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

DATA ACQUISITION AND PROCESSING REPORT

Type of Survey	**Hydrographic**
Project Number	**OPR-J347-KR-18**
Contract Number	**EA-133C-14-CQ-0037**
Task Order Number	**1305M218FNCNJ0138 and Modifications**
Time Frame	**August 2018**

LOCALITY

State	**Louisiana**
General Locality	**Mississippi River**

2018

CHIEF OF PARTY

Jonathan L. Dasler, David Evans and Associates, Inc.

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TABLE OF CONTENTS

List of Figures

List of Tables

List of Appendices

Data Acquisition and Processing Report
Project OPR-J347-KR-18
Locality: Mississippi River
August 2018
S/V *Blake* and RHIB *Sigsbee*
David Evans and Associates, Inc.
Chief of Party: Jonathan L. Dasler, PE, PLS, CH

INTRODUCTION

This report applies to surveys H13188, H13189, H13190, H13191, H13192, H13193, H13194, H13195, H13196, H13212, and H13330, all located on the Mississippi River in Louisiana between Baton Rouge and the entrance to Southwest Pass. The project area encompassed approximately 98 square nautical miles (SNM) and over 510 miles of shoreline. The original project area included in the *Hydrographic Survey Project Instructions* issued on July 20, 2018 extended from Baton Rouge (Mile 232.5 Above Head of Passes (AHOP)) to Head of Passes (Mile 0 AHOP). A contract modification was issued on December 11, 2018, extending the project area upriver from Baton Rouge to Mile 236 AHOP and Baton Rouge Harbor, and downriver from Head of Passes to the entrance to Southwest Pass (Mile 21 Below Head of Passes (BHOP)). A second contract modification issued on August 15, 2019 split the area upriver of Baton Rouge that was added to survey H13188 during the first contract modification into a new survey area, H13330. All surveys follow requirements defined in the *Statement of Work* (November 19, 2018), *Hydrographic Survey Project Instructions* (August 8, 2019), and National Ocean Service (NOS) *Hydrographic Surveys Specifications and Deliverables* (HSSD) (March 2018).

Historic flooding of the Mississippi River during OPR-J347-KR-18 survey operations impacted the ability of David Evans and Associates, Inc. (DEA) to efficiently and safely complete all project objectives within the scheduled project timeline. Flood conditions, unsafe currents, and restrictions from the United States Coast Guard (USCG) Captain of the Port prevented survey operations from Baton Rouge to New Orleans after December 2018. While the initial survey of this stretch of the river was completed in the Fall of 2018 and significant effort was made to investigate features and fill holidays, DEA was unable to acquire all independent feature investigations and all holidays in proximity to terminal facilities and the 2-meter inshore depth limit. Many of these features were in locations that restricted a 90-degree pass due to strong currents and proximity to shoreline, fixed structures or barge fleeting. The remaining features warranting additional investigation identified during review were planned to take place while transiting to the extension of the H13188 survey area upriver of Baton Rouge, which was added to the contract on December 11, 2018. This area was broken out of H13188 and designated with registry number H13330 in the August 15, 2019 contract modification.

Flooding also impacted acquisition and processing downstream of New Orleans, specifically in the vicinity of Head of Passes and Southwest Pass. The United States Army Corps of Engineers (USACE) was actively dredging during survey operations to address significant shoaling caused by the flooding. Numerous dredges participated in the emergency dredging which at times impacted DEA planned operations and caused artifacts in the multibeam sonar data when there was coverage overlap between pre- and post-dredge bottom conditions. Further, flooding and strong river currents resulted in significant sediment migration during and between survey operations, which is evident on all survey sheets.

The *Project Instructions* called for high resolution charting at 1:5,000 survey scale to support the National Oceanic and Atmospheric Administration's (NOAA) Precision Navigation initiative for the Mississippi River including: Object Detection Coverage for all waters in the survey area to the 2-meter depth contour; Ellipsoid Reference Survey (ERS) using a custom separation model for the Mississippi River; verification of Aids to Navigation (ATONs); assignment of shoreline and nearshore features (including bridges, overhead wires, revetments, assigned existing terminals, and all uncharted features) to be obtained by vessel based moble laser scanning tecnology; and delivery of LAS data referenced using ERS methods. Operational challenges included, but were not limited to: conducting surveys in a heavily congested industrial waterway; high river current velocities and transiting debris from high water levels; over 465 miles of shoreline surveys in restricted waters with small launch operations in close proximity to terminals, large barge fleets, wrecks, ruins, submerged piling, and numerous snags; minimal river access for provisioning and refueling; dynamic sediment migration exceeding 0.25 meters per hour in some areas; resolution of chart datum and revisions to the separation model; coordinating mapping efforts with ships at berth; dense fog; on-going dredging operations; and various navigational trials associated with a heavily trafficked industrial waterway. Due to these contingencies and the volume of shoreline operations required, survey operations were conducted during daylight hours only.

The project's survey purpose for all surveys, which was defined in the *Project Instructions*, is "The Ports of Southern Mississippi River represent the largest port complex in the world and one of the most heavily trafficked waterways in the United States. Annually, over 500 million tons of cargo is moved on the Lower Mississippi. This project area includes the Port of South Louisiana, the Port of New Orleans, the Port of Greater Baton Rouge, and Plaquemines Port, all ranking in the top 12 ports for annual tonnage in the United States. The Port of South Louisiana, river mile 114.9 to 168.5, is the largest tonnage port in the western hemisphere, handling approximately 262 million tons. The Port of New Orleans, river mile 81.2 to 114.9, handles approximately 90 million tons annually. The Port of Greater Baton Rouge, river mile 168.5 to 253, and Plaquemines Port, river mile 0 to 81.2, handle approximately 73 and 57 million tons annually, respectively. [1]

Critical charting updates are needed for the Mississippi River especially for areas outside of the USACE federally maintained channel areas. These areas outside of the federally maintained channel account for the majority of the navigable river and include ports and terminals essential for commerce and trade. The new bathymetric data in this project area encompassing 89 SNM will support high resolution charting products for maritime commerce and update National Ocean Service (NOS) nautical charting products."

[1] U.S Army Corps of Engineers, Navigation Data Center, Waterborne Commerce Statistics Center, Principal Ports of the United States, www.navigationdatacenter.us/data/datappor.htm

All references to equipment, software or data acquisition and processing methods were accurate at the time of document preparation. All changes to data acquisition and processing methods will be specifically addressed in the Descriptive Report for each project survey.

A. EQUIPMENT

For this project, DEA implemented state-of-the-art data acquisition systems on board the Survey Vessel (S/V) *Blake* and rigid-hulled inflatable boat (RHIB) *Sigsbee* in accordance with NOAA standards and modern remote sensing techniques. Operational systems used to acquire survey data and redundant systems that provided confidence checks are described in detail in this section and are listed in Tables 1, Table 2, and Table 3. Additional detail on sensor calibration and effective dates are detailed in Appendix IV *Sound Speed Sensor Report*.

Table 1. S/V *Blake* Hardware for Mobile Mapping Operations

Instrument	Manufacturer	Model	Serial No.	Function
Mobile Mapping System				
Primary Scanner	**RIEGL**	VUX 1HA	N/A	Primary mobile mapping laser scanner
Scanner Control Unit	**RIEGL**	VMQ-CU Control Unit	N/A	Laser scanner processor
Camera System	**FLIR (formerly Point Grey Research)**	Ladybug5 (LB5)		360-degree camera system
Secondary Scanner	**RIEGL**	z390i		Secondary laser scanner for fill during multibeam acquisition and primary H13212 and H13330 scanning
Navigation coupled in Riegl Scanner				
Deck Unit	**Applanix**	POS 620, Firmware: 9.83		Integrated Global Navigation Satellite System (GNSS) and inertial reference system for position, heading, heave, roll, and pitch data
IMU	**Applanix**	LV		
Primary Antenna	**Aero**	AT1675-540TS		
Secondary Antenna	**Aero**	AT1675-540TS		

Table 2. S/V *Blake* Hardware for Bathymetric Operations

Instrument	Manufacturer	Model	Serial No.	Function
Multibeam Echosounder				
Deck Unit	**Teledyne Reson**	T50-P RSP FP4 V4.2.019	3716029	Starboard Multibeam sonar processor
Sonar	**Teledyne Reson**	Projector TC2181 Receiver EM7218	TX 4516116 RX 2714147	Starboard Multibeam sonar
Deck Unit	**Teledyne Reson**	T50-R RSP+ FP4 V4.2.019	08961618025	Port Multibeam sonar processor
Sonar	**Teledyne Reson**	Projector TC2181 Receiver EM7218	TX 5015065 RX 4816020	Port Multibeam sonar
Sound Speed				
MVP30-350 Sound Speed Profiler	**AML Oceanographic**	Micro SVP&T	Sensor: 8704 SV: 204796 P: 304616 T: 404176	Primary sound speed profiler Effective until 03/27/2019
MVP30-350 Sound Speed Profiler	**AML Oceanographic**	Micro SVP&T	Sensor: 8704 SV: 205498 P: 300041 T: 400219	Primary sound speed profiler Effective after 03/27/2019
Surface Sound Speed	**AML Oceanographic**	Micro SV Xchange	Housing: 7561 Sensor: 204871	Sound speed at MBES (Effective until 03/27/2019)
Surface Sound Speed	**AML Oceanographic**	Micro SV Xchange	Housing: 10661 Sensor: 204678	Sound speed at MBES (Effective after 03/27/2019)
Sound Speed Profiler	**Sea-Bird Electronics, Inc.**	SBE 19+ SeaCAT	4962	Secondary sound speed profiler
Navigation				
Deck Unit	**Applanix**	POS MV 320 V5, Firmware: 5.03	7342	Integrated Global Navigation Satellite System (GNSS) and inertial reference system for position, heading, heave, roll, and pitch data
IMU	**Applanix**	LN200	750	
Port Antenna	**Trimble**	GA830	7337	
Starboard Antenna	**Trimble**	GA830	7235	
GNSS Receiver	**Trimble**	SPS 851	5005K65409	Secondary GNSS positioning system
GNSS Antenna	**Trimble**	Zephyr 3	1441039499	
GNSS Radio	**Trimble**	TrimMark III	050065010480	RTK corrections via Base Station in Southwest Pass
Intuicom	**Intuicom**	RTK Bridge	X151418	RTK corrections via NTRIP
GPS Positioning Equipment				
GNSS Rover	**Trimble**	R8 Rover	N/A	GNSS rover positioning system
Fixed Tripod	**SITECH**	2-meter Fixed	N/A	Fixed height rover rod
Base Station Receiver	**Trimble**	Net R5	4750K11589	Static Single Base Station – initialized for broadcasting RTK corrections in South West Pass (Installed 02/28/2019)
Base Station Antenna	**Trimble**	Zephyr Geodetic Model II	1441003378	
Base Station Radio	**Trimble**	TrimMark III	050065010480	

Table 3. RHIB *Sigsbee* Hardware for Bathymetric Operations

Instrument	Manufacturer	Model	Serial No.	Function
Multibeam Echosounder				
Deck Unit	**Teledyne Reson**	T50-P FP4 V4.2.019	95771416148	Multibeam sonar processor
Sonar	**Teledyne Reson**	Projector TC2181 Receiver EM7218	TX 5015057 RX 2714149	Multibeam sonar system
Sound Speed				
Sound Speed Profiler	**AML Oceanographic**	Base X2	Sensor: 25653 SV: 206748 P: 305746	Primary sound speed profiler (Offline for repairs 09/17/2018) (Reinstated as primary 04/14/2019)
Sound Speed Profiler	**Sea-Bird Electronics, Inc.**	SBE 19+ SeaCAT	4962	Primary sound speed profiler (Installed 9/18/2018 through 09/28/2018)
Sound Speed Profiler	**AML Oceanographic**	Smart X	Sensor: 5588 SV: 204011 P: 304610 T: 404001	Primary sound speed profiler (Installed as primary 09/29/2018)
Surface Sound Speed	**AML Oceanographic**	Micro SV Xchange	Housing: 8083 Sensor: 206832	Sound speed at MBES (Effective until 03/27/2019)
Surface Sound Speed	**AML Oceanographic**	Micro SV Xchange	Housing: 10992 Sensor: 201322	Sound speed at MBES (Effective after 03/27/2019)
Navigation				
IMU	**IXSEA iXBlue Company**	iXBlue Hydrins	88100214	Inertial Measurement Unit (IMU) and inertial reference system for position, heading, heave, roll, and pitch data
GNSS Receiver	**Trimble**	SPS855	5506R0075	Primary GNSS positioning system
GNSS Antenna	**Trimble**	Zephyr 3	1441039482	
GNSS Radio	**Trimble**	TrimMark III	4810146491	RTK corrections via Base Station in South West Pass
Intuicom	**Intuicom**	RTK Bridge	X162034	RTK corrections via NTRIP

A1. Survey Vessels

The S/V *Blake*, owned and operated by DEA (Figure 1), was the primary survey vessel for the project and was used as the primary acquisition platform in open water and depths greater than 9 meters. The S/V *Blake* served as the support vessel for an 18-foot rigid-hulled inflatable boat (RHIB), field processing center, and berthing quarters for all field staff**.**

The S/V *Blake* is a 92-ton USCG Subchapter T inspected vessel, Official Number 1256966, and Hull Number 213. She is an 82-foot aluminum catamaran with a 27-foot beam and a draft of 4.5 feet. The vessel is equipped with wave-piercing bows, Tier-3 diesel engines, twin 55-kilowatt generators, pole mounts on either side of the vessel for dual head multibeam deployment, stern mounted A-frame, bow mounted knuckle boom crane, climate-controlled equipment and server closet, one data acquisition station, and three data processing stations. The S/V *Blake* supports a hydrographic crew of six and is supported by four ship crew for 12-hour survey operations and 24-hour on-water operations. Survey operations were not conducted at night due to heavy vessel traffic, strong river currents, and large amounts of floating debris from high river levels.

Figure 1. S/V *Blake*

For shoreline development, areas too confined, or too shallow for the S/V *Blake*, a smaller survey launch running day operations was utilized. The RHIB *Sigsbee*, owned and operated by DEA (Figure 2) is an 18-foot rigid-hulled inflatable boat. The RHIB is housed in a cradle on the upper deck of the S/V *Blake*, deployed for daily survey operations by the side knuckle boom crane on the S/V *Blake*. The RHIB *Sigsbee* contains twin 40 horsepower Yamaha engines, an integrated Simrad radar, chart plotter, Class B AIS, and Satellite Weather Module. The RHIB *Sigsbee* has a deployable bow mount for multibeam operations, coupled with an iXBlue Hydrins motion reference unit. The RHIB *Sigsbee* supports a vessel operator and a hydrographer while running multibeam surveys.

Figure 2. RHIB *Sigsbee*

A2. Mobile Mapping System

The S/V *Blake* was outfitted with a RIEGL VUX-1HA mobile mapping system (MMS) consisting of an internal Applanix inertial navigation system, VUX-1HA "full circle" field of view high accuracy laser scanner, FLIR Ladybug5 (LB5) 360-degree camera system, VMQ-CU control system PC box, second Trimble Global Navigation Satellite System (GNSS) Aero-antenna AT1675-540TS for GNSS azimuth measurement subsystem (GAMS) configuration and power management system.

The MMS was structurally supported by an in-house custom-built mount on the bridge of the S/V *Blake*. Scanning missions were conducted with RIEGL RiACQUIRE version 2.3.2 (build 2018-05-25), Firmware version 9.83 on the Applanix POS 620, Applanix POSLV version 9.6.

The entire MMS was deflected 15 degrees forward-facing off the starboard side of the S/V *Blake*. Each day of data acquisition was fragmented into multiple project mission areas to aid in project processing and data management.

Figure 3: Mobile Mapping System

The lidar records from the VUX-1HA high accuracy laser scanner were acquired natively in the RIEGL RXP file format in conjuncture with imagery stream files in the FLIR PGR file format over the MMS mapping operations duration August 09, 2018 (DN221) to August 17, 2018 (DN229).

Survey H13212, a portion of H13330 upstream of the Huey P. Long (US-190) bridge, and holidays present in initial mobile mapping survey were filled during the bathymetric data collection phase of the project with a RIEGL z390i scanner. The scanner was centrally mounted on the S/V *Blake* for the duration of the multibeam acquisition. Unlike the MMS system, the RIEGL z390i scanner did not have an integrated inertial navigation system. The RIEGL z390i scanner was positioned using punchmarks established during the initial vessel survey and integrated into the POSMV V5 navigation system used during multibeam operations. All laser data acquired with the RIEGL z390i scanner logged in HYPACK HSX file format.

A3. Multibeam System

The S/V *Blake* and RHIB *Sigsbee* were equipped with Teledyne/Reson SeaBat T50 multibeam sonars capable of operating at 190-420 kHz and integrated AML Micro SV Xchange sound velocity sensors. The multibeam sonars were deployed in a dual head configuration with custom fabricated mounts on the starboard and port side of the S/V *Blake* and a single head configuration with a bow mount on the RHIB *Sigsbee*. For all surveys, the sonars operated using Frequency Modulated (FM) transmissions. All multibeam sonars for this project were operated with FP4 V4.2.019 in FM, Equi-Distant Beam mode at 350 kHz using a 140-degree swath width. Mainscheme acquisition typically used 256 beams per sonar in dual head configuration while single head configuration was acquired with 512 beams.

On the S/V *Blake*, the sonars were operated in Full Rate Dual Head mode which enabled the multibeam sonars to ping simultaneously using FM transmissions. The port sonar was configured to be triggered by the starboard (primary) sonar, meaning that the primary system controls the power, gain, ping rate, range scale, absorption, spreading and surface sound speed.

All multibeam data were acquired with the Reson T50 normal standard bracket selected in the hardware configuration. Range adjustments were made during acquisition as dictated by changes in water depth. HYPACK HYSWEEP was used to acquire multibeam data in HYSWEEP HSX file format and time series backscatter in 7k file format. The 7k files were logged individually per sonar, adding a 1 or 2 to the end of the naming convention, to indicate starboard and port sonar systems, respectively. Logging the 7ks individually was implemented by HYPACK to facilitate the ability to apply sonar specific calibration files during processing.

A4. Position, Heading and Motion Reference Systems

The S/V *Blake* was outfitted with a Position and Orientation System for Marine Vessels (POS/MV) 320 version 5 with GNSS and inertial reference system, which was used to measure attitude, heading, heave, and position. The system was comprised of an Inertial Motion Unit (IMU), dual frequency (L1/L2) GNSS antennas, and a data processor.

The RHIB *Sigsbee* was outfitted with an iXBlue Hydrins inertial navigation system (INS) integrated with a Trimble SPS855 GNSS receiver. The Hydrins was used to measure attitude, speed, heading, heave, and position. The system was comprised of an inertial Fiber-Optic gyroscope coupled to an embedded digital signal processor that runs a Kalman filter. The Hydrins Kalman filter holds Global Positioning System (GPS) combinations for surface alignment and accurate position and altitude computation.

On each vessel, an Intuicom receiver acquired real-time kinematic (RTK) corrections via Internet Protocol (NTRIP) from the Louisiana State University Center for GeoInformatics real-time network (C4GNet RTN), which is the home of the Louisiana Spatial Reference Center, creator and host for the National Geodetic Survey (NGS) Continuously Operating Reference Station (CORS) network. Correctors provided were used by vessel positioning systems (POS/MV and the iXBlue Hydrins) for horizontal positioning. In addition, each vessel was equipped with a GNSS receiver utilizing the same RTK correctors for vertical positioning and for redundant horizontal positioning. Ellipsoid heights from the RTK corrected receiver data were reduced to chart datum in HYPACK using the NOAA provided separation model converted to HYPACK KTD file format.

Positions from all systems were displayed in real-time using HYPACK and continuously compared during survey operations. A weekly position comparison between the primary and secondary positioning system was observed and documented while the vessel was either secured in port or within the extents of the survey area. Logged position data were extracted from the HYPACK RAW file and entered into an Excel file for comparison. Position check reports can be found in Separate I *Acquisition and Processing Logs* of each survey’s Descriptive Report.

Position, timing, heading, and motion data were output to the HYPACK acquisition system using the POS/MV or Hydrins via real-time Ethernet option at 50 Hz.

The POS/MV and Hydrins provided time synchronization of sonar instruments and data acquisition computers using a combination of outputs on the S/V *Blake* and RHIB *Sigsbee*, respectively. The Reson topside units and HYPACK acquisition computers were provided a Pulse Per Second (PPS) and National Marine Electronics Association (NMEA) Global Positioning System Timing Message (ZDA) to achieve synchronization with the POS/MV and Hydrins. All messages contained time strings that enabled the acquisition computers and sonars to synchronize to the time contained within the message. Time offsets between the instruments and computers, relative to the times contained in POS/MV and Hydrins network packets, were typically sub-millisecond.

The POS/MV was configured to log all the raw observable groups needed to post-process the real-time sensor data. The POS/MV logged 64-megabyte .000 files, which resulted in multiple files created per day. The TrueHeave™ data group was also logged to these files.

The iXBlue Hydrins were configured to log all the raw observable groups needed to post-process the real-time sensor data. The Hydrins logged daily .log files, which contained the SmartHeave™ data group. Detailed discussion of post-processing methods is provided in Section B. *SmartHeave Post-Processing*.

A5. Sound Speed Measurement Systems

Sound speed sensors were calibrated prior to the start of acquisition. Factory calibration results are included in Appendix IV *Sound Speed Sensor Report* of this report.

AML Micro Xchange SV sensors were mounted on the Reson T50-P sonar heads on both survey vessels. The SV sensor was only installed on the primary sonar (starboard side) of the S/V *Blake*. These data were input into the Reson processors and sound speed from the sensors were used in real-time during acquisition for beam forming on the T50-P sonars' flat arrays. The primary sound speed profiler for the S/V *Blake* was an AML Oceanographic Moving Vessel Profiler (MVP) 30-350, and an AML Oceanographic BaseX2 system for the RHIB *Sigsbee*. Both sound speed profilers were equipped with AML Oceanographic Micro Sound Velocity and Pressure sensors.

A Seabird SBE 19+ SeaCAT and an AML Oceanographic SmartX were used as secondary sound speed profilers. All sound speed calculations from the Sea-Bird Conductivity, Temperature, and Depth (CTD) profiler used the Chen-Millero equation. These profiles were used solely for confidence checks with the primary sensors.

A6. Acquisition and Processing System

The acquisition stations were custom-installed and integrated on the S/V *Blake* and RHIB *Sigsbee* by DEA and consisted of a HYPACK HYSWEEP multibeam acquisition and navigation computer, and a computer for digital logs and general administration. The S/V *Blake* had an additional moving vessel profiler (MVP computer and three processing computers.

Data collected from the S/V *Blake* were logged locally on the acquisition computer and continuously backed up to a QNAP network attached storage (NAS) device. Data collected from the RHIB *Sigsbee* were logged locally on an acquisition computer and backed up nightly to a QNAP aboard the S/V *Blake*. A secondary QNAP NAS was used to perform backups of the primary QNAP. At each port call, raw and processed data from both survey vessels were transferred to DEA's Vancouver, WA office via external USB 3.0 hard drives.

The software and version numbers used throughout the survey are listed in Table 4.

Table 4. Acquisition and Processing Software

Name	Manufacturer	Version
Bathymetric Acquisition		
HYPACK	HYPACK, Inc.	17.0.34.0
HYPACK Survey	HYPACK, Inc.	17.0.26.1
Hysweep	HYPACK, Inc.	17.0.26.1
SeaBat	Reson	V5.0.0.9
Hydrins	Web Interface Logging	N/A
MV-POSView	Applanix Corporation	8.32
Trimble Vessel Rover	Web Interface Logging	N/A
LineLog	David Evans and Associates, Inc. Marine Services Division	2.0.7 (S/V *Blake)* 2.0.3 (RHIB *Sigsbee*)
ODIM MVP Controller	ODIM Brooke Ocean	V2.450
HyperTerminal	Microsoft Windows	5.1.2600.0
Intuicom Bridge Pro	Intuicom	V2.3 (S/V *Blake)* V2.2 (RHIB *Sigsbee)*
Mobile Mapping Acquisition		
RiACQUIRE	RIEGL	V2.3.2
Ladybug CapPro	FLIR	v1.15.3.23
Processing		
CARIS Process Designer	CARIS 64-bit	4.4.14
HIPS	CARIS 64-bit	10.4.5
Base Editor	CARIS 64-bit	5.1.4
RIEGL RiProcess	RIEGL	
ArcPro2.4.1.0D Analyst	ESRI	10.6
ArcGIS	ESRI	10.6
Orbit GT	Orbit GeoSpatial Technologies	18.1.0 19.7.0 for overhead clearance analysis only
Delph INS	IXBlue	v.2.3
POSPac MMS	Applanix	8.0.6169.27588
Photoshop CS3	Adobe	10.0
ODIM MVP Controller	ODIM Brooke Ocean	V2.450
SeaCast	AML Oceanographic	4.4.0
SVP Convert	David Evans and Associates, Inc. Marine Services Division	2.0.4

Name	Manufacturer	Version
Other		
Microsoft Office Suite	Microsoft	365 ProPlus
Beyond Compare	Beyond Compare	4.1.1
Pydro Explorer	NOAA Office of Coast Survey	19.4
MRTIS	Mississippi River Traffic Information Service	N/A

A7. Survey Methodology

A7.a Mobilization

Mobilization of the S/V *Blake* for mobile mapping occurred from August 06 to 08, 2018. System calibrations were performed during a preliminary field test for the RIEGL VUX-1HA Mobile Mapping System (MMS) in the Gulfport Harbor on August 08, 2018 (DN220) by scanning water front structures and comparing to known positions acquired with RTK GNSS.

Mobilization of the S/V *Blake* and RHIB *Sigsbee* for bathymetric survey operations occurred from August 28 to 30, 2018. Multibeam system calibrations and a start of project patch test for both vessels were performed in the Gulfport Ship Channel on August 29, 2018 (DN241) overlaying preexisting data to evaluate quality assurance prior to time of survey.

Vessel offsets and associated measurement uncertainties for the S/V *Blake* were calculated from a vessel offset survey performed at Geo Shipyard in New Iberia, LA on September 23 to 24, 2014, with custom mount additions surveyed in on May 22, 2018 (DN142). All survey points were positioned using a terrestrial land survey total station, from a minimum of two locations, which allowed a position uncertainty to be determined. Vessel offsets and uncertainties were used in the HIPS Vessel File (HVF). Changes to the hardware offsets since the initial vessel offset survey were necessary to account for new equipment installation during the time of survey for this task order.

Vessel offsets and associated measurement uncertainties for the RHIB *Sigsbee* were calculated from a baseline vessel offset survey performed at DEA’s Vancouver, WA warehouse on August 15, 2018 (DN227). The RHIB *Sigsbee’s* pole mounted setup was leveled and hand measured, allowing the determination of a position uncertainty. Vessel offsets and uncertainties were used in the HVF for this task order.

A7.b Survey Coverage

Survey coverage requirements were specified as Object Detection Coverage for all survey areas. Object Detection Coverage was met by 100% multibeam bathymetric coverage, Option A, as defined in Section 5.2.2.2 Object Detection Coverage in the NOS HSSD (April 2018).

Bathymetric coverage was obtained to a depth of 2 meters below chart datum for all navigable extents. All multibeam acquisition included time series backscatter.

All new and assigned charted features were investigated using either 100% multibeam coverage or mobile scanning methods. For surveys H13188 through H13196, all shoreline and baring features, including assigned bridges, overhead cables, and terminal facilities, were surveyed with an integrated high definition mobile mapping system (RIEGL VUX-1HA). The shorelines of survey areas H13330 and H13212 were scanned with the RIEGL z390i laser scanner. All feature investigations followed guidance in accordance with section 7.3.2 New Features and 7.3.3 Feature Developments in the HSSD (April 2018) and the charted feature Investigation Requirement extended attribute in the project's Composite Source Files (CSFs).

Table 5 lists the Project Reference Files (PRFs) and CSFs used during the project. Copies of emails from NOAA issuing these files to DEA are included in *Project Correspondence*.

Table 5. Summary of NOAA Provided PRFs and CSFs

File Name	Date Issued to DEA	Comment
OPR-J347-KR-18_PRF_FINAL_Aug21_18.000	August 21, 2018	PRF for surveys H13188 through H13196
OPR-J347-KR-18_CSF_FINAL_Aug21_18.000	August 21, 2018	CSF for surveys H13188 through H13196
OPR-J347-KR-18_PRF_MOD.000	November 16, 2018	PRF for surveys H13212 and H13330
OPR-J347-KR-18_CSF_MOD.000	November 16, 2018	CSF for surveys H13212 and H13330

A7.c Mobile Mapping Operations

Mobile mapping operations were conducted in advance of the bathymetric data collection for surveys H13188 through H13196.

The *Project Instructions* required scanning of areas located in survey areas H13188 through H13193 which were identified in the PRF as Anchorage area feature types (ACHARE). This included the bridges, overhead cables, and terminal facilities depicted in Figure 4. Mobile mapping system acquisition was expanded outside of these assigned areas to encompass all of surveys H13188 through H13196 in order to facilitate the survey, management, and reporting of thousands of shoreline and nearshore features located within the project area.

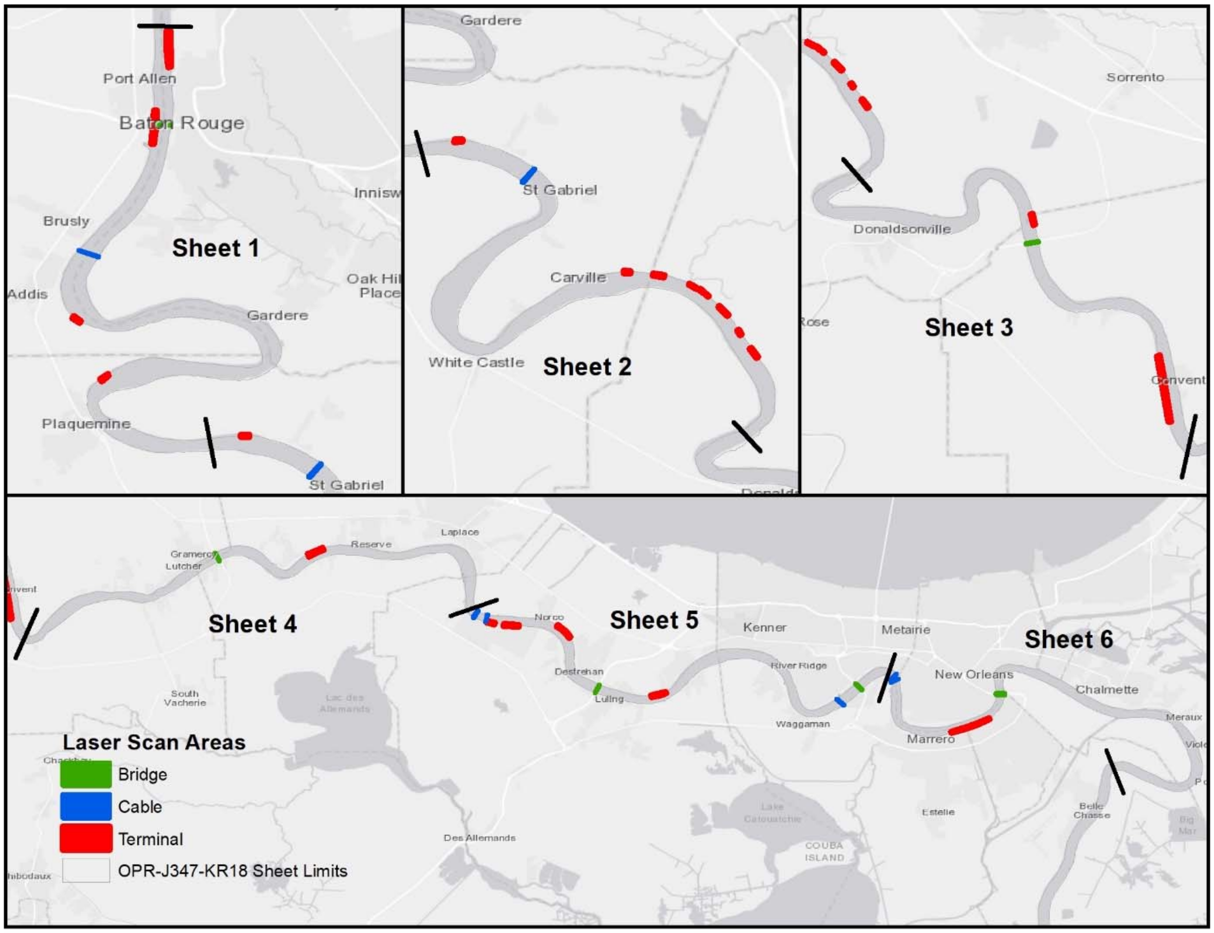

Figure 4: Assigned Laser Scan Areas

Survey areas H13212 and H13330, and any holidays present in the initial mobile mapping survey, were scanned during the bathymetric data collection phase of the project with a RIEGL z390i scanner.

The mobile mapping system was operated at specified integration settings deemed best fit for the scanner's environment and survey platform. Impacts of backlighting from the sun on the imagery data were minimized by timing acquisition to avoid low sun angles behind the camera. Areas that were found inaccessible or with an obstructed view of the shoreline during the initial acquisition were reattempted during bathymetric acquisition. These areas were typically caused by an obstructing vessel, fleeted barges or other conditions that hindered navigation to that area of shoreline.

The MMS data positioning was reliant upon a real-time GNSS correction provided by the C4GNet RTN over network transport of RTCM via NTRIP in RTCM 3.2 multi-signal message format by a cellular modem connected to the S/V *Blake*. The MMS GNSS trajectory solutions were dependent upon its GAMS configurations with the dual GNSS antenna heading measurement system. The decision to use GAMS for the acquisition was executed during survey due to the ability to minimize azimuth drift in real-time.

The integration settings for the VUX-1HA high accuracy laser scanner are listed in Table 6. The LB5 was set to a balanced exposure for the lighting conditions of the day and was triggered at 8-meter intervals where lidar was being actively logged by RiACQUIRE v2.3.2 pass-through to LadyBug CapPro.

Table 6. Typical RIEGL Integration Settings

RIEGL VUX -1HA Laser Scanner Parameters	Variable
Range Gate	7 m – 1500 m
Reflectance Gate	-25 dB through +25 dB
Range Set to Target	Max return +/- 250-meter
Max Return Frequency	507 kHz
Speed	5.5556 ms

A7.d Multibeam Sonar Operations

The multibeam sonars were operated at different range scales throughout the survey by adjusting the depth range to obtain the best coverage in varying depths of water. Gain and power were adjusted to record a strong bottom return capable of supporting quality depth and backscatter data.

During data acquisition, sound velocity profiles were acquired by manual or automatic deployment to obtain an adequate number of sound velocity profiles to properly correct the multibeam data during data processing. Casts were acquired when a noticeable change was detected at the sensor at the head of the multibeam. The location of casts along the survey track lines were varied to ensure adequate spatial coverage. If significant cast-to-cast variability was observed, the time between casts was decreased.

Multibeam investigations occurred over significant features after examining parameters such as coverage, density, feature height, depth, and navigational significance.

Table 7 lists the typical T50-P sonar settings for the survey.

Table 7. Typical Reson T50-P Sonar Settings

T50-P Parameter	Pulse Type: FM
Frequency	350 kHz
Operation Depth	Variable
Range	Variable, depth dependent
Receive Gain	10-40

Transmit Power	205-220 dB
Spreading	30 dB
Absorption	120 dB/km
Ping Rate	25 p/s max
Pulse Width	300-760 µs

A8. Quality Assurance

Acquisition and processing methods followed systematic and standardized workflows established by DEA. These systems include, but are not limited to, staff training and mentoring, a formalized project management program, record and log keeping standards, software version management, and a multilevel review process.

Multibeam survey data were converted and processed in CARIS HIPS version 10.4.5. Data processing methodologies followed standard CARIS HIPS workflows for multibeam data.

The default *CUBE Parameters.XML* was replaced with *CUBEParams_NOAA_2017.xml* which was issued by the Hydrographic Surveys Division (HSD) prior to the start of the project with version 5.7 of the CARIS support files. This updated XML file uses the resolution dependent maximum propagation distance values required in the NOS HSSD.

B. QUALITY CONTROL

B1. Data Acquisition

B1.a Mobile Mapping Data Acquisition

Each day of acquisition was conducted systematically for consistency in documentation. Mission logs were detailed for recording each day’s events, the data files acquired, settings and configurations for the project hardware and software.

A dynamic alignment was performed daily to bring the residuals of the GAMS-strengthened INS into specification prior to proceeding with each mission. GNSS was monitored for a fixed solution utilizing the corrector passing through the connected NTRIP.

The S/V *Blake* maintained a navigational course to achieve the desired residuals to the degree the waterways and access allowed. As missions were completed, low-density preview lidar records from the laser scanner were downloaded to visualize verification of coverage. In addition to pre-survey alignment and calibration, quality control was conducted utilizing random sampling locations from historical aerial lidar. Stream files from the camera were checked for size, length and integrity after each mission.

B1.b Multibeam Data Acquisition

Multibeam data were acquired in HYPACK HYSWEEP file format (HSX) on both vessels. Adjustments to the sonar, including changes in range, power, and gain, were made as necessary to acquire the optimum bathymetric data quality. Additionally, vessel speed was adjusted in accordance with the HSSD to meet the required along track coverage. Typical windows for monitoring raw sensor information included timing synchronization, vessel motion, number of satellites, horizontal dilution of precision, and position dilution of precision. Raw attitude and nadir depth were also recorded in HYPACK RAW format, as a supplementary backup. Time series backscatter data were logged in HYPACK 7K format.

The HYPACK acquisition station operator monitored and tuned the multibeam sonar, tracked vessel navigation, and maintained a digital acquisition log. Operators monitored primary and secondary navigation systems to verify quality position data were acquired.

B2. Methodology Used to Maintain Data Integrity

The acquisition systems and survey protocols were designed with some redundancy to demonstrate that the required accuracy was being achieved during the survey, and to provide a backup to the primary systems. Data integrity was monitored throughout the survey through system comparisons. Two positioning systems were used to provide real-time monitoring of position data. Tide floats at automated water level gauges along the river, position confidence checks, multibeam bar checks, and sound speed comparison checks were conducted regularly to confirm required accuracy was being maintained.

Although not required in the *Project Instructions*, tide float observations were conducted at the water level gauges established by both the USACE and NOAA Center for Operational Oceanographic Products and Services (CO-OPS). These observations consisted of the survey vessel floating near the gauge and observing an accurate water level using ERS methods, and correcting to chart datum using the NOAA provided separation model. The results identified discrepancies between water levels from USACE, CO-OPS and ERS methods, resulting in coordination meetings to resolve datum definitions between NOAA and USACE. A revised separation model issued by NOAA on June 21, 2019 was applied to all acquired data for this project.

Regular comparison checks were performed by comparing profiles from the primary and secondary sound speed sensors that were acquired concurrently. Sound speed profiles were computed for each of the sensors and compared to confirm instrumentation was functioning within required tolerances.

A flow diagram of the multibeam data acquisition and processing pipeline is presented in Figure 5. This diagram graphically illustrates the data pipeline and processing workflow from acquisition to delivery.

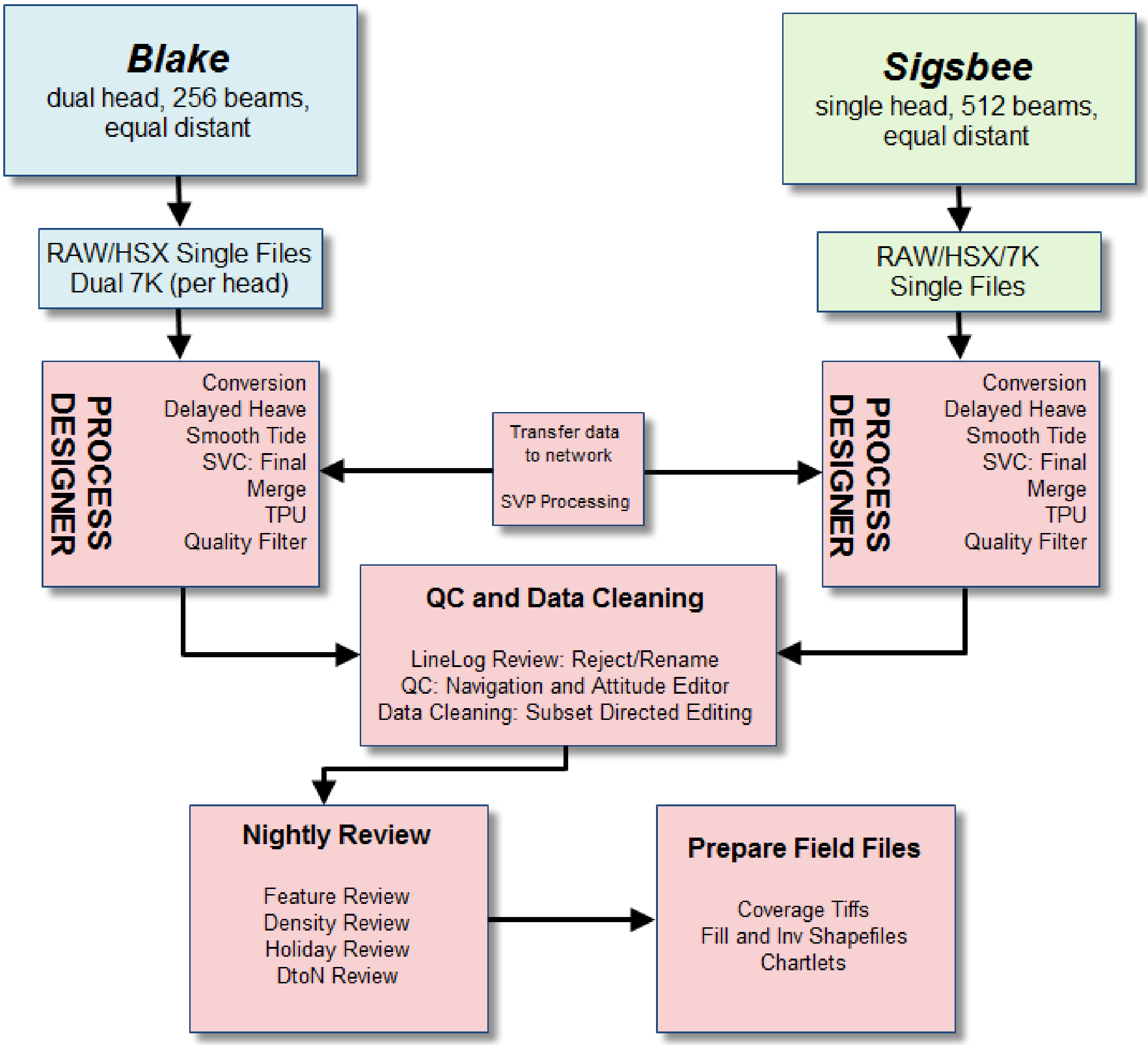

Figure 5. Flowchart of the Multibeam Data Acquisition and Processing Pipeline

B2.a HIPS Conversion

Multibeam data were converted using CARIS Process Designer. The Process Designer converted multibeam data from HSX format to CARIS HDCS format using the HYPACK RAW, HSX conversion wizard. When converting HSX multibeam data, the device numbers fields were left blank since there were no duplicate sensors logged in the HSX files. HIPS ground coordinates were specified as UTM NAD 83 Zone 15N for surveys H13188, H13189, H13190, H13191, H13192, H13193, and H131330. Surveys H13194, H13195, H13196, and H13212 used UTM NAD 83 Zone 16N. The post conversion workflow completed by the CARIS Process Designer is described in detail in section B4. Bathymetric Data Processing.

B2.b Vessel Files

The HIPS vessel files listed in Table 8 contain all offsets and system biases for the survey vessels and their systems, as well as error estimates for latency, sensor offset measurements, and attitude and navigation measurements. The S/V *Blake* vessel files were designated with BL and the RHIB *Sigsbee* vessel file was designated with SI.

Table 8. HIPS Vessel Files

HIPS Vessel File	HIPS Converter
OPR-J347-KR-18_MBES_BL_Single_Head	HYPACK 10.4.5
OPR-J347-KR-18_MBES_BL	HYPACK 10.4.5
OPR-J347-KR-18_MBES_SI	HYPACK 10.4.5

Sensor offsets for the S/V *Blake* and RHIB *Sigsbee* were calculated from the vessel surveys described in section A7.a Mobilization. To comply with the methodology used in the CARIS HIPS Sound Velocity Correct algorithm, a single approximate static waterline value was computed from multiple draft readings for each vessel and entered in the respective HVFs. The waterline value ensures the sound speed profiles are relative to a waterline rather than applying the cast information relative to the specified vessel reference point.

These corrections are listed in tabular and graphical format in Appendix I *Vessel Reports*. Amendments to the processing applications were conducted in conjunction with further analysis of the original separation model provided by NOAA for use during this project. Modifications to the separation model are detailed below in section B.4 Bathymetric Data Processing.

The HVF for the S/V *Blake* was setup with two transducers to comply with the CARIS HIPS convention for dual head sonars. The vessel file was configured with sonar specific sensor offsets for Transducer1/SVP1 and Transducer2/SVP2. Transducer1 was configured for the starboard sonar, beams 1 through 256. Transducer2 was configured for the port sonar, beams 257 through 512.

Best estimates for Total Propagated Uncertainty (TPU) values were entered into the vessel files based on current knowledge of the TPU/Combined Uncertainty and Bathymetry Estimator (CUBE) processing model. The manufacturers' published values were entered in the static sensor accuracy fields. Other values were either calculated or estimated.

Navigation and transducer separation distances from the motion sensor were computed relative to the phase center, vice the top hat, of the motion sensor; therefore, the vessel file standard deviation offsets will not exactly match the sensor offset values. TPU values for each individual HVF are listed in Table 9.

Table 9. Hydrographic Vessel File TPU Values

Input Values for Total Propagation Uncertainty Computation			
Parameters	**HIPS Vessel File (HVF)***		
Vessel	**OPR-J347-KR-18-MBES_BL**	**OPR-J347-KR-18-MBES_BL_Single Head**	**OPR-J347-KR-18-MBES_SI**
Motion Sensor	Applanix POS M/V Model 320 V5		iXBlue Hydrins
Position System 1			
Position System 2	SPS 851		SPS 855
Offsets			
MRU to Trans X (m)	3.759	3.759	0.121
MRU to Trans2 X (m)	-5.108	N/A	N/A
MRU to Trans Y (m)	-1.730	-1.730	0.000
MRU to Trans2 Y (m)	-1.727	N/A	N/A
MRU to Trans Z (m)	3.149	3.149	2.352
MRU to Trans2 (m)	3.157	N/A	N/A
Nav to Trans X (m)	3.206	3.206	-0.048
Nav to Trans2 X (m)	-5.661	N/A	N/A
Nav to Trans Y (m)	-6.428	-6.428	0.000
Nav to Trans2 Y (m)	-6.425	N/A	N/A
Nav to Trans Z (m)	9.553	9.553	2.641
Nav to Trans2 Z (m)	9.561	N/A	N/A
Trans Roll (°)	0.000	0.000	0.000
Trans2 Roll (°)	0.000	N/A	N/A
Gyro – Heading			
Gyro (°)	0.020	0.020	0.020
Heave			
Heave % Amplitude	5.000	5.000	5.000
Heave (m)	0.050	0.050	0.050
Roll and Pitch			
Roll (°)	0.020	0.020	0.010
Pitch (°)	0.020	0.020	0.010
Navigation			
Position Navigation (m)	0.100	0.100	0.100
Latency			
Timing Trans (s)	0.005	0.005	0.005
Nav Timing (s)	0.005	0.005	0.005
Gyro Timing (s)	0.005	0.005	0.005
Heave Timing (s)	0.005	0.005	0.005
Pitch Timing (s)	0.005	0.005	0.005
Roll Timing (s)	0.005	0.005	0.005
Measurement			
Offset X (m)	0.030	0.030	0.005
Offset Y (m)	0.030	0.030	0.005
Offset Z (m)	0.030	0.030	0.005
Speed			
Vessel Speed (m/s)	0.030	0.030	0.030
Draft and Loading			
Loading	0.000	0.000	0.000
Draft (m)	0.000	0.000	0.000
Delta Draft (m)	0.000	0.000	0.000
MRU Alignment errors*			
Gyro	0.065	0.065	0.047
Roll/Pitch	0.043	0.043	0.033
*All values given as 1 sigma			

In addition to published uncertainty values applied in the HVF, real-time sonar uncertainty sources were incorporated into the depth estimates of these data. For both vessels, real-time uncertainty values from the Reson T50-P Multibeam Echo Sounder (MBES) sonars were logged in the HYPACK HSX files per sounding and read into CARIS HIPS at the time of conversion.

For the S/V *Blake*, real-time estimates for vessel navigation, roll, pitch, yaw, and delayed heave were recorded and loaded into HIPS via Import Auxiliary Data function. These real-time uncertainty sources were applied during TPU computation.

The Hydrins onboard the RHIB Sigsbee did not output real-time uncertainty. During TPU computation, vessel uncertainty sources were used for navigation, attitude, heave and heading data. TPU computation is further detailed below in section B.4 Bathymetric Data Processing.

B2.c Static Draft

All surveys were collected with ERS methods. Static drafts were taken at the time of tide floats to obtain an accurate water surface elevation for both vessels for comparison of ERS water levels to gauge observations recorded by USACE and NOAA CO-OPS. The S/V *Blake* was built with draft dampening tubes in each hull providing a means to monitor vessel static draft. Static draft readings from the port and starboard side draft sight tubes were recorded and averaged at the time of tide float observations. The RHIB *Sigsbee* waterline was measured directly from the mounting plate of the Hydrins to the water line at the time of observation.

Due to the application of ERS methods for this survey, static draft observations had no impact on the vertical accuracy of the survey and was only used for the water level gauge comparison and obtaining an approximate waterline for the application of sound speed profiles.

B2.d Sound Speed

Sound speed profiles were applied to each line using the ‘nearest in distance within time (four-hour)’ option in the CARIS Sound Velocity Profiler (SVP) correct routine. During acquisition, profiles were taken at periodic intervals using the MVP30-350 on the S/V *Blake* and manually on the RHIB *Sigsbee*. Final sound speed correctors were computed from the up-cast portion of each profile taken over the course of a day.

B3. Mobile Mapping Data Processing

The mobile mapping data collected for this project was processed using a combination of Applanix POSPac, RIEGL RiPROCESS, ArcMap, Orbit GT and Teledyne CARIS software packages. Applanix POSPac & RIEGL RiPROCESS was used to process and correct MMS trajectories, laser records and image streams. RIEGL RiPROCESS was also used to export the corrected lidar in colorized-LAS v1.2 format and the imagery structured with precise geo-tags for export into Orbit GT. ArcMap was primarily used for data preparation and post feature digitization editing. Orbit GT software imported the colorized-LAS and structured imagery and allowed the team to use the collected lidar, imagery and composite source files to perform the validation/digitization of identifiable charting features in addition to evaluation data coverages. Teledyne CARIS software enabled the database updates from Orbit GT in the form of digitized shapefiles, feature classes and attribution to be packaged appropriately into the S-57 data standard.

Data acquired with the RIEGL z390i scanner were logged to HYPACK HSX format and processed using CARIS HIPS. A separate HVF, which included offsets for the navigation, attitude and heading, and laser sensors, was used to convert and process these data. Similar to the multibeam data workflow, the laser data were corrected to chart datum using ERS methods and the revised separation model. Data were exported to LAS format after processing.

The general acquisition and processing workflow for data collected with the RIEGL VUX-1HA MMS (primary acquisition system) and RIEGL z390i scanner (used to fill gaps in coverage and the primary sensor for surveys H13212 and H13330) is depicted in Figure 6. LAS data, Final Feature Files, and linked images are the final deliverables associated with the mobile mapping component of this project.

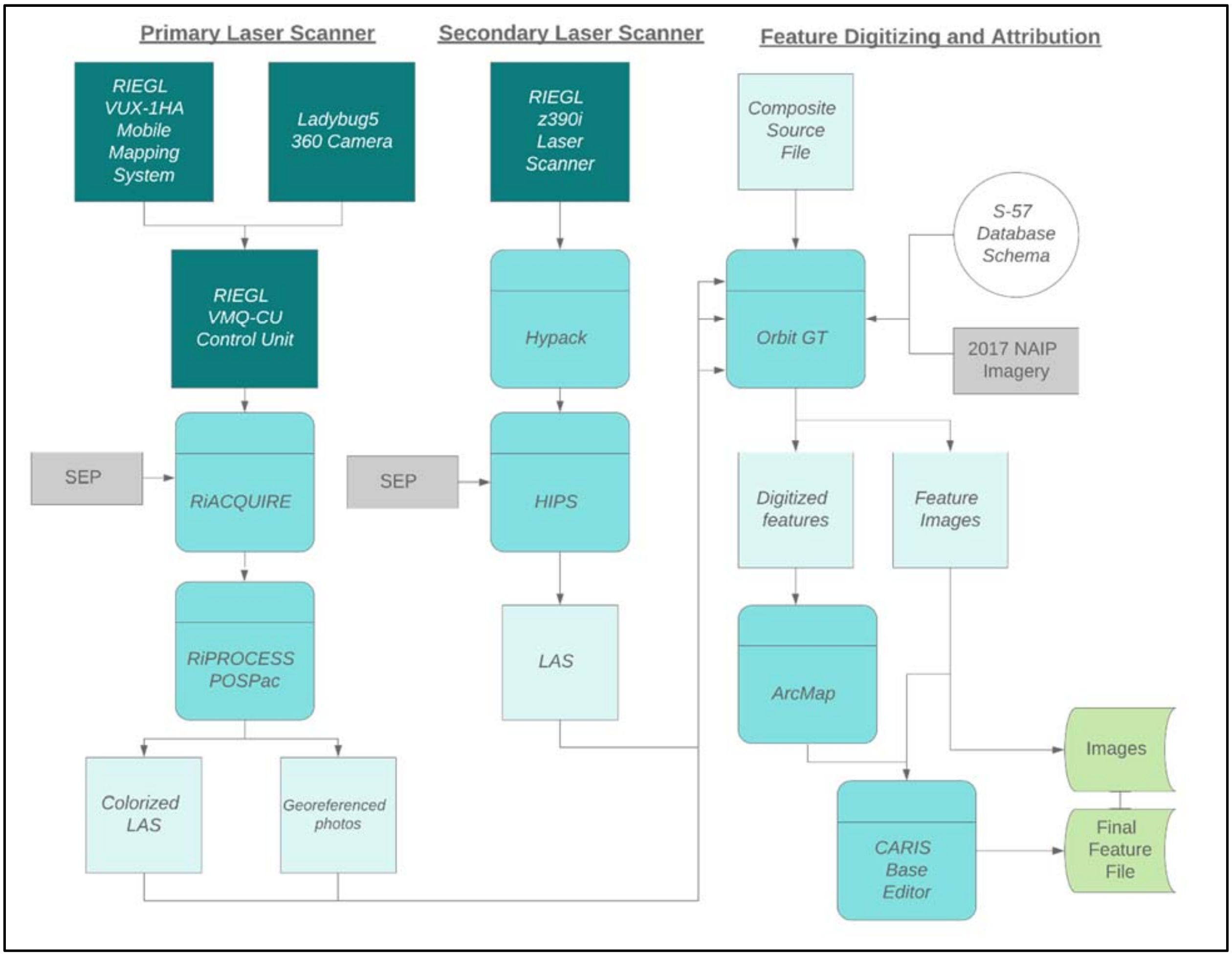

Figure 6. Flowchart of the Mobile Mapping Acquisition and Processing Pipeline

B3.a Formatting Feature Files for use in Orbit

The project's CSFs were imported into CARIS and broken into layers based upon sheet boundaries and then exported as shapefiles. In ArcMap, the features were merged based on geometry type and then additional attribute fields were added. The additional fields included but were not limited to CATMOR, CATOBS, CATSLC, COLOUR, CONDTN, descrp, remrks, and onotes.

The shapefiles were imported into Orbit as Asset Inventory Themes. The Asset Inventory tools require that all vector data is stored in a relational database. During the import process certain characters and words needed to be modified to avoid using restricted characters or reserved words.

Two Orbit workspaces were created for this project, one for each UTM Zone (15N & 16N) overlapping the project area. In addition to the coordinate system, the workspace defines which extensions, tools and asset inventory themes are available to the editors.

B3.b Formatting Supplemental Files for use in Orbit

Publicly available NAIP imagery from 2017 was used in Orbit as a reference and for added context while digitizing. Imagery was organized by sheet limit and projected into UTM, on an as needed basis before being placed as a resource in the corresponding sheet's supplemental folder. Supporting shapefiles containing sheet boundaries, assigned scan areas and HYPACK targets acquired during multibeam operations were also used within Orbit for reference. The sheet boundary file was used to partition features in the project wide CSF file into individual survey areas. The assigned scan area polygon was used to assess whether full coverage was achieved within the targeted scan areas. The target file provided additional observations from the field crew during multibeam acquisition.

B3.c Orbit Project creation/LAS and Imagery Import

Mobile mapping data were managed within the Orbit environment by creating runs and projects. A run was created by importing one or more LAS files, images, and a trajectory (optional and only available for RIEGL VUX-1HA data). A project was a collection of multiple runs that have a common coordinate system.

All MMS data were imported to individual runs. The runs were grouped into projects, based on survey registry number. The projects were added to the appropriate workspace, based on the coordinate system.

B3.d Feature Capture/Digitization and Review within Orbit

Orbit GT allowed the team to simultaneously view the lidar and imagery data (captured from the mobile mapping system) in 2D and 3D. Assigned features included in the CSFs were overlaid and reviewed in both 2D and 3D modes in order to determine the status and accuracy of charted features. Although both 2D and 3D modes were used for spatial context and awareness, new features were only digitized using 2D mode. At the time of feature digitization, a screen capture of the imagery or LAS point cloud in 3D mode was created and tagged as the source "image" attribute in CARIS. Figure 7 is a screengrab from a typical Orbit processing session showing charted features alongside newly digitized features. The LAS point cloud and 360-degree camera imagery are visible.

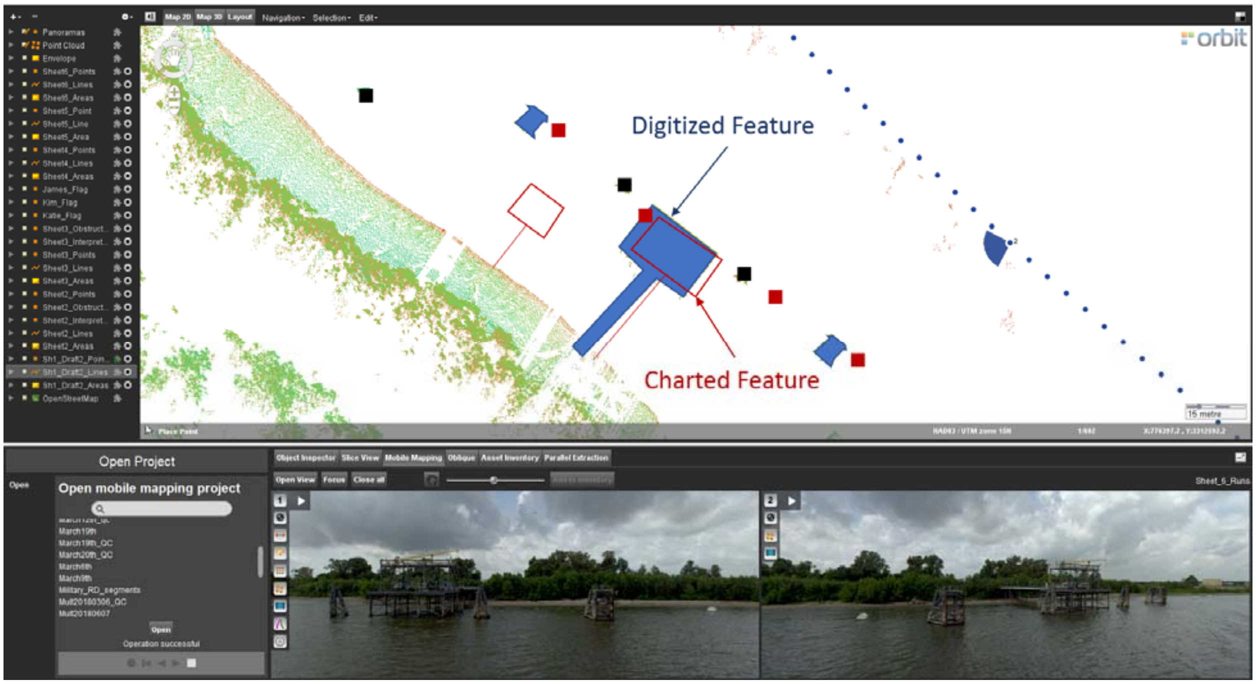

Figure 7. Example of feature digitizing and review using Orbit

Over the span of the project, through consultation with NOAA, several digitization rules were defined in order to maintain a standardized approach when addressing charted features and when new features should be captured. The following is a list of rules that were in place project-wide that aided in maintaining consistency:

- Fixed aids to navigation: if a charted ATON was surveyed more than 2 meters from the charted position, a new ATON was added. The charted ATON was attributed with descrp = Delete and the surveyed ATON was attributed with descrp = New. If the surveyed position was within 2 m of the charted ATON, the feature was retained.
- Floating aids to navigation: if a charted ATON was surveyed more than 2 meters from the charted position, a new ATON was added. The charted ATON was attributed with descrp = Delete and the surveyed ATON was attributed with descrp = New
- Unassigned charted AtoNs are in the final feature file and are attributed as descrp = Delete if the ATON was surveyed in a new position in the vicinity. Reference to the charted ATON is made in the remrks attribute of the surveyed ATON.
- Any linear features, such as piers, that were greater than 5m in width were created as area features. If a charted line feature was surveyed as a polygon feature, the charted feature would be attributed as descrp = Delete and a reference to the new surveyed polygon was made in the remrks attribute.
- Any charted point features, such as dolphins, that had a major axis greater than 5 meters and a minor axis greater than 2 meters were created as area features. If a charted point

feature was surveyed as a polygon feature, the charted feature would be attributed as descrp = Delete and a reference to the new surveyed polygon was made in the remrks attribute.

- If a surveyed pier could be determined to be floating from survey data or imagery, it was created as a PONTON feature object.
- If pier fenders were greater than 1meters from the pier face, they were digitized as a SLCONS feature.
- Any barge fleets that were surveyed were digitized for inclusion in a supplemental H13xxx_Notes_for_Reviewer.hob

Upon completion of the digitization process, each sheet was reviewed for completion using a series of quality control checks. The checks focused on accuracy of linework digitization and appropriate feature attribution. When a deficiency was identified, digitization issues were remedied, or attribution addressed and a secondary review, including MBES data, was performed in HIPS. After any rework was completed, a final review of the sheet was completed by a senior hydrographer before the sheet was exported from Orbit GT to shapefile format. Confirmation of feature name and coordinate reference system occurred before each export.

B3.e Post Digitization Editing in ArcMap

After shapefiles containing the features were exported from Orbit, additional editing was conducted in ArcMap to prepare the files for conversion into S-57 format. This included defining the coordinate system of the shapefiles, removing superfluous fields created by Orbit during digitizing, and cleaning up newly digitized linework. Snapping tools in Orbit had limited functionality and at times resulted in the creation of overshoots and undershoots at the junction between two lines. ArcMap was used resolve these mismatches in linework to ensure that lines were properly snapped together. Feature images were also renamed so that each image had a unique file name.

B3.f Feature Import into CARIS and S-57 Creation

The feature shapefiles were imported into a CARIS hob file using the Object Import Utility in Base Editor. An import script was created for each object acronym and geometry type required for import. The script defined the shapefile to be imported, the fields from the shapefile to be imported, a mapping to the appropriate S-57 attribute, and a mapping of field values from the shapefile to the appropriate S-57 attribute value. Once all the shapefiles were imported into hob format as S-57 feature objects using NOAA extended attributes (Version 5.7), additional editing on the hob occurred. Feature spatial geometry was rechecked and occasionally edited if needed. To comply with S-57 geometry rules, linework was edited where edges crossed or touched. Nodes were inserted by intersecting the edges at these locations. In a few cases, overshoots introduced by the intersection process were deleted. Attribution was added to each feature by a senior hydrographer designating whether each feature should be added, removed, updated or retained as well as any other pertinent information about the feature that should be captured. In addition, digital photos acquired during multibeam operations that provide additional context were attached where available. At this point, the baring features were ready to be combined with any submerged features identified in the multibeam data and added to the final feature file.

B3.g Overhead Clearance Computation

Orbit GT Version 19.7 was installed and used specifically for overhead clearance computation of assigned bridges and cables. Overhead clearances were computed by finding the valid LAS point with the minium elevation within a polygon. Input polygons were manully generated by DEA during processing and used to restict the minimum height query to the bounds of the overhead features. The bounding polygons for bridges were divided into sections to provide more resolution in the output reports, including clearances for bridges with multiple spans.

B4. Bathymetric Data Processing

Multibeam data processing followed the standard HIPS workflow for CUBE editing by primarily using a variety of tools and checksum processes to direct necessary edits to the multibeam data. Review of bathymetric data was conducted by reviewing multiple HIPS child layers coupled with utilizing NOAA QC Tool outputs for surface review guidance.

CARIS Process Designer was used at the onset of the data processing workflow which was initiated on the S/V *Blake* after data were acquired. Several of the steps were repeated during the data processing due to application of revised water levels and sound speed corrections. Over the course of the project, TPU was re-computed to reflect minor revisions to vessel file. The HIPS process log for each survey line includes a full audit of all steps undertaken during processing Any deviations from the following processing workflow are addressed in the individual Descriptive Reports for each survey.

B4.a CARIS HIPS and SIPS Conversion Wizard

All raw data were converted from HYPACK HSX format. The HSX contained three devices per vessel: an attitude sensor, a multibeam sonar, and a navigation device. The navigation device specified provided the tide value for all subsequent steps in the workflow. For the S/V *Blake* the secondary positioning system, the Trimble SPS 851, was responsible for writing all height information to the HSX, while the POS/MV was used for all additional navigation and attitude information. *Sigsbee* had all navigation, attitude, and tide records written from the Hydrins system for the duration of the survey.

B4.b Import Auxiliary Data

For the S/V *Blake*, real-time vessel navigation, roll, pitch, heading, and delayed heave logged to Applanix Trueheave files during acquisition were loaded into HIPS via the Import Auxiliary Data function. This replaced the navigation, roll, pitch and heading data initially converted from the HSX files and added delayed heave data for use in processing. For the RHIB *Sigsbee*, the Import Auxiliary Data tool was used to import delayed heave logged to Hydrins.log files in Trueheave format. Sensor data were recorded to Applanix Trueheave and Hydrins log files at 25 Hz and applied as mentioned in section B2.b Vessel Files.

Data acquired on *Sigsbee* prior to October 18, 2018 deviated from the standard workflow of importing auxiliary data. Section B.5 SmartHeave Post-processing describes the amendments to the application of navigation data to these data.

B4.c GPS Tides

During acquisition, ellipsoid elevations were obtained with a dedicated GNSS receiver and reduced to chart datum using Hypack KTD files as specified above. These chart datum referenced elevations were written to the .HSX file and then further reduced using documented offsets of the GNSS antenna to sonar reference point. During processing, CARIS calculated a 120-second moving average smoothed value to be applied to all data. CARIS HIPS Attitude editor was used to visually inspect applied smooth tide values. If the hydrographer was unable to 'reject with interpolation' within appropriate ranges, a HIPS.tide file was created and applied to specific lines. To ensure quality control, the tide record was exported to .tid format and assessed to identify that allowable vertical accuracies were met for all surveys. Because the KTD files used during acquisition were built from a separation model that was ultimately in need of revision, the original field observed values needed to be modified.

To ensure that all manual edits were protected, a complex multi-step process was performed. These processing steps are defined as follows:

1. Export the reviewed/edited smoothed tide sensor from CARIS to an ASCII tide file.
2. Generic Data Parse (GDP) these smoothed tides into the CARIS GPS Height sensor for each line. Resulting in incorrect GPS height sensor values but containing the reviewed tide values to be further processed.
3. Compute GPS Tide using an inverse separation model of that used during acquisition. Resulting in a GPS tide with ellipsoid values, effectively backing out the model that was in error.
4. Exporting the GPS Tide sensor from CARIS to a new ASCII tide file containing the actual GPS Heights.
5. GDP these new files into the CARIS GPS Height sensor for each line. Thereby overwriting the previously incorrect GPS heights with the correct ellipsoid value to have written to this sensor.
6. Compute GPS Tide using the revised separation model. Resulting in correct LWRP depths at the correct times and places.

This method, while correcting the separation model issues, also ensured that all data being submitted is in a similar state that NOAA is familiar with. Furthermore, if a new separation model is deemed more accurate in the future, these data can easily be transformed using typical work flows that exist in CARIS.

B4.d Sound Speed

All sound speed profiles were concatenated into a daily file per vessel. The profiles were applied using the 'nearest in distance within time' option. 'Delayed heave' source and 'use surface sound speed' were selected for all sound speed corrections. Time selection was based on appropriate application per survey area. Except for H13212, all survey areas experienced minimal to no variation from sound speed and were corrected using a time window of four hours. The H13212 survey area is influenced by the Gulf of Mexico, and therefore cast frequency was increaseed during acquisition to capture variations in sound speed. To adequately capture this change in HIPS, sound speed profiles were applied using the nearest in distance within a 1 hour time window. Any adaptation from the standard acquisition and processing workflow for sound velocity is addressed in detail in individual survey Descriptive Reports.

B4.e Merge

As mentioned, during acquisition RTK tides were smoothed and applied during the merge process. Observed and predicted tides, delayed heave and a smooth tide sensor were applied to all data. Due to a discrepancy in the vertical separation model, a variable workflow was identified and applied to all data collected for this survey, as outlined in section B4.c GPS Tides. All submitted data are merged with GPS Tides, delayed heave source, and no smooth sensors applied. The revision of the separation model is detailed below in section C4. Tide and Water Level Corrections.

B4.f Compute Total Propagated Uncertainty

The vertical uncertainty for the separation model was provided in the *Project Instructions* and used in the computation of sounding TPU. The separation uncertainty was entered in the HIPS Tide Value Zoning field during TPU computation at 1-sigma. An uncertainty estimate of 3 centimeters was entered to account for inaccuracies of the RTK GNSS network height solution. Sound speed and tide TPU values applied to all data are listed in Table 10.

Table 10: TPU Computation Values in CARIS HIPS

Total Propagation Uncertainty Computation in CARIS HIPS	
Tide Values	**1-Sigma Uncertainty (m)**
Tide Value Measured	0.030
Tide Value Zoning	0.084
Sound Speed Values	**1-Sigma Uncertainty (m/s)**
Sound Speed Measured	1.000
Surface Sound Speed	0.500

During TPU computation, HIPS also used real time uncertainty estimates logged during acquisition. For total vertical uncertainty this included ranged errors output by the sonars. For total horizontal uncertainty this included Root Mean Square (RMS) values for position, roll, pitch, and heading.

B4.g Filter Observed Depths

Soundings with quality flags assigned as 0 and 1 were rejected on import. The HIPS Filter Observed Depths tool was used to reject data based on International Hydrographic Organization (IHO) Order and beam angle. All data were filtered based on IHO Order 1a limits. Angular swath filters were applied as necessary and on a survey specific basis. Additional angular filters applied to specific days are detailed in each survey's Descriptive Report.

B4.h Data Review and CUBE Surface Creation

HIPS Process Designer was run at the conclusion of each survey day using a process model that included all steps detailed above. Single resolution CUBE surfaces were created over the entire survey area using Object Detection grid-resolution thresholds and resolution dependent maximum propagation distances as specified in the NOS HSSD. Other gridding options selected were IHO S-44 Order 1a sounding cut off values and the 'Density and Local Disambiguation' method. All processing computers were set up to use the 2017 NOAA CUBE parameters file.

Surfaces were reviewed for artifacts indicative of systematic errors, data fliers impacting the surface, and for consistency with the grid requirements set in the HSSD.

Node density was evaluated to verify that at least 95% of soundings were populated with at least five soundings. All multibeam data collected were reviewed in HIPS 3D Subset Editor with the in-house defined shoal biased reference surface active.

Soundings rejected by quality filters, with the exception of filtered TPU, were displayed during editing and any feature removed by a filter was manually re-accepted. Fliers making the CUBE surface shoaler than expected by more than the allowable IHO Order 1a vertical error were rejected. Designated soundings were used as necessary to force the finalized depth surface through reliable shoaler soundings. Following requirments set in the HSSD, soundings were designated when the difference between the surface and sounding met the depth based total vertical uncertainty threshold, and the sounding was greater than 1 meter proud of the surrounding depths. In addition, data processors reviewed sounding data and CUBE surfaces for excessive motion artifacts or systematic biases. All cross lines were manually reviewed for high internal consistency between the datasets and comparison statistics were also computed using the HIPS QC Report tool.

A portion of the data processing, QC, and review was performed on the S/V *Blake* during survey acquisition. Data acquired by the RHIB *Sigsbee* were monitored in real-time and processed and reviewed onboard the S/V *Blake* shortly after acquisition. These processing routines were used to maintain up to date coverage surfaces and generate plans to fill holidays and investigate features. Dangers to Navigation (DTONs) were reported directly to the DEA project manager via a cellular modem connection to expedite submission to the processing branch. Because of the significant change that occurred within the project area since the last survey of the Mississippi River, HSD staff advised DEA to limit reporting of DTONs to immediate hazards that could cause loss of life or impact waterborne commerce.

B5. SmartHeave Post-processing

The initial processing workflow included the application of real-time heave to RHIB *Sigsbee* MBES data. Upon detailed review of *Sigsbee* data at the start of the project, a heave drift artifact was identified. However, the artifact was not present in the post-processed Hydrins delayed heave message (SmartHeave).

All Hydrins data collected prior to October 18, 2018 (DN291) were post-processed using DelphINS software. The post-processed solution included the manufacturer's 'smart heave' messages, exported in a custom *.txt file format. All data acquired prior to DN291 had the delayed heave file reapplied in CARIS using the GDP application. Post October 18, 2019, a delayed heave message was logged daily to a .log file and applied during processing in Process Designer for all RHIB *Sigsbee* data acquired for the remainder of the survey.

B6. Final Bathymetric Processing

Upon the completion of editing multibeam data in HIPS, finalized CUBE grids were generated using the 'greater of the two' option for the final uncertainty value.

Designated soundings were used as a starting point for S-57 feature creation. Designated soundings that were determined to be obstructions, rocks, wrecks, or other significant features were imported into the S-57 feature files and attributed. S-57 objects were created for all new and incorrectly charted baring features. Additional discussion on the baring feature workflow is included in Section B3. Mobile Mapping Data Processing.

All features were created using the NOAA Profile object catalogue version 5.7 which references the NOAA Extended Attributes defined in the NOS HSSD. All mandatory feature attributes have been populated. In addition, the Images attribute has been used to provide screengrabs of multibeam data on features.

C. CORRECTIONS TO ECHO SOUNDINGS

C1. Bar Check Comparisons

Weekly bar checks were performed to confirm that the multibeam sonar was functioning properly and static draft was accurately documented. A Ross Laboratories Inc. Model 5150 lead target ball attached to the end of a wire cable and chain, marked at 2 meters, was used to bar check the multibeam on the S/V *Blake*. The RHIB *Sigsbee* was equipped with the same target ball, which was marked at 1 meter. The marks were checked periodically with a measuring tape. The bar check device was lowered to depth below the water surface, a point above the natural bottom, where it could be clearly ensonified. The depth of the ball was compared to the depth of the ball reported by the sonars. Observations were recorded in a comparison log. Tabulated ball check comparisons may be found in the Weekly Bar Check logs included in Appendix II *Echosounder Reports.*

C2. Heave, Roll, and Pitch Corrections

The S/V *Blake* and RHIB *Sigsbee* were equipped with an Applanix POS/MV 320 V5 and an iXBlue Hydrins system, which served as the motion sensors for this survey. Both systems utilized integrated dual frequency RTK GNSS positioning and inertial reference systems.

The POS/MV 320 is a 6-degree of freedom motion unit, with a stated accuracy of 0.05 meters or 5% for heave, 0.02 degrees for roll, pitch, and heading. The Hydrins, with 3D positioning and 3-axis velocity, are stated to have an accuracy of 0.05 meters or 5% for heave, 0.01 degrees for roll and pitch, and ±0.1 degrees secant latitude. Real-time displays of the vessel motion accuracy were monitored throughout the survey with the MV-POSView controller program and via

IXSEA data logger program. The manufacturer reported accuracies, as published on the CARIS HIPS TPU website (http://www.caris.com/tpu/), were entered into the HVF and used for TPU computations for multibeam data acquired by both vessels. Schematics of the vessels and sensor set-up are located in Appendix I *Vessel Reports*.

C3. Patch Tests

Multibeam patch tests were conducted to measure alignment offsets between the IMU sensor and the multibeam transducer and to determine time delays between the time-tagged sensor data. Multiple patch tests were performed throughout the project to verify the adequacy of the system biases. Patch tests were performed periodically throughout the project including at the beginning of the project, after any system replacement, whenever the system was suspected to have contact with debris or the bottom, and at the end of the project. Each patch test consisted of a series of lines run in a specific pattern, which were then used in pairs to analyze roll, pitch, and heading alignment bias angles.

A precise timing latency test was performed by running a single line over a flat bottom with induced vessel motion. The line was then opened in HIPS Subset Editor (after applying tide and SVP corrections) and a small along-track slice of data was evaluated in the outer swath of the line for motion artifacts. Incremental changes to the roll time offset were made to evaluate the performance of the precise timing setup and to determine if a latency correction was needed.

Roll alignment was determined by evaluating the reciprocal lines run over a flat bottom used for the latency test. Pitch tests consisted of a set of reciprocal lines located on a steep slope or over a submerged feature. The yaw error was determined by running parallel lines over the same area as the pitch tests. All lines were run at approximately 3 to 6 knots. Patch tests were run in various optimal locations in the Mississippi River. Selected pairs of lines were then analyzed in HIPS Subset Editor to measure the angular sensor bias values. Visual inspection of the data confirmed each adjustment.

Sonar offsets and alignment angles computed during patch tests were input into the HVF. Sonar roll and pitch values were added to the HVF SVP1 field rather than the Swath1 field in order for the HIPS sound velocity correction algorithm to account for sonar mounting angles during ray tracing of the multbeam data. This practice is based on guidance (HIPS Request ID 01201595) received from Teledyne CARIS on July 10, 2012.

Uncertainty estimates for the MRU alignment for gyro, pitch, and roll were calculated by taking the average of the standard deviation on multiple iterations of patch test lines. Calibration values and date conducted entered into the HVFs are included in Appendix II *Echosounder Reports*.

C4. Tide and Water Level Corrections

ERS methods with RTK GNSS was used for sounding reduction. Correctors were obtained from the C4GNet RTN, described earlier in this report. NAD83 (2011) ellipsoid heights were reduced to chart datum using a separation model provided by NOAA. Chart datum for the project area included two datums, Mississippi River Low Water Reference Plane, 2007 (LWRP) up river of mile 13.4 AHOP and Mean Lower Low Water down river of mile 13.4 AHOP.

Initially, the separation model NAD83-LWRP2007_MLLW12B_Buffered, provided to DEA by NOAA on August 27, 2018, was used to reduce soundings to chart datum. The separation model was applied in real-time during acquisition and used to develop preliminary products in the field, including coverage maps used to determine if the project's 2-meter inshore limit was achieved.

Throughout the project, vessel tide floats were used to record water surface elevations obtained by ERS methods at fourteen water level gauges operated by USACE and NOAA within project extents. These floats were performed as quality control checks to confirm the accuracy of the computed GPS water levels and the validity of the separation model. Table 11 lists the gauge where vessel floats occurred.

Table 11. Vessel Float Locations

Water Level Gauge	River Mile	ID	Operator
Baton Rouge, LA	226 AHOP	01160	USACE
Donaldsonville, LA	174 AHOP	01220	USACE
Reserve, LA	139 AHOP	01260	USACE
Bonne Carre North of Spillway, IHNC	129.2 AHOP	01275	USACE
Bonne Carre, LA	127 AHOP	01280	USACE
New Orleans, LA	103 AHOP	01300	USACE
IHNC Lock	92.7 AHOP	01340	USACE
Algiers Lock	88 AHOP	01380	USACE
Alliance, LA	62 AHOP	01390	USACE
Venice, LA	10 AHOP	01480	USACE
West Bay	5 AHOP	01515	USACE
Pilottown, LA	1 AHOP	8760721	NOAA
Head of Passes	0	01545	USACE
Southwest Pass	7.5 BHOP	01575	USACE
Southwest Pass East Jetty	17.9 BHOP	01670	USACE
Pilots Station East, Southwest Pass, LA	17.9 BHOP	8760922	NOAA

These comparisons identified discrepancies between NOAA and USACE river datums and inaccuracies in the separation model used during acquisition. DEA notified HSD about these issues on May 1, 2019 and received a revised model on June 21, 2019. This revised model, NAD83-LWRP2007_RM13.4_MLLW2012-2016_Geoid12B, was applied to all multibeam and MMS laser point data collected in support of this project.

Discussion of the tide float results and separation model analysis is detailed in the *Horizontal and Vertical Control Report.*

C5. Sound Velocity Correction

Checks were completed to verify pressure sensor and sound speed instrument performance. Corrections for the speed of sound through the water column were computed for each sensor. Sound speed profiles were imported and overlaid for comparison into an Excel file. All comparisons were well within survey specification. Sound speed check results are included in Separate II *Sound Speed Data Summary* of the Descriptive Reports.

The sound speed correction was applied to each line using the 'nearest in distance within time (four hour)' option in the HIPS SVP correct routine. All casts were concatenated into a HIPS

SVP file for each survey day. Time, position, depth, and sound speed for each profile were included in the HIPS file. Profiles above Head of Passes were generally vertically consistent with more variable structure observed in the lower portion of Southwest Pass.

D. APPROVAL SHEET

The letter of approval for this report follows on the next page.

DAVID EVANS AND ASSOCIATES INC.

LETTER OF APPROVAL

OPR-J347-KR-18
DATA ACQUISITION AND PROCESSING REPORT

This report and the accompanying data are respectfully submitted.

Field operations contributing to the accomplishment of OPR-J347-KR-18 were conducted under my direct supervision with frequent personal checks of progress and adequacy. This report and associated data have been closely reviewed and are considered complete and adequate as per the OPR-J347-KR-18 *Statement of Work* (November 19, 2018) and *Hydrographic Survey Project Instructions* (August 8, 2019).

Digitally signed by Jon L. Dasler
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Jonathan L. Dasler, PE, PLS, CH
NSPS/THSOA Certified Hydrographer
Chief of Party

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David Evans and Associates, Inc.
August 2018

E. TABLE OF ACRONYMS

AHOP	Above Head of Passes
AML	Applied Microsystems, Ltd
ATON	Aid to Navigation
BHOP	Below Head of Passes
CO-OPS	Center for Operational Oceanographic Products and Services
CORS	Continuously Operating Reference Station
CSF	Composite Source File
CUBE	Combined Uncertainty and Bathymetry Estimator
DEA	David Evans and Associates, Inc.
DTON	Danger to Navigation
ERS	Ellipsoid Reference System
FM	Frequency Modulated
GAMS	GNSS Azimuth Measurement Subsystem
GDP	Generic Data Parse
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HIPS	Hydrographic Information Processing System
HOB	Hydrographic Object Binary
HSD	Hydrographic Surveys Division
HSSD	Hydrographic Survey Specifications and Deliverables
HSX	HYPACK Hysweep File Format
HVF	HIPS Vessel File
IHO	International Hydrographic Organization
IMU	Inertial Motion Unit
INS	Inertial Navigation System
LAS	Airborne Lidar Data File
MBES	Multibeam Echo Sounder
MMS	Mobile Mapping System
MVP	Moving Vessel Profiler
NAS	Network Attached Storage
NGS	National Geodetic Survey
NMEA	National Marine Electronics Association
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NTRIP	Networked Transport of RTCM via Internet Protocol
POS/MV	Position and Orientation System for Marine Vessels
PPS	Pulse per Second
PRF	Project Reference File
RHIB	Rigid-hulled Inflatable Boat
RMS	Root Mean Square
RTK	Real-time Kinematic
SNM	Square Nautical Miles
S/V	Survey Vessel
SVP	Sound Velocity Profiler
TPU	Total Propagated Uncertainty
USACE	United States Army Corps of Engineers
USCG	United States Coast Guard
UTM	Universal Transverse Mercator
ZDA	Global Positioning System Timing Message