CAMERON MEADOWS MARSH CREATION AND TERRACING (CS-66)
GEOPHYSICAL INVESTIGATIONS DATA REPORT

Prepared by:

CB&I Coastal Planning & Engineering, Inc.

Kristina McCoy, P.G.
Melany Larenas, P.G.
Beau Suthard, P.G.
Jeffrey Andrews, PSM, CH

Prepared for:

Coastal Protection and Restoration Authority
Baton Rouge, Louisiana

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Executive Summary

CB&I Coastal Planning & Engineering, Inc. (CB&I) was contracted by the Coastal Protection and Restoration Authority (CPRA) to conduct a concurrent geophysical and cultural resource survey, a geotechnical survey, and numerical modeling of the potential borrow area offshore of Cameron Parish, Louisiana for the Cameron Meadows Marsh Creation and Terracing Project (CS-66). The geophysical and geotechnical investigations were conducted in order to locate marsh compatible material. The project features include creating approximately 334 acres of marsh and 18 acres (35,000 linear feet) of earthen terraces, along with reestablishing hydraulic flow patterns within 30,000 linear feet of canals. The numerical modeling was conducted in order to assess the potential nearshore erosional impacts from dredging the offshore borrow area. This investigation was undertaken as a collaborative and cooperative effort between CPRA and the National Marine Fisheries Service (NMFS). The project is being funded by the Coastal Wetlands Planning, Protection, and Restoration Act.

The Cameron Meadows potential offshore borrow area is located approximately 2.7 miles south of Highway 82 and Young's Road, south of Johnson's Bayou in the Gulf of Mexico, between the -19 ft. and -24 ft. bathymetric contour, offshore of Cameron Parish, Louisiana. The investigation area for the pipeline corridor extends from the northern edge of the borrow area investigation area approximately one mile north towards the project area. The project area is located approximately 18 miles west of Cameron, 5 miles north of the Gulf of Mexico shoreline, northeast of Johnson's Bayou and south of the Cameron Meadows Gas Field in Cameron Parish, Louisiana.

On November 19th 2014, a concurrent magnetometer, seismic reflection profiling, sidescan sonar and bathymetric survey was conducted within the pipeline corridor investigation area with CB&I's 28 ft. Parker. Between January 23rd through 24th and February 4th through 5th 2015, a concurrent magnetometer, seismic reflection profiling, sidescan sonar and bathymetric survey was conducted within the borrow area investigation area using AVS' survey vessel, the M/V *Thunderforce.* During this geophysical and cultural resource investigation, approximately 84.5 nautical line miles of geophysical data were collected by CB&I at approximately 30 meter (m) (98 ft.) line spacing. There were 25 vibracores collected by AVS, under the direction of CB&I, on January 29th, 30th, and 31st 2015. GeoEngineers, Inc. logged, sampled and tested the vibracores, and the final geotechnical report with the results is located in Appendix 8. Photographs were not collected for these vibracores.

The seismic data was correlated with the vibracore data in an attempt to understand the potential borrow area deposit's surficial geology. The seismic data located in the potential borrow area indicate that the Cameron Meadows surficial geology is primarily composed of layers soft clay over firm (medium) clay. In the southeastern area, there was the presence of shallow gas in which acoustic penetration was limited. To the north and south of the potential borrow area, paleofluvial channels were identified. These paleofluvial channels exhibit good potential for beach compatible sand and could be targeted as future sand deposits for beach nourishment projects.

The depth of the reflector representing the top of unsuitable material for marsh construction (i.e. stiff clays with torvane values greater than 1.0 tons per square foot (tsf) and predominantly sandy sediment) was unable to be determined due to the discontinuous nature of the reflector in this area. The thickness of the marsh-compatible material was unable to be determined seismically, and therefore an isopach (sediment thickness) map was not developed for the area.

The cultural resource survey identified four total clusters of magnetic and acoustic anomalies as being culturally significant and potentially associated with the remains of a shipwreck or other debris. These significant magnetic and acoustic anomalies have been buffered by four clusters designated for avoidance during dredge operations. Three clusters are located within the borrow area investigation area, and the size and orientation of each buffer is dependent upon the magnetic intensity and duration along with the acoustic target area. The one cluster located inside the pipeline corridor investigation area has an approximate 160 ft. radius buffer. The seismic records did not identify any evidence of prehistoric habitation, such as shell middens, relict channels or lagoon complexes. Appendix 7 contains the cultural resource reports prepared by TAR, which include a description of the seismic analysis and buffers for avoidance. The final cultural resource reports for the pipeline corridor and borrow area investigation areas have been submitted to the State Historic Preservation Office (SHPO) for concurrence. The potential borrow area may need to be revised based on SHPO's evaluation of the avoidance buffers.

The targeted material for the marsh design was soft to firm (medium) clay, with torvane values of less than 1.0 tsf. This potentially marsh compatible material is typically mixed with minor amounts of silt and sand, and is considered the highest quality material. The potential borrow area was refined to take into account the quality of material indicated by the vibracores.

A potential borrow area, designated as the Cameron Meadows Borrow Area, was designed to contain marsh compatible material offshore of Cameron Parish, Louisiana. Any identified potential cultural resources were avoided in the borrow area design and removed from the volume calculations. The material in this potential borrow area is predominantly soft clay with minor amounts of firm (medium) clay. The final borrow area contains a total of 4,723,000 cubic yards (cy) of sediment.

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INTRODUCTION

CB&I Coastal Planning & Engineering, Inc. (CB&I) was contracted by the Coastal Protection and Restoration Authority (CPRA) to conduct a concurrent geophysical and cultural resource survey, a geotechnical survey, and numerical modeling of the potential borrow area offshore of Cameron Parish, Louisiana for the Cameron Meadows Marsh Creation and Terracing Project (CS-66). The geophysical and geotechnical investigations were conducted in order to locate marsh compatible material. The project features include creating approximately 334 acres of marsh and 18 acres (35,000 linear feet) of earthen terraces, along with reestablishing hydraulic flow patterns within 30,000 linear feet of canals. The numerical modeling was conducted in order to assess the potential nearshore erosional impacts from dredging the offshore borrow area. This investigation was undertaken as a collaborative and cooperative effort between CPRA and the National Marine Fisheries Service (NMFS). The project is being funded by the Coastal Wetlands Planning, Protection, and Restoration Act.

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The targeted material for the marsh design was soft to firm (medium) clay, with torvane values of less than 1.0 tsf. This potentially marsh compatible material is typically mixed with minor amounts of silt and sand, and is considered the highest quality material. The potential borrow area was refined to take into account the quality of material indicated by the vibracores.

This data report summarizes the geophysical data collection and processing results, geotechnical investigation, and the results of the cultural resource survey that was overseen and reviewed by Tidewater Atlantic Research, Inc. (TAR). On November 19th 2014, a concurrent magnetometer, seismic reflection profiling, sidescan sonar and bathymetric survey was conducted within the pipeline corridor investigation area with CB&I's 28 ft. Parker. Between January 23rd through 24th and February 4th through 5th 2015, a concurrent magnetometer, seismic reflection profiling, sidescan sonar and bathymetric survey was conducted within the borrow area investigation area using AVS' survey vessel, the M/V *Thunderforce.*

The reconnaissance geophysical survey was conducted first in order to target promising areas for the placement of the vibracores, identify magnetic anomalies for avoidance during vibracore collection, and target a suitable area for the detailed geophysical investigations. The survey data was reviewed by a registered marine archaeologist and a professional geologist, and vibracore locations were selected after the sites were reviewed and cleared. After the

reconnaissance geophysical survey was conducted and vibracores were collected, the detailed geophysical survey and cultural resource investigation was conducted. The cultural resource investigation focused on the areas identified for borrow area development and supplemented the data acquired during the reconnaissance geophysical investigation to obtain the 30 meter line spacing required to perform the cultural resource assessment.

During this geophysical and cultural resource investigation, approximately 84.5 nautical line miles of geophysical data were collected by CB&I at approximately 30 meter (m) (98 ft.) line spacing. The geotechnical survey plan was developed based on the results of the geophysical survey. The geotechnical survey includes collecting vibracores to investigate promising locations identified during the geophysical survey. There were 25 vibracores collected by AVS, under the direction of CB&I, on January 29th, 30th, and 31st 2015. GeoEngineers, Inc. logged, sampled and tested the vibracores, and the final geotechnical report with the results is located in Appendix 8. Photographs were not collected for these vibracores.

The general geophysical and geotechnical investigations are discussed first, followed by an analysis of results from these investigations. The characteristics of the identified marsh resources and borrow area development are then discussed. The results from the numerical modeling that was conducted, in order to assess the potential nearshore erosional impacts from dredging the offshore borrow area, are located in Appendix 9.

GEOPHYSICAL AND GEOTECHNICAL INVESTIGATIONS

Investigation Details

CB&I researchers conducted geophysical and cultural resource surveys across the Cameron Meadows borrow area and pipeline corridor investigation areas. On November 19th 2014, a concurrent magnetometer, seismic reflection profiling, sidescan sonar and bathymetric survey was conducted within the pipeline corridor investigation area with CB&I's 28 ft. Parker. This survey vessel has a shallow draft that allows for surveying in shallow water depths. Between January 23rd through 24th and February 4th through 5th 2015, a concurrent magnetometer, seismic reflection profiling, sidescan sonar and bathymetric survey was conducted within the borrow area investigation area using AVS' survey vessel, the M/V *Thunderforce* (Figure 1). A registered marine archaeologist from TAR was onboard for the cultural resource survey on November 19th 2014 and from February 4th through 5th 2015.

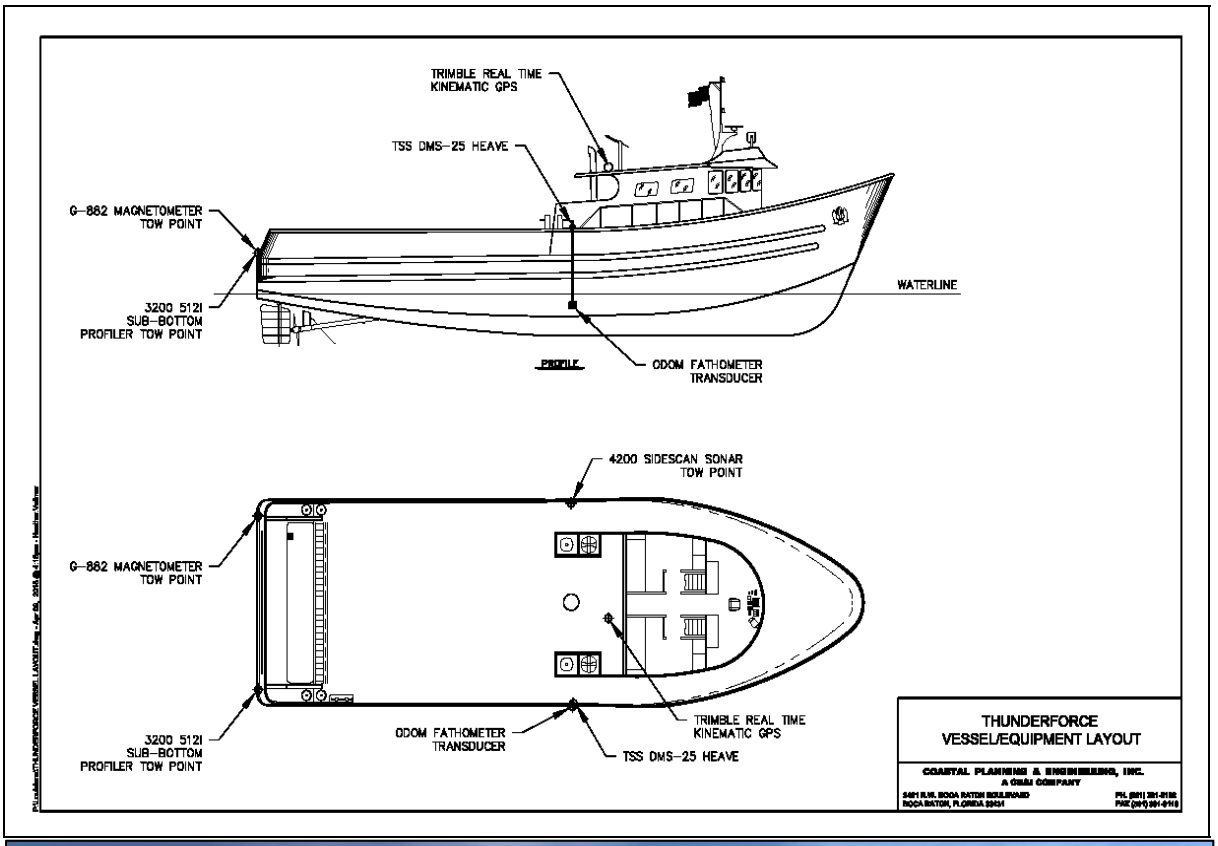
The M/V *Thunderforce* is a specialized survey vessel capable of assisting scientists in conducting offshore geophysical and geotechnical investigations. The M/V *Thunderforce* includes a full crew with a licensed and qualified marine Captain to pilot the vessel throughout the day, a deckhand to assist the Captain and scientific crew with at-sea needs, access to a marine engineer to troubleshoot vessel issues and assist with the development and deployment of scientific instruments, as well as understanding and operating systems on the boat (A-Frames, pole-mounts, etc.). The M/V *Thunderforce* is equipped with twin Detroit 780 horsepower diesel

engines, and has a length overall of 110 ft. During the geophysical and cultural resource investigations, approximately 84.5 nautical line miles of geophysical data were collected at approximately 30 m (98 ft.) line spacing. Appendix 1 shows the location of the tracklines that were run during this concurrent geophysical survey.

Figure 1. The M/V *Thunderforce*. AVS' vessel for the geophysical and geotechnical survey operations.

Equipment and Methods

The geophysical and cultural resource investigations included bathymetric, sidescan sonar, seismic reflection profiling and magnetometer surveys. These surveys were conducted concurrently using the configuration illustrated in Figure 2 and Appendix 5. The collection and processing of this data is described below. The geophysical equipment used during the investigation is listed in Table 1 and described below.



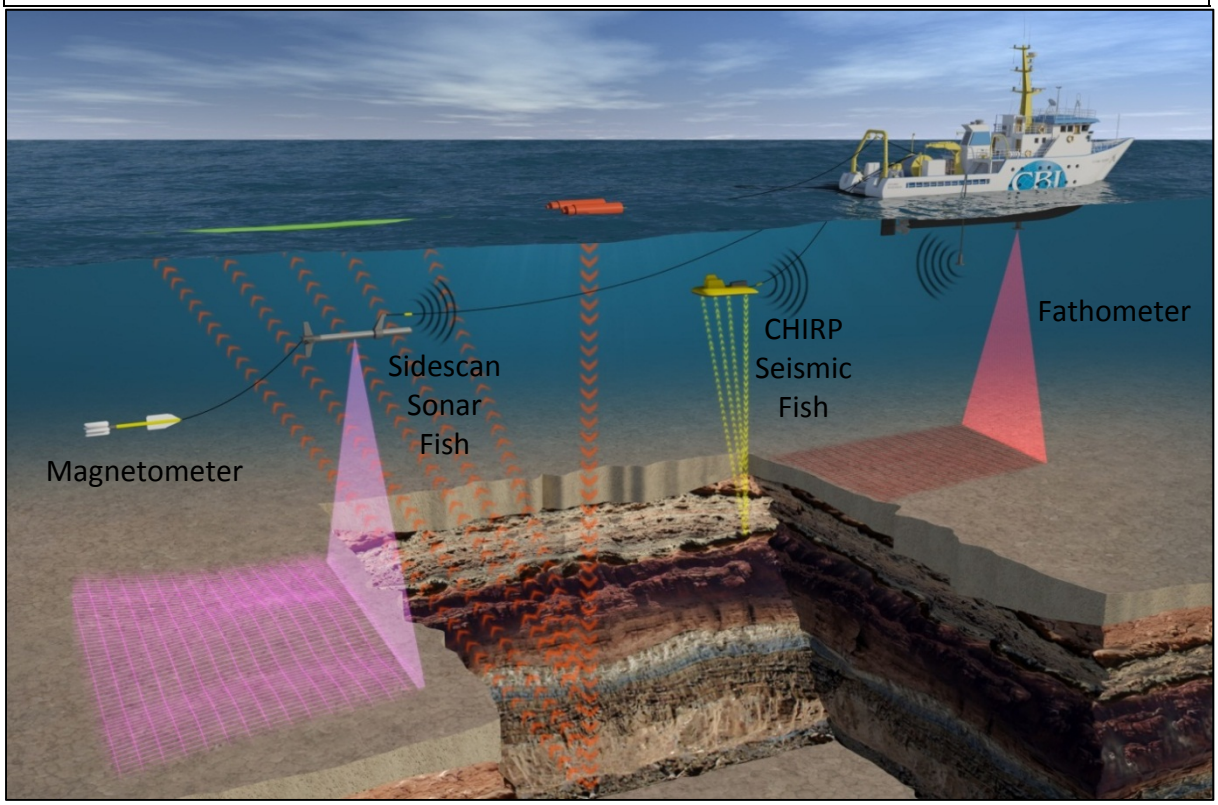


Figure 2. Schematic diagrams showing the deployment of a concurrent seismic reflection profile, bathymetric, magnetometer and sidescan sonar survey.

Table 1. *Equipment used during the geophysical investigations.*

Equipment Type	Description	
	Pipeline Corridor Survey	**Borrow Area Survey**
Navigation	Trimble Differential Global Positioning System (DGPS) interfaced with Hypack, Inc.'s Hypack 2014® software	
Sounder (Bathymetry)	Odom Hydrographic Systems, Inc. "Hydrotrac" Hydrographic Echo Sounder	
Sub-bottom Profiler (Seismic Reflection)	EdgeTech SB-216S Sub-bottom Profiler	EdgeTech X-STAR SB-512i Sub-bottom Profiler
Sidescan Sonar	EdgeTech 4125	
Magnetometer	Geometrics G-882 Digital Cesium Marine Magnetometer	

Navigation Systems

All navigation and survey control for the geophysical survey was conducted under the direction of an ACSM Certified Hydrographer. The navigation and positioning system deployed for the geophysical and geotechnical surveys was a Trimble Differential Global Positioning System (DGPS) interfaced to Hypack, Inc.'s Hypack 2014®. A Pro Beacon receiver provided DGPS correction from the nearest U.S. Coast Guard Navigational Beacon. The DGPS initially receives the civilian signal from the global positioning system (GPS) NAVSTAR satellites. The locator automatically acquires and simultaneously tracks the NAVSTAR satellites, while receiving precisely measured code phase and Doppler phase shifts, which enables the receiver to compute the position and velocity of the vessel. The receiver then determines the time, latitude, longitude, height, and velocity once per second. Most of the time the GPS accuracy with differential correction provides for a position accuracy of one (1) to four (4) ft. This is within the accuracy needed for geophysical investigations.

Hypack, Inc.'s Hypack 2014® Data Collection and Processing Program

Navigational, magnetometer, and depth sounder systems were interfaced with an onboard computer, and the data was integrated in real time using Hypack, Inc.'s Hypack 2014® software. Hypack 2014® is a state-of-the-art navigation and hydrographic surveying system. The location of the fish tow-point on the vessel in relation to the DGPS was measured, recorded and entered into the Hypack 2014® survey program. The length of cable deployed between the tow-point and each towfish was also measured and entered into Hypack 2014®. Hypack 2014® then takes these values and monitors the calculated position of each towfish in real time. Online screen graphic displays include the pre-plotted survey lines, the updated boat track across the survey area, adjustable left/right indicator, as well as other positioning information such as boat speed, quality of fix measured by Position Dilution of Precision (PDOP), and line bearing. The digital data is merged with positioning data (DGPS), video displayed and recorded to the acquisition computers hard disk for post processing and/or replay.

Bathymetric Survey

The Odom Hydrographic Systems, Inc.'s Hydrotrac, a single frequency portable hydrographic echo sounder, was used to perform the bathymetric survey. The Hydrotrac operates at frequencies of 24, 33, 40, 200, 210, or 340 kilohertz (kHz) and is a digital, survey-grade sounder. A 210 kHz transducer was used for the bathymetric survey.

Real-time navigation software (Hypack) was used to provide navigation to the helm in order to minimize deviation from the online azimuth. This software provides horizontal position to the sounding data allowing real-time review of the data in plan view or cross section format. Soundings were collected at intervals sufficient to provide an accurate depiction of the seafloor. Cross lines (tie lines) were collected to verify survey accuracies.

Upon completion of the field work, data was edited and reduced with Hypack 2014®. The observed tide data was compared to local predictions and other regional gauges for verification purposes. The offshore raw digital data was viewed and edited in Hypack 2014®. Vertical data were corrected based on overlap and tie line analysis. Digitized data was scanned for noise and compared to the analog record. False soundings were removed and a comma delimited ASCII file was created and exported.

Magnetometer Survey

High-resolution magnetic remote sensing is needed to identify any metallic objects that could represent a potential cultural resource or hazard to construction. A Geometrics G-882 Digital Cesium Marine Magnetometer, capable of a plus or minus 0.1 gamma resolution, was used to perform a cursory investigation of magnetic anomalies within the potential sediment sources (Figure 3). The purpose of the magnetometer survey was to establish the presence, and subsequent exclusion zones around any potential underwater wrecks, submerged hazards, or any other features that would affect future borrow area delineation or dredging activities. The Hypack 2014® software records magnetic anomalies directly from the Geometrics magnetometer.

To produce a magnetic record of sufficient resolution, the sensor was deployed and maintained in the water column at a depth of 4 ft. to 10 ft. below the water surface in the borrow area investigation area. The sensor was floated just below the water surface in the pipeline corridor investigation area due to the shallow water depths. A computer recorder provided a continuous permanent record of the magnetic background and target signatures. Positioning data generated by the navigation system was tied to magnetometer records by regular annotations to facilitate target location and anomaly analysis. Annotations include line number, date and time of start and end of each line, and target identification. Upon completion of the general magnetometer survey, the data were examined by a registered marine archaeologist, who provided the locations of magnetic anomalies. Appendix 7 contains the cultural resource reports prepared by TAR, which includes a description of the magnetic anomalies.

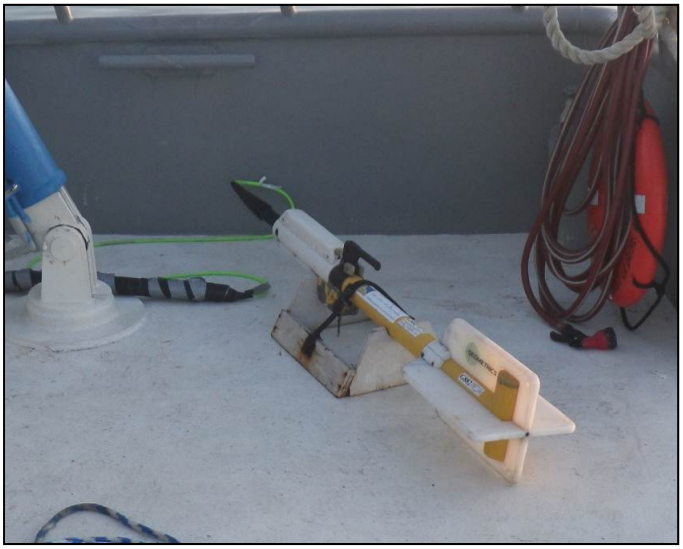


Figure 3. Geometrics G-882 Digital Cesium Marine Magnetometer used to investigate magnetic anomalies within the potential sediment source.

Seismic Reflection Profile Survey

"Chirp" sub-bottom seismic-reflection data is used to show sedimentary stratigraphy and identify potential project-compatible sediment resources. The use of chirp sub-bottom data allows common stratigraphic layers to be mapped throughout the study area while determining the thickness and extent of potential project compatible sediment.

Throughout the offshore seismic reflection survey, selection of the chirp pulse was monitored and adjusted in real time to obtain the best possible resolution of geological features and the sequence stratigraphy (i.e. vertical sequence and lateral distribution of sediment bodies comprised by different grain sizes and sediment composition) that in turn optimizes data quality and enhances subsequent interpretation. High frequency and/or short duration pulses are, for example, used to obtain highest resolution (clearest reflector image) in near surface situations; low frequency or longer duration pulses are used where deeper penetration is required.

An EdgeTech 3200 216s chirp sub-bottom system was used to conduct the pipeline corridor investigation area seismic reflection profile survey (Figure 4). The 3200 Full Spectrum Sonar is a versatile wideband FM sub-bottom profiler that collects digital normal incidence reflection data over many frequency ranges. This instrumentation generates cross-sectional images of the seabed. The 3200 216s transmits an FM pulse that is linearly swept over a full spectrum frequency range (also called a "chirp pulse"). The tapered waveform spectrum results in images that have virtually constant resolution with depth.

The seismic towfish (which operates as both the source and receiver for the sub-bottom system) was deployed and towed alongside the research vessel, just beneath the sea surface, and interfaced with RTK GPS via Hypack 2014® navigational software. The location of the tow

point (as referenced to the RTK GPS antenna), together with the length of cable deployed from the tow point, were entered into Hypack 2014® in order to account for the layback and provide accurate positioning of the seismic fish during the survey. The sub-bottom system was operated by the Discover-SB® software program.

An EdgeTech X-STAR SB-512i was used to conduct the borrow area investigation area seismic reflection profile survey (Figure 4). The X-STAR Full Spectrum Sonar is a versatile wideband FM sub-bottom profiler that collects digital normal incidence reflection data over many frequency ranges. This instrumentation generates cross-sectional images of the seabed. The X-STAR SB-512i transmits an FM pulse that is linearly swept over a full spectrum frequency range (also called a "chirp pulse"). The tapered waveform spectrum results in images that have virtually constant resolution with depth. The Chirp systems have an advantage over 3.5 kHz and "boomer" systems in sediment delineation because the reflectors are more discrete and less susceptible to ringing from both vessel and ambient noise. The full-wave rectified reflection horizons are cleaner and more distinct than the half-wave rectified reflections produced by older analog systems.

The X-STAR SB-512i, the newest model in the EdgeTech suite of Chirp Full Spectrum Sub-bottom towfish, differs from the older X-STAR SB-512 (which had four (4) 6" diameter transducers) by having a single 13" diameter low frequency transducer and a single 6.5" diameter high frequency transducer. The new low frequency transducer provides more low frequency energy at all pulse settings, which allows deeper penetration of seafloor sediments while at the same time maintaining the high resolution of the original configuration.

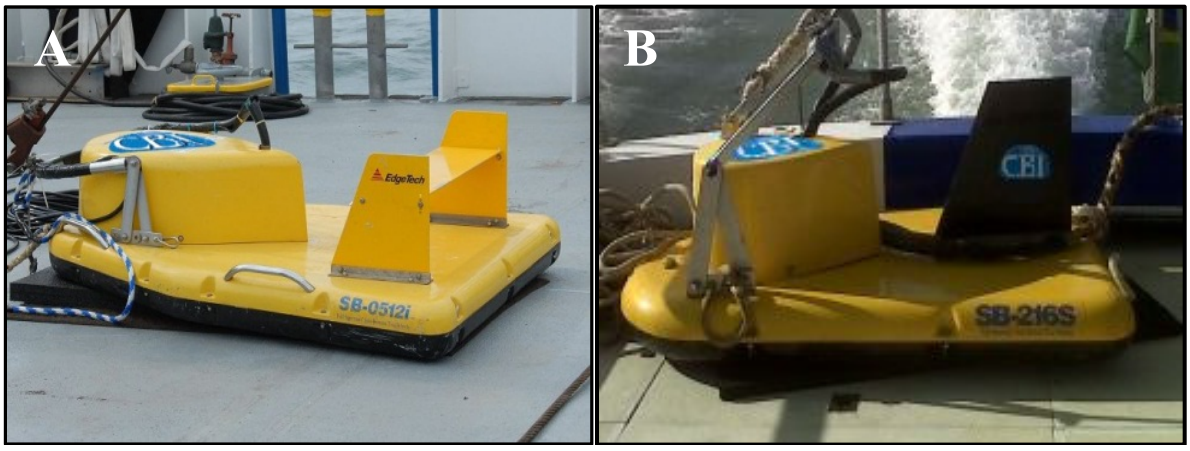


Figure 4. EdgeTech X-STAR SB-512i sub-bottom profiling system (A); and 3200 216S sub-bottom profiling system (B); prior to deployment.

In order to minimize noise related to the survey vessel and sea conditions, the seismic towfish (which operates as both the source and receiver for the sub-bottom system) was deployed and towed behind the research vessel. The sub-bottom system was interfaced with DGPS via Hypack 2014® navigational software. The location of the fish tow point (as referenced to the DGPS antenna), together with the length of cable deployed from the tow point, were entered into Hypack 2014® in order to account for the fish layback and provide accurate positioning of the seismic fish during the survey. The sub-bottom system was operated by the Discover-SB® software program.

At the start of each of the sub-bottom profiling surveys (pipeline corridor and borrow area investigation areas), the sweep frequencies of the outgoing pulse together with the different gain settings available within Discover-SB® were adjusted to obtain the best possible resolution for the survey. The data was continuously bottom-tracked to allow for the application of real-time gain functions in order to have an optimal in-the-field view of the data. Automatic gain control (AGC) was used to normalize the data by strengthening quiet regions/soft returns while simultaneously reducing/eliminating overly strong returns by obtaining a local average at a given point. A time-varying gain (TVG) was used to increase the returning signal over time in order to reduce the effects of signal attenuation.

All sub-bottom data was recorded on each of the acquisition computer's hard disk and transferred to a USB memory stick and/or portable hard drive at the end of each survey day to back-up raw survey data. Notes regarding line name, time, event, and direction of collection were recorded for the beginning and end of each survey trackline. Post collection processing of the seismic data was completed using Chesapeake Technology, Inc's SonarWiz.MAP +SBP® software. This software allows the user to apply specific gains and settings in order to produce enhanced sub-bottom imagery that can then be interpreted and digitized for specific stratigraphic facies relevant to the project goals.

The first data processing step is to calculate the approximate depth of the reflector below the sound source by converting the two-way travel time (the time in milliseconds that it takes for the "chirp pulse" to leave the source, hit the reflector and return to the source) to feet by utilizing an approximate value for the speed of sound through both the water and underlying geology. For this survey, a detailed hydrographic and geologic sound velocity structure was not available, so CB&I geophysicists used an estimated sound velocity of 1.6 meters per millisecond (m/ms) in order to convert two-way travel time to feet. This estimate of the composite sound velocity is based on several assumptions including the speed of sound through water which is typically 1.5 m/ms as well as on the speed of sound through the sediment which can vary from 1.6 m/ms for unconsolidated sediment to >1.7 m/ms for limestone.

CB&I geophysicists then processed the imagery to reduce noise effects (commonly due to the vessel, sea state, or other natural and anthropogenic phenomenon) and enhance stratigraphy. This was done using the processing features available in SonarWiz.MAP +SBP®; AGC, swell filter, and a user-defined gain control (UGC). The SonarWiz.MAP +SBP® AGC is similar to the Discover-SB® AGC feature, where the data are normalized in order to remove the extreme high and low

returns, while enhancing the contrast of the middle returns. In order to appropriately apply the swell filter and UGC functions, the sub-bottom data was bottom-tracked to produce an accurate baseline representation of the seafloor. Once this was done through a process of automatic bottom tracking (based on the high-amplitude signal associated with the seafloor) and manual digitization, the swell filter and UGC were applied to the data. The swell filter is based on a ping averaging function that removes vertical changes in the data due to towfish movement caused by the sea state. The swell filter was increased or decreased depending on the period and frequency of the sea surface wave conditions, however, special care was taken during this phase to not remove or smooth over geologic features that are masked by the sea state noise. The final step was to apply the UGC. The SonarWiz.MAP +SBP® UGC feature allows the user to define amplitude gains based on either the depth below the source, or the depth below the seafloor. For this survey, the UGC was adjusted so that the gain would increase with depth below the imaged seafloor (and not the source), mimicking a TVG. The user was able to remove the noise within the water column, increase the contrast within the stratigraphy, and increase the amplitude of the stratigraphy with depth, accounting for some of the signal attenuation normally associated with sound penetration over time.

After data processing, sub-surface data interpretation was performed using SonarWiz.MAP +SBP® software. Using the SonarWiz.MAP +SBP® platform, processed seismic profile lines were opened to digitally display the recorded sub-surface stratigraphy. Using the software's Sonar File Manager, color coded vibracore descriptions were added directly to the seismic profiles. A project-specific color scheme was developed for the vibracores based on the compatibility of the prospective nourishment material with that on the existing marsh (Table 2). Using the vibracore descriptions as a guide, the seismic stratigraphy was interpreted. The depth of the reflector representing the top of unsuitable material was unable to be determined due to the discontinuous nature of the reflector in this area. The thickness of the marsh-compatible material was unable to be determined seismically, and therefore an isopach (sediment thickness) map was not developed for the area. Upon completion of the general seismic reflection and cultural resource surveys, the data were examined by a registered marine archaeologist. Appendix 7 contains the cultural resource reports prepared by TAR, which includes a description of the seismic analysis.

Sidescan Sonar Survey

Sidescan data is required to verify the location and extent of unconsolidated sediment and to map ocean bottom features such as benthic habitats, exposed pipelines, cables, underwater wrecks, potential cultural resources, etc. The sidescan survey was conducted to identify features that may affect borrow area delineation, introduce hazards to dredging, or adversely impact the environment.

During this marsh investigation, an EdgeTech 4125 sidescan sonar system was used (Figure 5). This system uses full-spectrum chirp technology to deliver wide-band, high-energy pulses coupled with high resolution and good signal to noise ratio echo data. The sonar package included a portable configuration with a laptop computer running EdgeTech's Discover® acquisition software and a 400/900 kHz dual frequency towfish running in high definition mode.

Dual frequency provides a more complete sidescan return that aids interpolation at the outer portions of the swath, which in turn provides a more complete data set.

During the investigations, the sidescan was towed from the survey vessel at a position and depth that limited exposure to sources of interference and provided the best possible record quality. The survey was conducted in such a manner to achieve total bottom coverage within the survey area. The line spacing was set up to ensure that 100% overlap was obtained (i.e. all areas of the seafloor were covered twice). The digital sidescan data was merged with positioning data (DGPS via Hypack 2014®). Position data appeared in the video display and was logged to disk for post processing and/or replay. The acoustic data was recorded digitally.

Figure 5. EdgeTech 4125 sidescan sonar system.

Post collection processing of the sidescan data was completed using Chesapeake Technology, Inc's SonarWiz.MAP software. This software allows the user to apply specific gains and settings in order to produce enhanced sidescan imagery that can be interpreted and digitized for specific benthic habitat features and debris throughout the survey area. The first step in processing was to import the data into the software and bottom track the data. Bottom tracking is achieved using an automated bottom tracking routine and in some cases manual bottom tracking. This step provides the data with an accurate baseline representation of the seafloor and eliminates the water column from the data.

After bottom tracking, the data was processed to reduce noise effects (commonly due to the vessel, sea state, or other anthropogenic phenomenon) and enhance the seafloor definition. In most cases automatic TVG is sufficient to provide the best imagery. TVG divides the data into parallel swaths and equalizes backscatter of each swath to create a normalized image highlighting contrast change throughout the image, which creates a better mosaic and allows the processer to pick out areas with similar acoustic properties. In areas with high levels of noise in the data it was necessary to apply AGC which normalizes the data by strengthening quiet regions/soft returns while simultaneously reducing/eliminating overly strong returns by obtaining a local average at a given point. Upon completion of the general sidescan sonar survey, the data were examined by a registered marine archaeologist, who provided the locations of acoustic anomalies. Appendix 7 contains the cultural resource reports prepared by TAR, which includes a description of the acoustic anomalies. Appendix 2 also contains the individual acoustic anomaly images.

Vibracore Survey

The 25 vibracores were collected by AVS, under the direction of CB&I, on January 29th, 30th, and 31st 2015. The vibracores were logged, sampled and tested by GeoEngineers, Inc., and the vibracore logs and lab results are provided in Appendices 3 and 4. GeoEngineers, Inc.'s final geotechnical report with the results is located in Appendix 8. Photographs were not collected for these vibracores. Appendix 1 shows the locations of the vibracores that were collected during the geotechnical survey.

RESULTS AND DISCUSSION

Seismic Reflection Profiling Data

Each seismic profile was inspected to determine if any debris, pipelines or culturally significant targets existed in the survey area as well as the presence of any significant geologic features or bottom types. The seismic data was correlated with the vibracore data in an attempt to understand the potential borrow area deposit's surficial geology. The seismic data located in the potential borrow area indicate that the Cameron Meadows surficial geology is primarily composed of layers of soft clay over firm (medium) clay. In the southeastern area, there was the presence of shallow gas in which acoustic penetration was limited. To the north and south of the potential borrow area, paleofluvial channels were identified. These paleofluvial channels exhibit good potential for beach compatible sand and could be targeted as future sand deposits for beach nourishment projects.

The depth of the reflector representing the top of unsuitable material for marsh construction (i.e. stiff clays with torvane values greater than 1.0 tsf and predominantly sandy sediment) was unable to be determined due to the discontinuous nature of the reflector in this area. The thickness of the marsh-compatible material was unable to be determined seismically, and therefore an isopach (sediment thickness) map was not developed for the area. The seismic records also did not identify any evidence of prehistoric habitation, such as shell middens, relict channel confluences or lagoon complexes. Appendix 7 contains the cultural resource reports prepared by TAR, which includes a description of the seismic analysis.

Sidescan Sonar Data

Each line of sidescan data was inspected to determine if any debris, pipelines or culturally significant targets existed in the survey area as well as the presence of any significant geologic features or bottom types. After analyzing the data, the sidescan sonar data within the borrow area investigation area identified 23 acoustic targets. Of these 23 targets, 7 targets were identified as being significant and potentially associated with the remains of a shipwreck or other debris. These significant acoustic anomalies have been buffered by a total of 3 clusters designated for avoidance during dredge operations based on the acoustic target area. The remaining acoustic targets have been identified as non-significant, and appear to be associated with pipeline debris or small objects. The pipeline corridor investigation area did not have any acoustic targets. Appendix 7 contains the cultural resource reports prepared by TAR, which

includes a description of the acoustic anomalies and buffers for avoidance. Appendix 2 also contains the individual acoustic anomaly images.

Magnetometer Data

The magnetometer data identified 296 magnetic anomalies in the borrow area investigation area and 11 within the pipeline corridor. Of these 307 targets, 24 were identified as being significant and potentially associated with the remains of a shipwreck or other debris. These significant magnetic anomalies have been buffered by a total of 4 clusters designated for avoidance during dredge operations. Three clusters are located within the borrow area investigation area (23 significant magnetic anomalies) in which the size and orientation of each buffer is dependent upon the magnetic intensity and duration. One cluster is located inside the pipeline corridor investigation area (1 significant magnetic anomaly) with an approximate 160 ft. radius buffer. The remaining magnetic anomalies have been identified as non-significant and appear to be associated with pipeline debris or small objects. Appendix 7 contains the cultural resource reports prepared by TAR, which includes a description of the magnetic anomalies and buffers for avoidance. A map with the magnetic anomaly locations is provided in Appendix 6.

Bathymetric Data

The bathymetric data that was collected from the borrow area and pipeline corridor was reduced, reviewed and contoured. A map with the bathymetry contours for the 2014-2015 bathymetric data is provided in Appendix 6, and a finalized XYZ file will be provided digitally with the deliverables.

Vibracore Data

The vibracore logs and sample data provided by GeoEngineers, Inc. were reviewed by CB&I. Torvane tests were conducted by GeoEngineers, Inc. on selected samples within the vibracores to determine sediment consistency. These results were provided on the logs and were evaluated for the design. The sediment layers within the vibracores were classified according to the Army Corps of Engineers Unified Soils Classification System. A map with the vibracore locations is provided in Appendix 1.

The vibracores in the northern portion of the investigation area (cores 1 through 4) contained soft to firm (medium) clay with intermittent mixtures of clays with silt and sand. Cores 3 and 4 had increased amounts of sand from approximately 4 to 12 feet in the uppermost portion of these cores (clayey sand to sand with little to trace fines). The vibracores in the central portion of the investigation area (cores 5 through 18) are predominantly soft clay in the uppermost 10 ft. to 12 ft., underlain by firm clay, and including intermittent layers of clayey silt and silty sand up to approximately 3 ft. in thickness. Core 7 had approximately 6 ft. of sand with some to little fines in the uppermost portion of the core. Cores 9, 11, 12, and 13 had stiff clay up to approximately 3 ft. in thickness at the bottom of each core. The vibracores in the southern portion of the investigation area (cores 19 through 25) contained soft to firm clay with mixtures of silt and fine sand, and increased amounts of sand from approximately 3 to 8 feet in the uppermost portion of these cores (clayey sand to sand with little to trace fines).

The material is typically classified as CH (inorganic clays of high plasticity) or CL (inorganic clays of low to medium plasticity, sandy clays, silty clays), along with intermittent layers of CL-ML (inorganic silty lean clays) with increased occurrences of SM (silty sands, sand-silt mixtures), SC (clayey sands, sand-clay mixtures), SC-SM (silty clayey sand) and SP-SM or SP (sands with little or no fines) in the northern and southern portions of the investigation area due to an increased sand content in these cores.

The targeted material for the marsh design was soft to firm (medium) clay. This potentially marsh compatible material is typically mixed with minor amounts of silt and sand, and is considered the highest quality material. The potential borrow area was refined to take into account the quality of material indicated by the vibracores. The highest quality material was classified as green, based on the color coding scheme listed in Table 2, and used in the design of the final maximum after dredge elevations.

CB&I reviewed the 2015 vibracore logs for sediment quality. The logs were color coded according to marsh compatibility, where green is the highest quality, yellow is marginal, orange is below marginal and red is the lowest quality material. Material classified as orange and red were excluded from the design. Table 2 lists the criteria for color coding the vibracores. Appendices 3 and 4 contain vibracore logs and lab results provided by GeoEngineers, Inc. The laboratory data for the samples collected from the vibracores and torvane results were presented on the logs.

Table 2. *Vibracore color code scheme showing the range of sediment differentiation.*

Color Code	Description
Green	Soft to Medium Clay; Torvane < 1.0 tsf
Yellow	Sand/Clay, Sand/Silt mixtures
Orange	Sand, with trace to some fines
Red	Stiff Clay; Torvane > 1.0 tsf

BORROW AREA DESIGN

A potential borrow area, designated as the Cameron Meadows Borrow Area, was designed that contained marsh compatible material offshore of Cameron Parish, Louisiana. The material in this potential borrow area is predominantly soft clay with minor amounts of firm (medium) clay. Any identified potential cultural resources were avoided in the borrow area design and removed from the volume calculations. The potential borrow area contains a total of 4,723,000 cy of sediment, and four (4) maximum after dredge elevations that include -34.5 ft., -35.0 ft., -

35.5 ft. and -37.0 ft. NAVD88. The actual thickness of material within these final maximum after dredge cuts ranged from approximately 12.5 ft. to 15 ft. A map of the potential borrow area is provided in Appendix 6.

A detailed review and interpretation of the collected and processed data indicated that there were no seafloor resources (or other benthic habitat of concern) located within the entire survey area, including the potential borrow area. While some modern debris and some potential culturally significant targets (which were subsequently buffered for protection) were identified within the survey area, there were no identified targets of environmental concern. The size and orientation of the three avoidance buffers in the borrow area investigation area were dependent upon the magnetic intensity and duration along with the acoustic target area. The one buffer located inside the pipeline corridor investigation area has an approximate 160 ft. radius buffer. Seismic data was not used in the borrow area design. As such, isopach (sediment thickness) maps were not developed for the area because reflectors in this area were discontinuous and unable to be mapped seismically.

The potential borrow area was designed using the vibracores, since the seismic reflector for the marsh compatible material was unable to be mapped seismically. The targeted material for the design was soft to firm (medium) clay. The potential borrow area's horizontal boundary was determined by the area of influence of each core and avoidance of cultural resource buffers and pipeline infrastructure. The vibracore layer descriptions, lab analysis and torvane results were reviewed. The preliminary maximum vertical cuts were placed 2 feet above the bottom of the core or along the layer boundaries of the soft to firm (medium) clay with the stiff clay to determine the maximum disturbance depth that may be reached during dredging. This maximum disturbance depth contains marsh compatible material. The maximum disturbance depth was then projected up 3 feet to produce the final maximum after dredge elevations for each individual vibracore. These elevations were then grouped into the 4 final maximum after dredge elevations based on dredgability.

CONCLUSIONS

Concurrent geophysical and cultural resource surveys were conducted offshore of Cameron Parish, Louisiana for the Cameron Meadows Marsh Creation and Terracing Project. The geophysical and cultural resource review identified 4 clusters of magnetic and acoustic anomalies as being significant and potentially associated with the remains of a shipwreck or other debris. These areas were designated for avoidance during dredge operations and were avoided in the borrow area design and removed from the volume calculations. The seismic records also did not identify any evidence of prehistoric habitation, such as shell middens, relict channels or lagoon complexes that would need to be avoided during the design. The targeted material for the marsh design was soft to firm (medium) clay. A potential borrow area, designated as the Cameron Meadows Borrow Area, was designed that contained marsh compatible material offshore of Cameron Parish, Louisiana. The potential borrow area contains a total of 4,723,000 cy of sediment, and is shown in Appendix 6.