W00437

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Ocean Service

DESCRIPTIVE REPORT

Type of Survey:	Navigable Area
Registry Number:	W00437

LOCALITY

State(s):	Mississippi
General Locality:	Mississippi Coastline
Sub-locality:	Pass Christian Harbor

2015

CHIEF OF PARTY
Alberto Neves

LIBRARY & ARCHIVES

Date:

U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION	REGISTRY NUMBER:
HYDROGRAPHIC TITLE SHEET	**W00437**

INSTRUCTIONS: The Hydrographic Sheet should be accompanied by this form, filled in as completely as possible, when the sheet is forwarded to the Office.

State(s):	**Mississippi**
General Locality:	**Mississippi Coastline**
Sub-Locality:	**Pass Christian Harbor**
Scale:	**40000**
Dates of Survey:	**06/08/2015 to 06/18/2015**
Instructions Dated:	**N/A**
Project Number:	**ESD-PHB-18**
Field Unit:	**University of Southern Mississippi**
Chief of Party:	**Alberto Neves**
Soundings by:	**Kongsberg Maritime EM 2040C (MBES)**
Imagery by:	**N/A**
Verification by:	**Pacific Hydrographic Branch**
Soundings Acquired in:	**meters at Mean Lower Low Water**

Remarks:

Any revisions to the Descriptive Report (DR) applied during office processing are shown in red italic text. The DR is maintained as a field unit product, therefore all information and recommendations within this report are considered preliminary unless otherwise noted. The final disposition of survey data is represented in the NOAA nautical chart products. All pertinent records for this survey are archived at the National Centers for Environmental Information (NCEI) and can be retrieved via https://www.ncei.noaa.gov/. Products created during office processing were generated in NAD83 UTM 16N, MLLW. All references to other horizontal or vertical datums in this report are applicable to the processed hydrographic data provided by the field unit.

DESCRIPTIVE REPORT MEMO

October 19, 2021

MEMORANDUM FOR: Pacific Hydrographic Branch

FROM: Report prepared by PHB on behalf of field unit
Alberto Neves
Hydrographic Science Program Coordinator, University of Southern Mississippi

SUBJECT: Submission of Survey W00437

The primary objective of conducting a hydrographic survey in this area was to investigate the bathymetry and sediment movement around the harbor using a tilted Multibeam Echo Sounder (MBES). While the attached report includes discussion of a pole mounted Side Scan Sonar (SSS), this data was not provided to NOAA and no products were generated as a result. The survey also provided positions for the newly constructed Aids to Navigation (ATONs), for the new harbor approaches, and bathymetry for those approaches.

A MBES surface, gridded at 50cm, was produced from this survey.

All soundings were reduced to Mean Lower Low Water using Discrete Zoning. The horizontal datum for this project is North American Datum of 1983 (NAD 83). The projection used for this project is Universal Transverse Mercator (UTM) Zone 16.

All survey systems and methods utilized during this survey were as described in the Data Acquisition and Processing Report with the exception of the pole mounted Side Scan Sonar data, which was not provided and could not be validated.

Two DTONs were submitted to MCD from the original 2015 survey. They were confirmed to be charted as submitted. Additional attributions was provided during review.

University of Southern Mississippi acquired the data outlined in this report. Additional documentation from the data provider may be attached to this report.

This survey does meet charting specifications and is adequate to supersede prior data.

THE UNIVERSITY OF SOUTHERN MISSISSIPPI
HYDROGRAPHIC SCIENCE PROGRAM

15USM02
Descriptive Report

Pass Christian Harbor and Approaches

University of Southern Mississippi Class of 2015

Associated Authors

Dominic Correa

Maylord De Chavez

Min Sung Kim

Chris McHugh

Michiel Mosch

Imtiaz Shaikh

Short Details

Type of Survey:	Ellipsoid Referenced Hydrographic Survey
Locality:	Pass Christian, Mississippi
Date:	08 June – 18 June 2015
Vessel Used:	University of Southern Mississippi's R/V GCGC
Registry Number:	15USM02
Team Members:	Dominic Correa
	Maylord De Chavez
	Min Sung Kim
	Chris McHugh
	Michiel Mosch
	Shaikh Imtiaz bin Firoz
Chart No. and Scale:	NOAA Chart 11371 (Scale 1: 80,000) and 11372 (Scale 1: 40,000)
Product Scale:	Bathymetric Sheet (1: 2,500), ENC (1: 2,500)
Positional Accuracy:	IHO Special Order
	NOAA 1-m Object Detection Survey
Horizontal Datum:	NAD83 (2011/MA11/PA11) (Bathymetric Sheet), WGS84 (G1674) (ENC)
Sounding Datum:	MLLW (NTDE 1983-2001)

Table of Contents

List of Figures

List of Tables

Acronyms DR

ATONs	Aids to Navigation
BAC	Beam Angle Correction
BWYC	Bay Waveland Yacht Club
COALNE	Coastline
CUBE	Combined Uncertainty and Bathymetric Estimater
DAPR	Data Acquisition and Processing Report
DD	Decimal Degree
DEPARE	Depth area
DEPCNT	Depth Control
DGPS	Differential Global Positioning System
DTON	Dangers to Navigation
EGN	Empirical Gain Normalization
ENC	Electronic Navigation Chart
GAMs	GPS Azimuth Measurement Subsystem
GCGC	Gulf Coast Geospatial Center
GNSS	Global Navigation Satellite System
Gt	Great diurnal range
HSS	Hydrographic Survey Specifications
HVCR	Horizontal and Vertical Control Report
HWI	High Water Interval
IHO	International Hydrographic Organization
ITRF	International Terrestrial Reference Frame
LNDARE	Land Area
LWI	Low Water Interval
MBES	Multibeam Echo Sounder
MLLW	Mean Lower Low Water
MSL	Mean Sea Level
NAD83	North American Datum of 1983
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Survey
NTDE	National Tidal Datum Epoch
PCYC	Pass Christian Yacht Club
POS MV	Applanix Position and Orientation System for Marine Vehicles
PPK	Post Processed Kinematic
PPS	Pulse per Second
PU	Processing Unit
QC	Quality Control
RTK	Real Time Kinematic
RTN	Real Time Network

SEP	Separation Between Ellipsoid and Chart Datum
SIS	Seafloor Information System
SLCONS	Shoreline Construction
SSS	Side Scan Sonar
SVP	Sound Velocity Profiles
TPU	Total Propagated Uncertainty
USM	The University of Southern Mississippi
VCS	Vessel Configuration Survey
VRS	Virtual Reference Station

A. Area Surveyed

A.1 Purpose and Description

The survey designated 15USM02 was conducted to meet the specifications of The University of Southern Mississippi (USM). It was designed and executed in accordance with the requirements of the National Oceanic and Atmospheric Administration (NOAA) and International Hydrographic Organization (IHO). The survey will be made available to NOAA Coast Survey, City of Pass Christian, and Pass Christian Yacht Club (PCYC.

The survey area was divided into three-areas. Area 1 was specified as the primary or highest priority area of the survey. A new harbor, constructed in the past year, is an expansion of the existing Pass Christian Harbor. Current charts do not depict the new harbor. Area 2 designates the west and east approaches to the entrance of the new harbor, and Area 3 was assigned for shoreline delineation of the harbor structure.

Dredging and construction for the harbor expansion began in 2011 and was completed in 2014. The new harbor provides berthing for up to 102 commercial fishing boats and up to 62 recreational boats. The primary objective of conducting a hydrographic survey in this area was to investigate the bathymetry and sediment movement around the harbor using a tilted Multibeam Echo Sounder (MBES) and a pole mounted Side Scan Sonar (SSS). The survey also provided positions for the newly constructed Aids to Navigation (ATONs), for the new harbor approaches, and bathymetry for those approaches. The survey areas are shown in Figures 1 and 2.

Figure 1. Surveyed area overlaid on Google Earth and extents are portrayed in DD WGS84.

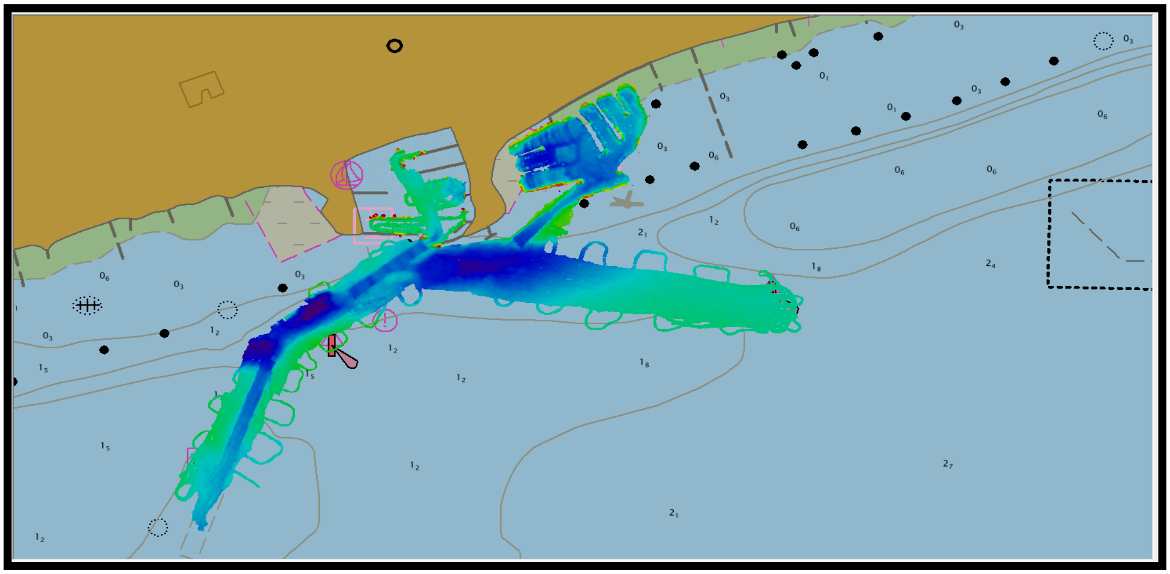

Figure 2. Combined MBES coverage overlaid on the Electronic Navigation Chart (ENC) US5MS11M.

A.2 Survey Statistics

The overall coverage statistics of each surveyed area is shown in Table 1.

Table 1. Overall survey statistics.

Area	Mainlines Linear m	Crosslines Linear m	SSS 200%m^2	Seabed Samples	ATONs
1	11325.35	2505.47 (22.1 %)			
2	67307.40	4134.77 (6.1 %)			
Total	78632.75	6640.24 (8.4 %)	149426	4	9

A.3 Chronology

All survey related activities, including calibrations and deployments, are summarized in Table 2.

Table 2. Chronology of activities.

Date	Activity
18 May 2015	Reconnaissance survey of the Pass Christian Harbor. Recovered National Ocean Survey (NOS) benchmark (BM) 6819 B 1979. Established five temporary benchmarks
19 May 2015	Tide gauge calibration inside USM Support Facility (Bldg 1029). Rigged tide staff for deployment at the Pass Christian Harbor
22 May 2015	Installed tide gauge and staff and secondary tide staff at Pass Christian Harbor. Conducted a three-wire leveling tied to the recovered and established benchmarks, tide gauge, and staff. Conducted three hours of simultaneous observation of tide. Conducted over six hours of static Global Navigation Satellite System GNSS observation over 6819 B 1979.

29 May 2015	Conducted two hours of simultaneous observation of tide
02 June 2015	Conducted vessel configuration survey (VCS) Processed VCS data to find sensors offsets
03 June 2015	Serviced Research Vessel Gulf Coast Geospatial Center (R/V GCGC) motor Installed equipment on R/V GCGC
04 June 2015	Mounted the Kongsberg MBES on the tilt mount Conducted patch test at Pearl River
05 June 2015	Trailered R/V GCGC to the Pass Christian Harbor Conducted initial MBES test at Pass Christian Harbor Concluded that all systems worked correctly. Conducted a two-hour simultaneous observation of tide
08 June 2015	Conducted a two-hour simultaneous observation of tide Collected MBES data in Area 1; transducer tilted at 30° Conducted roll test after survey Grabbed bottom samples at four different locations
09 June 2015	Conducted roll test for approach Areas 1 and 2 Conducted GPS Azimuth Measurement subsystem (GAMs) calibration test Collected MBES data to fill in holidays inside the harbor Collected MBES data at approach Areas 1 and 2 at 30° angle Kongsberg Processing Unit (PU) time was 5 hours ahead of GPS
10 June 2015	Continued MBES data acquisition; transducer mounted at 0° Positioned ATONs Determined water clarity using Secchi disk Conducted patch test at Area 1
11 June 2015	Conducted Patch Test Continued MBES data acquisition to fill in gaps Conducted crosslines survey Replaced the Kongsberg sonar head with the EdgeTech 4600 to the side mount for side scan survey Conducted side scan survey
12 June 2015	MBES data analysis and processing at PCYC
15 June 2015	Conducted MBES survey to cover holiday inside the harbor; sonar tilted to 30° Conducted roll test
16 June 2015	Conducted MBES survey to cover holidays along the approach channel, sonar mounted at 0° Trailered R/V GCGC to Stennis Space Center, MS
17 June 2015	Conducted patch test at Pearl River; EM 2040c sonar tilted at 30°
18 June 2015	Conducted two hours of simultaneous observation of tide
22 June 2015	Conducted three hours of simultaneous observation of tide
25 June 2015	Conducted three-wire leveling at Pass Christian Harbor Conducted three hours of simultaneous observation of tide Retrieved tide gauge and staffs
26 June 2015	Completed shoreline delineation
01 July 2015	Performed tide gauge re-calibration at Bldg. 1029

B. Data Acquisition and Processing

B.1 Equipment

B.1.1 Survey Vessel Equipment

The USM R/V GCGC was used for data collection. The R/V GCGC has a medium V- planning hull constructed of aluminum. The dimensions of the vessel are: 8 m in length, 2.5 m at the beam, with a draft of 0.5 m.

On 03 June 2015, the R/V GCGC was mobilized with one starboard side pole mount. The pole mount had suitable fitting plates for both multibeam and side scan sonars. The two sonars were switched when the survey with one was completed. The vessel remained mobilized and stationed at the Pass Christian Harbor throughout the survey period.

Vessel offsets and associated measurement uncertainties of the R/V GCGC were determined from two separate vessel configuration surveys conducted at the USM John C. Stennis Space Center campus on 20 April 2013 and 02 June 2015. The surveys were conducted using Leica Total Station TP S600 with observations referenced to a pre-established bolt network located behind USM Building 1029. The major equipment used during the survey is shown in Table 3.

Table 3. Descriptions and serial numbers of major equipment installed aboard R/V GCGC.

Description	Equipment	Serial Number
Multibeam	Kongsberg Transducer Kongsberg EM2040c PU	1154 10055
Side Scan Sonar	EdgeTech 4600, 540Hz (mounted)	Transducer: 215070
Attitude and Navigation	Applanix OceanMaster POS MV Zephyr 2 GNSS antennas	Applanix: 2791 Primary Antenna: 1440912441
Sound Velocity	Digibar Pro V	214819
Surface Sound Speed	AML Oceanography SV Sensor	5046
Static Observation (Base Station)	Topcon GR3	433-0511
Secondary Navigation	Topcon Net-G3	374-0659

B.1.2 Geodetic and Tidal Equipment

For approximately 33 days an In-Situ Level TROLL 700 tide gauge was installed within the vicinity of Area 2 at the T-Pier south of the PCYC building to collect tide data for approximately 33 days. An additional tide staff was installed inside the old Pass Christian Harbor, west of the In-Situ sensor to provide a confidence check for the tide data. Five benchmarks were established and connected to both the In-Situ TROLL 700 tide gauge and the tide staff by means of geodetic leveling using a Leica NA2002 Auto Level. The C-Check and level closure all met the IHO and NOAA requirements.

A dual frequency Topcon GR3 GNSS receiver was placed on a tripod over NOS benchmark 6819 B to collect data for over six continuous hours. The Topcon GR3 was also set up over the same bench mark each day prior to the start of the survey. Topcon Net-G3 rover data were combined and processed with data from the Topcon GR3 base station to provide a Post Processed Kinematic (PPK) solution. The antenna height above the benchmark was measured at the beginning and end of the GNSS session to check for inconsistencies. Geodetic and tidal equipment used during the survey are shown in Table 4.

Table 4. Geodetic and tidal equipment for tide gauge and benchmark installation.

Equipment	Description	Serial Number
In-Situ Level TROLL 700	Water level logger	144816
Topcon GR3 GNSS	Used for static observation and PPK	433-0511
Leica NA2002 Auto Level	Used to level tide gauge and staffs to benchmarks	283624

The In-Situ Level TROLL tide gauge was calibrated against a graduated tiny metal rod in a freshwater cylindrical plastic tank in Building 1029 prior to and after its deployment. The results met the NOAA 1 mm accuracy specification.

B.1.3 Data Acquisition Processing Software

Data processing software used throughout this survey are shown in Table 5 below.

Table 5. Data acquisition and processing software versions.

Software	Use	Version
Chesapeake SonarWiz	SSS processing, target Classification and mosaicking	V V5.07.0008
CARIS HIPS & SIPS	Bathymetric data processing	9.0.14
HYPACK/HYSWEEP	Collect bathymetric data	2015
Seafloor Information System ( ) v4.0	Collect bathymetric data	
EdgeTech Discover Bathymetric	Real-time collection of SSS data	33.0.1.112
Applanix Position and Orientation System for Marine Vehicles (POV MV) OceanMaster v4.0	POS view real-time monitoring and configuration of POS MV	6.05
NovAtel WayPoint GrafNav	Post-processing of Topcon GR3 and Net-G3	8.30.2105
Leica Geo Office	Post-processing of TP S300 Total Station data	
Win-Situ	Tide collection and analysis	5.6.21.0
MATLAB (Developed Code from Tide Class)	Tide analysis	5
GeographicLib	Single Separation Between Ellipsoid and Chart Datum (SEP) verification	June, 2015

B.1.4 Data Consistency

No major issue was noticed or encountered during acquisition of the MBES data. A minor issue on the first and second day was that the data for the *.all files were set primarily to log with PU time. GPS times, however, were also stamped into the file. Therefore, for the files for the 8th and 9th of June, data was imported with GPS time (ZDA string), using the CARIS HIPS and SIPS format. This was corrected on the third survey day by setting the data to be logged primarily with a GPS time stamp. Navigation was supplemented with Real Time Network (RTN) corrections through a Real Time Kinematic (RTK) connection to a Virtual Reference Station (VRS) formed by the GCGC RTN. GPS solutions oscillated between fixed and float RTK solutions.

The pulse-per-second (PPS) cable, which syncs the timing of data recording among all systems, was not connected between the Applanix OceanMaster POS MV and the EM 2040c PU. It was noticed by Dr. Ian Church on the third day during his site visit. The MBES data collection was paused for the morning session until the PPS cable was retrieved from Building 1029 at Stennis Space Center. When comparing the data with just ZDA time sync against data with ZDA plus PPS, no major differences were noticed inside the harbor. To assure the first two days of data collection were accurately covered, the areas were re-surveyed with the PPS cable attached.

PPK data were obtained using the surveys base station data (TopCon GR3) set up over the primary benchmark (NOS BM 6819 B). These data were used as the navigation source for MBES processing. Ambiguities were fixed for 98% of the survey with a few cycle slips and floating integer ambiguities at infrequent points during each day. Uncertainties were consistently low.

B.2 Quality Control

B.2.1 Cross-line Comparison

The CARIS HIPS Line Quality Control (QC) Report tool was used to perform cross-line comparisons between the 30° tilt and 0° tilt data. A finalized Combined Uncertainty and Bathymetric Estimator (CUBE) surface was made of only cross check lines. Then the main scheme lines were compared to this surface using the QC Report tool. The QC Report tool was set to compare main scheme lines to cross-lines at a ten-beam interval. All beams have a performance higher than IHO Special Order at the 95% confidence interval (Cl). Table 6 shows the summarized crossline results by beam number of Area 1, Area 2, and total areas, respectively. The total QC output can be found in Appendix I

Table 6. QC Report results for each area and combined. All areas meet IHO Special Order at a 95% CI.

Area	Average Max (+) (m)	Average Min (-) (m)	Average Mean (m)	Average Std. Dev. (m)	Special Order (%)	Order 1A (%)
Area 1	0.554	2.013	-0.005	0.061	99.667	99.964
Area 2	0.469	0.560	-0.017	0.039	99.929	99.997
All Areas	0.831	2.367	-0.009	0.069	99.483	99.928

B.2.2 Coverage and Junctions

The quality assurance for the finalized CUBE surface was done using CARIS HIPS and SIPS. There were 25 holidays detected in Area 1 and 86 holidays detected in Area 2. Statistical results of finalized CUBE surfaces of Area 1, Area 2, and all areas are shown in Section 3.1.4 of the Data Acquisition and Processing Report (DAPR). There are numerous holidays greater than two nodes. Most of these are from gaps around/under/behind harbor structures (seawalls and piers) and not located in navigable waters. The remaining holidays do not affect the survey from meeting IHO Special Order or NOAA object detection specifications due to 200% SSS coverage in bathymetric areas. There are also no MBES or SSS holidays over significant target features. Data sets from both areas were merged so one single area CUBE surface could result in a smooth overlap between Areas 1 and 2.

B.2.3 Sonar Confidence Checks

The performance of each sonar was checked before data acquisition. SSS checks were conducted on pilings within the old Pass Christian Harbor near the vessel's berth. Real-time mosaics were monitored to ensure correct placement of the passing pilings at the start and end of each survey day. MBES confidence checks were done by overlaying base surfaces from the patch test site on the Pearl River where different sonar systems (RESON 7125, EM 2040C, and EdgeTech 4600) were used. The EM 2040C was also checked against a single beam and gave the same depths at the same position over time. These checks indicated that the sonars were capable of resolving objects that met the NOAA and IHO specifications designated for this survey.

For a final confidence check and quality control measure for multibeam data, leadline soundings were taken at five different positions in the new marina of Pass Christian on 22 July 2015. A heavy shackle tied to a line graduated at half meters was used. The positions of the soundings were determined with a handheld GNSS device. The vertical accuracy achieved is expected to be around 0.15 m in water depth up to 3 m. The horizontal accuracy was around 3 m using a stationary Differential Global Positioning System (DGPS) receiver. Soundings were reduced to Mean Lower Low Water (MLLW) and compared to the MBES MLLW surface. Depths agreed to within 0.10 m.

B.2.4 Other Factors Affecting Quality

Vessel stability played a major role in this survey. The R/V GCGC is not a well-balanced boat making it difficult to maneuver. Severe roll instability in moderate to rough seas led to high signal to noise ratios and data gaps in the MBES coverage. A large play in the steering system, inoperable trim tabs, and vessel design made straight line steering almost impossible even for experienced captains.

B.2.5 Sound Speed Collection Methods

Sound speed profiles were collected off the back deck of the R/V GCGC every half hour or whenever the SIS warned that the surface sound speed was (+/-) 2 m/s different than the previous Sound Velocity Profiles (SVP). The high number of SVP casts were done to account for the higher refraction errors that are associated with a tilted MBES.

B.2.6 Specification Deviations

The survey did not deviate from the developed hydrographic survey specifications (HSS). Due to the small size of the survey area, the team was able to finish both multibeam and sidescan data collection within the proposed timeline. The multibeam data were carefully analyzed and cleaned. From the clean data, the team realized that 100% ensonification was not achieved and some holidays existed. All equipment and survey methods used can be found in detail in the DAPR.

B.3 Corrections to Echo Sounding

B.3.1 Vessel Configuration

All corrections to echo soundings conformed to those detailed in the DAPR.

B.3.2 Calibration

Patch tests was conducted on 05 June 2015 and 17 June 2015 on the Pearl River. The test used the 30° tilt transducer. When the transducer was rotated to a zero degree position, another patch test was conducted in the old Pass Christian Harbor over a small target that was found on the first survey day. Daily roll offset checks were performed at the beginning of each survey day. Patch test checks were performed each day on areas where track lines allowed the calibration to be run. This led to some minor changes to the original patch-test values mainly caused by weight distribution of the vessel changing from day to day. These changes were applied in the CARIS vessel file for the respective day. The values from each day are shown in Table 7. Figure 3 shows the initial patch test surface overlaid with track lines. The DAPR, Section 4.1.2, has further detailed calibration information and surfaces.

Table 7. Calibration results.

Day	Pitch	Roll	Yaw
06/08/15	-0.87	-1.30	2.28
06/09/15	-0.87	-1.30	2.28
06/10/15	0.67	-1.60	1.75
06/11/15	0.67	-1.85	1.75
06/15/15	-0.87	-1.73	2.10
06/16/15	-0.87	-1.30	2.10
06/18/15	-0.87	-1.20	2.10

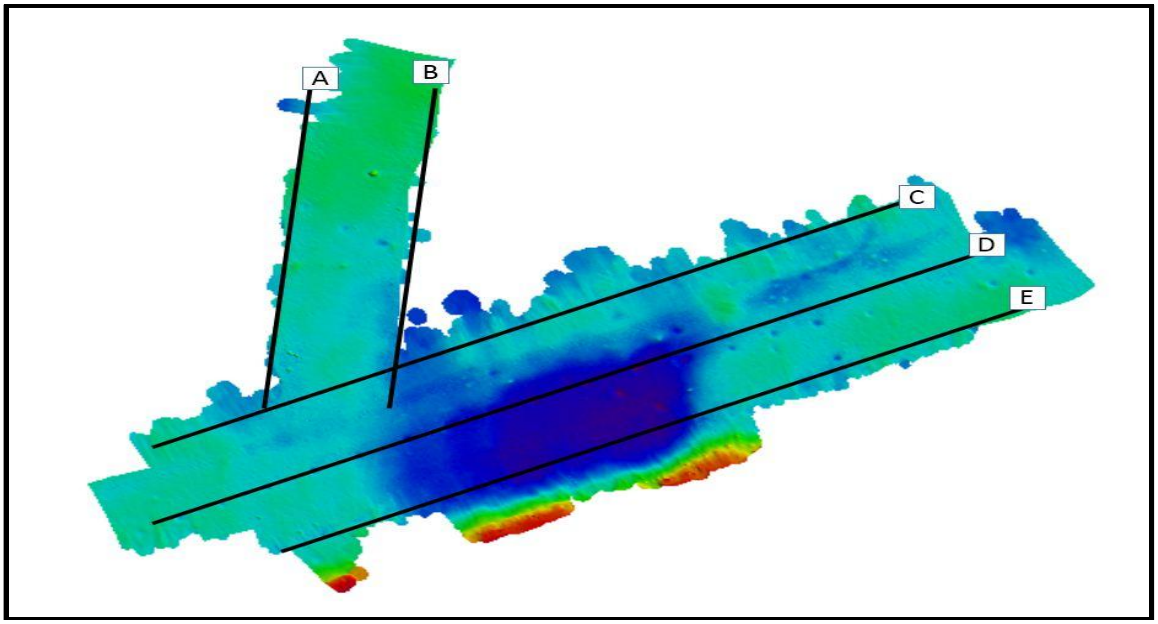

Figure 3. Patch test survey lines overlaid on the processed surface.

B.4 Backscatter

Backscatter data were collected using EM 2040C at 300 kHz frequency. The data were not used for analysis of targets. The backscatter was only used for generalized visualization of seafloor hardness/roughness. The nature of the seabed and target detection/identification was analyzed using Edgetech4600 side scan sonar. The backscatter of EM 2040c is shown in Figure 4.

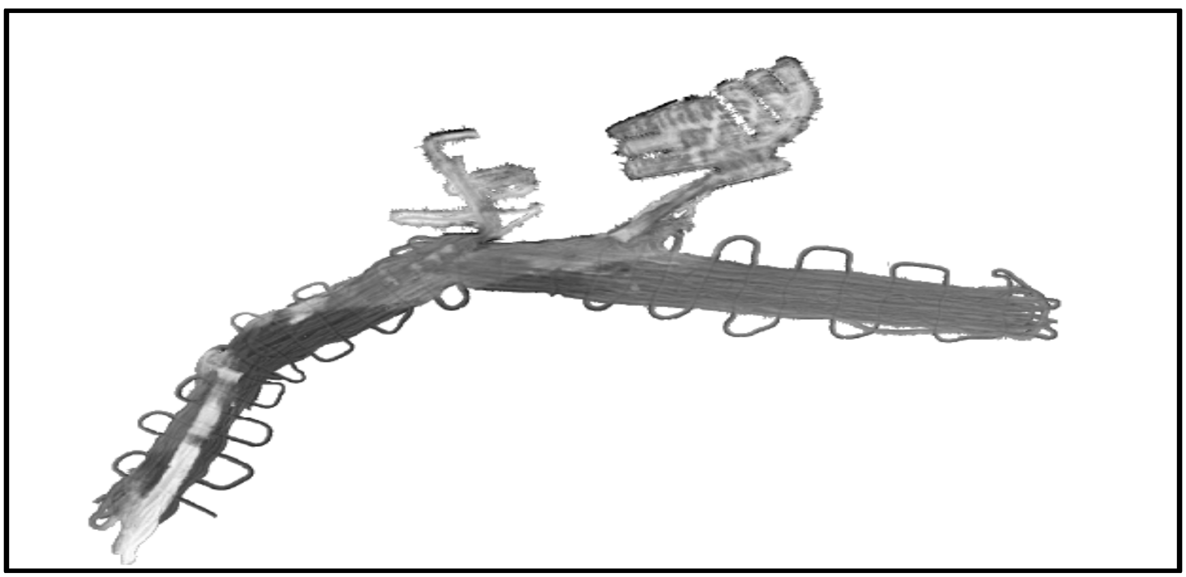

Figure 4. Backscatter image from EM 2040c. Higher intensity returns are defined by darker contrasts. Low intensity defined by lighter contrasts.

B.5 Data Processing

B.5.1 Software Updates

There are no software versions that have been updated or changed from the details listed in the DAPR.

B.5.2 Preliminary CUBE Surfaces

The *.all files from the EM2040C were brought into CARIS HIPS. Data reduction and cleaning procedures were followed. Each line was cleaned individually in swath editor then cleaned again as a merged surface in subset editor. After cleaning, 0.5 m (0.5 m was chosen because it is half the object detection size of 1-m) gridded CUBE and swath surfaces were created. A 0.5m backscatter intensity surface was also created to help with feature detection while cleaning. Feature detection was also aided by the compiled georeferenced SSS mosaic.

B.5.3 Subset Editing

Preliminary surfaces were examined for any areas that needed further cleaning or hypothesis editing. After this was completed a finalized surface was created. This was used for Total Propagated Uncertainty (TPU) calculations and deliverables.

B.5.4 CUBE Finalization

After editing was complete the CUBE surface was finalized and TPU calculations were done for the entire surface using the quality control tool in CARIS HIPS and SIPS. Results can be seen in Figure 5 and Table 8.

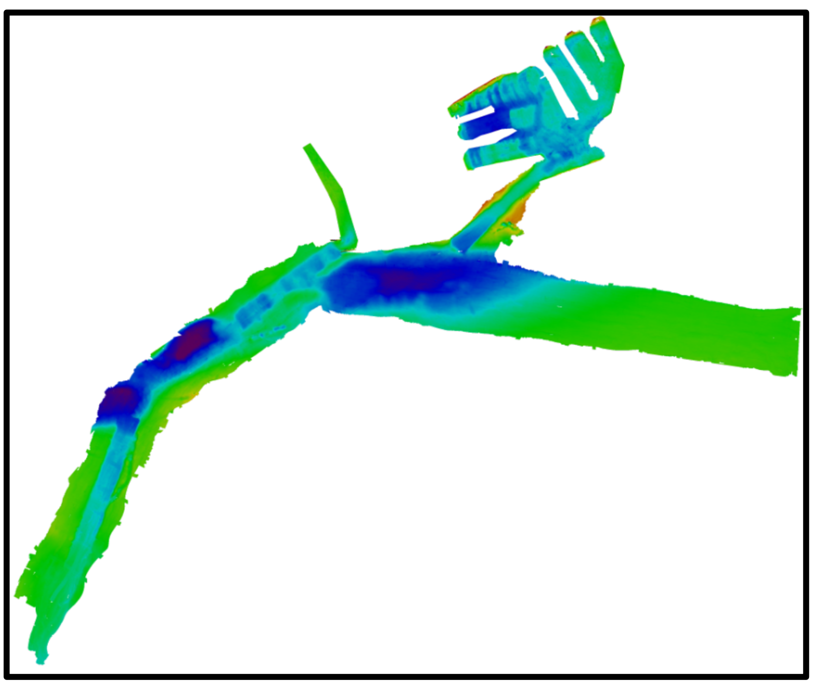

Figure 5. Finalized 0.5-m CUBE surface ready for export.

Table 8. TPU results from the finalized CUBE surface for all Areas.

All Areas		
Holidays Detected	111	
Range	- 1.00 to 4.00	
Number of Nodes Considered	1448782	
Number of Nodes within	IHO S-44 Special Order	1439439 (99.36%)
	S-44 Order 1A	1448585 (99.99%)
Residual Mean	IHO S-44 Special Order	-0.186
	S-44 Order 1A	-0.436

Once TPU results were calculated and accepted, finalized MBES .csar files and backscatter .csar files were exported and saved in the HSS specified file structure to deliver to NOAA.

B.5.5 SSS Mosaics

After importing the SSS data files into SonarWiz they were checked and amended, if needed, for a correct bottom track. For the final gain settings Beam Angle Correction (BAC) was enabled with a value of 30 for Pings and 20 for Average. The Empirical Gain Normalization (EGN) Table was rebuilt and EGN was enabled with an intensity of -4 for both port and starboard side. The resulting mosaic had a relatively equal intensity and clarity for the entire survey area. Small objects could be detected easily by the depicted echoes and distinctive shadows. Georeferenced Tiff files were exported (Figure 6) as a deliverable, as well as target reports for possible Dangers to Navigation (DTONs).

Figure 6. SSS mosaic georeferenced and exported into Google Earth for visualization.

B.5.6 Feature Selections

According to the specifications the minimum object size that needs to be resolved is 1 m cubed. However, considering the relatively shallow depth of the survey area of around 2.5 m to 3 m, all detected objects with a measured height of a few decimeters were included in the Contact Report. Contacts with a measured height of close to 0.5 m or more were given special attention and checked whether they could be considered as a danger to navigation. Only one of the detected objects had a measured height of more than 1 m. All the objects were found in the approaches to both marinas and none inside the new marina itself. The charted wreck in the western approach could not be found in either SSS or MBES data. There are some objects in the vicinity of the charted position of the wreck. However, none of these could be identified as remains of the wreck itself.

C. Vertical and Horizontal Control

For further details refer to the Horizontal and Vertical Control Report (HVCR).

C.1 Vertical Control

C.1.1 Vertical Datum

The Pass Christian Survey used MLLW National Tidal Datum Epoch (NTDE) 1983-2001 as the vertical datum. All vertical and horizontal positions were referenced to the North American Datum of 1983 (NAD83) (2011/MA11/PA11) Epoch 2010 (except for ENC creation, which was done in WGS84), utilizing the GRS80 Ellipsoid.

C.1.2 Existing Tidal Infrastructure

Bay Waveland Yacht Club (BWYC) gauge (ID #: 8747437) is the nearest tide gauge (about 4.5 nautical miles away) to the Pass Christian Harbor and its approaches. It is operated by the NOAA NOS.

A temporary tidal station was deployed at the PCYC (ID #: 8746819) from 20 June 1979 to 17 December 1980. The historic tidal station datum was analyzed for the period of 01 December 1979 up to 30 November 1980. On 12 June 2003, the tidal datum was accepted and was valid for the current NTDE 1983 -2001 epoch.

C.1.3 Tide Gauge Calibration

The pressure type In-Situ Level TROLL 700 tide gauge was calibrated in a freshwater cylindrical tank at John C. Stennis Space Center before and after deployment. The gauge met the NOAA’s 1-mm resolution specification. Pre-deployment calibration was done on 19 May 2015. During post-deployment calibration, it was observed that the sensor readings were about 0.15 m off the actual water height. It was suspected that the discrepancy with the gauge happened during the dismantling of the tide gauge. A least-squares linear fit of the data from the simultaneous observations between tide staff and tide gauge readings was conducted. This was done to ensure there were no significant changes in the uncertainty with tide gauge readings from the initial calibration up to its deployment. Maximum water level reading uncertainty of the tide gauge remained the same from the initial calibration to before its retrieval. A 0.005 m tide gauge water level measuring uncertainty was used in the computation of the SEP uncertainty value. More detailed calibration can be found in the HCVR.

C.1.4 Tidal Zoning

Pass Christian project site is relatively small in terms of area coverage and is situated in between two operational NOAA tide stations—Bay Waveland and Pascagoula. Bay Waveland tide station is about 7.5 km from the survey area and 72 km from Pascagoula. There used to be a NOAA tide station at Cat Island, which is about 15 km southeast of Pass Christian. All three stations (Figure 7) have published datums corrected to the present NTDE Epoch 1983-2001.

Figure 7. Nearest NOAA tide station to the survey area.

Considering Bay Waveland as the main tide gauge and using the published great diurnal range (Gt) values (Table 9), a linear interpolation was done to generate co-range curves. From the co-range curves it was shown that a single tide range value may be used for the entire Pass Christian survey. A 0.506 m Gt for Pass Christian was determined from the datum transfer.

There were no high water interval (HWI) or low water interval (LWI) values published for all three stations. To test whether a single tide phase may be used for the entire survey area, the differences in time of high and low waters in Pascagoula (verified) and Cat Island (predicted) with Bay Waveland from 01-25 June 2015 were noted. During the same period, the time difference values between high water and low water between Bay Waveland and the USM-established tide station in Pass Christian were also noted. Both the mean high water and mean low water time intervals between Bay Waveland and Pass Christian were approximately 0.04 hours (2.4 minutes). This confirms that a single tide zone is sufficient for the whole survey area. More details on tide zoning are discussed in HVCR.

Table 9. NOAA published great diurnal range (Gt) values for tide stations surrounding the survey.

Status	Station	Great Diurnal Range (Gt) NTDE Epoch 1983-2001 (m)
Accepted (Feb 16 2012)	8747437, Bay Waveland Yacht Club, MS	0.529
Accepted (Aug 23 2012)	8741533, Pascagoula NOAA Lab, MS	0.468
Accepted (Feb 03 2004)	8745799, Cat Island, Mississippi Sound, MS	0.479

There were no high water interval (HWI) or low water interval (LWI) values published for all of the three stations. To test whether a single tide phase may be used for the entire survey area, the differences in time of high and low waters in Pascagoula (verified) and Cat Island (predicted) with Bay Waveland from 01-25 June 2015 were noted. During the same period, the time difference values between high water and low water between Bay Waveland and the USM-established tide station in Pass Christian were also noted. Both the mean high water and mean low water time intervals between Bay Waveland and Pass Christian were approximately 0.04 hours (2.4 minutes). This confirms that a single tide zone is sufficient for the whole survey area. More details on tide zoning are discussed in HVCR.

C.1.5 SEP Values

To determine if multiple SEP values would have to be used, a geoid undulation calculator from GeographicLib (Karney, 2015) was used to determine geoid–ellipsoid separation at the extents of the survey area to within 1 mm (RMS error). Point calculations were made at four corners of the survey area, and changes in elevation were calculated between them (Figure 8). The largest slope in ellipsoid height across the survey area was 4.15 cm, which was determined to be insignificant enough to require more than a single SEP value to be applied for sounding reduction.

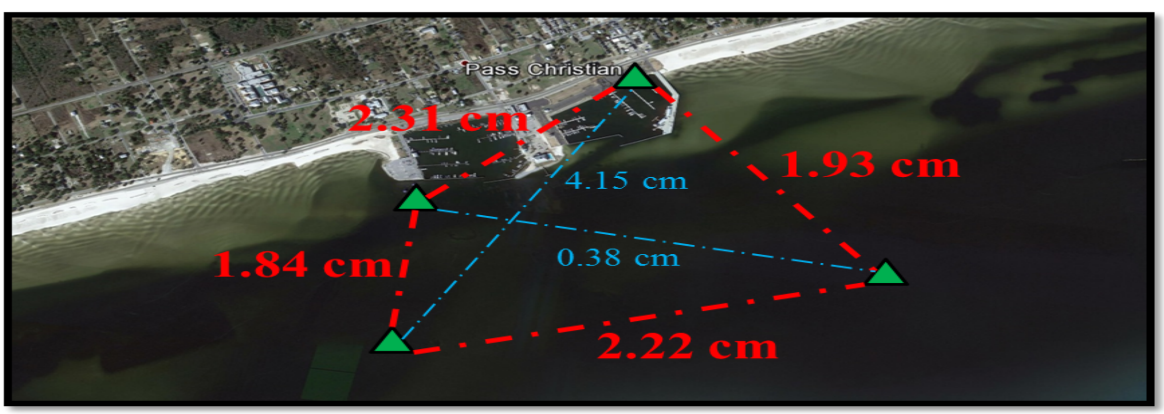

Figure 8. Height undulations between the WGS84 ellipsoid and EGM2008 geoid. Values obtained from http://geographiclib.sourceforge.net/cgi-bin/GeoidEval.

By using the derived ellipsoidal height from the GNSS static observation, benchmark elevations (from three-wire leveling), and MLLW/MSL values from the tidal datum transfer, an SEP value can be calculated (Method 1). Another Method (2) was derived by using the established chart datum/tidal relationships for the NOS BM 6819 B data and ellipsoidal height from the GNSS static survey. Method 3 utilized NOAA's VDatum Vertical Datum Transformation (v3.4) program to determine a SEP value by providing the datum, coordinates, and zero height over the primary benchmark. SEP values for each method are summarized in Figure 9. Uncertainty values were calculated to a 95% confidence interval and are shown in Table 10.

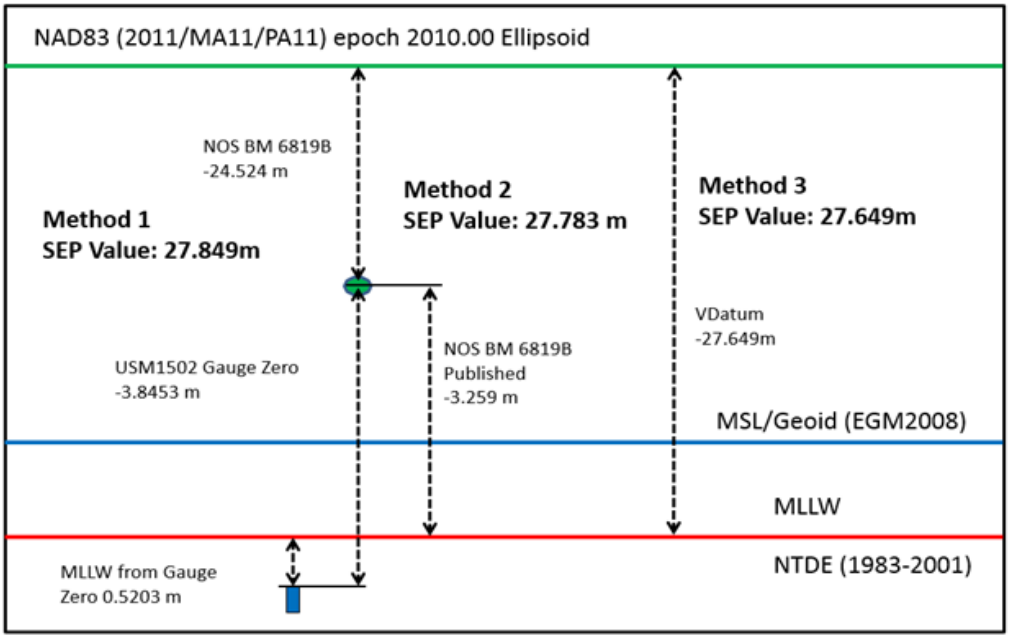

Figure 9. SEP value from three different methods.

Table 10. SEP values with uncertainties at 95% confidence interval.

	Method 1		Method 2		Method 3
SEP (m)	27.849		27.783		27.649
Uncertainty Components (m)					
Gauge Uncertainty	0.0005	GNSS Observation	0.011	ITRF to NAD83	0.020
Leveling Misclosure	0.00225	Datum Uncertainty (published)	0.011	NAD83 to NAVD88	0.050
Datum Transfer	0.0548			NAVD88 to MSL	0.148
GNSS Observation	0.011			MSL to MLLW	0.029
$\Sigma (\sigma^{2n})$	0.003129		0.000242		0.025645
Total Uncertainty at 95% C.I. (m)	0.110		0.030		0.314

C.2. Horizontal Control

C.2.1 Positioning Methods

The survey vessel was equipped with two dual frequency positioning systems. The primary navigation system was a POS MV equipped with dual GPS antennas. The secondary system, a GNSS TopCon Net-G3, served as a PPK rover. The Applanix POS MV unit logged all raw data over an ethernet connection at 50 Hz. The TopCon Net-G3 was configured to log positioning data at a rate of 1 Hz, the same frequency as the survey's base station.

The Applanix POS MV raw data were supplemented with RTK corrections from a VRS established in the center of the survey area. The VRS used corrections from networked reference stations in the GCGC RTN network. There are five network reference stations having less than a 50 km baseline from the VRS. Corrections were received over an AT&T internet connection via CMR+ messages. A fixed ambiguity status (RTK fixed solution) was able to be maintained for 60% of the survey, while the remaining 40% was a floating integer solution (RTK float solution). This could have been caused for several reasons, but internet connections are thought to be the main contributor.

The TopCon Net-G3 rover data were combined and processed (using Waypoint's GrafNav) with data from the TopCon GR3 base station set up on NOS BM 6819B. PPK solutions were obtained by using a combined, forward, and reverse kinematic solution with a 7° elevation mask.

C.2.2 Positional Uncertainty

Using GravNav, statistics were computed and estimated for all survey days. All estimated uncertainty values were well within survey requirements for IHO Special Order and NOAA's 1 m Object Detection Surveys. RTN and PPK data were also compared. This was done in CARIS HIPs and SIPs by creating new line files with the PPK data and overlaying them with the RTN ship track lines. Horizontal differences of up to 1.7 m can be seen between the two track lines. This is thought to be caused by the RTN solution switching between a fixed and float solution. The PPK data consistently produced low uncertainty solutions and was determined to be used as the primary positional source.

D. Results and Recommendation

D.1 Chart Comparison

All chart comparisons were done in CARIS S-57 Composer 2.2. There are updated versions of this software but they were not able to run on the survey computers. There were no raster chart requirements for this project. All comparisons were made in ENC format. The soundings obtained during this survey and used in creating/updating the ENC differed by 0.3 in most places compared to those published on NOAA ENC US5MS11M. However, there are very few soundings on the US5MS11M in the vicinity of the harbor with which to compare. Notice to Mariners were checked and no additions have been made for the survey areas. There are no maritime boundaries or charted features in the survey areas.

Areas 1 and 3

There are no depth comparisons to be made in Areas 1 or 3 because they currently do not exist on NOAA ENC US5MS11M (Figure 10). The complete harbor structure (SLCONS and LNDARE) and adjoining shorelines (COALINE) were added to the 15USM02 ENC US6MS99M (Figure 11). DEPARE, DEPCON, and soundings were also added to the US6MS99M ENC for this area. These areas are approximately 0.3 m shoaler than the dredged depth listed on the harbor's website. The accuracy of the depth listed on the website could not be verified from any source data or any other reliable source. There were no obstructions or DTONs found in this area. Shoaling and sediment deposition can be seen around the harbor structure (seawalls and retaining walls) as well as in the harbor itself. It appears that sediment is moving in through the entrance and being deposited throughout the harbor. There was one AWOIS around Area 1 that was charted as always being dry. This wreck was not found by visual inspection at low tide and very shoal waters prevented sonar investigation. This AWOIS can be seen charted on ENC US5MS11M in Figure 10.

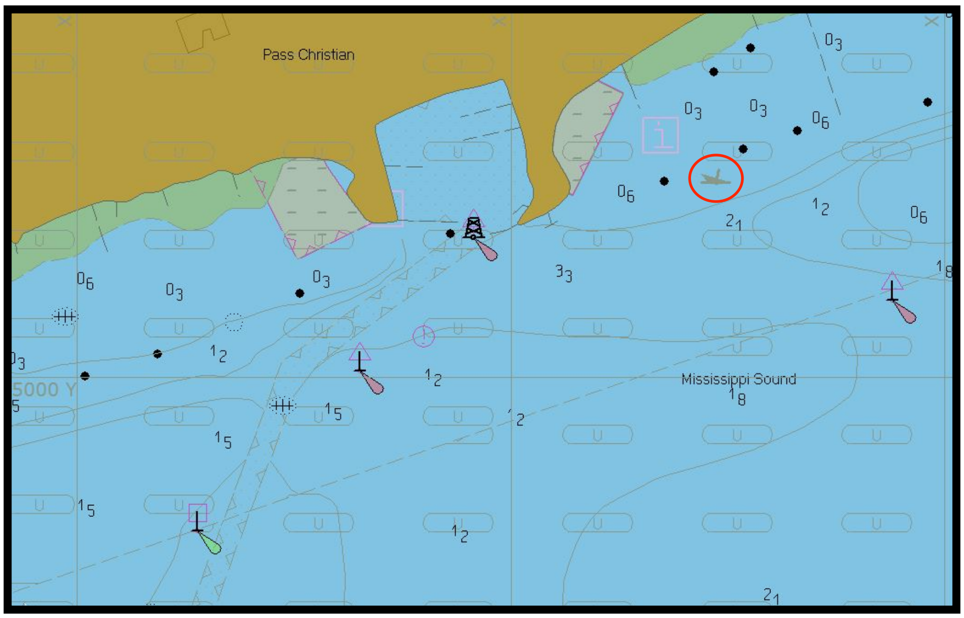

Figure 10. ENC US5MS11 without the harbor expansion east of the existing harbor.

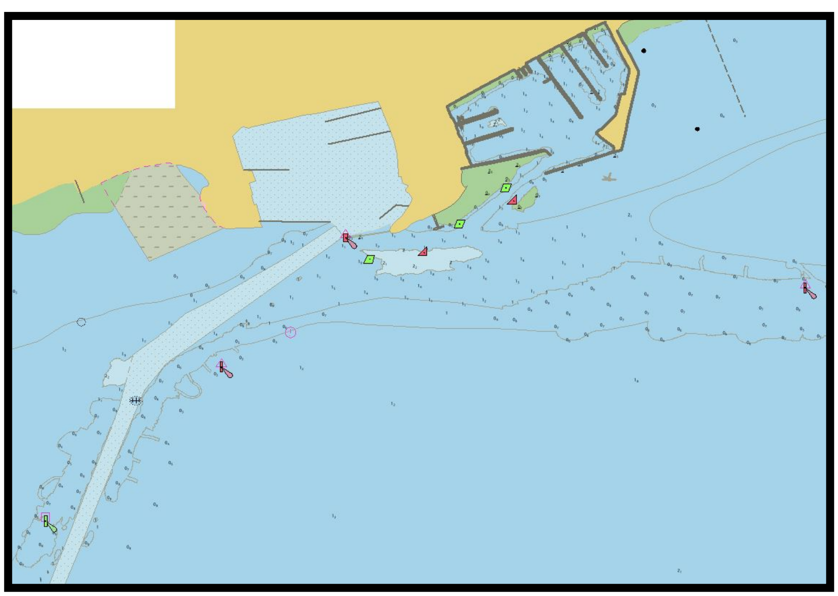

Figure 11. ENC US6MS99M with new harbor added. Also has updated depth areas and ATONs. All soundings are in meters.

Area 2

There are very few soundings/contours for this area on ENC US5MS11M. This made comparison with US6MS99M minimal. Most major depth contours agreed very well. New minor depth contours were added along with a larger sounding density. Soundings in some areas matched well with existing depths, while in other areas were different by (+/-) 0.3 m. There were nine total ATONs positioned in this area, four of which were charted. Only two of the charted ATONs changed position. They were updated to the correct positions on ENC US6MS99M and can be seen in Figure 12 below. The other five ATONs were not charted on the NOAA ENC and were added to ENC US6MS99M. These newly installed ATONs mark the safe entrance to the new harbor and have yet to be numbered. There were 2 significant DTONs found in this area. DTON reports were made for each one. However, none were added to the chart because they were no larger than the required 1 m x 1 m object. There was one AWOIS in this area. Full MBES and SSS ensonification of its charted area did not identify any features that resemble a submerged wreck. There is a dredged fairway that exists leading into the old harbor. It is charted to a controlling depth of 7 ft. This was left unchanged because it is shoaler than our depths inside of the fairway of approximately 9 ft.

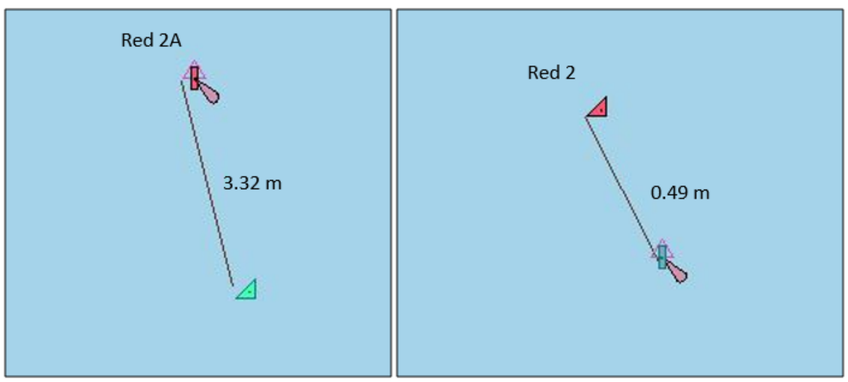

Figure 12. Movement of ATONs Red "2A" and Red "2".

D.2 Seabed Samples

Seabed sampling was completed on Monday June 08, 2015. A Wildco Petite Ponar Grab bottom sampler was used to collect and analyze seabed samples throughout the survey. GPS time and position were recorded when a sample was collected. Targets were also created in HYPACK to document where the bottom samples were collected. Pictures were taken and samples were described and recorded before being washed off the stern deck.

Sediment samples (Figures 13 -16) were collected in the center of each area at the positions listed in Table 11. Backscatter intensities were used to identify potential bottom sample locations. Only one area outside the new harbor presented any significant change in backscatter and, when sampled, showed that it was most likely an oyster reef.

Table 11. Seabed samples with their corresponding S-57 encoding values.

Sample Number	Time UTC	Latitude	Longitude	Sediment Description/NAT	NATQUA	Color
1	10:52	30 18 48.4923 N	89 14 28.8855 W	Mud (1) Clay (2)	Sticky (5)	Black (2)
2	11:45	30 18 47.3716 N	89 14 35.4756 W	Mud (1) Clay (2)	Sticky (5)	Black (2)
3	19:57	30 18 39.3883 N	89 14 38.4546 W	Mud (1) Clay (2)	Sticky (5)	Black (2)
4	15:03	30 18 26.7588 N	89 15 02.2506 W	Shell (Mainly Oyster) (17)	Calcareous(9)	-

Figure 13. Bottom sample 1.

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Figure 14. Bottom sample 2.

Figure 15. Bottom sample 3.

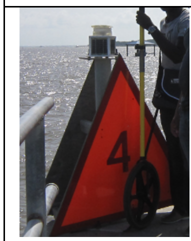
Figure 16. Bottom sample 4.

D.3 Aids to Navigation

Nine ATONs were investigated. All the ATONs investigated were within Area 2. The bow of R/V GCGC was moored to the ATON, and the exact distance and heading to the TopCon Net-G3 antenna was noted. A distance of 6.37 m was measured to account for the offset from the Topcon GR3 to the marker. The positions were post-processed using GrafNav Waypoint to acquire a PPK solution. The ATONs investigated are listed in Table 12.

Table 12. Aids to navigation.

Imagery	Area	Name	Verified Position (NAD83)	Charted Position (NAD83)	Distance off Charted position (m)	Bearing from Charted position (˚)
	2	Green 1	30-18- 08.2089 N 89-15- 13.2005 W	30-18-15.0000 N 89-15-13.3475 W	-	~170
	2	Red 2A	30-18- 20.3446 N 89-14- 59.4305 W	30-18-27.8877 N 89-14-58.9778 W	3.2	~170
	2	-	30-18- 28.8343 N 89-14- 47.8205 W	-	-	~170
	2	-	30-18- 29.3452 N 89-14- 43.5205 W		-	~170
	2	-	30-18- 31.6122 N 89-14- 40.7605 W	-	-	~170
	2	-	30-18- 33.4130 N 89-14- 36.5305 W	-	-	~170
	2	-	30-18- 37.6644 N 89-14- 37.0857 W	-	-	~170

	2	Red 2	30-18 26.6701 N 89-14- 13.7005 W	30-18-33.6654 N 89-14-13.4864 W	0.49	~170
	2	Red 4	30-18- 30.5092 N 89-14- 49.6818 W	30-18-37.4150 N 89-14-49.8921 W	-	-

D.4 Dangers to Navigation

Only one of the detected objects has a measured height of more than 1 m. All objects identified were in the approaches to both marinas, and none were found inside the new marina itself. The charted wreck in the western approach could not be detected with the SSS or the MBES. There were some objects in the vicinity of the charted position of the wreck; however, none of those could be identified as remains of the wreck itself. The feature report is included in Appendix BII, with measured lengths, widths, and the height derived from the shadows.

There are areas that are shoaling, especially close to the harbor entrances. These areas should be monitored for potential dredging to keep the channel open for passage of the large vessels docked in the harbor.

D.5 Shoreline Delineation

Delineation of the new harbor sea walls, piers, and docks was completed with a rolling wheel pole mounted with a GNSS TopCon GR3. These data were post processed to obtain a PPK solution, using another GNSS TopCon GR3 as a base station. Due to the high accuracy of the data, the widths of the finger piers and seawalls were also captured by the GNSS survey. There was no need to follow the NOAA guideline of time of data collection relative to a high or low stand of mean sea level because all structures are permanently constructed and always dry. Figure 17 shows the shoreline delineation data in GravNav after PPK processing. Figure 18 shows the data overlaid on Google Earth and shows how well the Landsat 7 georeferenced imagery fits with the delineated shoreline.

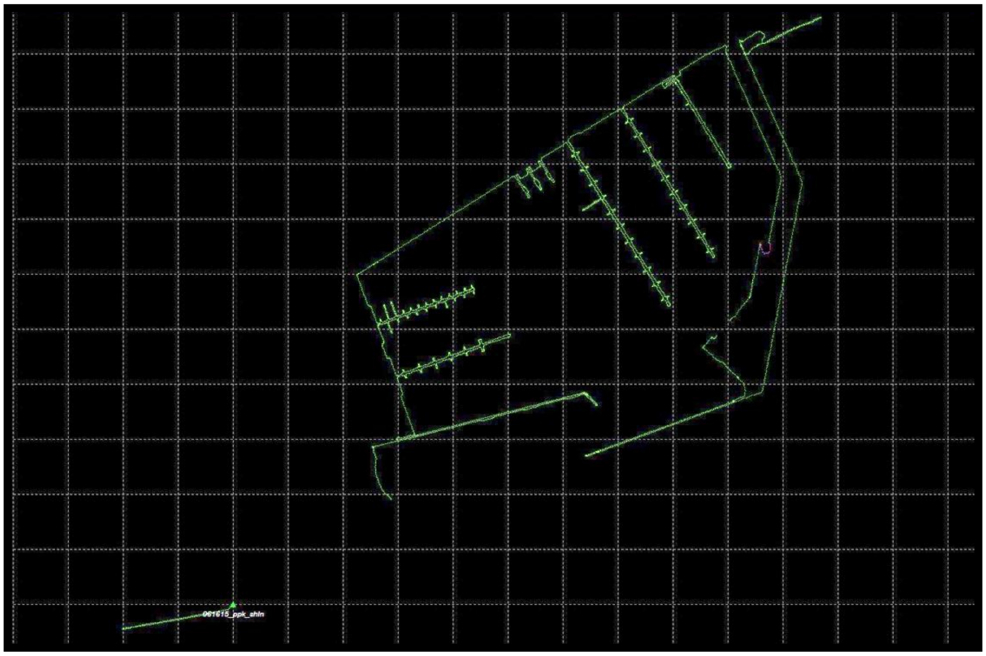


Figure 17. Shoreline delineation of new harbor using PPK GNSS data.

Figure 18. PPK GNSS data overlaid on Google Earth imagery.

D.6 Recommended Amendments to Sailing Directions/Coast Pilot

In 2014 dredging and construction for the harbor expansion, east of the east mole, was completed. The east side was bounded by the construction of a seawall. Protruding from the mole and the constructed seawall are two breakwaters that extend seaward and define the entrance to the new harbor marked by one navigation light. The new harbor provides berthing for up to 102 commercial boats (25 ft. wide and 71 ft. long or less) and up to 62 recreational boats (24 ft. wide and 40 ft. long or less). The harbor is noted at a depth of 10 ft. However, it is currently at a depth of 9.5 ft. The surrounding waters are very shallow and littered with changing shoals and oyster reefs. It is recommended to adhere strictly to channel passage ways.

E. Approval Sheet

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Acknowledgements

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Bibliography

Gulf Coast Geospatial Center/University of Southern Mississippi (2015). *GCGC Real Time Network, NAD83 (2011) epoch 2010.00.* Retrieved from http://vrsnet.gcgcusm.org/

Hare, R. (1995), Depth and position error budgets for multibeam echo sounding. *International Hydrographic Review*. Monaco, 72(1), March, pp. 33

International Hydrographic Organization (2000) Publication S-57 - IHO Transfer Standard for Digital Hydrographic Data; Appendix A - Chapter 1 Object Catalog (31ApAch1.pdf) http://www.iho.int/iho_pubs/standard/S-57Ed3.1/31ApAch1.pdf

International Hydrographic Organization. (2008). *IHO Standards for Hydrographic Surveys S-44 5E.* Monaco: International Hydrographic Bureau. Retrieved from http://www.iho.int/iho_pubs/standard/S-44_5E.pdf

Karney, Charles (2015, June 24). *GeographicLib.* Retrieved from http://geographiclib.sourceforge.net

National Oceanic and Atmospheric Administration. (2003). *Computational Techniques for Tidal Datums Handbook.* US Department of Commerce. Retrieved from http://tidesandcurrents.noaa.gov/publications/Computational_Techniques_for_Tidal_Datums_handbook.pdf

National Oceanic and Atmospheric Administration (2014). Estimation of Vertical Uncertainties in VDatum. *Vertical Datum Transformation: Integrating America's Elevation Data.* Retrieved from http://vdatum.noaa.gov/download/publications/Estimation_of_Vertical_Uncertainties_in_VDatum_Dec2013.pdf

National Oceanic and Atmospheric Administration (2014). *NOAA OCS Field Procedures Manual.* US Department of Commerce. Retrieved from http://www.nauticalcharts.noaa.gov/hsd/fpm/2014_FPM_Final.pdf

National Oceanic and Atmospheric Administration. (2014). *NOS Hydrographic Surveys Specifications and Deliverables.* US Department of Commerce. Retrieved from http://www.nauticalcharts.noaa.gov/hsd/fpm/fpm.htm

OPUS-RS. (2014). KKC OPUS-RS version 1.95