TE-134 West Fourchon Marsh Creation & Nourishment Project

Coastal Wetland Planning, Protection, and Restoration Act PPL 24

95% Design Report

State Project Engineer:
Thomas McClain, P.E.

State Project Manager:
Bevin Barringer, P.E.

Federal Project Manager:
Donna Rogers, Ph.D.

TABLE OF CONTENTS

TABLES	PAGE NO.

FIGURES	PAGE NO.

APPENDICIES

A. Design Calculation Packet
B. Survey Monument Data Sheet
C. Marsh Creation Area Topographic Survey Drawings
D. Marsh Creation Area Magnetometer Survey Drawings
E. Average Healthy Marsh Survey Drawings
F. Offshore Borrow Area Geophysical Data Report
G. Bayou Lafourche Survey Data
H. Marsh Creation Area Geotechnical Data Report
I. Offshore Borrow Area Geotechnical Data Report
J. Geotechnical Engineering Report
K. 95% Design Drawings
L. 95% Project Specifications

1.0 INTRODUCTION

1.1 Authority

The West Fourchon Marsh Creation and Nourishment Project (herein referred to as TE-0134) was selected for Phase I Engineering and Design by the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA) as part of the 24th Priority Project List (PPL) in partnership with the National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS). The Coastal Protection and Restoration Authority (CPRA) is serving as the local sponsor and is also performing the engineering and design work.

The engineering and design, environmental compliance, real estate negotiations, operation/maintenance planning, and cultural resources investigation detailed in this design report have been completed to the 95% design level as required by the CWPPRA Standard Operating Procedures Revision 25.

1.2 Regional History

TE-0134 is located in the Terrebonne Basin directly west of Port Fourchon between Timbalier Bay and Bayou Lafourche (Figure 1). The project area was historically comprised of tidal creeks, bayous, and marshlands. The network of swamps, marshes, and ridges in the region was created as nutrient rich sediment was deposited along the banks of the numerous distributaries associated with the Lafourche delta complex which was formed approximately 3,500 years ago. Bayou Lafourche was one of the final subdeltas to form during the Lafourche delta period before the Mississippi River switched its flow to the Plaquemines and Modern delta complexes. When the Mississippi River shifted to the east, the sediment and freshwater supply to the area decreased considerably. In 1904, a dam placed at the junction of the Mississippi River and Bayou Lafourche essentially eliminated the source of river sediments to the area. This loss of sediment to the area and erosion from tropical storms and hurricanes have impacted the marshlands in the area and the barrier islands and headlands at the entrance to Timbalier Bay that have historically provided protection to the project area. As the landbridge between Timbalier Bay and Bayou Lafourche deteriorates, critical infrastructure, including Port Fourchon, LA Highway 1, and the lower Lafourche levee system become threatened.

Historic wetland loss in the project area stems from interior marsh loss due to factors such as subsidence, tropical events, sediment deprivation, and construction of pipeline canals. TE-0134 is located between a busy navigation canal to the east and open water in Timbalier Bay to the west and is subject to many sources of erosion.

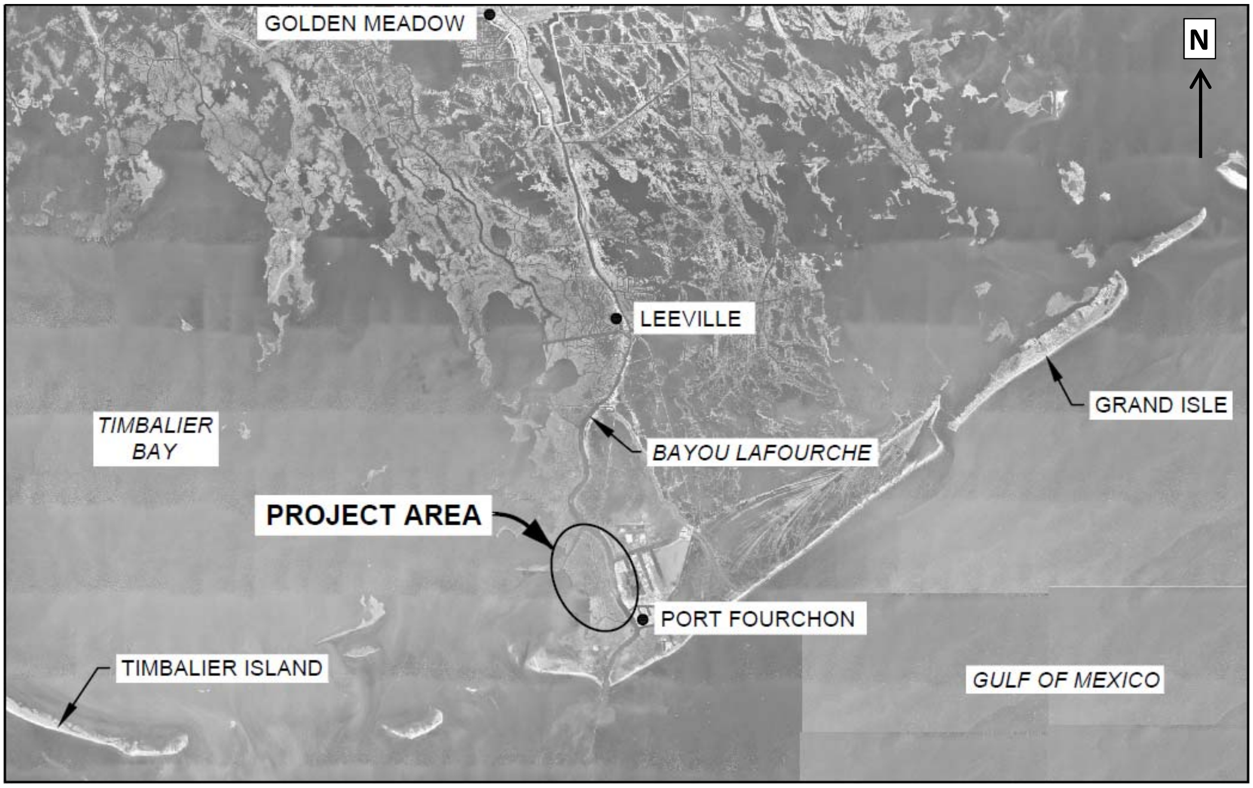


Figure 1: TE-0134 Vicinity Map

1.3 Project Goals

The primary goals of TE-0134, as defined in Phase 0, are to create and nourish approximately 614 acres of saline marsh, by pumping sediment from an offshore borrow site in the Gulf of Mexico, to improve the longevity of the marsh and resistance to waves with a secondary benefit of protecting the people and infrastructure of Port Fourchon. Throughout the Phase 1 process, the target acreage has been reduced to 537 acres due to refinement of the Phase 0 project outlined in this report.

1.4 Project Team

NMFS is serving as the federal project sponsor in addition to providing environmental compliance and coordination for cultural resources. CPRA is serving as both the local project sponsor and providing engineering and design services. The Project's Consulting Team included Coastal Engineering Consultants, Inc. (CEC), Tetra Tech, Inc. (Tetra Tech), T. Baker Smith, LLC (TBS), and Ardaman & Associates, Inc. (Ardaman). CEC of Baton Rouge, Louisiana and Naples, Florida was tasked with a cultural resource investigation, geophysical surveys, and geotechnical sampling associated with the offshore borrow area and conveyance corridor. The CEC team consisted of the following sub-consultants: Ocean Surveys, Inc. (OSI) of Old Saybrook, Connecticut performed the geophysical survey and soil sampling data collection efforts; GeoEngineers of Baton Rouge, Louisiana performed material characterization testing of the collected offshore borrow area samples; and RC Goodwin and Associates of Baton Rouge, LA provided cultural resource consultation. A Hazardous, Toxic, and Radioactive Waste Investigation and Phase I environmental site assessment was conducted by Tetra Tech, Inc. of Baton Rouge, Louisiana. T. Baker Smith, LLC (TBS) of Prairieville, Louisiana was tasked with topographic, bathymetric and magnetometer surveys within the marsh creation area and Bayou Lafourche. Ardaman & Associates, Inc. (Ardaman) of Jefferson, Louisiana was tasked with the geotechnical engineering investigation, laboratory testing and geotechnical analyses.

2.0 EXISTING CONDITIONS

2.1 Land Ownership

The project area is entirely situated on land owned by the Louisiana Land and Exploration Company (LL&E). LL&E has been provided information on the 30% design. A preliminary landownership map is shown in Figure 2. Five pipelines in and adjacent to the immediate Marsh Creation Area are shown in Figure 2 and detailed in Table 1. Based on preliminary information, the pipelines within the project area are owned by Kinetica, Enlink, Chevron, and Kinder Morgan. Preliminary coordination with these pipeline owners has begun and will continue through design and construction. The dredge pipeline corridor crosses numerous pipelines in the gulf. Identification, ownership, and pipeline owner coordination efforts are ongoing and coordination will continue throughout construction.

2.2 Preliminary Cultural Resources Assessment

CPRA tasked CEC with conducting a Phase I cultural resources survey and geophysical survey of the proposed offshore borrow area in the Gulf of Mexico. CPRA reviewed historic records and archives and identified potential cultural resources within the area of the proposed dredge pipe corridor.

The NMFS contacted the Louisiana State Historic Preservation Office (SHPO) to request a determination of effect for any Area of Potential Effects (APE) that might be recorded within the marsh creation areas, proposed offshore borrow area, and pipeline access corridor. In May 2018, SHPO concurred in response to the draft geophysical/cultural resources report that no properties listed in or eligible for listing would be affected by the use of the borrow area and gulf conveyance corridor. SHPO previously confirmed in December 2015 that no cultural resources would be affected in the Phase 0 marsh creation area and in February 2016 that no cultural resources would be affected in the marsh creation areas and the Bayou Lafourche dredge pipeline corridor.

2.3 Oyster Lease Assessment

There are no oyster leases directly within the TE-0134 project area. Two existing oyster leases approximately 4.5 and 8.2 acres in size are located west of the marsh creation area. Due to their proximity to the project area, it is expected that at least 5 acres of oyster leases will be acquired and extinguished following a third party assessment. The assessment and acquisition processes will be performed upon approval of Phase II funding to ensure that no leases are extinguished without construction certainty.

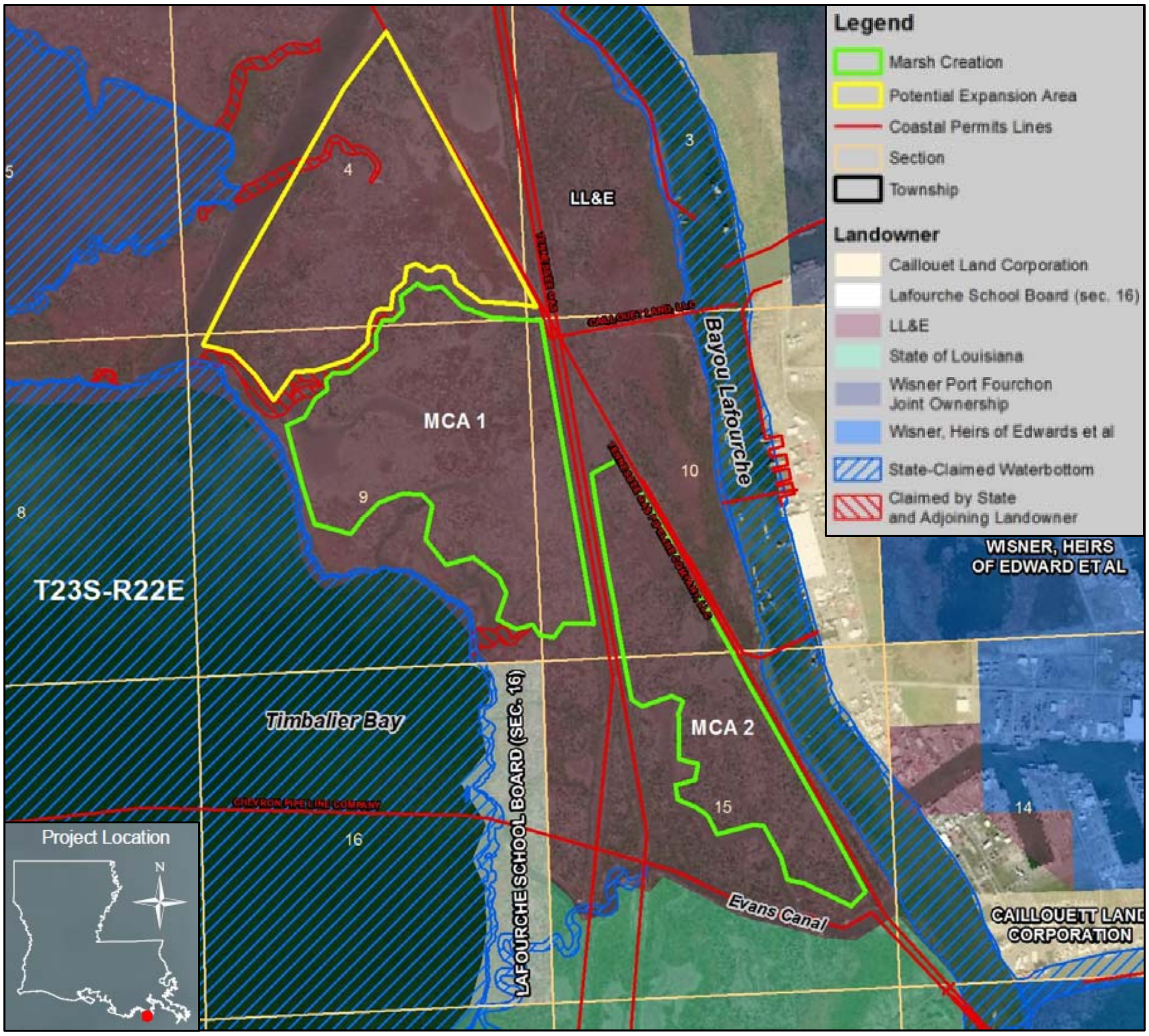


Figure 2: Tax Ownership Map

Table 1: Preliminarily Identified Pipelines within Project Area

Pipeline	Owner	Relation to Project Area
16-inch Natural Gas	Kinetica (previously owned by Tennessee Gas)	In twin pipeline canals between the marsh creation areas
16-inch Natural Gas	Kinetica (previously owned by Tennessee Gas)	In twin pipeline canals between the marsh creation areas
12-inch Natural Gas*	Enlink	Runs parallel to the two 16-inch pipelines just east of the easternmost pipeline canal
10-inch Crude Oil	Chevron	Runs along Evans Canal just south of the project area
Abandoned 6-inch	Kinder Morgan	Just east of the project area
*Not Shown in Figure 2		

2.4 Tidal Datum

The tidal datum is a standard elevation defined by a certain phase of the tide and issued to measure local water levels. The tidal datum for TE-0134 was established in the early stages of preliminary engineering since it pertains to many aspects of the project design including surveys, geotechnical analysis, and constructability. However, the primary objective for computing the tidal datum is to establish the target construction fill elevation that maximizes the duration that the restored marsh will be at intertidal elevations throughout the 20-year project life.

A tidal datum is referenced to a fixed point known as a benchmark and is typically expressed in terms of mean high water (MHW), mean low water (MLW), and mean tidal levels (MTL) over the observed period of time. MHW is the average of all the high water elevations observed over one tidal epoch. MLW is the average of all the low water elevations observed over one tidal epoch. MTL is the mean of the MHW and MLW for that time period. A normal tidal epoch lasts approximately 19 years; however, since this project is located near the Gulf of Mexico and has anomalous sea-level changes, a modified tidal epoch of 5 years is typically used. After consulting with the CPRA Planning Division, it was determined that the full period of record would also yield accurate water level information. The calculated full period of record water levels and the 5-year modified tidal epoch from TE-0134 differed by less than one tenth of a foot.

The Coastwide Reference Monitoring System (CRMS) monitoring station CRMS0292 located at 29°08'31.85"N, 90°13'45.12"W was selected as the control station. The full period of record used was May 12, 2006 to December 14, 2017. A detailed summary of the tidal datum calculations is shown in the Design Calculations Packet in Appendix A. The results of the tidal datum determination for the TE-0134 project area are as follows:

- MHW = +0.86 ft, NAVD88 Geoid 12A
- MLW = -0.46 ft, NAVD88 Geoid 12A
- MTL = +0.20 ft, NAVD88 Geoid 12A

Historically, the tidal range has been the accepted range for healthy marsh. However, this method neglects non-tidal water level influences such as climatic conditions and management regimes. To account for tidal and non-tidal influences, an additional water level determination method known as Percent Inundation was used to determine the optimal marsh elevation range and is discussed in Section 2.6.

2.5 Relative Sea-Level Rise

Since all projects within the CWPPRA program are built and evaluated based on a 20-year project life, they are expected to continue to perform the goals listed in Section 1 throughout the design life. Therefore, to properly design the project to meet the 20-year goal, certain natural processes are assessed. One process is Relative Sea-Level Rise (RSLR). RSLR can be broken down into two components, Eustatic (or Global) Sea-Level Rise and Subsidence.

Eustatic Sea-Level Rise refers to a global change in water level. The value associated with Sea-Level Rise is based on a global average rate of increase of water level that takes into account a number of variables such as thermal expansion, loss of glaciers and ice caps, runoff from thawing permafrost, to name a few. This means of measuring the sea level rise rate is expressed by the Intergovernmental Panel on Climate Change (IPCC). The 2007 IPCC evaluation determined the global sea-level rise to be 0.005576 feet/year. The CPRA uses the slightly higher historical linear rate of Gulf sea-level rise (0.008858 feet/year) as the basis for sea-level rise calculations.

To determine the most likely change in relative sea level over time along coastal Louisiana, the CPRA Planning Division provided forecasted sea-level rise rates consistant with the 2017 Master Plan. These rates are bracketed to provide a lower and higher value to account for uncertainty. The range for possible Eustatic Sea-Level Rise by 2041 is 3 to 11 inches. TE-0134 based future water levels on the 1 meter scenario from the 2017 Master Plan. The 1 meter scenario assumes that sea level will increase by 1 meter (40 inches) by the year 2100.

Subsidence is the other natural process that needs to be considered in the design of the project to achieve the project goals over the 20-year project life. Subsidence is defined as the rate of local vertical land movement. Causes of subsidence vary by location include natural processes such as tectonics (faulting) and Holocene sediment compaction, as well as human-related causes such as removal of subsurface fluids.

To calculate subsidence rates across coastal Louisiana, the CPRA Planning Division used the projected moderate scenario subsidence ranges (based on historical data) from the 2017 CPRA Master Plan as shown in Figure 3. Figure 3 was created using some of the lowest and highest subsidence rates researchers found in those areas. The Terrebonne and Barataria Basins have a wide range of subsidence rates, with an average of 6.4 mm/yr (0.244 inches/yr) calculated. Combining the range for possible eustatic sea-level rise by 2041 calculated in Section 2.6, equates to a combined subsidence and sea-level rise of approximately 8 to 16 inches over the 20-year design life of this project as shown in Figure 3. This information was included to predict water levels at year 20 on the marsh creation fill settlement curves provided in Section 4.4. Unlike past projects which utilized relative sea-level rise (RSLR) to account for regional subsidence as a component of water level, this project has separated the ESLR and regional subsidence components. This was done so that the historically derived regional subsidence could be applied to the surveyed mudline of the Marsh Creation Areas and the forecasted ESLR could be applied to the water/inundation levels to represent real world conditions.

Accretion measurements collected at the nearby CRMS 0292 station averaged approximately 9.2 mm/year (0.362 inches/year) over a 10-year period of record from July 2007 through July 2017. We expect accretion to at least partially offset the impact of subsidence on the relative vertical position of the marsh platform over the life of the project. However, because of spatial and temporal variability and uncertainty about extrapolating short-term accretion data over the project life in addition to uncertainty of the effects construction will have on the observed accretion data, we are not incorporating accretion in the estimated settlement curves or SLR calculations.

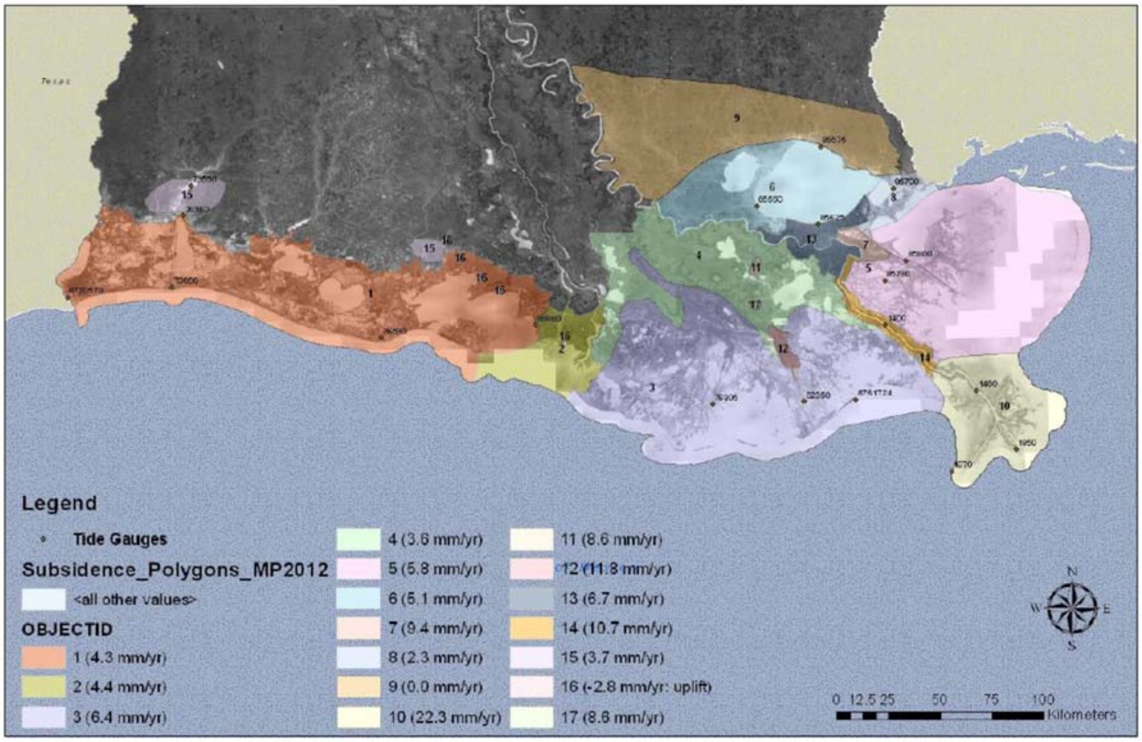


Figure 3: Map of Projected Subsidence Ranges 2017 CPRA Master Plan, Moderate Scenario Subsidence

2.6 Percent Inundation Determination

The vertical positioning of marsh platforms and the frequency with which the marsh floods strongly influence plant communities and marsh health. Historically, the tidal range between mean high water (MHW) and mean low water (MLW) has been the accepted range for healthy marsh. This approach has worked well in tidal salt marshes where most of the water level variability is due to astronomical tides. Across Louisiana's coastal wetlands, non-tidal influences such as meteorological events, river discharge, and management regimes often have a significant impact on water levels along with the astronomical tides. Therefore, using percent inundation rather than tidal range as a proxy for marsh health can give a more accurate representation of the water levels found in the area. Percent inundation refers to the percentage of the year a certain elevation of land would be flooded. To illustrate the two approaches, Figure 4 shows both MHW and MLW and 20% and 80% inundation levels.

To determine percent inundation, the percentiles were calculated based on data from the CRMS 0292 station. A detailed summary of the percent inundation calculations is shown in the Design Calculations Packet located in Appendix A. The results of the percent inundation determination for TE-0134 at TY0 (2021) and TY20 (2041) are shown in Table 2.

Table 2: Percent inundation elevations for TY0 and TY20

TY0 (2021)		TY20 (2041)	
Percent Inundated	Elevation (ft) NAVD88 Geoid 12A	Percent Inundated	Elevation (ft) NAVD88 Geoid 12A
10%	1.010	10%	1.498
20%	0.760	20%	1.248
30%	0.570	30%	1.058
40%	0.410	40%	0.898
50%	0.250	50%	0.738
60%	0.080	60%	0.568
70%	-0.110	70%	0.378
80%	-0.330	80%	0.158
90%	-0.620	90%	-0.132

Saline marshes, like those in the TE-0134 project area, are most productive when flooded between 20% and 80% of the time. The project team utilized best professional judgment to identify target constructed marsh elevations that would maximize short-term and long-term marsh function while taking into account eustatic sea-level rise (ESLR) (Figure 4).

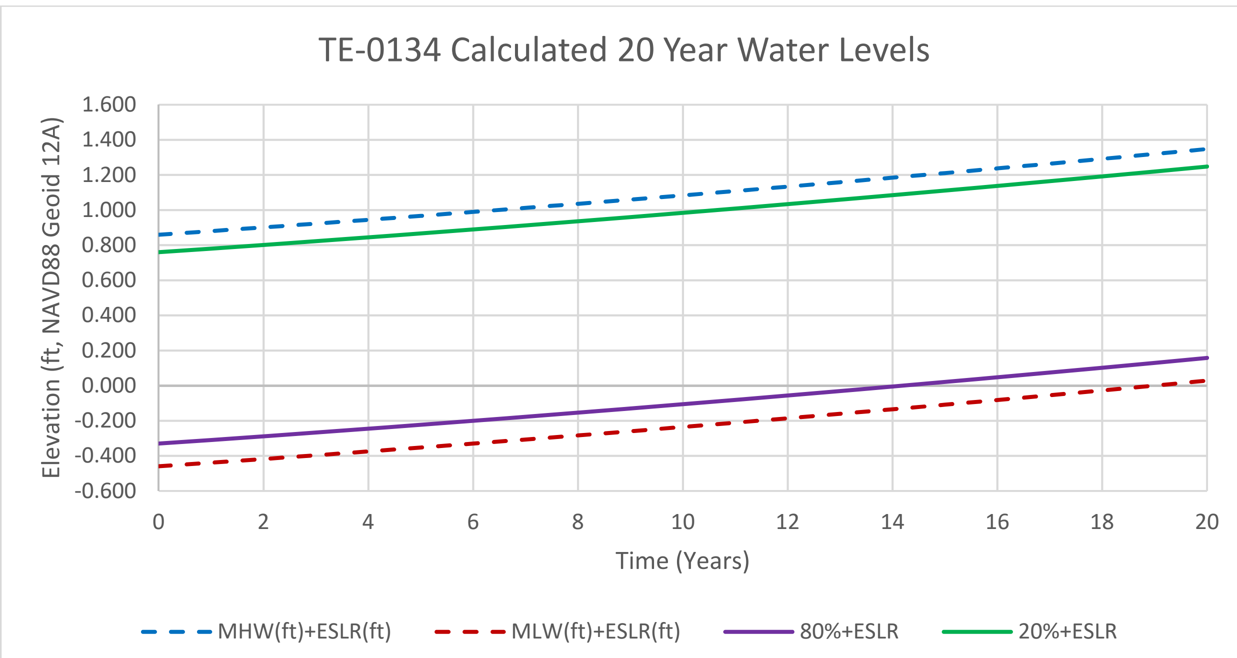


Figure 4: Percent inundation and MHW, MLW comparison.

3.0 SURVEYS

3.1 Topographic, Bathymetric, Magnetometer, and Geophysical Surveys

Topographic, bathymetric, magnetometer, and geophysical survey data was collected within the project area, offshore borrow area, equipment access and dredge pipeline corridors to facilitate the design of the marsh creation areas and offshore borrow area. The marsh creation areas and Bayou Lafourche components of the survey effort were performed from July 2016 to September 2016 by TBS. The offshore borrow area and dredge pipeline corridor surveys, to the Bayou Lafourche components of the design survey effort, were performed in two stages; February 2017 and September 2017 by OSI as a sub-contractor to CEC. All horizontal coordinates are referenced to Louisiana State Plane Coordinate System South Zone (1702), North American Datum of 1983 (NAD 83). All elevations are referenced to North American Vertical Datum of 1988 (NAVD 88) Geoid12A.

3.2 Horizontal and Vertical Control

One National Geodetic Survey (NGS) primary monument (TE23-SM-01) is located in the vicinity of the project area. NGS monument TE23-SM-01 is located southeast of Port Fourchon, 40 feet east of the centerline of La Hwy 3090 and 65 feet northeast of the bridge approach near Pass Fourchon, Louisiana. The field survey was accomplished utilizing RTK surveying procedures and checked using Gulfnet Virtual Real-Time Network (VRS). The data sheet for the survey monument is in Appendix B. The offshore raw bathymetry data was referenced to the NOAA tide gauge (Station ID 8762075) before being converted to Geoid 12A elevations using NOAA's VDatum (V3.6.1) conversion tool.

3.3 Marsh Creation Area Surveys

Survey transects were laid out in a 1000 ft by 500 ft grid oriented in a northwestern alignment to better capture the marsh creation area as shown in Figure 5. In addition, centerline and cross-section transects spaced at approximately 1000 ft were taken along canals and bayous within, and adjacent to, the project area as shown in Figure 6. Transects were taken over open water areas, broken marsh and across pipeline canals. Position and elevation were recorded every 25 feet along each transect or where elevation changes were greater than 0.5 feet. Applicable topographic and bathymetric survey methods were used to obtain all transects consistent with CPRA Standards (outlined in the CPRA Marsh Creation Design Guidelines). The topographic and bathymetric data sets were merged at the appropriate land/water interfaces with a maximum separation of 25 feet between the data sets. Side shots were taken as necessary to pick up variations in topographic features (highs and lows) such as trenasses, meandering channels, broken marsh areas or any other existing infrastructure (pipelines, well heads, wooden gates, warning signs, etc.), which may affect project design. A fixed-height aluminum rod (8ft or 10 ft in length) with a 6-inch diameter metal plate as the base of the rod was used to prevent the rod from sinking when topographic data was collected. The topographic survey drawings are included in Appendix C. The average elevation of the northern marsh creation area was approximately -0.63ft NAVD88 with most survey points within -2.0 ft and +1.0 ft range. The average elevation of the southern marsh creation area was approximately -0.21ft NAVD88 with most survey points within a -2.0 ft and +1.0 ft range.

3.4 Infrastructure Surveys

To locate existing infrastructure such as pipelines and obstructions in the project area, a magnetometer survey was taken along the same topographic transects, within Havoline Canal, just north of the project area, and within Evans Canal, just south of the project area, as shown in Figure 7. A Marine Magnetics SeaSpy Magnetometer was utilized and correlated to a position with RTK GPS using the Hypack Navigation Software package. For each magnetic finding, a closed loop path was run with the magnetometer. The path completely enclosed the original finding location, while maintaining a distance of approximately 25 feet from that location.

The magnetometer survey verified the existence of five pipelines within the project area. The plugged and abandoned in place 6-inch Kinder Morgan Pipeline is located along the eastern boundary of the project area. This pipeline has an average depth of cover of approximately 11 feet along the pipeline canal. This pipeline canal is actively being filled with spoil from maintenance dredging at Port Fourchon. The two pipelines that bisect the marsh creation areas are 16-inch Kinetica Pipelines which have an average depth of cover of approximately 9 feet. Running parallel to the two Kinetica Pipelines is the 12-inch Enlink Pipeline. This pipeline is not within a pipeline canal and is just east of the existing Kinetica spoil bank with a four-foot average depth of cover. The 10-inch Chevron Pipeline is located south of the project area in Evans Canal. Depth of cover varies from 2 feet to over 14 feet within Evans Canal. The magnetometer survey lines and locations of anomalies and intensities are shown on the magnetometer survey drawings in Appendix D.

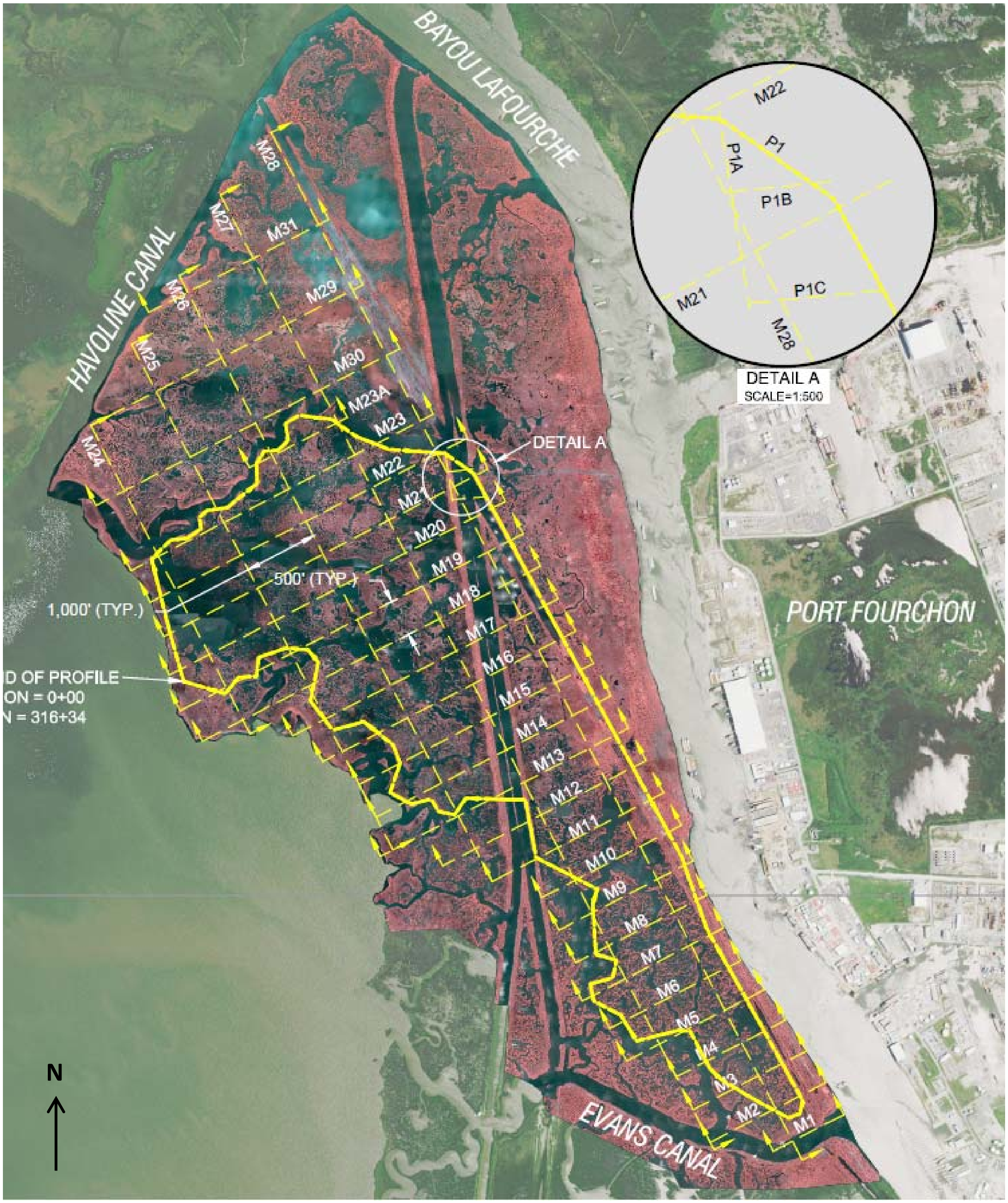


Figure 5: Marsh Creation Area Survey Transects.

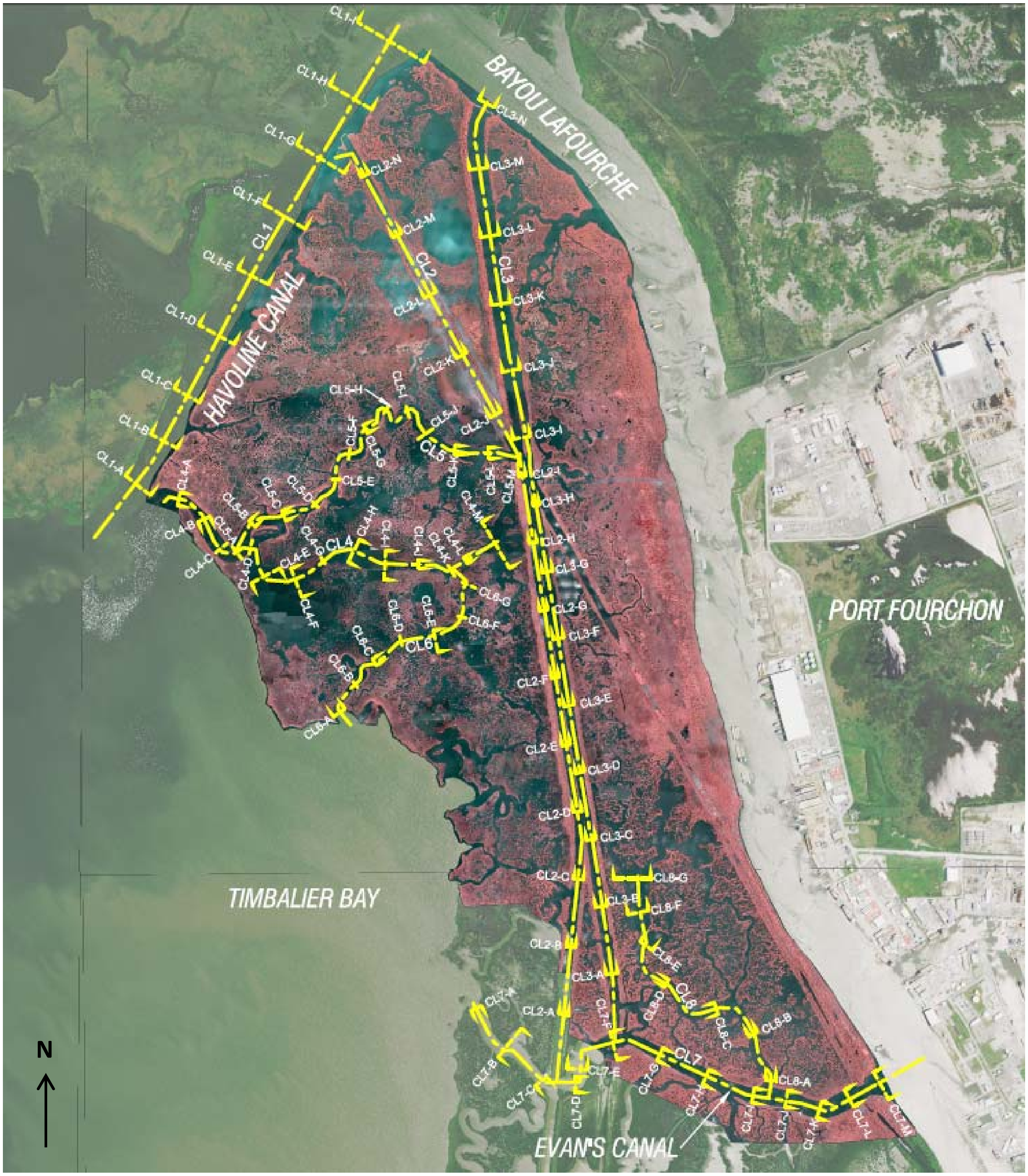


Figure 6: Canal and Bayou Survey Transects.

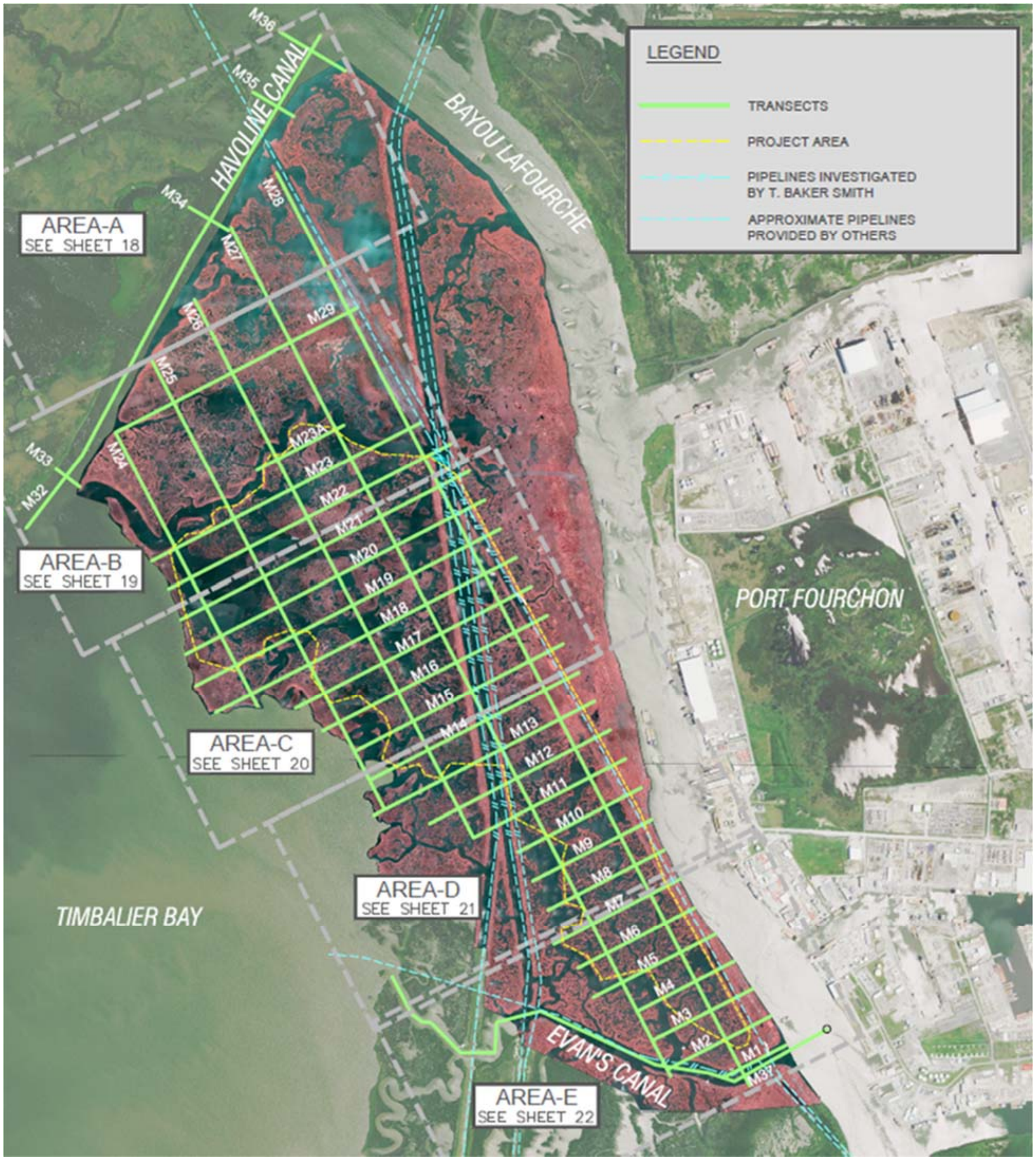


Figure 7: Marsh Creation Area Magnetometer Survey Transects.

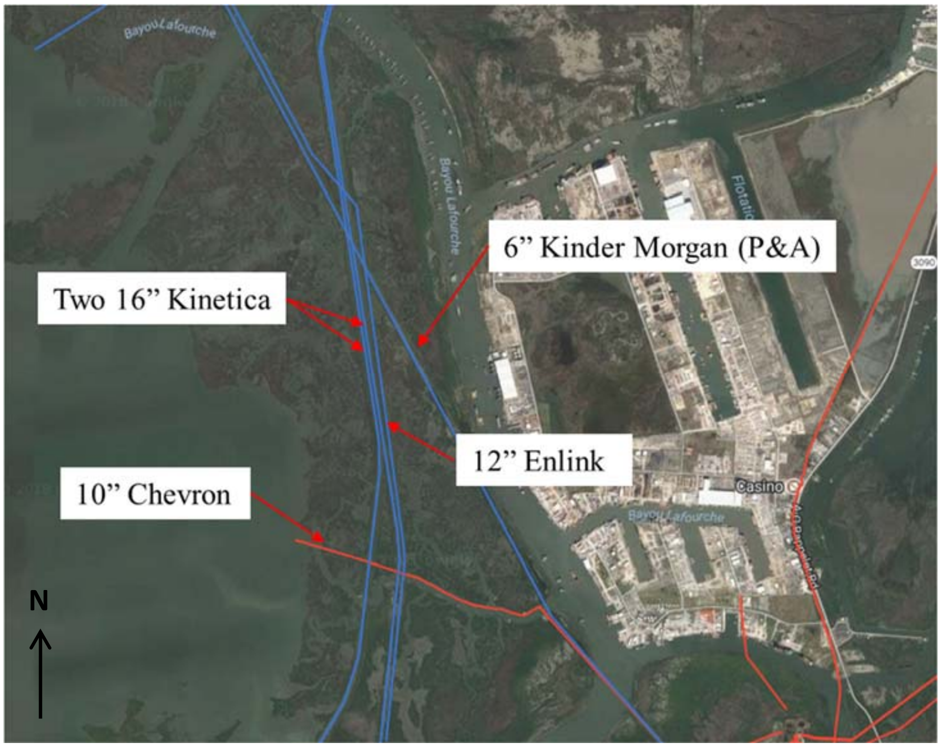


Figure 8: Pipeline Locations within Marsh Creation Area.

3.5 Healthy Marsh Elevation Survey

To better understand what elevations coincide with healthy, productive, marsh habitat in the area, Elaine Lear (CPRA field biologist) identified five areas considered to be healthy marsh within the project area. The surveyor recorded approximately 40 elevation readings at each healthy marsh area to determine an average elevation for each location. Elevations from points, shown in Appendix E, which appeared to have healthy marsh were utilized to determine an average elevation of healthy marsh. Table 3 shows the results of the average healthy marsh survey. According to this survey, the healthy marsh elevation averaged across the project area is +0.32 ft NAVD88 Geoid 12A. This elevation is used in conjunction with the percent inundation methodology to inform the design and is used to measure project performance against the goals previously defined.

Table 3: Average healthy marsh elevation survey results.

Location	Elevation (ft. NAVD88 Geoid 12A)
AV1	+0.50
AV2	+0.26
AV3	+0.29
AV4	+0.28
AV5	+0.26
Average	**+0.32**

3.6 Offshore Borrow Area Survey

A previously defined offshore borrow area for the West Belle Barrier Headland Project (TE-52) marsh was considered, but was scheduled for use by another coastal restoration project. A borrow area search was initiated. The offshore borrow area surveys were performed in two separate data collection efforts. The first reconnaissance level investigation performed a full geophysical survey consisting of bathymetry, magnetometer, side-scan sonar and sub-bottom profiling at 1,500 ft transects in a grid pattern shown in Figure 9. This reconnaissance effort was performed over a 2,800-acre area to narrow down potential borrow areas with suitable mixed sediment for marsh fill devoid of any cultural resources or existing infrastructure. Three potential borrow areas were identified within the initial 2,800-acre footprint. Vibracore samples were taken at each potential borrow area (Figure 10) and analyzed before selecting Borrow Area 1 (Figure 11) as the final proposed borrow area for a full geophysical investigation according to SHPO guidelines.

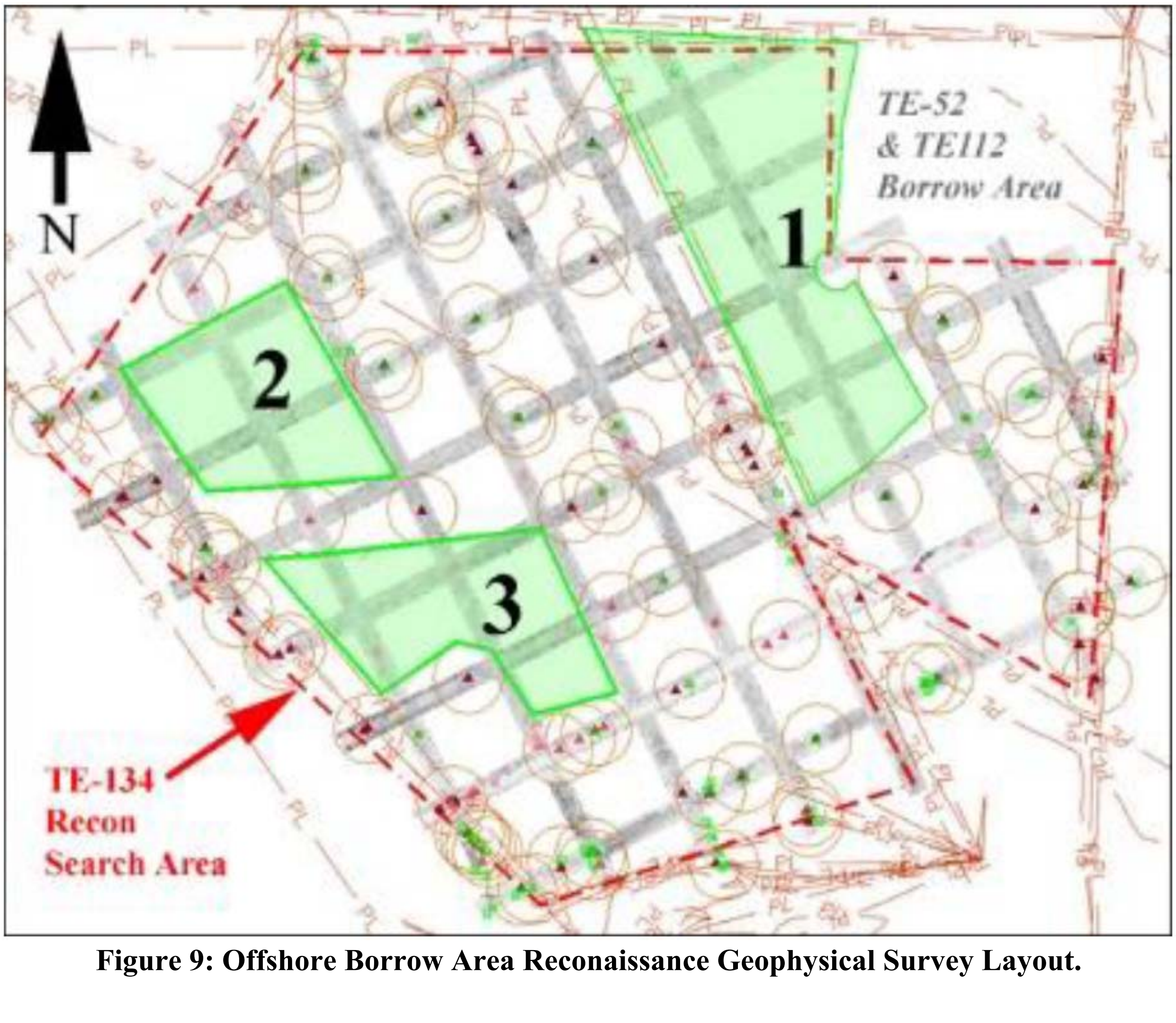


Figure 9: Offshore Borrow Area Reconaissance Geophysical Survey Layout.

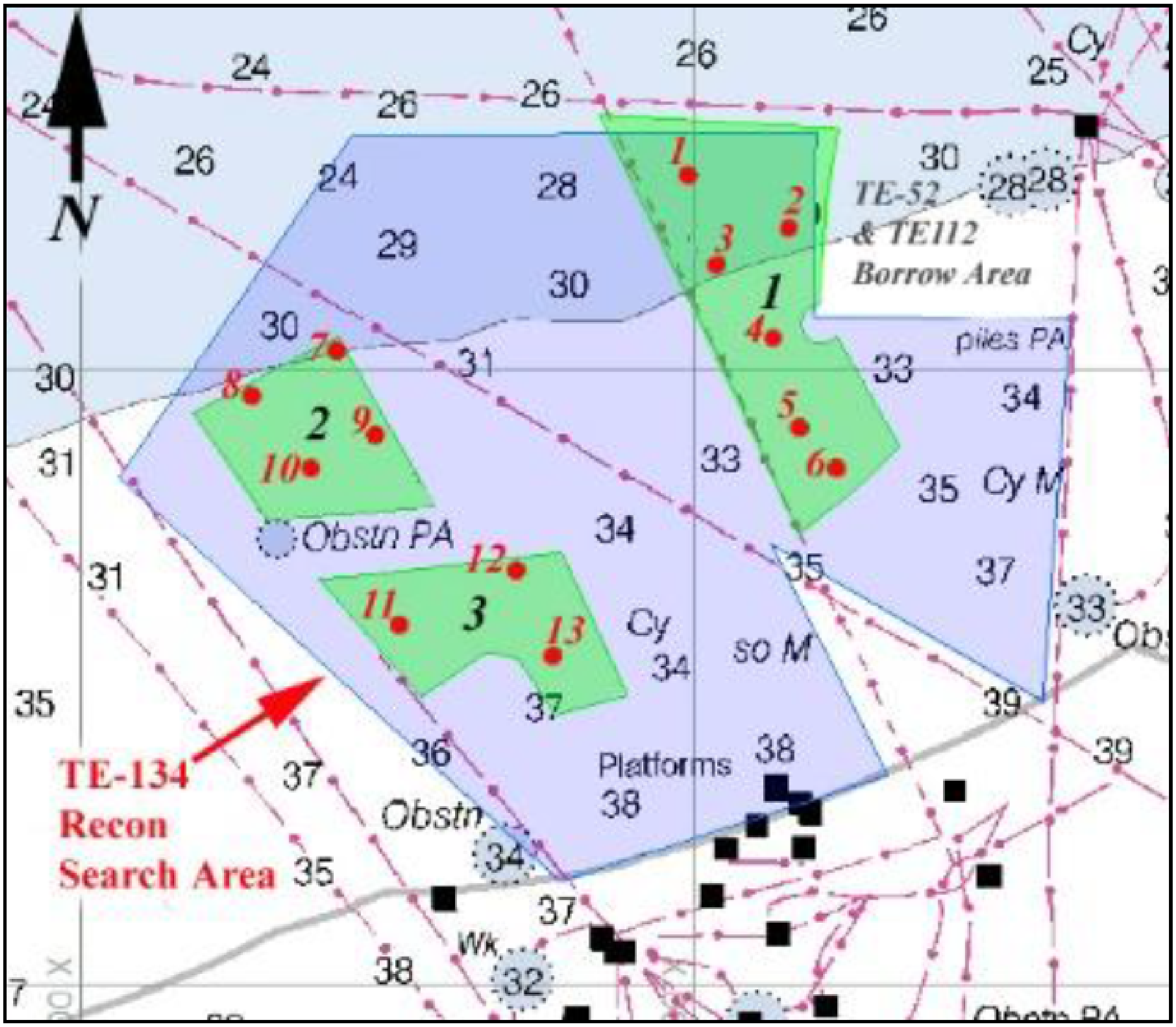


Figure 10: Offshore Borrow Area Reconaissance Vibracore Locations (labeled 1 through 13).

Bathymetric, magnetometer, and geophysical survey transects in the final proposed borrow area (Borrow Area 1) were taken every 98 feet with perpendicular cross or "tie" transects spaced every 1,000 feet to comply with the SHPO requirements for geophysical surveys (Figure 11). Bathymetric survey methods consistent with CPRA Standards (outlined in the CPRA Marsh Creation Design Guidelines) were used to obtain all transects. Water depths of the borrow area ranged from 28 to 36 feet with a gentle slope of 1 foot vertical in 900 feet horizontal in a southward direction.

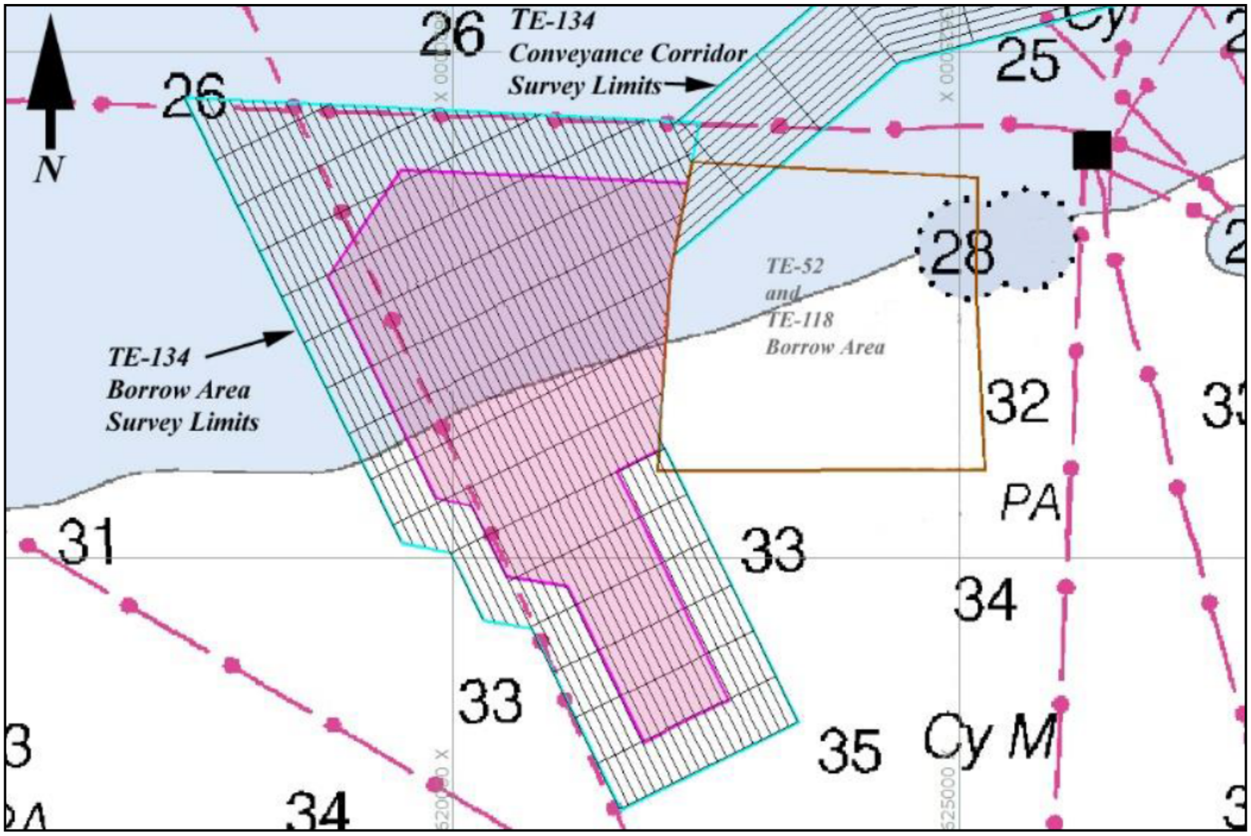


Figure 11: Offshore Borrow Area Geophysical Survey Transects.

The magnetometer component of the geophysical survey verified the existence of multiple pipelines and magnetometer anomalies in the vicinity of the proposed borrow area. The water depth in this area of the Gulf of Mexico ranges from 20 to 40 feet and probing for depth of cover was not possible without additional equipment. The borrow area was designed to avoid most magnetometer hits and 100- to 500-foot radius dredging avoidance buffers were applied in the few locations that magnetometer hits could not be avoided. Locations of these magnetometer anomalies are presented in Appendix F.

3.7 Dredge Pipeline Corridor Surveys

The dredge pipeline corridor survey was conducted as three separate efforts: desktop research of publicly available U.S. Army Corps of Engineers (USACE) navigation surveys in Bayou Lafourche; Evans Canal and Bayou Lafourche bathymetry and magnetometer surveys performed by TBS; and full geophysical surveys from the Belle Pass jetties to the offshore borrow area performed by OSI. Bathymetric survey methods consistent with CPRA Standards were used to obtain all transects.

The USACE maintains the navigation channel in Bayou Lafourche and performs annual surveys within the bayou to determine the need for maintenance dredging events. This data is publicly available and was used as the starting point in determining the suitability of utilizing Bayou Lafourche as a potential dredge pipeline corridor. As can be seen in Figure 12, the annual USACE surveys provide coverage of the Bayou Lafourche navigation channel from Port Fourchon to past the Belle Pass jetties.

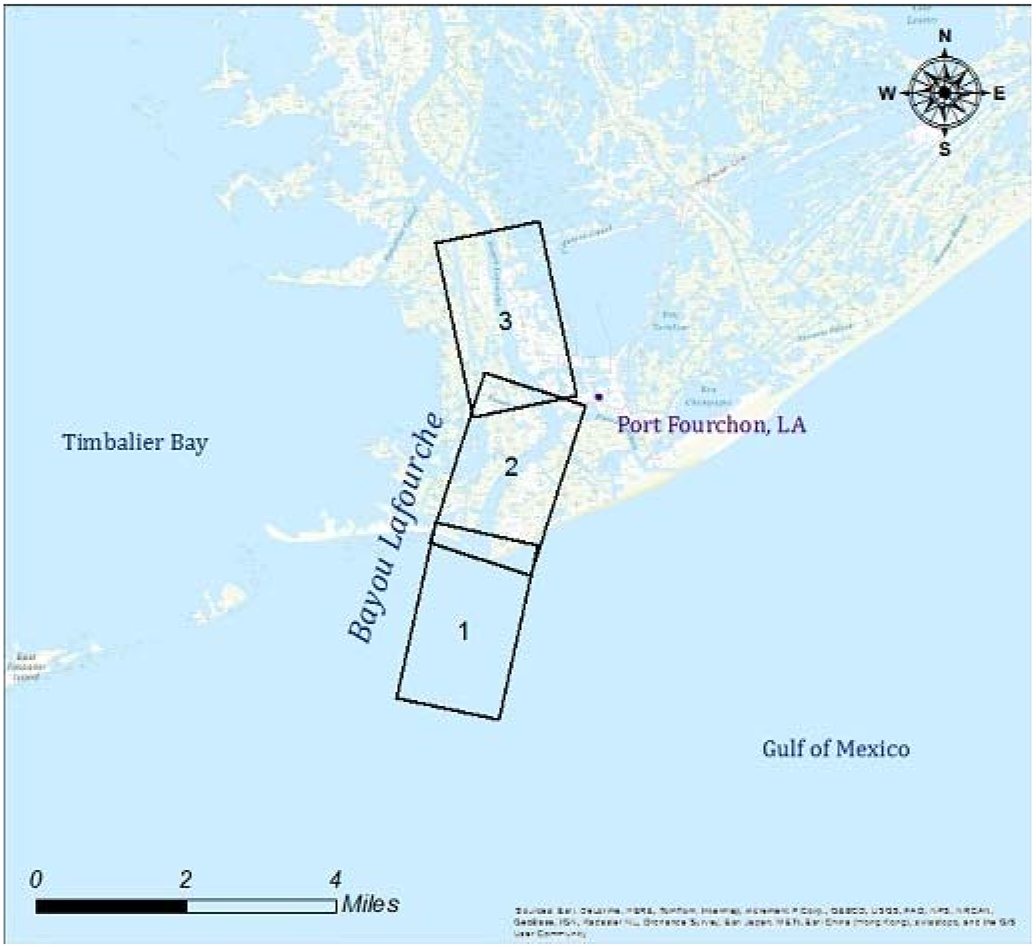


Figure 12: Location of USACE Bayou Lafourche Surveys.

The TBS Bayou Lafourche survey consisted of sidescan sonar, magnetometer, and RTK GPS data collection along three profile transects on 100-ft centers with 1000-ft spaced cross-sections with position and elevation data collected every 100 ft. The TBS Evans Canal survey efforts consisted of magnetometer, sidescan sonar, multibeam bathymetry, and RTK GPS data collection. Approximately 2,000 ft of Evans Canal was surveyed from the intersection of Bayou Lafourche to the west before turning north for approximately 400 ft into a small bayou that formed the boundary of the Phase 0 project area. This survey provided sufficient overlap with the bayou surveys conducted as part of the marsh creation area surveys. Several pipelines crossing Bayou Lafourche were located along this section of the dredge pipeline corridor but should not have any impacts due to the current plan to float the dredge pipeline along the bankline of the bayou. The results of the bathymetric and magnetometer survey can be found in Appendix G.

Upon selection of the final offshore borrow area, a bathymetric, magnetometer, and geophysical survey was performed on the proposed alignment from the selected offshore borrow area to the intersection with the rock jetties of Belle Pass. Since Bayou Lafourche is an active and maintained navigation channel, existing available data should provide sufficient and current data in the bayou and the geophysical data collection effort was terminated at the mouth of the Belle Pass jetties. The purpose of this survey was to identify any potential access issues for the dredge pipeline including existing pipelines or wellheads and culturally significant areas. Transects were spaced every 98 feet with perpendicular cross or "tie" transects spaced every 1,000 feet, as shown in Figure 11 to comply with the SHPO requirements for geophysical surveys. The magnetometer portion of the geophysical survey verified the existence of the multiple pipelines that cross the dredge pipeline corridor. Since the water depth in this area of the Gulf of Mexico is approximately 30 feet, probing for depth of cover was not possible without additional equipment. The project team is coordinating with individual pipeline owners as the project moves toward construction. The results of the geophysical survey are in Appendix F.

4.0 GEOTECHNICAL ENGINEERING ANALYSIS

In order to determine the suitability and physical characteristics of the soils in the TE-0134 project area, a geotechnical subsurface investigation and geotechnical engineering analysis was conducted by Ardaman. Ardaman collected 11 soil borings and performed 23 Cone Penetration Tests (CPTs) within the TE-0134 Project area. In addition, Ardaman performed laboratory tests to determine soil characteristics, perform global slope stability analysis of the proposed earthen containment dikes, estimated the total settlement of the proposed earthen containment dikes and marsh creation areas, and evaluated soil strength conditions at multiple locations along the proposed earthen containment dike alignment.

A geotechnical subsurface investigation of the offshore borrow area was conducted by OSI to determine the suitability and physical characteristics of the dredge material. Preliminary material characterization testing was performed by GeoEngineers. OSI collected 13 vibracores from three potential borrow areas (Figure 10). In addition, OSI collected water samples from the location of the vibracore samples to be used in the laboratory testing. GeoEngineers conducted unit weight, moisture content, and Atterberg Limits tests on composite samples of each vibracore to aid in selecting the final offshore borrow area for final geophysical surveys. Additionally, Ardaman analyzed the vibracores taken in the offshore borrow area by OSI; performed unit weight, moisture content, and Atterberg Limits tests on each collected sample to determine dredge fill characteristics; and performed settlement and consolidation tests in order to aid in the settlement determination of the marsh creation areas. The vibracore samples were split in half so that both GeoEngineers and Ardaman could perform laboratory testing and analysis per their respective scopes.

4.1 Marsh Creation Area Soil Investigation

Soil conditions were evaluated in the marsh creation area by advancing 11 soil borings and 23 CPTs to depths ranging from approximately 10 to 60 feet below the existing mudline. The approximate soil boring locations are shown in Figure 13. Seven pairs of soil borings and CPTs were taken in the immediate vicinity of each other across the Phase 0 footprint to assist in correlating the soil parameters for the remaining CPTs.

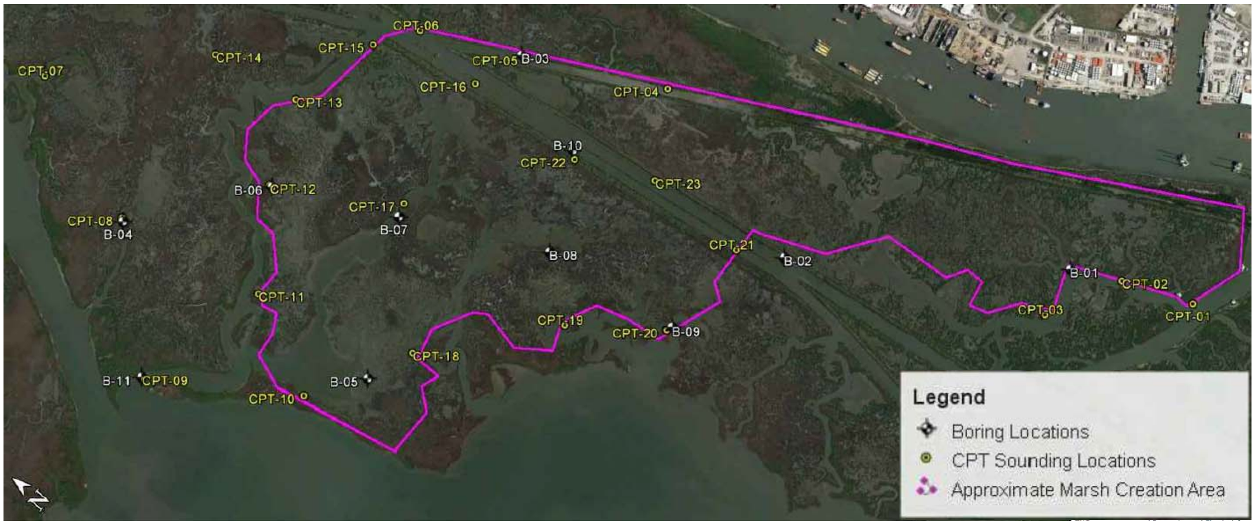


Figure 13: Marsh Creation Area Soil Boring and CPT Locations.

The soil borings were taken in 0 to 3 feet of water to depths ranging from approximately 40 to 60 feet. One boring was terminated at 18 feet below the mudline due to an impenetrable deep shell layer. Samples were collected continuously in the upper 20 feet of the soil and on 5-foot centers thereafter to boring completion depths. The soil borings were completed in February 2017 using an airboat-mounted rotary-drill rig. Soil strength, unit weight, and index properties observed during drilling and laboratory test results are located in the soil boring logs in Appendix H.

The CPTs were performed in 0 to 3 feet of water to depths ranging from 10 to 40 feet below the mudline depending on the soil refusal depth. The CPTs were completed in February 2017 using an airboat-mounted CPT rig. Processed CPT plots are located in Appendix H.

Laboratory tests included unconsolidated undrained triaxial compression tests, consolidation tests, Atterberg limits, moisture content tests, grain size analysis, and unit weight determinations.

Subsurface conditions vary slightly across the marsh creation area. Generally, there is 2 to 4 feet of very soft to soft clay with organics underlain by layers of sand, silty sand, clayey sand, or shell to depths of about 15 feet below the mudline. These soft surficial soils are underlain by alternating layers of medium to stiff clay, sandy clay, sand, and silt layers.

4.2 Offshore Borrow Area Soils Investigation

Soil conditions were evaluated in the proposed offshore borrow area by advancing 13 vibracores over the three potential offshore borrow areas identified in the reconnaissance geophysical offshore borrow area survey as shown in Figure 10. The vibracores were taken in approximately 30 feet of water. Samples were collected to a depth of approximately 20 feet below the mudline. The vibracores were collected in June 2017 using a pneumatic vibratory corer onboard a lift boat. Index properties observed during coring and laboratory test results are located on the vibracore logs in Appendix I.

Unit weight, moisture content, and Atterberg limit tests were performed by GeoEngineers on composite samples of each vibracore, and the results can be found in Appendix I.

Once Ardaman received the six vibracore samples taken from the final borrow area, unit weight, moisture content, and Atterberg Limits tests were performed on each sample to determine the optimum composite samples for settling column tests and low-pressure self-weight consolidation tests. The results of these tests were used for the marsh creation settlement analysis and are included in the final geotechnical design report by Ardaman in Appendix J.

Subsurface conditions of the offshore borrow area were very homogenous high plasticity clay interspersed with silt streaks, lenses, seams, pockets, and thin layers across all three potential borrow areas.

4.3 Marsh Creation Settlement Analysis

Conceptually, settlement analyses are performed to determine the construction marsh fill elevation of the marsh creation areas and the total volume of fill material required for construction. The final year 20 elevation of the marsh creation area is governed by two forms of settlement: (1) the settlement of the underlying soils in the marsh creation areas caused by the loading exerted by the placement of the dredged fill material; and (2) the self-weight consolidation of the dredged material (Figure 14). It should be noted that during the course of 30% design, it was decided to divide the original Phase 0 marsh creation area footprint into two separate marsh creation areas (MCA 1 and MCA 2); this is discussed in Section 5.1. Dividing the project area into two separate marsh creation areas requires analyzing the predicted settlement for each marsh creation area based on the collected samples and mudline elevations pertaining to each marsh creation area.

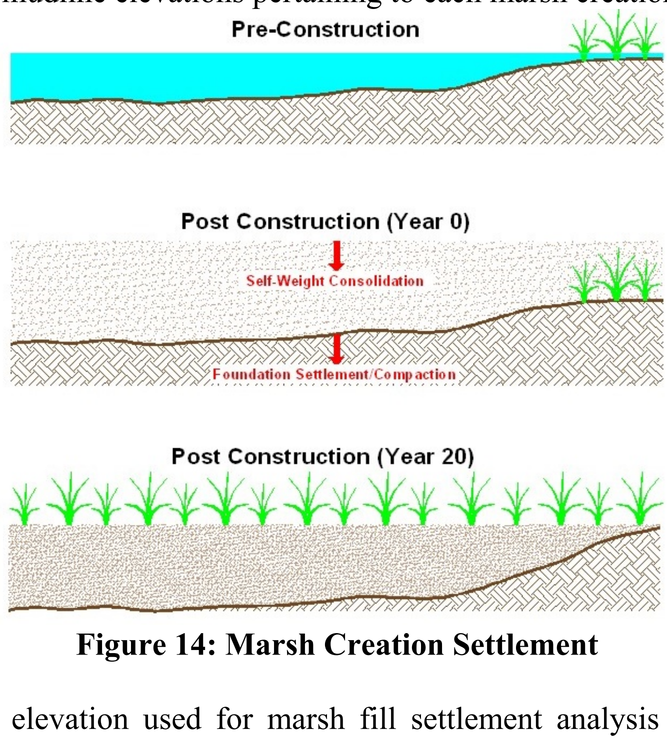


Figure 14: Marsh Creation Settlement

The existing mudline elevation used for marsh fill settlement analysis can greatly affect the required construction elevation to achieve end of project 20-year elevations. The goal is to find an elevation that is representative of the entire marsh creation area while accounting for deeper areas due to open water or bayous. Determining the existing mudline elevation to analyze for each marsh creation area involved looking at the survey points that fell within each marsh creation area. From Figure 15, it can be seen that the existing mudlines in both MCA 1 and 2 are concentrated between -1.0 and +0.5 feet NAVD88 Geoid 12A at 65% and 77% respectively. MCA 1 existing mudline elevations are more heavily weighted to the lower end of the range while MCA has a fairly even distribution above and below the -1.0 and +0.5 feet NAVD88 Geoid 12A range.

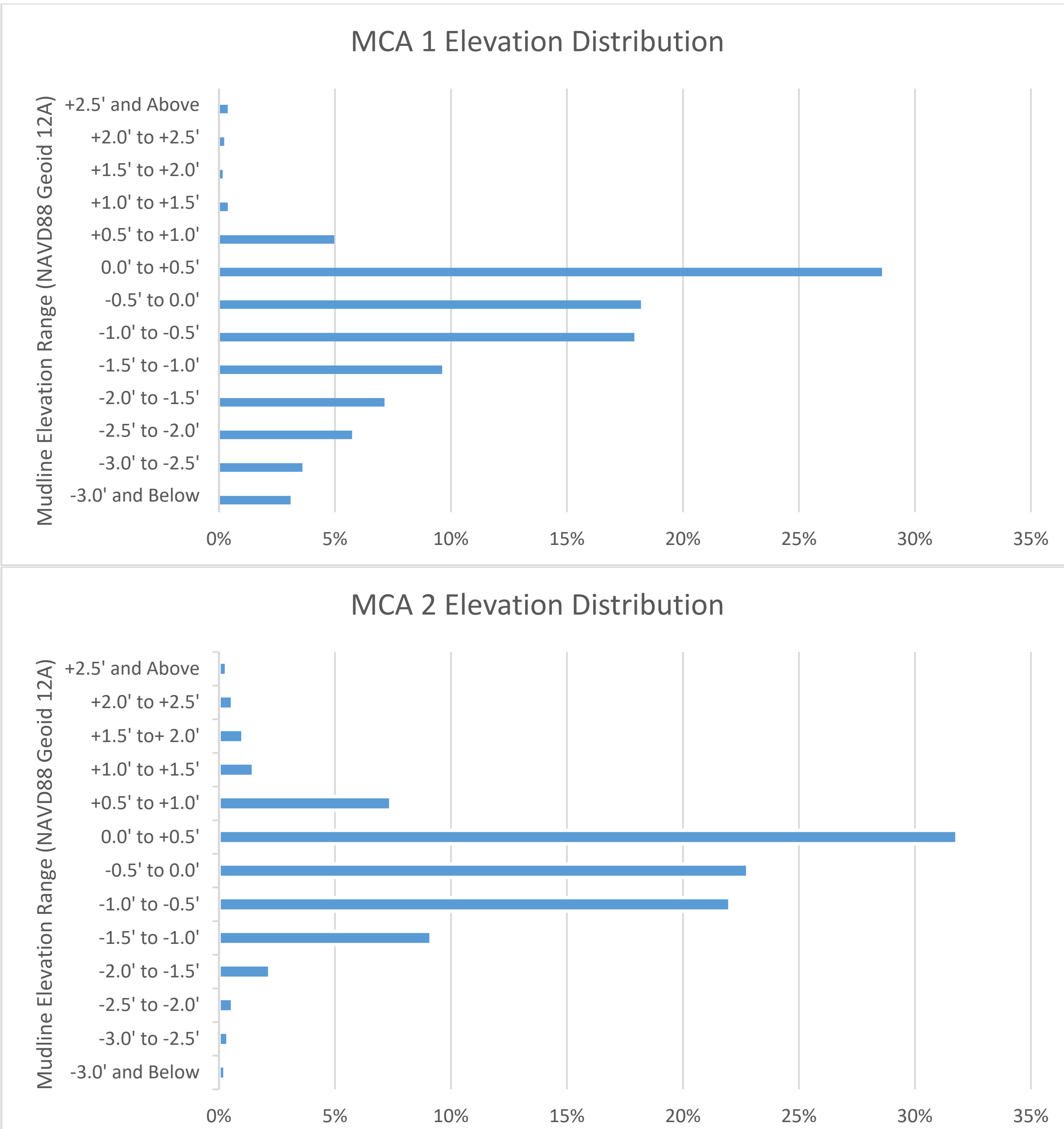


Figure 15: Elevation Distributions of MCA 1 & 2

Comparing the average existing mudline elevations of MCA 1 (-0.63 feet NAVD88 Geoid 12A) and MCA 2 (-0.21 feet NAVD88 Geoid 12A) to the distributions presented in Figure 15, it was determined that the average existing mudline elevations were good overall representations of each MCA and were selected for marsh fill settlement analysis. It is acknowledged that the constructed marsh fill may behave differently for mudlines other than those analyzed, settling more in lower areas and less settlement in higher areas, but the overall range and distributions of existing elevations within each MCA are such that any differential settlement of the marsh fill should be minimal and not detrimental to the function and health of the constructed marsh.

Self-weight consolidation tests were performed on a composite sample from the borrow area material in two different slurry concentrations (12% and 18% solids) to estimate the self-weight consolidation of the dredged fill material. These two concentrations were selected to provide a *performance band* of the dredge material behavior. Dredge material concentrations vary for a multitude of reasons including but not limited to dredge size, pumping distance, use of booster pumps, and production rates. Since the dredge size and production rates are unknown until after the construction contract is awarded, analyzing multiple concentrations can provide insight on how the dredge material will behave under multiple pumping scenarios. Low-pressure consolidation test results from the marsh creation area borings are used to estimate the time-rate of settlement for those underlying soils.

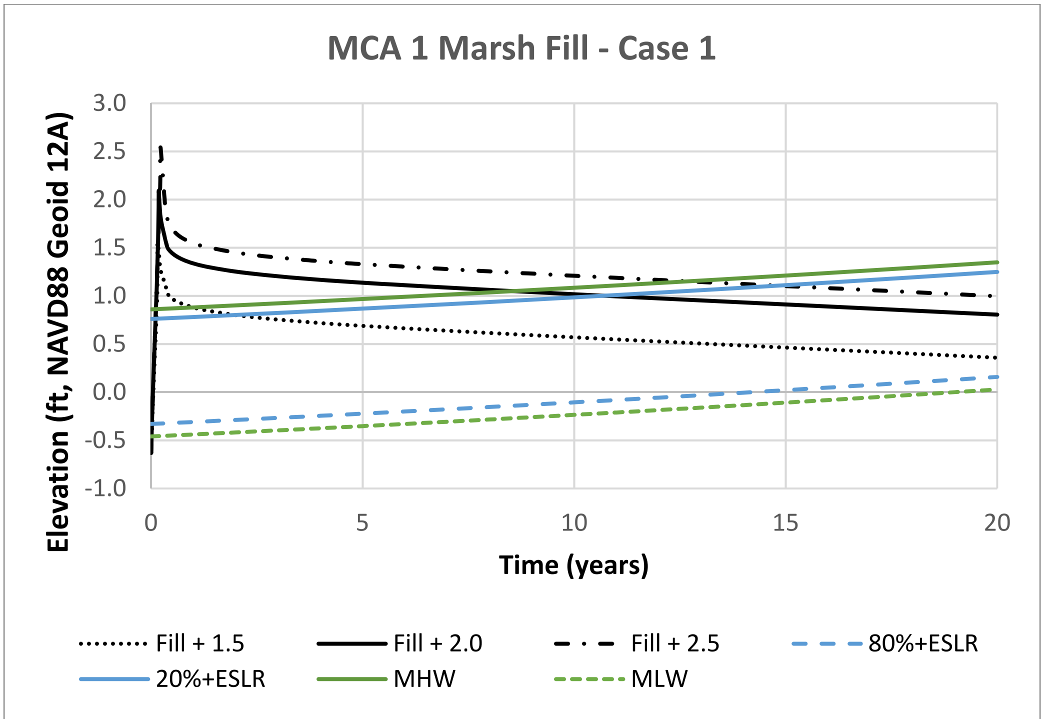
To determine the final constructed marsh fill elevation that would yield the most productive marsh at the end of the 20-year project life, water levels, inundation ranges, regional subsidence, and sea-level rise were considered. Accretion was not included due to the uncertainty of applying short-term accretion rates to the full project life as discussed in Section 2.5. The regional subsidence values (6.4 mm/year) have been incorporated into the mudline and dredge material elevations shown in Figures 16 and 17. The optimum range for long-term performance of the constructed marsh platform is bounded by Mean High Water, Mean Low Water, and the 80% and 20% Inundation Levels. The goal is to maximize the amount of time that the constructed marsh platforms spend within the 80% to 20% inundation band over the 20-year project life.

For the marsh creation area settlement analysis, an incremental loading of each marsh creation area was used to better represent construction conditions. Two different incremental loading cases were examined for both marsh creation areas; Case 1 assumed a fill period governed by placing a half foot of material every 10 days and Case 2 assumed a fill period governed by placing one foot of material every 10 days. This loading approach allows for interim settlement of the dredge fill material during construction and each case yielded different behavior of the dredge material for a given target fill elevation. The slower loading rate of Case 1 drastically increases the time required for the dredge material to settle into the 80% to 20% inundation band whereas the Case 2 loading rate shows the dredge material settling into the 80% to 20% inundation band in a time frame more typical of marsh creation projects (Figures 16 and 17). In addition, the Case 2 loading rate of 1 foot of fill placed every 10 days corresponds to more realistic production rates of 25,000 to 35,000 cubic yards (cy) of material per day for a large dredge in the Gulf of Mexico compared to the Case 1 assumptions (10,000 to 16,000 cy/day). Consequently, the Case 2 scenarios have been selected to be the controlling scenarios for dredge material settlement.

As discussed in the 30% Design Report, the 50% desiccation case has been chosen to be the controlling factor for predicting long-term marsh platform performance and is presented in Figures 16, 17, and 18. Maximum desiccation assumes that after fill material dewaters, it will never be hydrated again, which can greatly increase the estimated settlement. This does not account for tidal influence, rainfall, vegetation, and other natural processes that will ensure that some level of moisture is retained in the marsh fill over the life of the project. Conversely, desiccation cannot be completely ignored since it is known that some desiccation occurs on marsh creation projects. This is why the project team feels that the 50% desiccation case provides a realistic representation of real world conditions.

Three target fill elevations were analyzed for both loading cases at +1.5, +2.0, and +2.5 feet NAVD88 Geoid 12A for long-term settlement over the project life (Figures 16 and 17). The corresponding MCA mudline settlements were also analyzed but are not shown for clarity. As can be seen from the curves, the 30% design +2.5 fill elevation for both MCAs was more conservative than needed for the project goals.

At the +1.5 and +2.0 fill elevations (Figure 18), the marsh creation area platforms settle into the optimum inundation range between years 1 and 5 and remain within that range through year 20; this would meet project goals. Since the +1.5 curve is on the verge of falling below the 80% inundation range at the end of the project life, the target construction elevation is based on Case 2 at a +2.0 feet NAVD88 Geoid 12A fill height with a negative half-foot tolerance. This fill elevation provides a construction range that should perform well over the life of the project. The mudline presented in Figure 18 is the +2.0 feet NAVD88 Geoid 12A fill height to present the higher end of expected foundation settlement. These mudlines include the 6.4 mm/year (0.244 inches/yr) of regional subsidence discussed in Section 2.5. It can be seen that the majority of foundation settlement due to construction is on the order of 0.5 feet and will occur within the first two years post construction for both MCAs with the remaining foundation settlement over the project life attributed to regional subsidence.



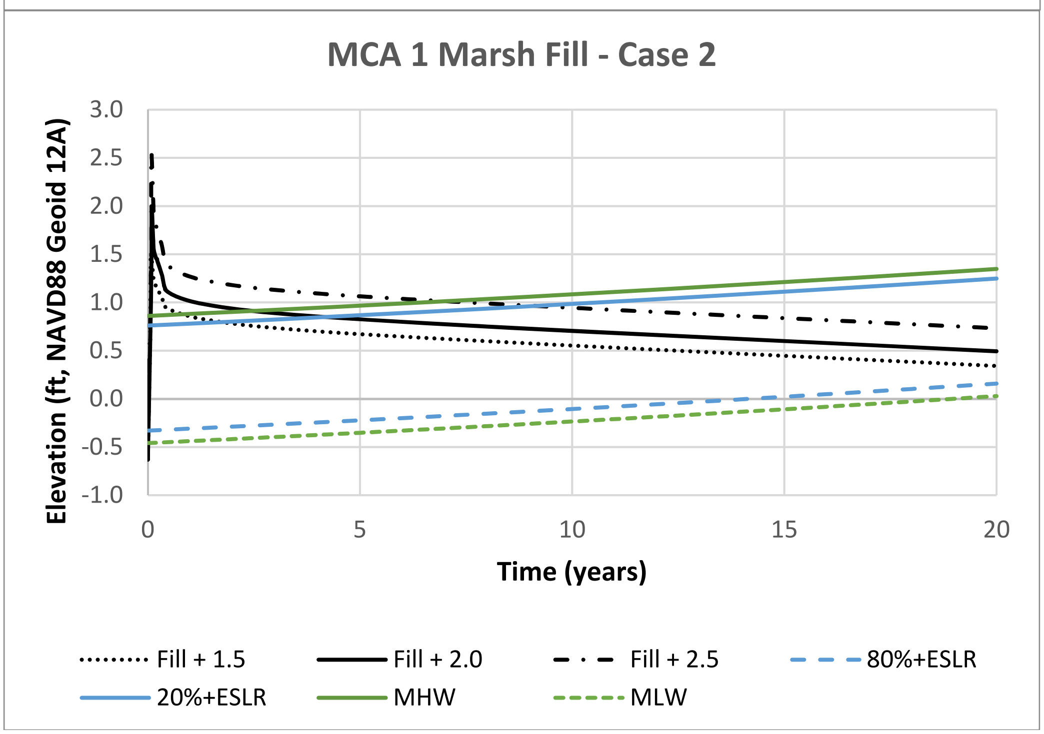


Figure 16: Estimated Total Settlement Curves for MCA 1

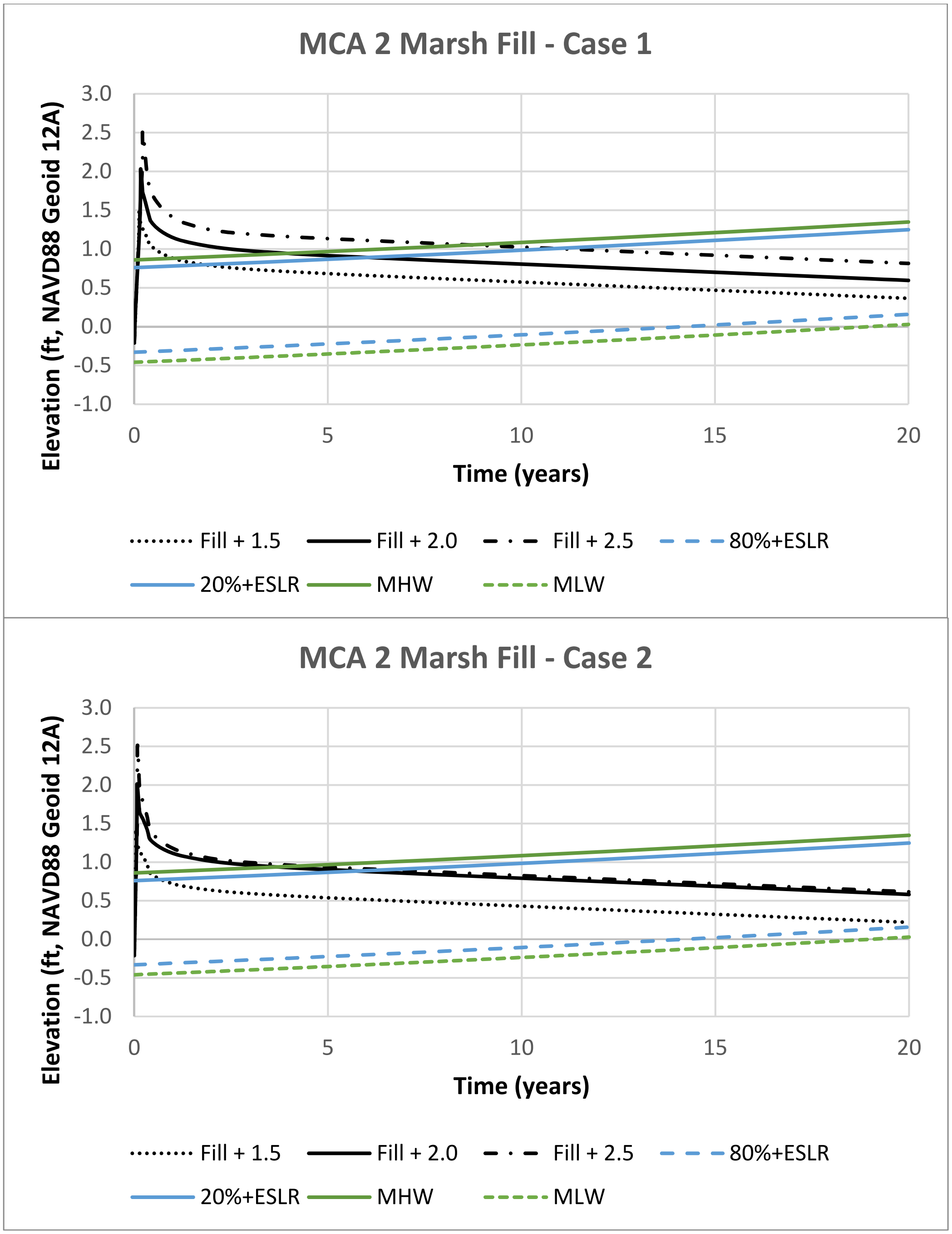
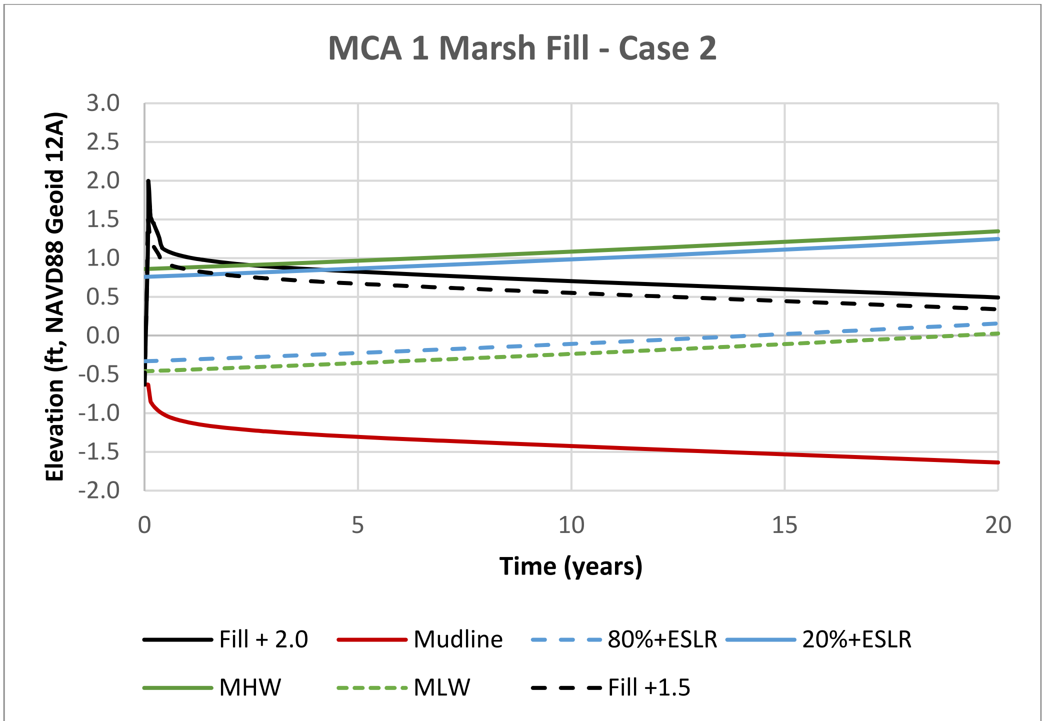


Figure 17: Estimated Total Settlement Curves for MCA 2



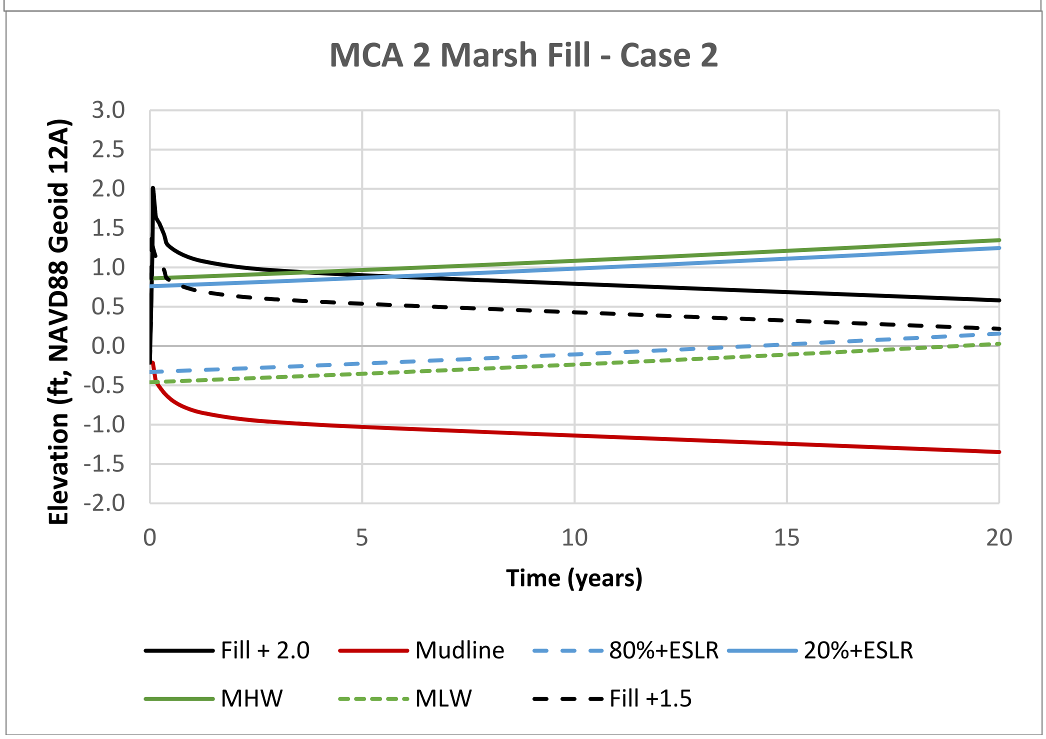


Figure 18: Estimated Total Settlement Curves for Marsh Fill Elevations +1.5' and +2.0' with Foundation Settlement (Case 2)

4.4 Cut to Fill Ratio Recommendations

A cut to fill ratio is typically applied to the calculated fill volume to account for losses due to dredging, containment maintenance, and dewatering. Due to numerous factors that are unknown until the project is awarded to a contractor such as dredge size, production rate, and dewatering structure management, actualized cut to fill ratios can vary from project to project.

Historically, a design level cut to fill ratio of 1.5 would be applied for all hydraulically dredged marsh fill sediment. Recently constructed projects have shown that that a cut to fill value of 1.5 may be too conservative, as actual cut to fill values have varied between 1.0 and 1.3; Bonfouca MC (PO-104): 0.75 C:F, Goose Point MC (PO-33): 1.07 C:F, Lost Lake MC (TE-72): 1.09-1.13 C:F, and Grand Liard MC (BA-68): 1.1 C:F. Based on this information, the design level cut to fill ratio applied to TE-0134 will be 1.1.

Mechanical dredging of the containment dikes has generally yielded a cut to fill ratio approximately between 1.2 and 1.6. This value not only accounts for losses and initial consolidation of the dike material but also for needed quantity due to dike maintenance during construction. For this project, a cut to fill of 1.5 will be used for mechanical dredging to construct the containment dikes.

5.0 MARSH CREATION DESIGN

The project proposes to create and nourish marsh by hydraulically dredging material from an offshore borrow area located approximately 3.5 miles southwest of Belle Pass in the Gulf of Mexico for placement into the designated marsh creation areas shown in Figure 19 and the 95% Design Drawings located in Appendix K. The marsh creation design was broken into four (4) components: the marsh creation areas, the earthen containment dikes, the offshore borrow area, and the dredge pipeline corridor. The design of each component is discussed below.

5.1 Marsh Creation Area Design

The Phase 1 goal of the marsh creation area feature has been refined from Phase 0 to create and nourish approximately 537 acres of saline marsh habitat, by pumping sediment from an offshore borrow site in the Gulf of Mexico, to improve the longevity of the marsh and improve coastal resiliency. The Phase 0 proposal was to create a single large marsh creation area of approximately 614 acres that filled in the existing twin pipeline canals that bisect the project area. However, as a result of field reconnaissance visits and survey investigations, it was determined that closing the ends of the pipeline canals would be difficult due to the width and depth of the canals in addition to mandatory excavation restrictions due to the active natural gas pipelines within the canals. In addition, the twin Kinetica pipeline canals intersect with the Kinder Morgan pipeline canal at the northern end of project area forming a large, relatively deep region of the marsh creation area which would necessitate double-handling, if not triple-handling, of material to construct earthen containment dikes due to excavation restrictions.

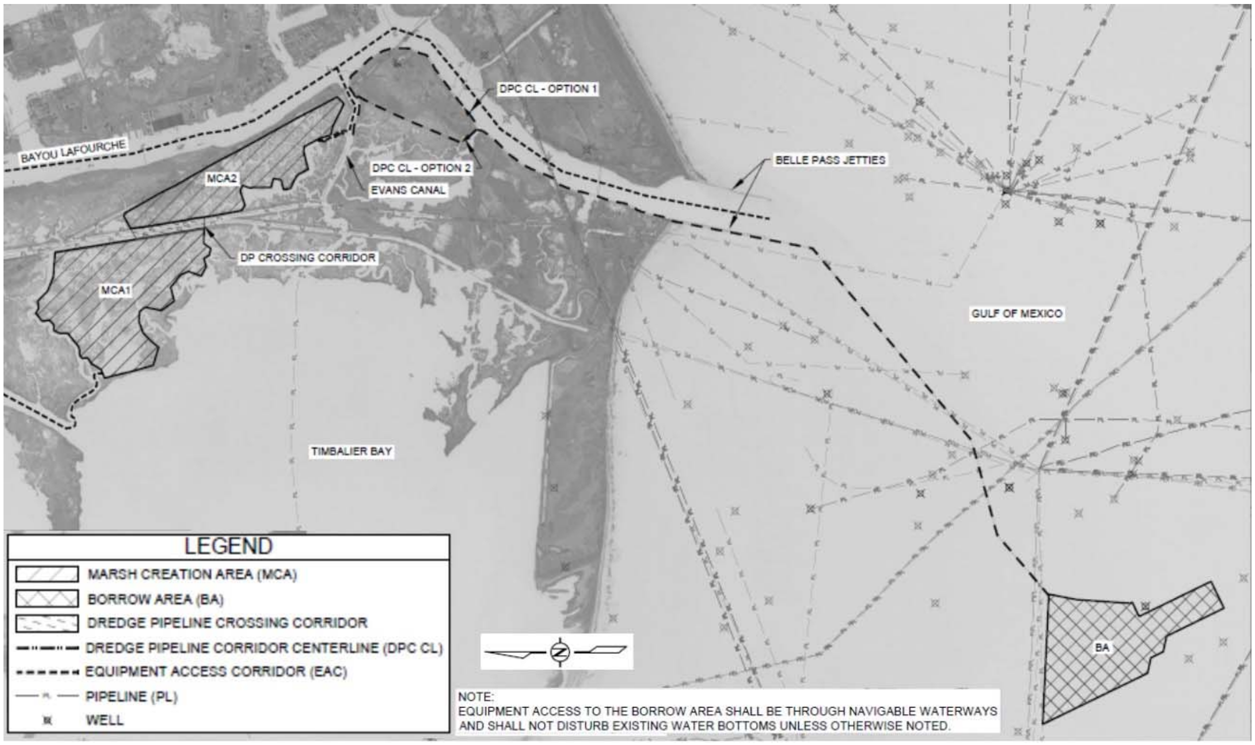


Figure 19: Project Area Layout.

The single continuous Phase 0 marsh creation area was divided into two marsh creation areas due to these findings. As a benefit, this design would take advantage of the existing pipeline canal spoil banks for use as existing containment features. As a result, some Phase 0 acreage was lost due to optimizing the two marsh creation areas for constructability of the earthen containment dikes. During 30% Design, approximately 30 acres located at the southern end of the project area were removed to preserve the existing black mangrove habitat shown in Figure 20. After discussions with the project team, it was decided to reincorporate this area into the project area for the 95% design due to concerns that an extremely cold winter during the life of the project could kill off the black mangrove and degrade the marsh at an accelerated rate. Twenty (20) acres were reincorporated into the project area after optimizing the ECD alignment and applying a buffer of approximately 275 feet from the existing camps to avoid damage to those structures should a dike failure occur during construction.

Figure 20: Location of Black Mangrove Habitat.

The next step in the marsh creation design involved determining an appropriate target marsh fill elevation. This elevation was governed by several factors including the tidal range, percent inundation, the existing healthy marsh elevation, the physical properties of the borrow material, and the geotechnical properties of the foundation soils in the marsh creation area. The target marsh fill elevation was determined based on the average marsh elevation over the project life with respect to the intended marsh function from a habitat perspective and meeting the project goals and objectives. One element of the design is to maximize the period of time that the constructed marsh platform is at an elevation within the functional saline marsh inundation range (80% to 20% inundated). Over the 20-year project life, and with estimated eustatic sea-level rise (see Section 2.5), the preferred inundation range is expected to rise approximately 0.49 ft. As discussed in Section 2.6, the year 20 final target marsh elevation range is 0.002 ft to +1.212 ft NAVD88 Geoid 12A. To achieve the desired final elevation, the marsh platform will initially have to be pumped to a constructed fill elevation above the functional saline marsh range and then will settle into the range over the design life. The marsh creation area will be pumped to an elevation of +2.0 ft NAVD88 Geoid 12A in order to satisfy these conditions.

After determining the constructed marsh fill elevations, the total volume of the marsh creation areas was calculated using AutoCAD Civil 3D software. The software creates a 3-Dimensional surface based on XYZ coordinate data from the survey cross-sections. This surface is known as the Triangulated Irregular Network (TIN). The TIN model represents a surface as a set of contiguous, non-overlapping triangles. A TIN surface containing the 2016 survey data from TBS and a flat TIN surface at the marsh creation construction elevation were created by AutoCAD. AutoCAD then uses the XYZ differences of each surface to calculate the volume of each marsh creation area. The containment dike borrow area must be refilled and the volume to build the containment dikes, plus a cut-to-fill ratio of 1.5 for the dikes, is added to the volume required to fill the marsh creation areas. The cut-to-fill ratio of 1.1 is then applied to estimate the final cut volumes for each marsh creation area. The fill volumes for the TE-0134 project are summarized in Table 4.

Table 4: Summary of Marsh Creation Acreage and Volume

Marsh Creation Area	Fill Height (ft NAVD88 Geoid 12A)	Area (Acres)	Cut to Fill Ratio	Volume of Fill (yd^3)	Volume of Cut (yd^3)
MCA 1	+2.0	331	1.1	967,907	1,064,698
MCA 2	+2.0	226	1.1	540,322	594,355
Totals		**537**		1,508,229	**1,659,052**

5.2 Earthen Containment Dike Design

The primary design parameters associated with the earthen containment dike design include crown elevation, crown width, and side slopes. One foot of freeboard will be used to contain the dredge slurry within the marsh creation areas. Therefore, the earthen containment dikes will be constructed to an elevation of +3.0 ft NAVD88 with a half-foot upper construction tolerance.

From the geotechnical data report in Appendix H, laboratory tests indicate that soil shear strengths range from approximately 60 to 85 pounds per square foot (psf) at the depths that earthen containment dike fill will be excavated. These soil strengths are consistent with past constructed projects, which did not encounter major issues with earthen containment dike construction or stability. Therefore, it is not envisioned that special measures will be required for earthen containment dike construction.

As prescribed in the CPRA Marsh Creation Design Guidelines (MCDG), the earthen containment dikes were analyzed for three different slope stability cases to ensure that a minimum factor of safety of 1.2 would be achieved for the selected earthen containment dike geometry. These stability cases, outlined in Table 5 and shown in Figure 21 analyze the earthen containment dike geometry for the three most likely earthen containment dike failure scenarios.

Table 5: MCDG Earthen Containment Dike Stability Cases

Stability Case	Description
A-1	Global stability check; During ECD borrow excavation; MHW (opposite side of borrow), MLW (borrow side)
A-2	Local stability check; During ECD borrow excavation; Distributed load from excavation equipment, MLW (borrow side)
B	Marsh fill placed to construction elevation, MLW (opposite side of borrow)

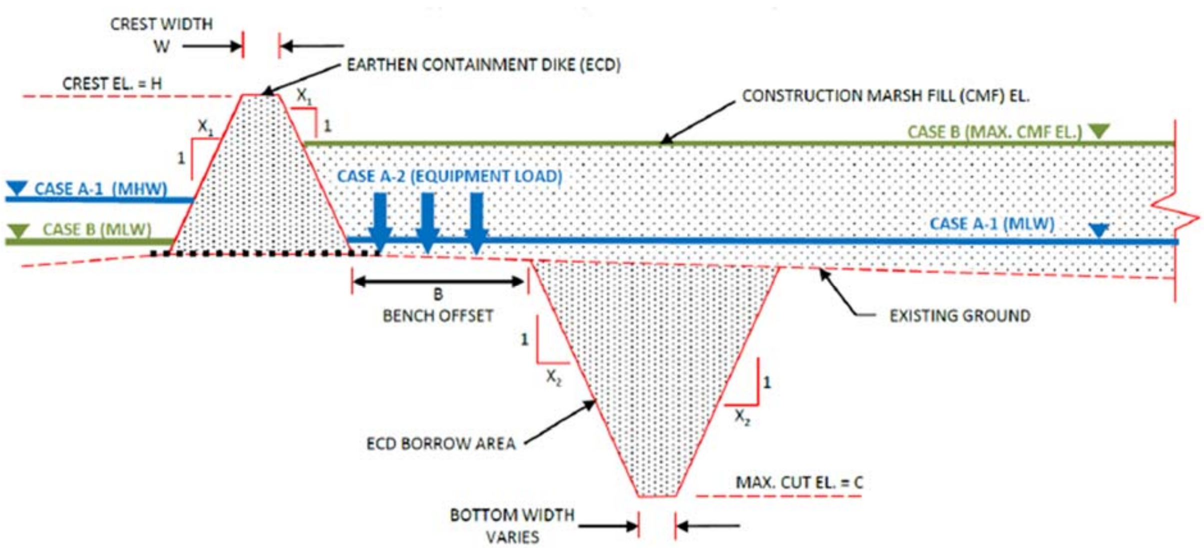


Figure 21: Earthen Containment Dike Stability Cases

All earthen containment dikes will be constructed with a crown width of 5 feet. A side slope of 4 feet horizontal for every foot of vertical rise (4H:1V) was shown to provide the earthen containment dike templates with adequate slope stability safety factors the three controlling stability cases. Earthen containment dikes will be constructed using in-situ material from inside both marsh creation areas and will incorporate a 25-foot wide construction/stability berm between the inside toe of the dike and the interior excavation pit. It should be noted that the stability analysis was performed with a 20-foot wide berm between the inside toe of the dike and the interior excavation pit. The larger 25-foot berm called for in the plans is a more typical bench width for marsh creation projects and will not negatively impact the stability of the earthen containment dikes. The earthen containment dike borrow pits will have 3H:1V side slopes and a maximum bottom elevation of -10.0 ft, NAVD88. A typical section of the marsh creation containment dikes is shown in Figure 22.

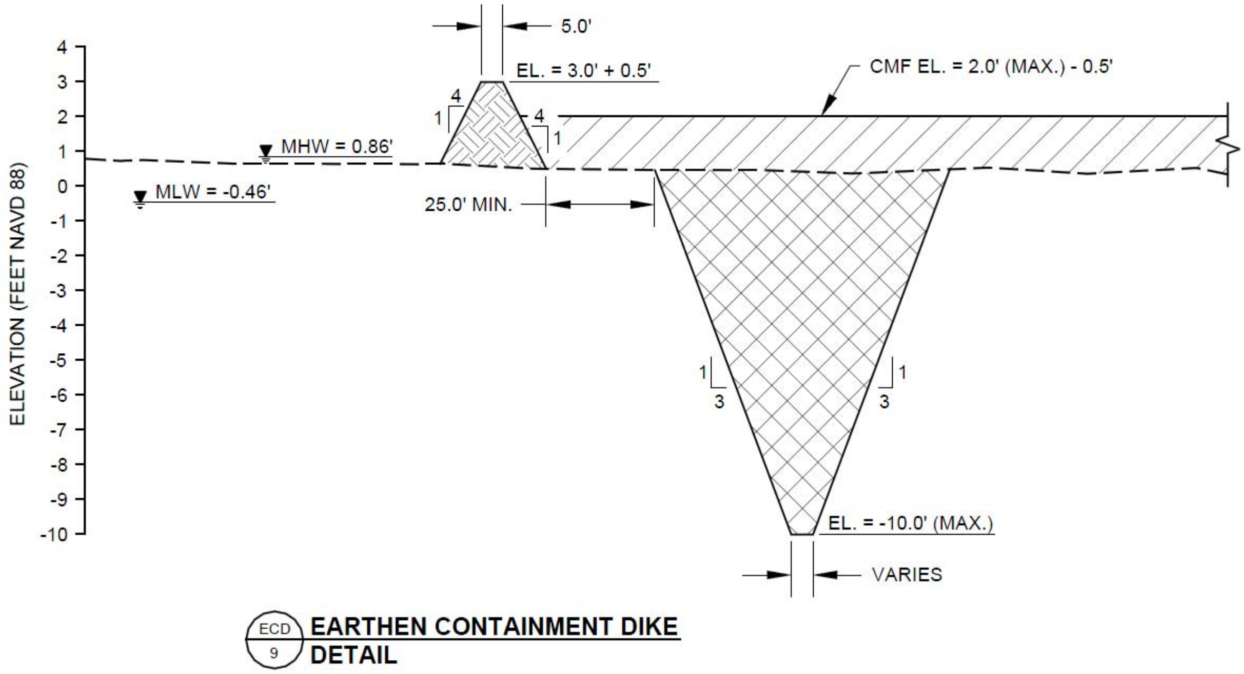


Figure 22: Typical Earthen Containment Dike Section for Marsh Creation Areas

The 95% design specifications of the earthen containment dikes are detailed in Table 6.

Table 6: Summary of Earthen Containment Dike Design

Marsh Creation Area	Design Elev. (ft, NAVD88 Geiod 12A)	Side Slopes	Stability Case	Factor of Safety	Crown Width (ft)	Bench Width (ft)	Cut to Fill	Volume of Cut (yd³)
MCA 1	+3.5	4H : 1V	A-1	1.40	5	20	1.5	55,452
			A-2	1.29				
			B	1.32				
MCA 2	+3.5	4H : 1V	A-1	1.33	5	20	1.5	48,369
			A-2	1.27				
			B	1.27				
Note: +3.5' Crown elevation presented to account for construction tolerance							**Total**	103,821

5.3 Offshore Borrow Area Design

The typical controlling factors in the proposed offshore borrow area design are the location, size, existing infrastructure, and available material. It is preferred that the offshore borrow area is located in close proximity to the marsh creation area to minimize the pumping distance of the dredged material. The offshore borrow area should be clear of any existing oyster leases, culturally significant sites, and oil and gas infrastructure, if possible. The preliminary goal was to identify 8 to 9 million cubic yards of mixed sediment material from an offshore location. An offshore borrow area is preferable to one in Timbalier Bay because the marsh creation area is near the gulf and potential borrow material in the bay could be reserved for future projects further inshore. When the offshore borrow area development was initiated during early design, the unknown final material quantity led to a conservative preliminary material estimate. Initial assumptions that guided the project team to the preliminary goal of identifying 8 to 9 million cubic yards of mixed sediment material are shown in Table 7. These volume assumptions were based on the Phase 0 footprint with conservative assumptions. The initial estimated quantity of required borrow material was back calculated for the offshore borrow area development based on different potential fill elevations and levels of offshore borrow area utilization.

Table 7: Preliminary Phase 0 Footprint Volume Assumptions for Borrow Area Sizing

TE-134 Rough CAD Volumes Based on TBS Surface										
Fill Elev	Fill Vol CY	C:F	Cut Vol CY	ECD Vol CY*	ECD C:F	ECD Cut Vol CY	Required Cut Vol CY	50% BA Usage Vol	60% BA Usage Vol	70% BA Usage Vol
1.5	1,677,905	1.5	2,516,858	126,762	2	253,524	**2,770,382**	**5,540,763**	**4,617,303**	**3,957,688**
2	2,162,347	1.5	3,243,521	126,762	2	253,524	**3,497,045**	**6,994,089**	**5,828,408**	**4,995,778**
2.5	2,652,389	1.5	3,978,584	126,762	2	253,524	**4,232,108**	**8,464,215**	**7,053,513**	**6,045,868**
3	3,145,607	1.5	4,718,411	126,762	2	253,524	**4,971,935**	**9,943,869**	**8,286,558**	**7,102,764**
Earthen Containment Dike (ECD) Assumes 5' of total height, 4:1 Slopes, 5' crown width. (105 ft3/ft over 32,596 LF)										

The original Phase 0 offshore borrow area polygon had numerous pipeline concerns in addition to potential impacts to the nearby constructed West Belle Pass Barrier Headland Restoration Project (TE-0052) due to its close proximity. After a cursory desktop review of existing information, further investigation of the Phase 0 borrow area was decided against due to these potential issues. Before launching a full borrow area development effort, the TE-0052 offshore borrow area was investigated for potential utilization and expansion for the TE-0134 project. The benefits of reusing the TE-0052 offshore borrow area included having a proven previously permitted borrow area in addition to possessing full geotech, wave modeling, and construction survey data. Unfortunately, the TE-0052 offshore borrow area was already being incorporated into the TE-0118 East Timbalier Island project for marsh fill and use as a hopper dredge rehandling area. After coordinating with the TE-0118 project team, it was decided that the TE-0134 project would not use the TE-0052 offshore borrow area.

In the fall of 2016, CEC was tasked to investigate and identify a new offshore borrow area containing approximately 9 million cubic yards of mixed sediments suitable for TE-0134. The borrow area development effort was broken into three main steps as outlined in previous sections to narrow a large reconnaissance area to a final delineated borrow area of suitable size for the TE-0134 project. First, a large reconnaissance geophysical data collection was performed as discussed in Section 3.6. The results of this effort informed the delineation of three potential borrow areas clear of major infrastructure and cultural sites for geotechnical sampling and analysis. Upon review of the results of the geotechnical effort, a final borrow area was delineated for the detailed geophysical survey to be performed per SHPO requirements.

A maximum cut depth of 20 feet was determined sufficient to ensure adequate available volume and is a typical cut depth for offshore borrow areas. Cross-sectional areas of each borrow area survey transect were calculated to compute the available volume using the average end area method and compared to the volume calculated in AutoCAD. A typical cross-section of the offshore borrow area limits is shown in Figure 23 and on the 95% design drawings in Appendix K. Approximately 7.5 million cubic yards of material were delineated in the borrow area which will more than suffice the sediment requirements for the marsh creation areas (Table 7). It is envisioned that the TE-0134 will utilize approximately 40 percent of the sediment resources within this offshore borrow area, which will provide the contractor flexibility to move around should unforeseen issues arise while dredging. It is important to note however, that flexibility does not absolve the contractor of their responsibility to utilize sound sediment management practices when dredging the offshore borrow area. The selected TE-0134 borrow area is adjacent to the TE-0052 borrow area and the project team decided it was unnecessary to perform additional wave modeling. The two borrow areas have a similar location, cut depth, and distance to the shoreline and the previous TE-0052 wave modeling effort showed no negative impact to the wave environment or sediment transport in the area.

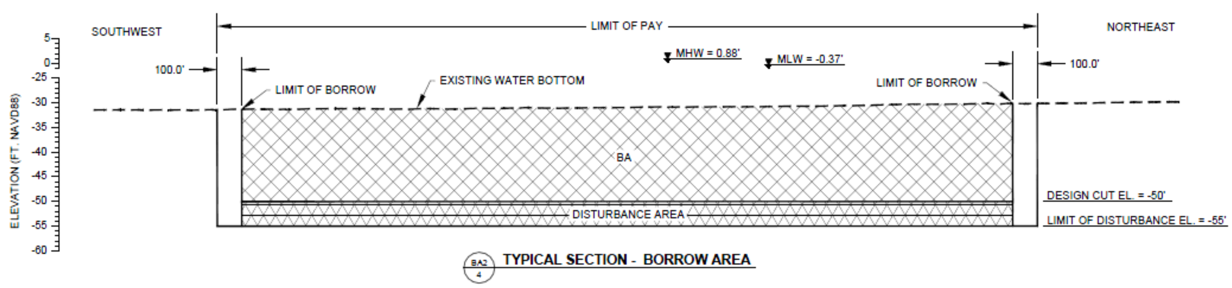


Figure 23: Borrow Area Typical Section.

5.4 Dredge Pipeline Corridor and Equipment Access Design

The dredge pipeline corridor went through several iterations before settling on the corridor presented in the 95% Plans. Originally, the plan was to sink the dredge pipeline along the centerline of Bayou Lafourche with submerged dredge pipeline (subline) from the end of the rock jetties at Belle Pass to the borrow area. After consultation with representatives from Port Fourchon, this plan was abandoned due to the deep draft requirements of some ships that use the port. An earlier corridor option was from the gulf, across the TE-0052 beach and headland, and along one of the existing pipeline canals to the project area. This approach was abandoned due to numerous concerns with impacts to the TE-0052 project, potential issues with equipment access due to active pipelines buried in the canals, and multiple rock weirs in the canals that would need to be crossed. The selected dredge pipeline corridor has two alternatives around the Fourchon Liquefied Natural Gas (LNG) project that is currently in the data collection and environmental permitting stage.

The proposed dredge pipeline corridor design can be broken into two main components: (1) inshore; and (2) Bayou Lafourche to offshore borrow area. Water depths are generally deep and access dredging will not be required for either component.

The design of the offshore component of the dredge pipeline corridor began after selection of the final borrow area. The expense of the detailed geophysical survey to satisfy SHPO requirements necessitated waiting for the final borrow area selection so that all detailed geophysical surveys could be conducted at once. As described in Section 3.6, the geophysical surveys were conducted on a 1,000-ft wide corridor from the offshore borrow area to the centerline of Belle Pass at which point available USACE surveys and bathymetric/magnetometer data collected by TBS provided coverage to the marsh creation areas. Since Bayou Lafourche is an actively dredged navigation channel, potential cultural resources within the bayou were not a concern. It is assumed that subline will be used from the offshore borrow area to the beach west of the western Belle Pass jetty. Due to the presence of numerous pipelines that intersect with the dredge pipeline corridor in the gulf, special care will need to be taken to cross the pipelines with the dredge pipeline. Solutions such as placing mats down or floating the dredge pipeline will need to be coordinated through the design process and agreed upon by both the project team and the various pipeline representatives prior to construction.

At the point at which the dredge pipeline corridor reaches the western rock jetty of Belle Pass, the dredge pipeline corridor width reduces from 1,000 ft to 100 ft and follows the outside alignment of the western rock jetty to the shore of West Belle Pass. Welded or plastic pipe will be used to cross onto the beach past the end of the rock jetty structure and will cross over into Bayou Lafourche behind the rock jetty to avoid any adverse impacts to the USACE structure. The pipeline will then be floated (submerged where required) approximately 6,700 ft through a 40-ft wide corridor adjacent to the western bank of Bayou Lafourche to avoid identified potential cultural resource sites. Due to the previously mentioned port development, two alternatives were developed to continue the dredge pipeline north toward the project area. The first alternative (shown in blue in Figure 24) assumes that the LNG plant development will either not proceed or will still be in the design/permitting stage at the time of TE-0134 construction and continues floating the dredge pipeline in Bayou Lafourche to Evans Canal at the southern end of the project area. The corridor would then turn west into Evans Canal and then turn north into a small bayou that leads to the southern marsh creation area. Alternative 2 assumes that the LNG plant will proceed or will be in construction concurrently with the TE-0134 project. In this case (shown in green in Figure 24) shore pipe would be utilized to run along the back side of the LNG plant property before utilizing a small existing bayou to proceed north to Evans Canal where it would follow the same corridor as Alternative 1 to the southern marsh creation area. This approach would minimize impacts to wetlands outside of the project area while reducing the pumping distance by approximately 3,000 ft. Preliminary discussions have begun with Port Fourchon and consulting engineers for the developer who have been receptive to the initial plan and open to further coordination as both projects progress. The total dredge pipeline distance from borrow area to the project area for both alternatives is approximately 6 miles.

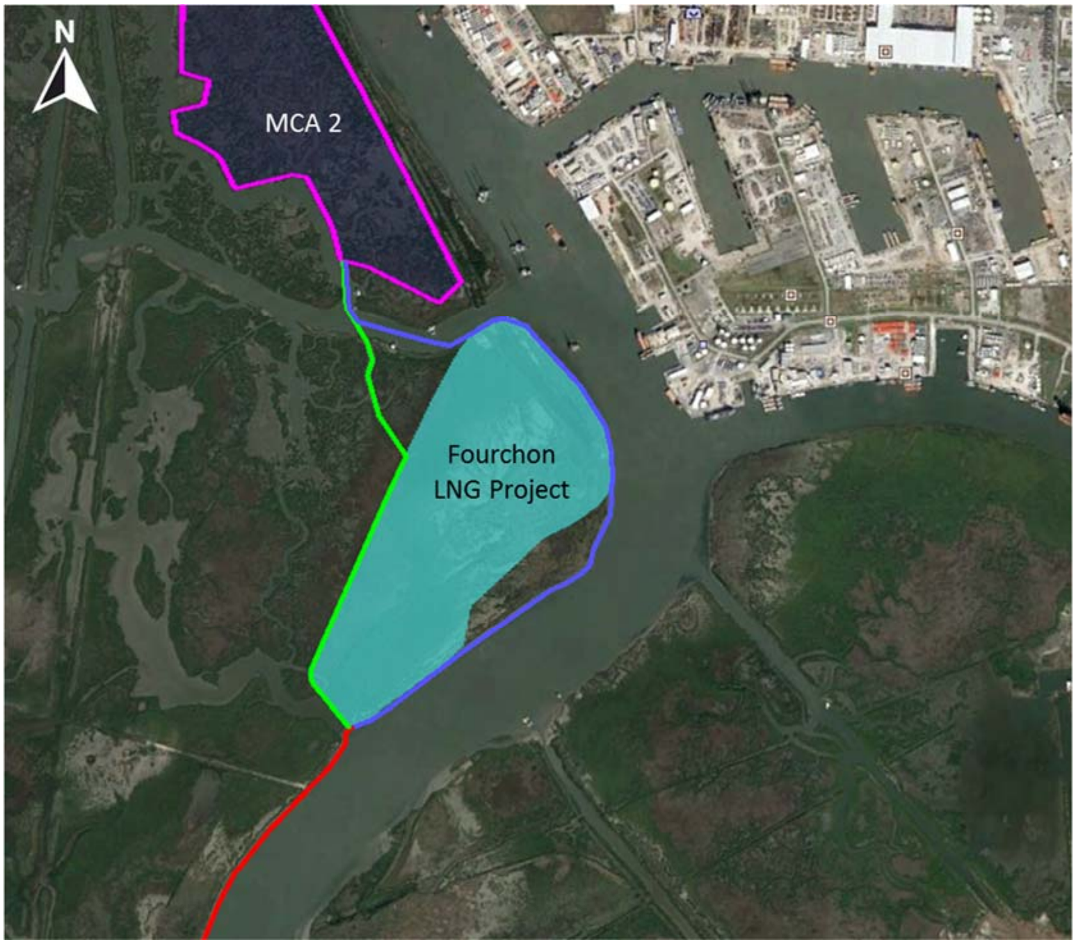


Figure 24: Dredge Pipeline Corridor Alignment Alternatives Near Proposed Fourchon LNG Plant

6.0 CONSTRUCTION

6.1 Duration

An approximate construction duration was developed using the CDS Dredge Production and Cost Estimation Software and Microsoft Project. Assuming construction of the containment dikes will be completed prior to dredging, the time to complete containment dike construction and to fill marsh creation areas would be approximately 8 months using a 30-inch dredge. The total construction duration including mobilization and construction surveys is estimated to be 12 months. A detailed breakdown is provided in the Sample Calculations Packet in Appendix A.

6.2 Cost Estimate

An Engineer's Estimate of Probable Construction Cost was prepared for this project using the CWPPRA PPL 28 spreadsheet, CPRA Bid Tabulations of past projects, the CDS Dredge Unit Rate Cost Estimation spreadsheet, and additional CPRA-developed cost estimation spreadsheets. The estimated construction cost has been provided to the CWPPRA Engineering Workgroup in the updated PPL 28 format.

7.0 30% DESIGN MODIFICATIONS TO APPROVED PHASE 0 PROJECT

As a result of Phase 1 activities, the features originally approved in Phase 0 were modified to maintain a cost-effective and competitive project for consideration for Phase II funding. These modifications included dividing the original project area into two marsh creation areas, reducing approximately 100 acres for constructability and black mangrove concerns, and relocating the borrow area further offshore to prevent interference with the East Timbalier Island Project. The approximately 100-acre reduction in project area from the approved Phase 0 footprint is within the 25% CWPPRA SOP for both project size and construction cost and will not require a scope change request from the Technical Committee. The modifications to the approved Phase 0 Project are shown in Figure 25. Areas shaded in green show the 517-acre 30% design footprint and the area outlined in blue represents the 618-acre Phase 0 footprint.

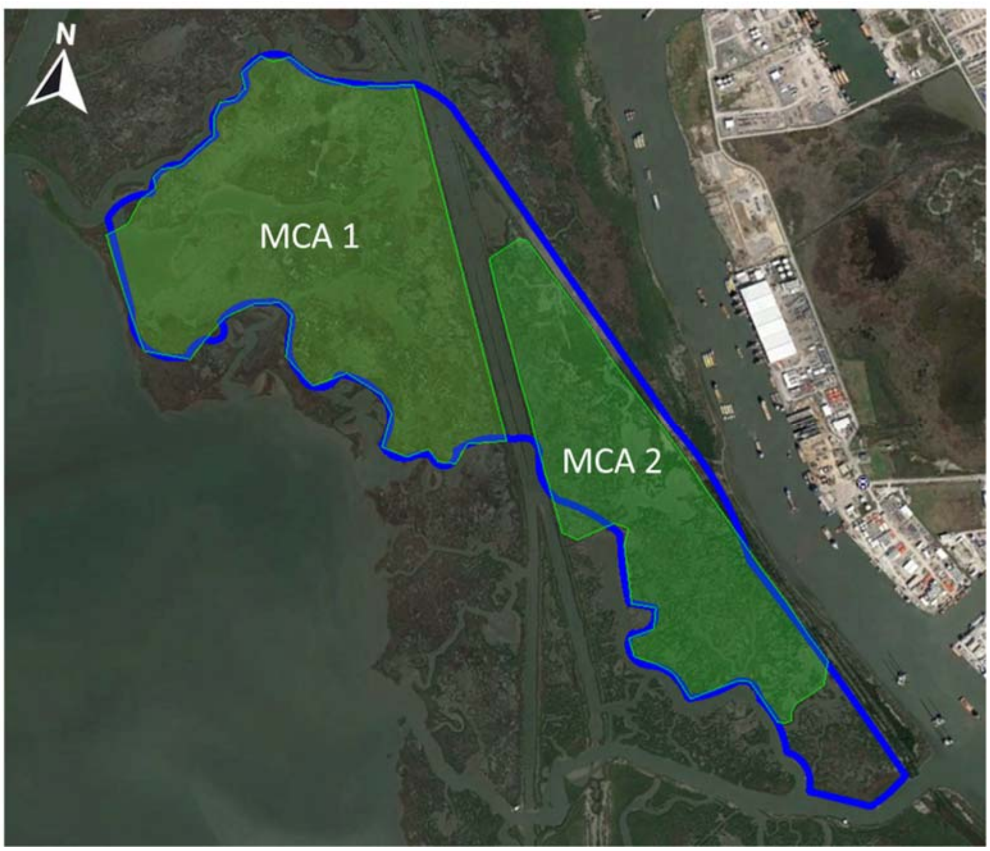


Figure 25: Modifications to Phase 0 Project Layout

8.0 MODIFICATIONS FROM 30% DESIGN

As a result of post-30% design activities, the features originally proposed in the preliminary design have been modified while maintaining a cost-effective and competitive project for consideration for Phase II funding. These modifications include reincorporating approximately 20 acres of the black mangrove area at the southern end of MCA 2, reducing the target construction fill elevation by 0.5 feet to elevation +2.0 ft NAVD88 Geoid 12A, and reducing the required earthen containment dike template to accommodate the reduced target construction fill elevation. The approximately 80-acre reduction in project area from the approved Phase 0 footprint is within the 25% CWPPRA SOP for both project size and construction cost and will not require a scope change request from the Technical Committee. The modifications from the 30% project layout are shown in Figure 26. Areas shaded in green show the 517-acre 30% design footprint and the area outlined in pink represents the 537-acre 95% design footprint.

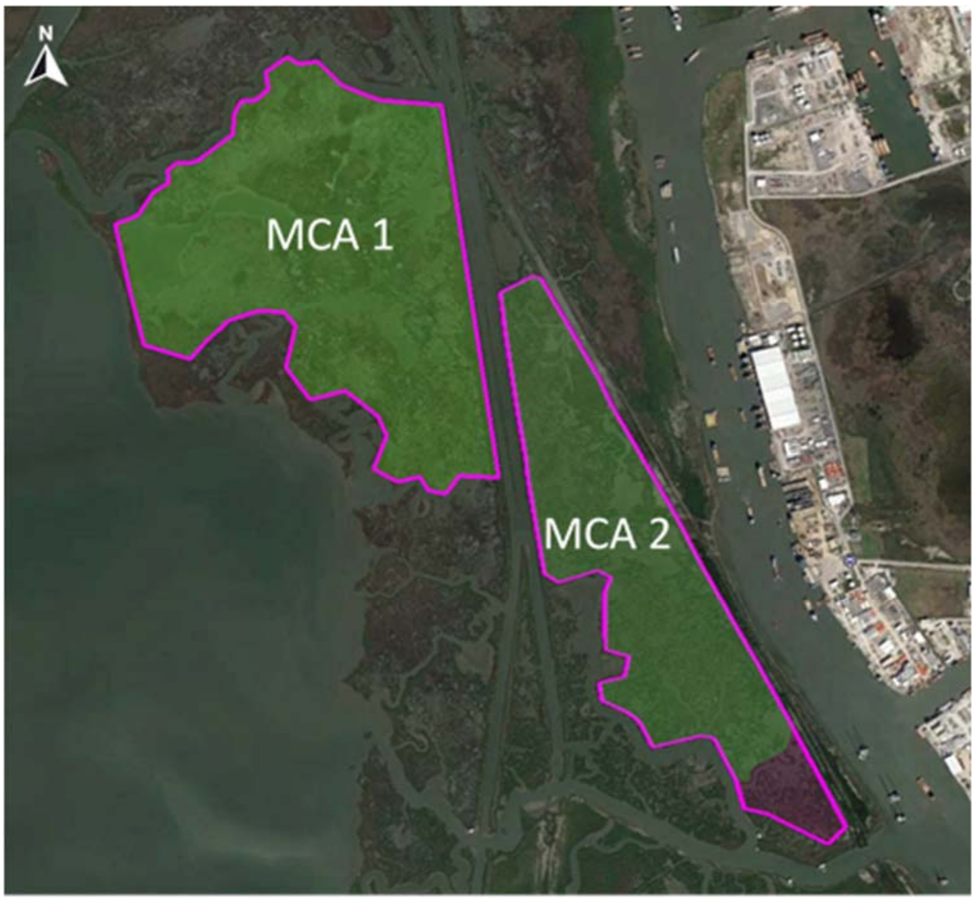


Figure 26: Modifications from 30% Project Layout

9.0 Basis of Design

This design document was prepared by the CPRA Engineering Division with collaboration from the project federal sponsor, the NMFS, for the CWPPRA. The CPRA Marsh Creation Design Guidelines

(MCDG1.0), November 2017, were utilized as guidance for the design of the proposed marsh creation project.

10.0 References

Ardaman & Associates, Inc. *Data Report Field and Laboratory Data Collection Phase West Fourchon Marsh Creation & Nourishment (TE-134).* April 2017.

Ardaman & Associates, Inc. *Design Report West Fourchon Marsh Creation & Nourishment (TE-134).* October 2018.

Coastal Protection and Restoration Authority of Louisiana. *A Contractor's Guide to Minimum Standards*. Baton Rouge, LA. March 2017.

Coastal Protection and Restoration Authority of Louisiana. *Marsh Creation Design Guidelines*. Baton Rouge, LA. November 2017.

Conservation, Louisiana Coastal Wetlands, et al. *Coast 2050: Toward a sustainable coastal Louisiana*. Louisiana Department of Natural Resources, Baton Rouge, Louisiana (1998).

DeMarco, K. E., J. Mouton., J. W. Pahl. *Recommendations for Anticipating Sea-level Rise impacts on Louisiana Coastal Resources on Project Planning and Design: Technical Report*. January 2012.

GeoEngineers Inc. *Borrow Area Geotechnical Services West Fourchon Marsh Creation and Nourishment Project (TE-134).* July 2017.

La DOTD. *Louisiana Standard Specifications for Roads and Bridges*, Section 1019.01. 2006.

Louisiana's Coastal Master Plan 2017

Mitsch,W.J., Gosselink, J.G., 1986.Wetlands. Van Norstrand Reinhold Company, New York, NY, USA, p. 539.

Office of the Federal Register, National Archives and Records Administration. Federal Register: March 19, 2003 (Volume 68, Number 53)

R. Christopher Goodwin. *Draft Report Geophysical/Cultural Resources Survey to Support the West Fourchon Marsh Creation and Nourishment Project (TE-134).* December 2017.

R. Christopher Goodwin. *Geophysical/Cultural Resources Survey to Support the West Fourchon Marsh Creation and Nourishment Project (TE-134).* April 2018.

Reed, D. and Yuill, B., 2016, 2017 *Coastal Master Plan: Attachment C2-2: Subsidence. Version I.* (p. 15). Baton Rouge, Louisiana: Coastal Protection and Restoration Authority.

Snedden, G.A., and Swenson, E.M., 2012, *Hydrologic index development and Application to selected Coastwide Reference Monitoring System sites and Coastal Wetlands Planning,* *Protection and Restoration Act projects: U.S. Geological Survey Open-File Report 2012–1122*, 25 p.

T. Baker Smith, LLC, *West Fouchon Marsh Creation and Nourishment Project No. TE-134 Data Collection Report*, April 2017

United States Army Corps of Engineers, EM 1110-2-5027. *Confined Disposal of Dredged Material.* Washington, D.C. 1987

United States Department of Commerce, National Oceanic and Atmospheric Administration National Ocean Service Center for Operational Oceanographic Products and Services (2003), "Computational Techniques for Tidal Datums Handbook", NOAA Special Publication NOS CO-OPS 2.

Visser, J.M., G.D. Steyer, G.P. Shaffer, S.S. Höppner, M.W. Hester, E. Reyes, P. Keddy, I.A. Mendelssohn, C.E. Sasser and C. Swarzenski. 2003. LCA/CLEAR Habitat Switching Module, Chapter 9.

Appendix A-Design Calculation Packet

Appendix B-Survey Monument Data Sheet

Appendix C-Marsh Creation Area Topographic Survey Drawings

Appendix D-Marsh Creation Area Magnetometer Survey Drawings

Appendix E-Average Healthy Marsh Survey Drawings

Appendix F-Offshore Borrow Area Geophysical Data Report

Appendix G-Bayou Lafourche Survey Data

Appendix H-Marsh Creation Area Geotechnical Data Report

Appendix I – Offshore Borrow Area Geotechnical Data Report

Appendix J – Geotechnical Engineering Report

Appendix K – 95% Design Drawings

Appendix L – 95% Project Specifications