost*. Leadlines were performed as an independent check of the multibeam sonar systems aboard all vessels.

C.2. VESSEL OFFSET MEASUREMENTS AND CONFIGURATION

C.2.1. Vessel Configuration Parameters and Offsets

C.2.1.1. R/V *Sea Scout*

During construction of the R/V *Sea Scout* a full survey was conducted in dry dock using a Leica TPS 1200+ total station to measure offsets from the Central Reference Point (CRP) to all survey equipment on the vessel. Additional full surveys have been conducted periodically thereafter to verify the offsets. Figure 4 shows a picture of the R/V *Sea Scout* 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 *Sea Scout*.

C.2.1.2. R/V *C-Wolf*

The offsets for the R/V *C-Wolf* were measured with a total station while the vessel was trailered. Figure 5 shows a picture of the R/V *C-Wolf* and a vessel diagram with all measured offsets from the central reference point is shown in Appendix 1: Vessel Reports – Vessel Offset Reports.

Figure 5. R/V *C-Wolf*

C.2.1.3. R/V C-*Ghost*

The offsets for the R/V *C-Ghost* were measured with a total station while the vessel was trailered. Figure 6 shows a picture of the R/V *C-Ghost* and a vessel diagram with all measured offsets from the central reference point is shown in Appendix 1: Vessel Reports – Vessel Offset Reports.

Figure 6. R/V *C-Ghost*

C.2.2. **Layback**

Layback was applied to side scan XTF and HSX files during post-processing using SonarWiz 5 and 6. Refer to Appendix I: Vessel Reports – Vessel Layback Report for additional information.

C.3. STATIC AND DYNAMIC DRAFT

C.3.1. **R/V *Sea Scout***

Static draft measurements were read at least once daily during survey operations. The R/V *Sea Scout* is equipped with two draft tubes, one on the port side and one on the starboard side, near the MB rams. Each draft tube is marked 1.2 meters up from the hull. The distance from CRP to the 1.2 m mark is 5.144 and 5.270 m on the port and starboard sides respectively. Therefore, an addition of 1.2 m to each of these values (6.344 m and 6.470 m for port and starboard, respectively) provides the distance from CRP to the base of the draft tubes (the hull). The draft values observed from the draft tubes are subtracted from the 6.344 m and 6.470 m values to provide a waterline to CRP measurement for the port and starboard sides. These two values were averaged and input into the SIS software system as the waterline to CRP value; if only one head is in use, the one relevant draft measurement is used.

In order to correct for the dynamic draft of the vessel, a squat and settlement test was performed in Calcasieu Pass, LA on June 11th, 2015. Refer to Appendix I: Vessel Reports – Dynamic Draft Report for additional information.

C.3.2. **R/V *C-Wolf***

Static draft aboard the R/V *C-Wolf* is measured using a rod that is placed down through a hole in the top of the multibeam ram. The rod measures the distance from the waterline, to the top of the EM3002 mounting plate. This value is then put into the draft formula to obtain the waterline to CRP measurement, which is entered into SIS.

In order to correct for the dynamic draft of the R/V *C-Wolf*, a squat and settlement test was performed at Lake Dubuisson, LA on January 15, 2016. Refer to Appendix I: Vessel Reports – Dynamic Draft Report for additional information.

C.3.3. **R/V *C-Ghost***

Static draft aboard the R/V *C-Ghost* is measured using a rod that is placed down through a hole in the top of the multibeam ram. The rod measures the distance from the waterline, to the top of the EM3002 mounting plate. This value is put into the draft formula to obtain the waterline to CRP measurement, which is entered into SIS.

In order to correct for the dynamic draft of the R/V *C-Ghost*, a squat and settlement test was performed in Lake Dubuisson, LA on March 18, 2015. Refer to Appendix I: Vessel Reports – Dynamic Draft Report for additional information.

C.4. **POSITIONING AND ATTITUDE SYSTEMS**

The R/V *Sea Scout* is equipped with three (3) GPS systems: two (2) C-Nav 3050 receivers and one (1) Coda Octopus 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 R/V *C-Wolf* and R/V *C-Ghost* have similar set ups using C-Nav 3050 receivers

The C-Nav 3050 receivers use the C-Nav Subscription Services, which can achieve 8 cm horizontal accuracy and 15 cm vertical accuracy. These systems are controlled and monitored with either a C-Navigator system (R/V *Sea Scout)* or the C-Setup control software as on the R/V *C-Wolf* and R/V *C-Ghost.*

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 2.148 m on the R/V *Sea Scout*, 1.485 m on the R/V *C-Wolf*, and 1.560 m on the R/V *G-Ghost*. Manufacturer accuracies are shown in Table 35.

Table 35. Manufacturer accuracies for the Coda Octopus F180 attitude and positioning system.

Baseline	Heading	Roll	Pitch	Heave
2 meter	0.05º	0.025º	0.025º	The greater of 5% of heave amplitude or 5 cm
1 meter	0.1º	0.025º	0.025º	The greater of 5% of heave amplitude or 5 cm

C.5. **EQUIPMENT OFFSETS**

Equipment offsets from the CRP were entered directly into the Simrad SIS software aboard the R/V *Sea Scout*, R/V *C-Ghost* and R/V *C-Wolf*. The Primary C-Nav 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, if applicable. The F180 offsets were entered in POS, COM4, Attitude 1, COM2 and Attitude 2, COM3.

C.6. **MULTIBEAM CALIBRATION**

C.6.1. **R/V *Sea Scout***

Prior to commencement of survey operations, a standard patch test was performed on April 29, 2015 to quantify the error biases for navigation timing, pitch, roll, and heading. CARIS HIPS and SIPS 8.1 was used to calculate the error biases, and C & C Technologies' proprietary software Hydromap was used to verify the results (Table 36). Refer to the patch test report for additional information. 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.

Table 36. Patch Test Results (R/V *Sea Scout* –April 29, 2015)

	Pitch	Roll	Yaw
Port Transducer	-0.47°	-1.05°	1.79°
Starboard Transducer	-0.22°	-0.90°	2.40°

C.6.2. **R/V *C-Wolf***

Prior to commencement of survey operations, a standard patch test was performed on September 6, 2015 to quantify the error biases for navigation timing, pitch, roll, and heading. CARIS HIPS and SIPS 9.0 was used to calculate the error biases (Table 37). Refer to the patch test report for additional information. 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.

Table 37. Patch Test Results (R/V *C-Wolf* – September 6, 2015)

	Pitch	Roll	Yaw
Multibeam Transducer	0.86°	-0.19°	-0.22°

C.6.3. **R/V *C-Ghost***

Prior to commencement of survey operations, a standard patch test was performed on September 3, 2015 to quantify the error biases for navigation timing, pitch, roll, and heading. CARIS HIPS and SIPS 9.0 was used to calculate these error biases (Table 38). Refer to the patch test report for additional information. 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.

Table 38. Patch Test Results (R/V *C-Ghost* – September 3, 2015)

	Pitch	Roll	Yaw
Multibeam Transducer	1.41°	0.08°	0.12°

C.7. SOUND SPEED CORRECTIONS

Seabird Electronics SBE19, SBE19 Plus CTDs and Valeport underway SVPs were used to collect sound speed data through the water column. Simultaneous sound speed profiles were acquired aboard the R/V *Sea Scout* (Figure 7) and reviewed together as a quality control check; only one cast was typically conducted aboard the R/V *C-Wolf and* R/V *C-Ghost* unless specifically conducting a comparison. The profile would be entered into the SIS control software and the multibeam data corrected for the water column sound speed in real-time. Prior to importation into SIS, the chosen sound speed cast was extended 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 single beam echo sounder data.

Figure 7. CTD set-up on the R/V *Sea Scout*.

Endeco YSI 600R sondes and AML SV•Xchange Calibrated Sensors were used to calculate the sound speed at the transducers. The difference between the sound speed measured by the CTD and the sound speed calculated at the transducer was monitored in the SIS software. A difference of more than 2 m/s indicated a new cast should 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. A .hob file and S-57 file, 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 8764227 (LAWMA, LA) provided water level reducers for this project.

During survey operations, preliminary 6-minute tidal data from the 8764227 water level station 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 39 shows the tide zones and correctors.

Table 39. LAWMA, LA (8764227) Tide Zones and Correctors.

Tide Zone	Reference Station	Time Corrector (min)	Range Ratio
WGM263	8764227	-30	x1.02
WGM264	8764227	-18	x0.99
WGM265	8764227	-18	x0.96
WGM278	8764227	-30	x1.06
WGM279	8764227	-36	x1.06
WGM280	8764227	-42	x1.09
WGM281	8764227	-54	x1.09
WGM282	8764227	-60	x1.15
WGM283	8764227	-66	1.18x

Tidal zoning correctors were applied to verified data from the 8764227 (LAWMA, LA) water level 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-K379-KR-15

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
Digitally signed by Tara Levy
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