East Leeville Marsh Creation and Nourishment Project

BA-0194

Coastal Wetland Planning, Protection, and Restoration Act PPL 25

95% Design Report

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ABBREVIATIONS

ACM	Articulated Concrete Mat
ACRE	Applied Coastal Reasearch and Enginering
BA	Borrow Area
CMFE	Constructed Marsh Fill Elevation
CPRA	Coastal Protection and Restoration Authority
CPT	Cone Penetration Test
CRMS	Coastwide Reference Monitoring System
CWPPRA	Coastal Wetlands Planning, Protection, and Restoration Act
CY	Cubic Yard
DPC	Dredge Pipeline Corridor
EAC	Equipment Access Corridor
ECD	Earthen Containment Dike
EME	Existing Marsh Elevation
ESLR	Eustatic Sea Level Rise
FT	Foot
GER	Geotechnical Engineering Report
MRHDM	Mississippi River Hydrodynamic and Delta Management
LF	Linear Foot
LS	Lump Sum
MC	Marsh Creation
MCA	Marsh Creation Area
MCDG	Marsh Creation Design Guidelines
MHW	Mean High Water
MLW	Mean Low Water
MNA	Marsh Nourishment Area
MRHDM	Mississippi River Hydrodynamic and Delta Management
MTL	Mean Tide Level
NOAA	National Oceanic and Atmospheric Administration
NMFS	National Marine Fisheries Service
NOS	National Ocean Service
NPMS	National Pipeline Mapping System
PPL	Project Priority List
RPA	Registered Professional Archaeologist
RSLR	Relative Sea Level Rise
SF	Square Foot
SHPO	State Historic Preservation Office
SONRIS	Strategic Online Natural Resources Information System
TME	Target Marsh Elevation
TY	Target Year
USACE	United States Army Corps of Engineers
WVA	Wetland Value Assessment

EXECUTIVE SUMMARY

The goal of the East Leeville Marsh Creation and Nourishment Project is to address the marsh loss in the areas east of Leeville in attempt to restore the structural framework of the marshes. The alignment of the fill areas went through several alterations from the original Phase 0 configuration through 30% design before arriving at the current configuration shown in the 95% plans. The Phase 0 configuration proposed three hundred fifty-eight (358) acres of marsh creation spanning four (4) marsh creation areas and one hundred twenty-four (124) acres of nourishment with containment features traversing multiple open water segments along the rim of Lake Jesse and the SWLA Canal. The feasibility study performed by Sigma assessed the constructability of the proposed Phase 0 cells as well as other cells that may be practical for construction. The study revealed several features within the project area that altered the alignment of the Phase 0 cells. The feasibility study resulted in the recommendation of six (6) marsh creation areas suitable for construction (all except MCA-1), spanning the northern shore of Lake Jesse, and bordering the SWLA Canal and North and South Lakes.

After completion of the surveys and geotechnical explorations, the cell alignments underwent further adjustments. Due to the presence of an exposed gas line discovered along the northwestern boundary of MCA-2 the northern cell alignment was shifted to the south. MCA-5 was removed from base scope of the project due to water depths and wave environment. MCA-6 was also removed from the base scope because the survey data revealed that a majority of the cell is existing marsh. However, MCA-5 and MCA-6 were evaluated as potential additional alternate bid items. The alignments of the remaining cells (MCA-3 and MCA-4, and MCA-7) were further adjusted to avoid deeper water areas and pipelines within the vicinity. As a result of these alterations, the proposed project spanned approximately two hundred ninety-four (294) acres across four (4) MCAs at 30% design.

Additional geotechnical and survey data collection efforts were performed after 30% design in order to further refine containment strategies and evaluate potential erosion control alternatives. The adjustment of containment features as a result of these data collection efforts resulted in a final configuration of two hundred ninety-seven (297) acres (measured to the outside toe of the containment dikes) spanning four (4) marsh creation areas. The total acreage when measuring to the centerline of the containment features is two hundred seventy-five acres (275) – two hundred twenty-five (225) acres of marsh creation and fifty (50) acres of marsh nourishment. The updated cell configuration is shown in Figure 5.

1.0 INTRODUCTION

1.1 Authority

The East Leeville Marsh Creation and Nourishment Project (herein referred to as BA-0194) is located in the Barataria Basin, east of Highway 1 and Leeville, as shown in Figure 1 below. The Louisiana Coastal Wetlands Planning, Protection and Restoration Task Force designated BA-0194 as part of the 25th Priority Project List. The National Oceanic and Atmospheric Administration's National Marine Fisheries Services (NOAA/NMFS) is approved as the lead federal sponsor with engineering and design funding approved through the Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA) of 1990 by the United States Congress and the Wetlands Conservation Trust Fund by the State of Louisiana. The Louisiana Coastal Protection and Restoration Authority (CPRA) is serving as the local sponsor and will also be providing engineering and design services.

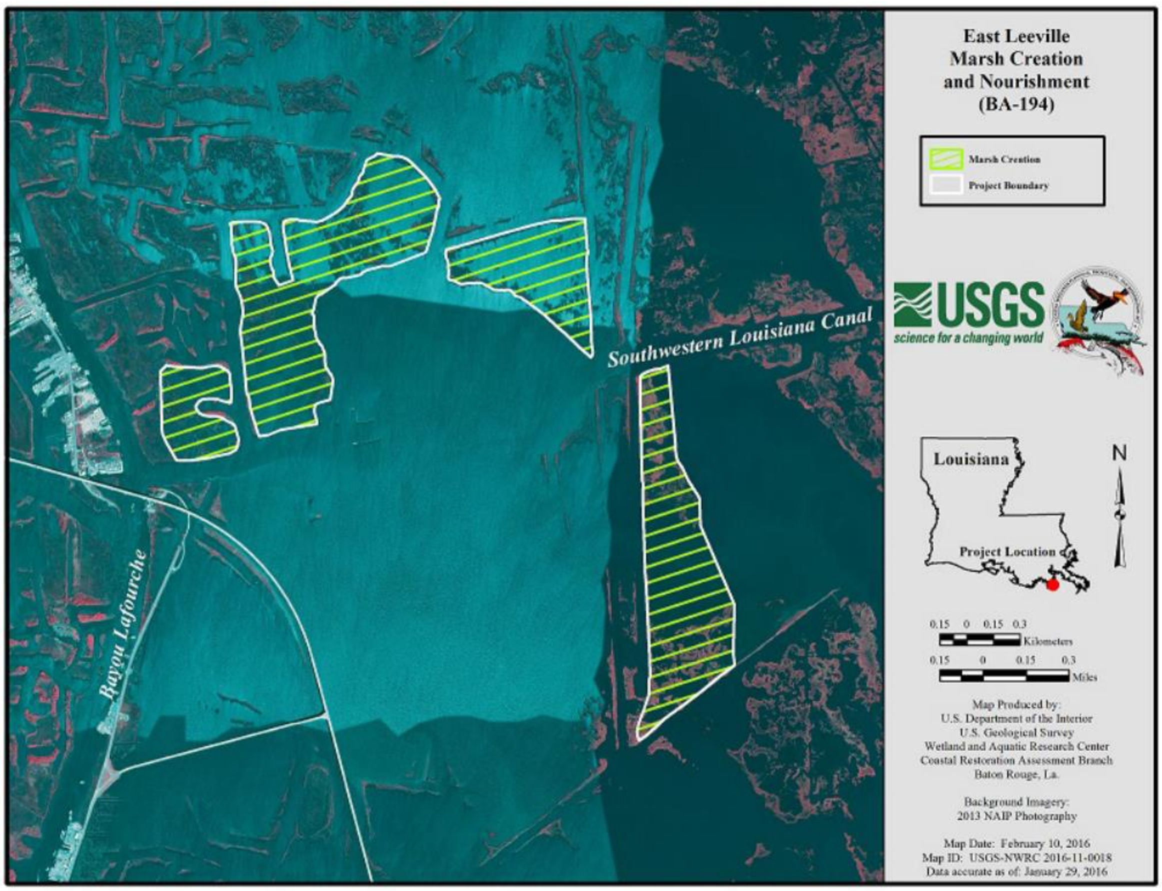


Figure 1: Phase 0 Project Area (CWPPRA 2017)

1.2 Project Team

The National Marine Fisheries Service (NMFS) is serving as the federal project sponsor in addition to providing environmental compliance and consultation for cultural resources. The CPRA is serving as both the local project sponsor and providing engineering and design services. The project's consulting team included Sigma Consulting Group, Inc. (Sigma), GCR Inc. (GCR), Coastal Environments, Inc. (CEI), Earth Search, Inc. (ESI), Tetra Tech, Inc. (Tetra Tech), GeoEngineers, Inc. (GeoEngineers), and Morris P. Hebert, Inc. (MPH).

Sigma was tasked with performing a feasibility study of the proposed Phase 0 project as well as investigating data available from other marsh creation areas for inclusion within the project scope (Section 3.2). GCR was tasked with performing title research, as well as a pipeline investigation of the project area by utilizing available information in the SONRIS database (Section 3.1 and 3.3, respectively). MPH conducted geophysical surveys, which included topographic, bathymetric, and magnetometer surveys within the marsh creation areas, Southwestern Louisiana (SWLA) Canal, Lake Jesse, and the borrow area located in Caminada Bay. CEI, as a sub-consultant under MPH, performed the borrow area cultural resource investigations. A Hazardous, Toxic, and Radioactive Waste Investigation and Phase I environmental site assessment was conducted by Tetra Tech. ESI performed the marsh creation area cultural resource investigations as part of the Tetra Tech team. GeoEngineers performed geotechnical exploration and engineering services for the project, including a preliminary desktop investigation as part of the Sigma team.

1.3 Project Area Location and History

The BA-0194 project area is located immediately east of Leeville, situated between Golden Meadow to the north and Grande Isle and Port Fourchon to the south, as shown in Figure 2 (29°15’18”N, 90°11’20”W). The project consists of an arc of wetlands that spans approximately two miles along the northern and eastern banks of Lake Jesse, and bisected by the SWLA Canal. On the eastern boundary, diminishing marsh areas border North Lake and South Lake. The SWLA Canal stretches from Timbalier Bay through Leeville to the proposed borrow area located in Caminada Bay.

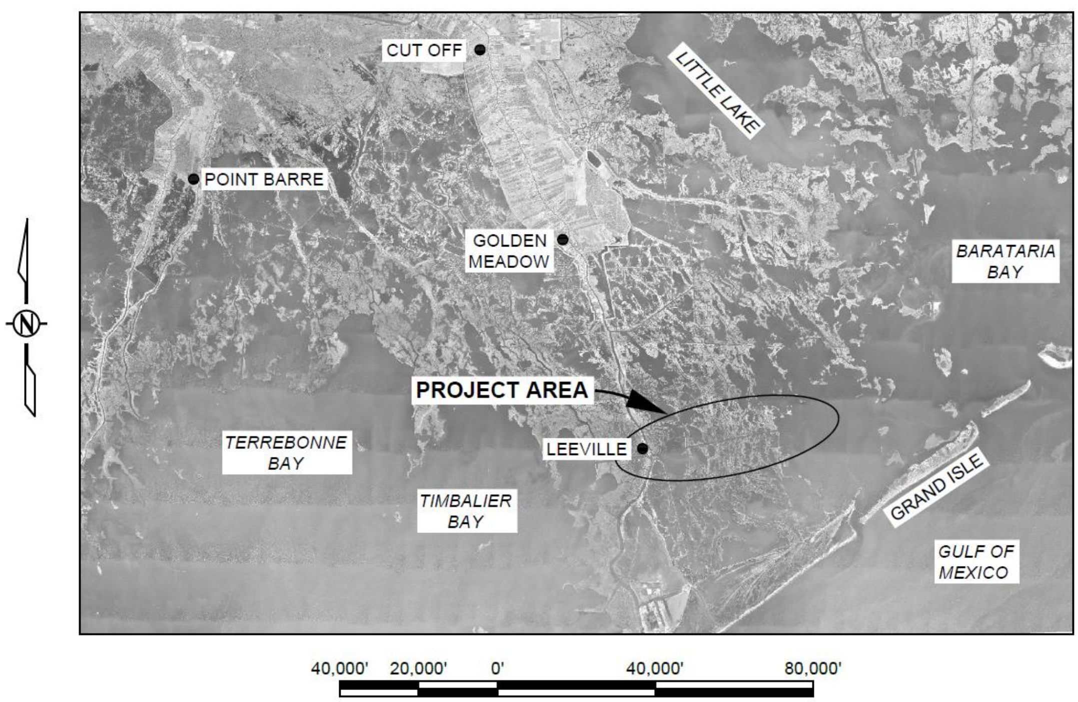


Figure 2: Project Area Vicinity Map

The project area is nestled within the Lafourche Delta Complex, formed by progradation of a series of Mississippi River courses and delta over the course of the last 9,000 years (Sigma 2017). As a result, the project area consists primarily of Holocene deposits formed by these areas of active and abandoned delta lobes. Bayou Lafourche continued to carry some Mississippi River water to the area until around 1906 when it was dammed off from the Mississippi at its head at Donaldsonville, depriving the area of fresh water and causing rapid deterioration of the inland marsh (Sigma 2017).

Exploration of the area began in 1888, when the SWLA Canal was cut thirty (30) feet wide and roughly four (4) feet deep as part of a proposed major east-west waterway across the Lafourche Delta (Doiron and Whitehurst 1974). With newfound, direct access from Bayou Lafourche, major oil and gas exploration began in 1931. By 1938, over one hundred (100) wells were located within the Leeville area (Sigma 2017). As a result of the rapid increase oil and gas exploration, the SWLA Canal was acquired by the State of Louisiana in 1951. The stretch of SWLA Canal from Bayou Lafourche to Caminada Bay was dredged to a depth of nine and a half (9.5) feet below sea level and expanded to ninety (90) feet wide (Doiron and Whitehurst 1974). With continued expansion throughout the field, marsh degradation continued at an amplified rate within the area. Sprawling flowlines and hundreds of wellheads comprise one of the oldest oil and gas fields in the state of Louisiana – commonly referred to as the Leeville Oil and Gas Field.

Since 2005, large portions of the northern rim and existing marsh of Lake Jesse have deteriorated, exposing additional areas to potential impacts of wind and tides. To the east, areas along South Lake have been lost, resulting in increased wave fetch and blurring boundaries between the water bodies in the vicinity. Additionally, the boundary of the SWLA Canal between North and South Lake has begun to erode.

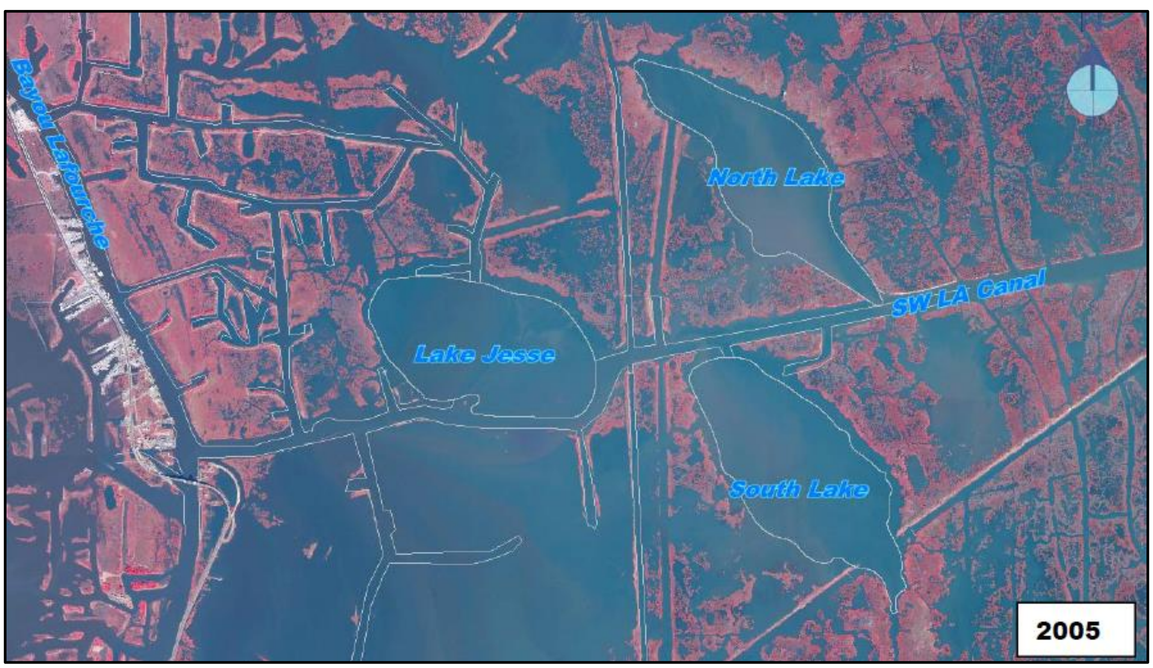


Figure 3: 2005 Aerial Photograpy of the Project Area (Sigma 2017)

Figure 4: 2016 Aerial Photography of the Project Area (SONRIS)

As previously discussed, the primary influences of marsh loss in the project area are due to oil and gas exploration, subsidence, wind and wave erosion, storms, and altered hydrology (WVA 2015). As such, the limits of the canal and surrounding lakes have become difficult to differentiate, and natural tidal flow and drainage patterns have been altered as a result of the increase in open water areas. Data shows that the Barataria Basin experiences the highest rate of wetland loss along the entire coast. USGS data from 1984 to 2015 suggests a wetland loss rate of -1.53% (WVA 2015).

1.4 Project Goals and Preliminary Alternatives Analysis

Prior to the development of the Phase 0 alignment as shown in Figure 1, several alternative alignments were considered. In general, each alignment considered features to re-establish the framework of the wetlands in the vicinity (WVA 2015). These alternatives included:

1. An arc of wetlands adjacent to Louisiana Highway 1, north and south of SWLA Canal;

2. Re-establishment of wetlands along the north side of SWLA Canal, Lake Jesse, North Lake, and the East side of South Lake, and;

3. Re-establishment of the wetlands along the north side of SWLA Canal, Lake Jesse, and the west side of South Lake.

Ultimately, Alternative 3 was selected due to the deeper water depths and potentially greater infrastructure challenges present in the other two alternatives (WVA 2015). Therefore, the preliminary goals of the BA-0194 project (as defined in Phase 0) were to create approximately three hundred fifty-eight (358) acres and to nourish an additional one hundred twenty-four (124) acres of saline marsh by hydraulically dredging material from a borrow source located in Little Lake, in order to begin rebuilding the structural framework of the wetlands east of Leeville and to provide protection from southeasterly winds and tides (WVA 2015, CWPPRA 2017). This material will be placed in four (4) designated marsh creation areas formed by constructing earthen containment dikes around the perimeter. Sections of the containment dike having a deeper mudline elevation will require a sheet pile gap closure feature.

Throughout the Phase I process, adjustments were made to the configuration of the marsh creation areas such that the project scope still consists of four (4) areas, but with a reduced area of approximately two hundred ninety-seven (297) total acres of marsh creation (measured to the outside toe of the containment features). Additionally, the borrow source was relocated from Little Lake to Caminada Bay to the east, as shown in Figure 5 below. The means and methods behind the design changes from Phase 0 are discussed in further detail in Section 7.0 Marsh Creation Design, and the modifications to the anticipated construction costs and benefited acres are discussed in Sections 8.0 and 9.0, respectively.

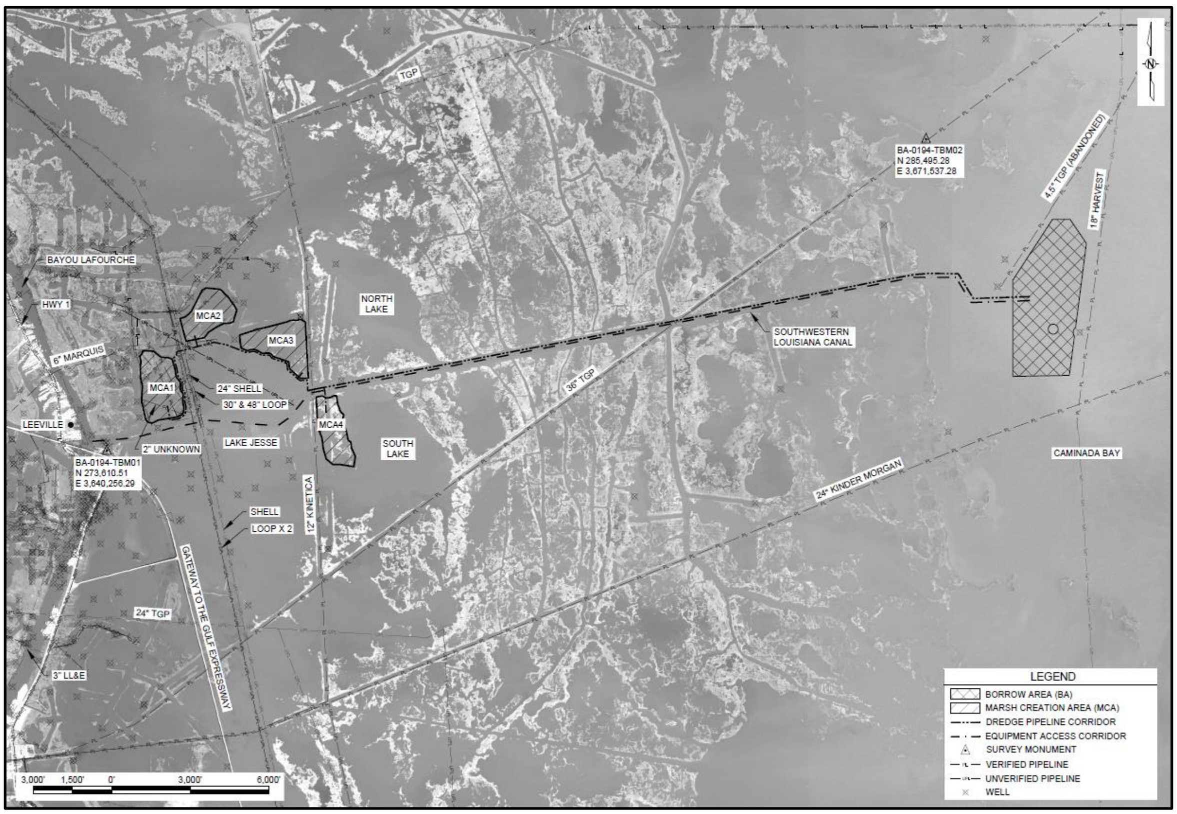


Figure 5: 95% Design Project Area and Features

The engineering and design, environmental compliance, real estate negotiations, operation/maintenance planning, and cultural resources investigation have been completed to the 95% design level as required by the CWPPRA Standard Operating Procedures Version 27.

2.0 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.

3.0 EXISTING CONDITIONS

3.1 Land Ownership

The project area is currently owned by several different landowner groups, as shown in Figure 6 below.

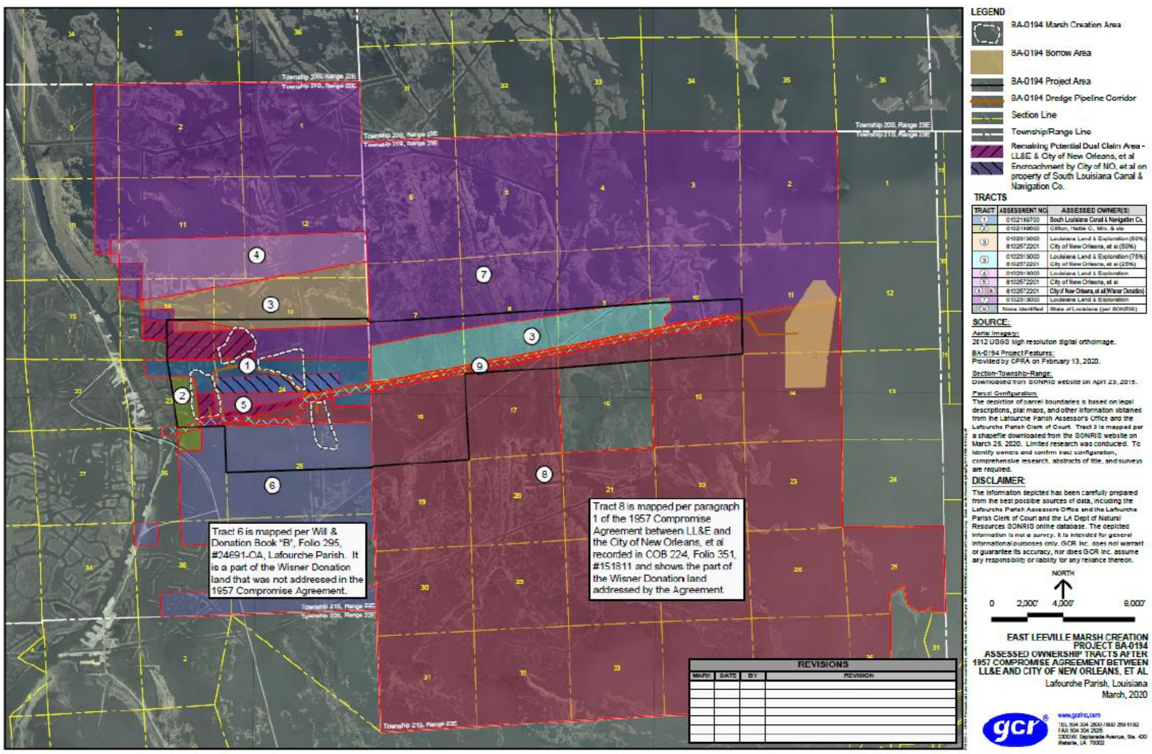


Figure 6: Land Ownership Map

A preliminary title assessment has shown that the project area is owned by Hattie C. Clifton, et al, South Louisiana Navigation and Canal Company, State of Louisiana, Wisner Donation (sometimes depicted as City of New Orleans), Louisiana Land & Exploration (LL&E), and a joint ownership between Wisner Donation and LL&E.

Lands shown to be owned by Hattie C. Clifton, et al are comprised of 47 undivided interest owners, with varying amounts of undivided interest held by each owner. The Estate of Hattie Grace Clifton owns the largest amount of interest of the property. Lands shown to be owned by South Louisiana Navigation and Canal Company are owned in full (100%), while lands shown to be owned by Wisner Donation and LL&E are also owned in full (100%) by each landowner, except in areas of joint ownership. Tract 3 shows a joint ownership of 50%

ownership by Wisner Donation and 50% ownership by LL&E in the northern portion, whereas the southern portion shows a joint ownership of 75% by LL&E and 25% by Wisner Donation.

The area shown on the map in Figure 6 as an encroachment by Wisner Donation onto the ownership of South Louisiana Navigation and Canal Company will be resolved with the completed title report. Additionally, the area shown on the map as a potential dual claim area between Wisner Donation and LL&E is assumed to be owned in full by both landowners, and will be resolved with the completed title report. The SWLA Canal and proposed borrow area are claimed by the State of Louisiana.

3.2 Feasibility Study

Sigma Consulting Group, Inc (Sigma) was contracted by the CPRA in August 2017 to perform a feasibility study and alternatives development for the BA-0194 project. Sigma generated alternatives for potential marsh creation areas and borrow sources with the intent to reduce cost yet still achieve the project goals described in Section 1.4 (Sigma 2017). Sigma performed the following tasks in their study:

- A review of available historical aerial photography and background information;
- Discussion of the LA1 Improvements Marsh Creation project constructed south of the project area;
- A desktop study of existing oil and gas infrastructure that includes information from LADOTD, SONRIS, and physical evidence from site investigations;
- A review of oyster leases, notable infrastructure, and known cultural resources;
- A review of existing topographic and bathymetric data, including a tidal datum evaluation utilizing CRMS 0164 and 0175 datasets;
- A review of existing geotechnical and geologic data performed by GeoEngineers, Inc.;
- Construction considerations for the project area, and;
- A preliminary estimate of fill quantities.

Sigma proposed several alternatives for marsh creation areas and borrow sources, providing detailed information pertaining to the feasibility and constructibility of each area for inclusion in the final design. The information presented in this study was utilized during the Phase I process, and pertinent information is referenced accordingly throughout this report. A detailed discussion of the changes made from the proposed Phase 0 project to the current alignment is discussed further in Section 7.1. The feasibility study can be found in Appendix A.

3.3 Existing Oil and Gas Infrastructure

Existing infrastructure was identified in order to assess their impact on the proposed project features. As discussed in Section 1.3, the project area is located within the Leeville Oil and Gas Field, and as such, oil and gas infrastructure is a primary concern. In addition to the pipeline investigation performed by Sigma in their feasibility study, GCR Inc. (GCR) was tasked to perform a pipeline investigation of the BA-0194 project area by utilizing available information in the SONRIS database. GCR reviewed a total of forty-nine (49) permits, revealing twenty-six (26) pipelines and one (1) utility line that has since been removed. GCR provided CPRA with a shape file revealing the locations of the permitted lines as well as a table detailing the status of the permits. The pipeline investigation report performed by GCR can be found in Appendix B. The project team also utilized information from SONRIS and National Pipeline Mapping System (NPMS) databases to determine any additional pipelines that are potentially within the project limits. This information was used to aid the magnetometer survey performed by MPH, as well as to assess the ability to perform construction activities on or near existing pipelines. Major oil and gas infrastructure findings include:

- Twelve (12) flowlines located within and adjacent to MCA-1, MCA-2 and MCA-3;
- Eleven (11) plugged and abandoned/dry and plugged wellheads within the marsh creation areas, access dredging areas, and along the dredge pipeline corridor, and one (1) dry and plugged wellhead near the borrow area that will require special construction considerations;
- The presence of the Shell MARS (24" crude) and LOOP pipelines (30" and 48" crude) located between MCA-1 and MCA-2;
- The presence of the Kinetica gas pipeline (12") located between MCA-3 and MCA-4;
- The presence of an overhead electrical powerline (note that this powerline has since been removed, however some portions of the foundations still remain on site);
- The presence of the Tennessee Gas pipeline (36") intersecting the dredge pipeline corridor within SWLA Canal, and;
- The presence of the Harvest Midstream pipeline (18" crude) located in the borrow area.

A magnetometer survey was performed to determine exact locations of existing pipelines and flowlines, and is discussed in further detail in Section 5.0. Discussion of the oil and gas infrastructure in relation to design considerations can be found in Section 7.0.

3.4 Cultural Resources Assessment

NOAA/NMFS, CPRA, and Sigma reviewed historical records and archives of previous cultural resource investigations and previously recorded archaeological sites in the project vicinity prior to the performance of a cultural resources survey. Findings revealed that MC-1 (westernmost cell in Figure 1, Phase 0 nomenclature) contained a previously recorded archaeological site located in the southwestern corner and extending westward outside of the cell boundary. Additional, previously recorded archaeological sites were also identified in the proximity of the southwest boundary of MC-1. Earth Search, Inc. (ESI) performed cultural resources surveys on the marsh creation areas in May 2018 and again in March 2019. These surveys confirmed the presence of the previously recorded sites located outside the southwestern portion of MC-1. This cell was later removed from the project scope, therefore avoiding potential impacts to these archaeological sites. No other new archaeological sites were identified within the marsh creation areas during the cultural resources survey.

As part of the survey of the borrow areas performed by MPH, a Registered Professional Archeologist (RPA), as per LR 20:410 (April 1994), was present for the efforts. The cultural resources survey for the proposed borrow area was performed by CEI in March 2019. The RPA recommended a total of nine (9) anomalies located within the borrow area survey be avoided with a 100-foot buffer, as their eligibility for the National Register of Historic Places (NRHP) under Criterion D was undetermined. These locations are shown in the drawings in Appendix J.

The NMFS consulted with the State Historic Preservation Office (SHPO) regarding the BA-0194 marsh creation areas and borrow area, and provided a finding of effect to cultural resources in the Area of Potential Effect (APE). After a review of the provided survey, the NMFS was issued a letter stating the following:

- There shall be no deepening or dredging within 500 feet of the LeFort Cemetery;
- Efforts shall be made to minimize boat traffic near the Lefort Cemetery, and;
- The 100-foot buffers recommended by the RPA shall remain in effect (shown in Appendix J).

Copies of the letters sent to the NMFS by the SHPO can be found in Appendix C. These restrictions shall be incorporated into the design of the BA-0194 project. Measures to avoid impacts to the Lefort Cemetary will be further evaluated upon Phase II authorization.

3.5 Oyster Lease Assessment

No existing oyster leases have been identified within the marsh fill area alignments. Two (2) existing oyster leases were discovered south of the SWLA Canal, near MCA-1, but are outside of the cell alignment, and beyond the extents of the canal. However a portion of one of the leases is located within the 1,500-ft study area. Dewatering of MCA-1 during construction will not be performed to the south in order to avoid any potential impacts to these leases. A small portion of another lease is located within 1,500 feet north of MCA-2.

Two (2) oyster leases were identified along the SWLA Canal, adjacent to the dredge pipeline corridor (DPC), as shown in the map in Appendix D. Additionally, the borrow area in Caminada Bay has been modified to maintain a minimum 1,500 ft. buffer to an existing oyster lease to the east. The list of oyster lease holders can be found in Appendix D. An appraisal of these oyster leases shall be performed upon Phase II authorization.

3.6 Neighboring Marsh Creation Project – LA 1 Improvements Mitigation

A neighboring project was evaluated to obtain design insight for constructing marsh creation projects in the Leeville area. In 2005, the Louisiana Department of Transportation and Development (DOTD) completed the construction of seventy-seven (77) acres of saline marsh (Site 3 in Figure 7) in the Leeville area as part of mitigation for wetland impacts from the construction of the new Highway 1. Site 3, as well as four (4) previously constructed marsh creation areas, are located west and south of the BA-0194 project area, as shown in Figure 7 on the following page.

These marsh creation areas were constructed by placing spoil to an elevation of +3.5 (+0.5) feet (NAVD88, Geoid99) contained by earthen containment dikes (ECD) constructed to an elevation of +4.0 feet (NAVD88, Geoid99), as shown in Figure 8. Both internal and external borrow sources were utilized to construct the ECDs. The estimated marsh elevation after consolidation was determined to be approximately +1.0 ft., and was selected based on the average existing elevation of nearby marsh ranging from +0.5 and +1.5 ft. (NAVD88, Geoid99).

Figure 7: LA 1 Improvements Mitigation Areas

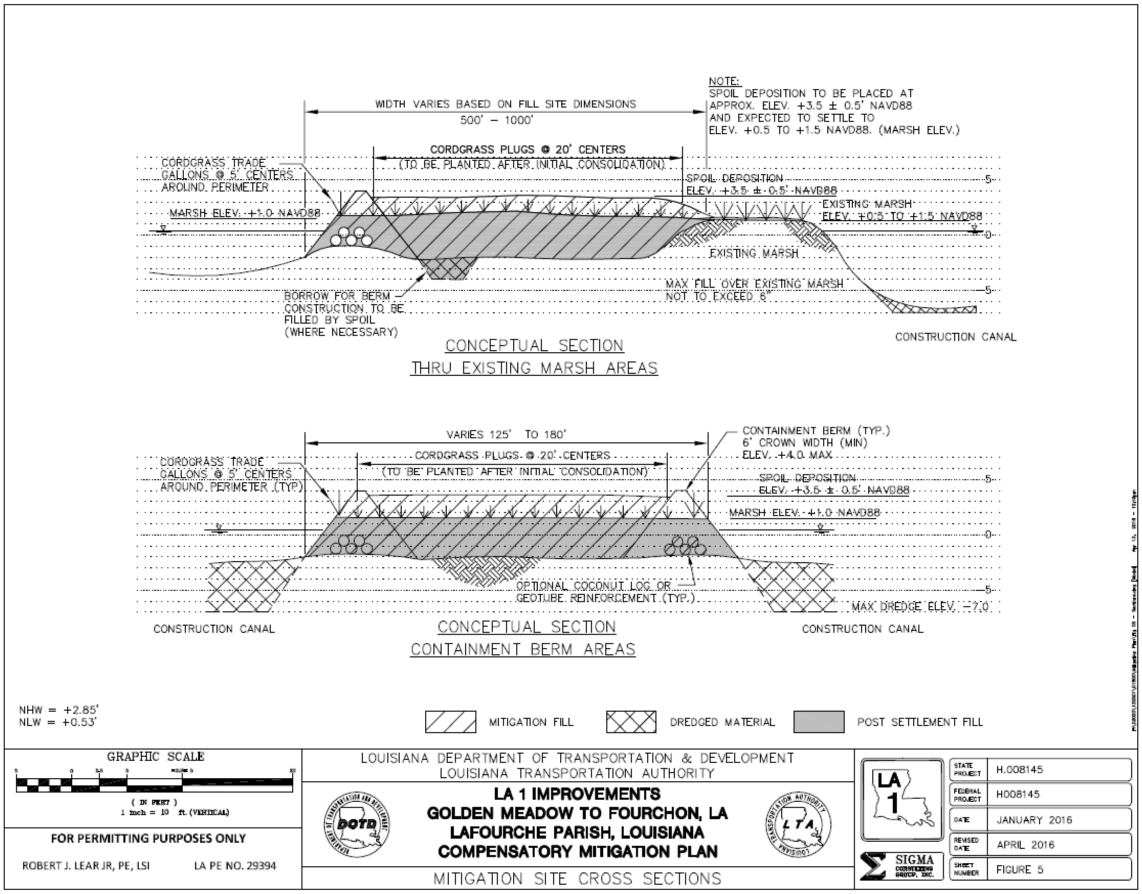


Figure 8: Typical Sections for the LA-1 Improvements Mitigation (Sigma 2016)

These sites were constructed prior to Hurricanes Katrina and Rita, and have sustained, on average, a 90% survivability over a 10-year period. However, Site 3 located along the new Highway 1 has experienced significant land loss from 2012-2017 due to its exposure to open water and wave action (Sigma 2017). Riprap was used where necessary in areas where containment berms were being eroded. No additional lifts to the marsh creation areas have been required to date.

4.0 HYDROLOGIC CONDITIONS

4.1 Relative Sea Level Rise

In order to properly design the BA-0194 project and ensure it is built and performs according to the objectives for the 20-year project life, certain natural processes such as eustatic (global) sea level rise (ESLR) and subsidence must be assessed. The combination of these two processes, termed relative sea level rise (RSLR), was analyzed for the purposes of this project.

The rate of ESLR refers to a global change in water level that accounts for a number of variables such as thermal expansion, the loss of glaciers and ice caps, and runoff from thawing permafrost. To determine the most likely change in ESLR along coastal Louisiana, the CPRA Planning Division provided forecasted rates consistent with the 2017 Master

Plan. These rates range from 0.5 to 1.98 meters of sea level rise by 2100, and are bracketed in various scenarios to account for uncertainty. The CPRA Planning Division recommends using the 1.0 meter (medium) scenario for the purposes of design of marsh creation projects. This accounts to nearly 0.5 feet of rise over the 20-year project life.

Subsidence is defined as the local decrease (sinking) in land elevation relative to a fixed datum. For the BA-0194 project area, the rate of subsidence was determined by utilizing information from the CPRA's 2017 Coastal Master Plan and the Mississippi River Hydrodynamic and Delta Management (MRHDM) feasibility study, as well as from a study performed by Applied Coastal Reasearch and Engineering (ACRE) in August 2018. The ACRE study assesed recent subsidence rates for the Barataria Basin by utilizing direct survey measurements at Continuously Operating Reference Stations (CORS) primary benchmarks and CPRA/NGS secondary benchmarks to determine subsidence velocities. According to the study, the BA-0194 project area falls into a subsidence range of 5-7 mm/year. Based on the information provided in the MRHDM (in conjunction with CPRA's 2017 Coastal Master Plan and recommendations by CPRA's Planning Division), the BA-0194 project area experiences a subsidence rate of 6.4 mm/year.

The rates of ESLR and subsidence were used to determine the annual incremental RSLR for the BA-0194 project area over the 20-year project life (Table 1) RSLR is calcuated using the following equation, beginning in the year 2019. A project start year of 2021 was estimated for design calcuations.

$$E(t) = at + bt^2 + St$$

Where E is the change in relative sea level at time, t
a is the rate of ESLR
b is an acceleration factor, and
S is the rate of subsidence

The annual incremental ESLR and RSLR is shown in the following table (Reed et al 2016).

For design analysis of the marsh creation area elevation over the 20-year project life, the subsidence rate was applied to the marsh fill elevation (settlement curves), while ESLR was applied to the tidal datum and the optimal inundation range. This process is discussed further in Section 6.5.

Table 1: Annual Incremental ESLR and RSLR (feet NAVD88, Geoid12B)

Year	Annual Incremental Subsidence (*St*) (ft)	Annual Incremental Eustatic Sea Level Rise (*at* + *bt*) (ft)	Annual Incremental Relative Sea Level Rise ($at + bt^2 + St$) (ft)
2019	0.000	0.000	0.000
2020	0.021	0.020	0.041
2021	0.042	0.040	0.082
2022 (TY0)	0.063	0.061	0.124
2023	0.084	0.082	0.166
2024	0.105	0.103	0.208
2025	0.126	0.125	0.251
2026	0.147	0.147	0.294
2027	0.168	0.170	0.338
2028	0.189	0.193	0.382
2029	0.210	0.216	0.426
2030	0.231	0.240	0.471
2031	0.252	0.264	0.516
2032	0.273	0.289	0.562
2033	0.294	0.314	0.608
2034	0.315	0.339	0.654
2035	0.336	0.365	0.701
2036	0.357	0.391	0.748
2037	0.378	0.418	0.796
2038	0.399	0.445	0.844
2039	0.420	0.472	0.892
2040	0.441	0.500	0.941
2041	0.462	0.528	0.990
2042	0.483	0.557	1.040

4.2 Tidal Conditions

The tidal datum is a standard elevation defined by a certain phase of the tide and issued to measure local water levels and establish design criteria. Typically, the primary objective for computing the tidal datum is to establish the target construction marsh fill elevation that maximizes the duration that the restored marsh will be at intertidal elevation throughout the 20-year project life. The tidal datum for BA-0194 was established in the preliminary stages of engineering, as it pertains to many aspects of the project including surveys, geotechnical analysis, and constructability.

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 heights 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.

The Coastwide Reference Monitoring System (CRMS) monitoring stations CRMS 0164 (29°11'37.92"N, 90°10'11.48"W) and CRMS0175 (29°17’21.62”N, 90°08’31.17”W)

(Appendix E) were selected as the control stations because of their proximity to the project area and their use in Phase 0 planning (as shown in Figure 9).

Figure 9: CRMS Station Locations Relative to the Project Area

The period of record used for both stations was April 9, 2014 to April 9, 2019, the most recent five-year period, as per CPRA's *Marsh Creation Design Guidelines 1.0 (MCDG 1.0):* Appendix D: *Marsh Inundation Methodology*. The most recent five year period with data available is used to better reflect the current mean sea level datum (NOAA Tides & Currents). The results of the tidal datum determination for the BA-0194 project area are shown in Table 2 on the following page.

Table 2: Tidal Datum Evaluation

CRMS Station	MHW, ft. (NAVD88, GEOID12B)	MLW, ft. (NAVD88, GEOID12B)	MTL, ft. (NAVD88, GEOID12B)
CRMS 0164	1.00	0.07	0.53
CRMS 0175	0.99	0.09	0.54
Average	**1.00**	**0.08**	**0.54**

While CRMS0164 and CRMS0175 are the closest stations to the project area, they are still located approximately 4.4 miles and 3.8 miles from the project area, respectively. In order to verify that hydrologic data from CRMS0164 and CRMS0175 were representative of the project area tidal conditions, a staff gage was installed by MPH during the survey effort near the southwest corner of MCA-1 (29°15’00.00”N, 90°12’08.34”W). Water level readings were collected at the beginning and end of each day from January 21, 2018 to April 25, 2018, as shown in Appendix 13 of the Survey Report (Appendix F). Since water level readings were only taken twice daily instead of hourly, and at varying times each day, mean high and mean low values for each day and month were unable to be accurately computed. Therefore, the Modified Range-Ratio Method was not used to evaluate the mean high and mean low water conditions. Instead, staff gage readings were directly compared to the values recorded by the CRMS stations to the nearest hour, as shown in the following figure, to confirm the tidal conditions from the CRMS station are representative of the project area.

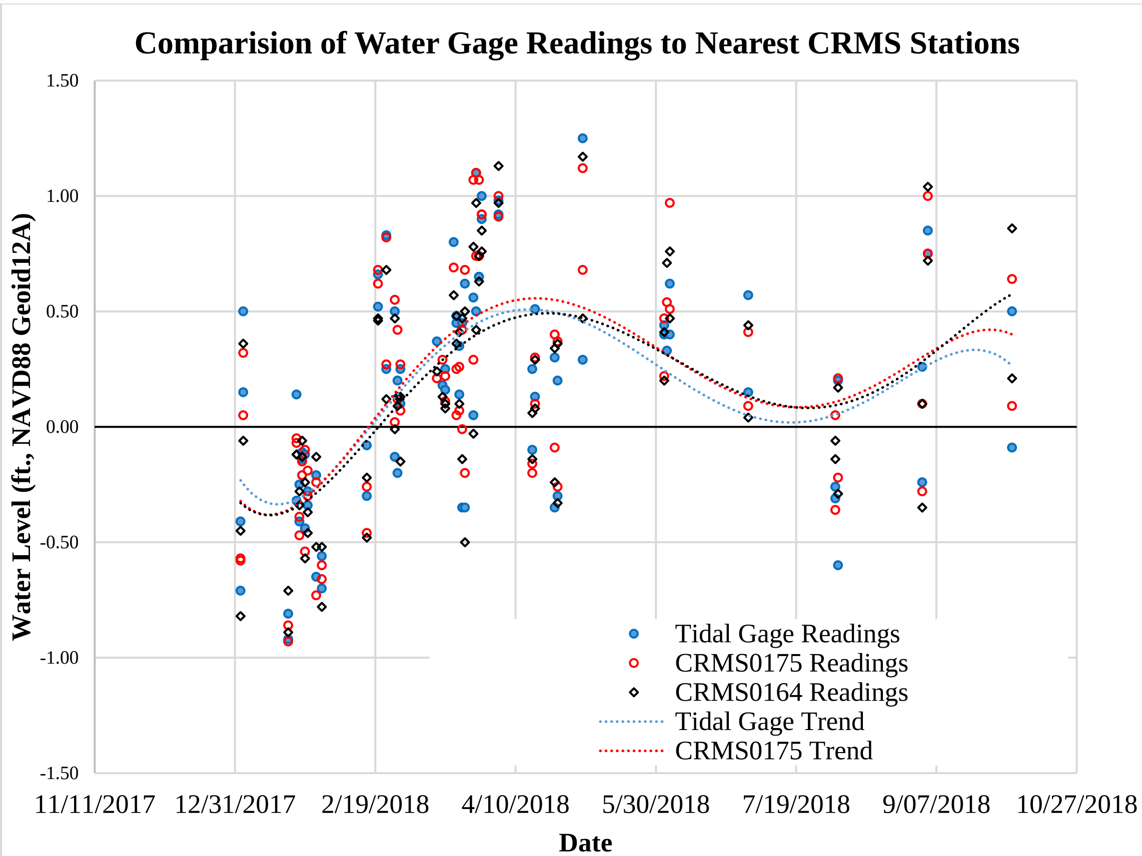


Figure 10: Water level readings from water gage, CRMS0175, and CRMS0164.

On average, the difference in recorded water level compared to the staff gage over the observed time period was approximately 0.14 ft (1.6 inches) for CRMS0175 and 0.13 ft (1.5 inches) for CRMS0164. Since construction tolerances for marsh creation project features (containment dikes and marsh fill elevations) are typically taken as ±0.5 ft, the difference between the staff gage readings and the CRMS station values are considered minimal. Therefore, the water level readings obtained from both of the CRMS stations were deemed acceptable for use in design.

4.3 Percent Inundation Determination

Historically, the tidal range between MHW and MLW has been the accepted range for healthy marsh. However, this approach only takes into account the tidal influences on the water levels, whereas in many areas, non-tidal influences such as meteorological events, river discharges, and management regimes often have a large impact on the water levels found in that region. In order to account for tidal and non-tidal influences, an additional water level determination method, the Percent Inundation Method, was used to determine the marsh elevation range corresponding to an appropriate inundation and established marsh vegetation (as per *MCDG1.0*, Appendix D).

The vertical positioning of marsh platforms and the frequency with which the marsh floods strongly influences plant communities and marsh health (Visser 2003, Mitsch 1986). Percent inundation refers to the percentage of the year a certain elevation of land would be flooded, by taking into account both tidal and non-tidal influences. 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.

To determine percent inundation, the percentiles were calculated based on data gathered from both the CRMS0164 and CRMS0175 stations, and averaged for the most recent 5-year period from April 9, 2014 to April 9, 2019, with ESLR factored in (Section 4.1). Table 3 presents the results of the average percent inundation determination for a Target Year 0 (2022) and Target Year 20 (2042).

Table 3: Percent Inundation Elevations with ESLR

Percent Inundated	TY0 Marsh Elevation (ft. NAVD88 GEOID12B)	TY20 Marsh Elevation (ft. NAVD88 GEOID12B)
1%	1.986	2.482
10%	1.286	1.782
20%	**1.041**	**1.537**
30%	0.871	1.367
40%	0.731	1.227
50%	0.591	1.087
60%	0.461	0.957
65%	0.386	0.882
70%	0.311	0.807
80%	**0.146**	**0.642**
90%	-0.089	0.407

Using data from the surrounding CRMS stations, the marsh type for BA-0194 was determined to be saline (WVA 2015). Saline marshes, like those in BA-0194, are most productive[1] when flooded between 20% and 80% of the time (Snedden and Swenson 2012). 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 RSLR. For design applications, the subsidence rate was applied to the marsh fill

[1] Productivity of the marsh is based on salinity and vertical position of the marsh in relation to water levels and the effect on emergent marsh vegetation.

elevation, while ESLR was applied to the tidal datum and the optimal inundation range (see Figure 11). This process is discussed in further detail in Section 6.5.

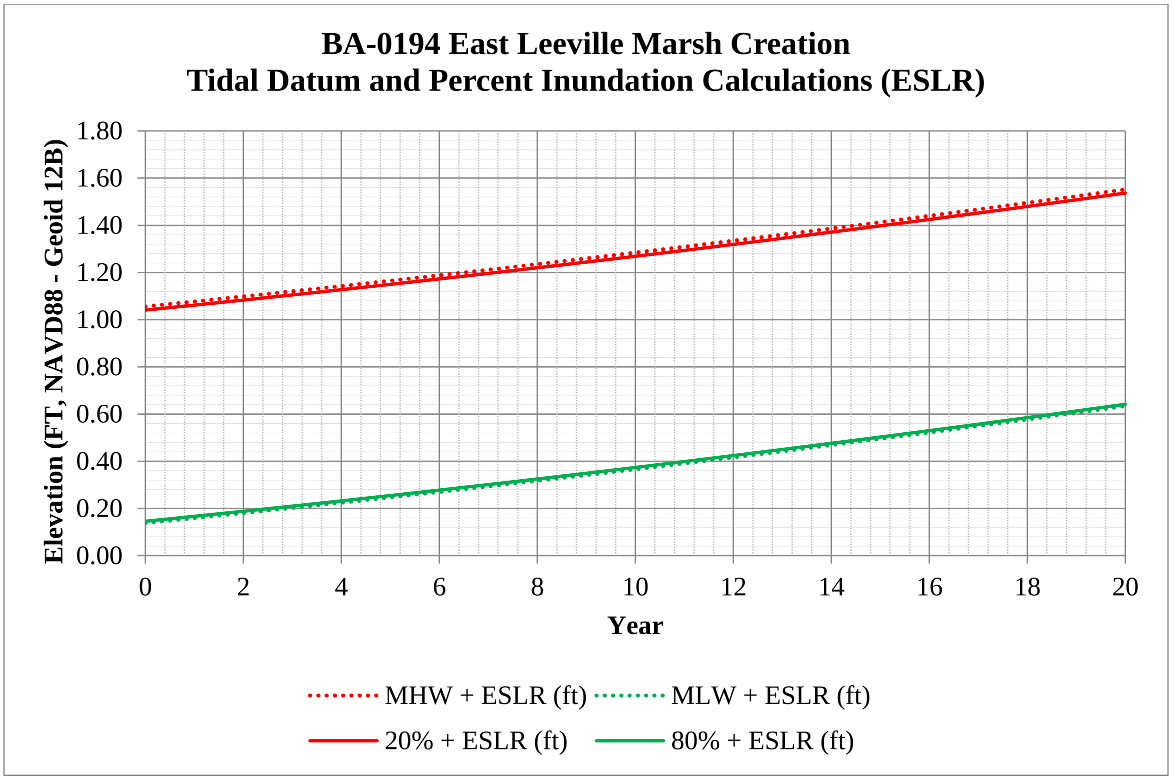


Figure 11: Percent inundation and MHW, MLW comparison.

5.0 SURVEYS

Topographic, bathymetric, magnetometer, and geophysical survey data were collected within the project area, proposed borrow areas, and potential dredge pipeline alignments in order to facilitate the design of the marsh creation area and the borrow area. The design survey effort was performed from January 16, 2018 through April 25, 2018 by MPH. MPH also collected survey data in the borrow area pertaining to a pipeline terminus, as well as to address construction access concerns on December 12th and 26th of the same year. Additional data collection was performed after 30% design (September 3rd-5th, 2019) by MPH along sections of cell alignments, along the proposed dredge pipeline corridor (DPC), and in the SWLA Canal due to gaps identified in the initial survey effort. All horizontal coordinates are referenced to Louisiana State Plane Coordinate System, North American Datum of 1983 (NAD83). All elevations are referenced to North American Vertical Datum of 1988 (NAVD88) GEOID12B. The survey report including the additional surveys can be found Appendix F.

5.1 Horizontal and Vertical Control

The surveying team set up two (2) temporary benchmarks, “BA-0194-TBM01” and “BA-0194-TBM02”, to establish horizontal and vertical control during the survey due to the condition and location of the existing Primary and Secondary Control Monuments that are part of the Louisiana Coast Zone (LCZ) GPS Network. The monuments were established by performing a GPS Static Survey. The revised monument data sheets are provided in MPH's Final Survey Report in Appendix F.

5.2 Staff Gage

One (1) staff gage was installed at the project site to monitor water levels during the survey effort, and is located near the southwest corner of MCA-1 at 29°15'00.00"N, 90°12'08.34"W. The gage was established with a "gage zero" at an elevation of 0.0 ft. NAVD88 (referenced to Geoid 12B). Water level readings were taken at the beginning and end of each day, and were used to help verify the calculated tidal datum, as previously discussed in Section 4.2.

5.3 Marsh Creation Area Surveys

RTK topographic and bathymetric surveys were performed within and around the marsh creation areas and potential access routes, with transects taken in a grid spaced approximately five hundred (500) feet, as shown in Appendix F. The initial bathymetry and topographic survey effort of the marsh creation areas was completed in April 2018, and additional data were collected after 30% design (September 2019) due to identified gaps in the survey data. A Trimble RTK/GPS base and rover setup was utilized for the topographic portion of the survey, and a 6-inch-diameter topo shoe was attached to the bottom of the survey rod to prevent the GPS antenna rod from sinking. In areas where the water depths were too great for the use of the GPS antenna rod, a level rod was used to take soundings. The bathymetric portion of the survey was performed using a Trimble DSM232 DGPS and Odom HydroTrac Echo sounder in conjunction with the Hypack software.

Transects were taken across open water areas, broken marsh, and across pipeline canals. Position, elevation, and water depths were recorded every fifty (50) feet along each transect or where elevation changes were greater than 0.5 feet. Topographic and bathymetric survey methods were used as applicable to obtain all transects and were consistent with CPRA's *Marsh Creation Design Guidelines Version 1.0 (MCDG 1.0):* Appendix A: *A Contractor's Guide to the Standards of Practice*. The topographic portions were merged with the bathymetric portions at the land/water interface and were separated by no more than twenty-five (25) feet. 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 such as pipelines, well heads, wooden pilings, and warning signs which may affect project design implementation. The use of a fixed height aluminum rod (8 feet or 10 feet in length) with a six (6) inch diameter metal plate at the base of the rod was used to prevent the rod from sinking when topographic data was collected.

A magnetometer survey was taken along the same transects performed during the topographic and bathymetric surveys in order to locate any pipelines or other existing infrastructure in the MCAs. A Geometrics G882 cesium 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 twenty-five (25) feet from that location. The magnetometer results revealed a large number of pipelines, flowlines, and wellheads present in the western portion of the BA-0194 project area, primarily in MCA-1 and MCA-2. Table 4 summarizes the magnetometer results of pipelines, ownership details, and their depths of cover within the marsh creation areas. The drawings in Appendices F and J show locations of the pipelines. A further discussion of the MCA delineations, some as a result of these pipelines, can be found in Section 7.1.

Table 4: Summary of Magnetometer Results in the MCAs

Pipeline/Flowline	Ownership/Operator Details	Location Description	Depth of Cover (ft)
Loop Pipeline (48" Crude Oil)	Loop, L.L.C.	Between MCA-1 and MCA-2	7.3-14.7
Loop Pipeline (30" Brine)	Loop, L.L.C.	Between MCA-1 and MCA-2	3.5-15.9
Shell MARS (24" Crude Oil)	Shell Pipeline Company, L.L.C.	Between MCA-1 and MCA-2	2.6-16
Kinetica 524A-100* (12" Natural Gas)	Kinetica Midstream Energy	Runs N-S adjacent to MCA-3 and MCA-4	7.2-13.6
6" Natural Gas Flowline	Marquis Resources	Northwest alignment of MCA-1	No Cover
2-6" Flowlines (MCA-1)	No Ownership Claim	Run throughout the cell in several locations	0-11.5
2-6" Flowlines (MCA-2)	No Ownership Claim	Northern and southern lines running generally W-E within MCA-2	0-3.9
4" Flowline (MCA-3)	No Ownership Claim	Runs along the NW alignment of MCA-3	0-0.4

* Same pipeline as denoted by an asterisk in Table 6.
** Items in red denote an increased construction risk.

5.4 Borrow Area Survey

Survey of the borrow area consisted of a multi-sensor marine hydrographic/geophysical survey with transects oriented north-south and spaced ninety-eight (98) feet apart. Additional cross lines were oriented in the east-west direction and spaced every five hundred (500) feet. The survey utilized a Trimble DGPS interfaced with a real-time survey trackline guidance and digital logging computer, single beam depth sounder, side scan sonar, Chirp subbottom profiler, and marine magnetometer. All sensors for this survey were acquired simultaneously. Position, elevation, and water depth were recorded every fifty (50) feet along each transect or where elevation changes were greater than 0.5 feet. Bathymetric survey methods were consistent with the CPRA *MCDG1.0*: Appendix A (*A Contractor's Guide to the Standards of Practice*).

All data collected from the borrow area survey was processed and interpreted by a marine archaeologist with CEI. CEI issued a Remote Sensing Survey and Archival Research Report for the project area, and identified three (3) magnetometer hits within the borrow area as areas of undetermined eligibility for the NRHP under Criterion D. The RPA and SHPO recommended a 100-ft buffer around these locations during dredging operations.

In addition to the bathymetric and cultural surveys, a magnetometer survey was performed along the same transects. This survey identified pipelines, well heads, potential cultural resources, and any other infrastructure within the borrow area. Similar equipment that was used on the marsh fill area magnetometer survey was utilized in the proposed borrow area. Two (2) pipelines were confirmed within the borrow areas during the magnetometer survey. A third pipeline, located on the south side of the borrow area, was outside of the scope of the survey. The details of the pipelines in the borrow area are shown in Table 5. The pipelines are shown in the preliminary design drawings in Appendix J, as well as in the survey report (Appendix F).

Table 5: Summary of Magnetometer Results in the BA

Pipeline/Flowline	Ownership/Operator Details	Location Description	Depth of Cover (ft)
TGP 524H-100 (4.5" Natural Gas)	Kinder Morgan (Abandoned)	NW of BA	4.6-8.3
Harvest Pipeline (18" Crude Oil)	Harvest Midstream	Center of BA running N-S	8-9.5
KEE 500-1 (24" Natural Gas)	Kinetica Energy Express, LLC	SE of BA	Not Surveyed

* Items in red denote an increased construction risk.

An additional borrow area/access corridor survey was performed on December 12th and 26th, 2018 in the areas west of the proposed borrow area and along the access corridor. Bathymetric and magnetometer transects previously performed along the access corridor were extended to the borrow area or for an additional 200 feet, whichever distance was less. This was done to assess the need for potential access dredging to the borrow area from the SWLA Canal, as well as to determine the terminal limits of the TPG 524H-100 pipeline. Furthermore, the surveyed area may also serve as a source of additional borrow should the need arise. The additional magnetometer survey revealed a large number of assorted items, primarily crab traps and scrap metals, in an area that appears to be an old channel, as shown on Sheet 52 in Appendix F. An additional six (6) magnetometer hits were identified as areas to avoid during construction by the RPA, for a total of nine (9). The 100-foot buffers recommended by the RPA and upheld by SHPO are shown on the drawings (Appendix J).

5.5 Dredge Pipeline Corridor (DPC) Surveys

RTK topographic and bathymetric surveys of the dredge pipeline corridor were performed in the same manner as the MCA surveys discussed in Section 5.3, and in accordance with the CPRA's *MCDG1.0*: Appendix A: *A Contractor's Guide to the Standards of Practice*. Forty-three (43) survey transects were taken approximately every five hundred (500) feet along the length of the dredge pipeline corridor in a northwesterly to southeasterly direction as shown in Appendix F.

A magnetometer survey was performed along the potential dredge pipeline alignments to check for any anomalies. Scattered crab traps, scrap metals, and pilings were discovered within the SWLA Canal during the magnetometer survey. In addition, the locations that two (2) pipelines intersect the dredge pipeline corridor were confirmed. Pipeline details within the dredge pipeline corridor are shown in the table below.

Table 6: Summary of Magnetometer Results in the Dredge Pipeline Corridor

Pipeline/Flowline	Ownership/Operator Details	Location Description	Depth of Cover (ft)[1]
TGP 500-2 (36" Natural Gas)	Tennessee Gas Pipeline Company	Intersecting the dredge corridor, running SW-NE	7.3-13
Kinetica 524A-100* (12" Natural Gas)	Kinetica Midstream Energy	Runs N-S adjacent to MCA-3 and MCA-4	7.2-12

1. Does not include depths of cover measured outside of the dredge pipeline corridor.
* Same pipeline as denoted in Table 4.

As discussed in Section 5.4, an additional survey was performed in December 2018 to extend the transects of the access corridor from the opening of the SWLA Canal at Caminada Bay to the proposed borrow area, to assess the potential need for access dredging to the borrow area from SWLA Canal. Further surveys were performed in September of 2019 along lengths of the DPC within SWLA Canal in order to determine mudline elevations in areas where existing navigable waterways and private property access intersect the DPC. Along the navigable waterways and in select areas along private property, it may be necessary for the dredge pipeline to be submerged or buried in order to maintain navigation (see Section 7.6).

Due to the presence of the existing pipelines described in the table above, the dredge pipeline will be floated and coordination with the local Operators will be necessary to avoid any potential damages during construction. The sections of floated pipe are denoted in the drawings in Appendix J. Conversely, for the sections of the dredge pipeline that cross navigation canals or would otherwise restrict access to private property, the pipeline will need to be submerged or buried, depending on the mudline elevation. Considerations pertaining to existing pipelines, access dredging, and maintaining access to private lands and navigable waterbodies is discussed further in Section 7.6.

5.6 Existing Marsh Elevation Survey

To better understand what marsh elevations coincide with existing marsh habitat in the area, Elaine Lear (CPRA field biologist) identified five (5) areas within the project area for elevation surveys. These areas were utilized to determine an average elevation of existing marsh (locations of the surveys can be found in Appendix F). Table 7 shows the results of the existing marsh survey. According to this survey, existing marsh elevation is approximately +0.64 ft, NAVD88, Geoid 12B. At this elevation, the marsh surface is estimated to be inundated between 40-50% of the time based on water elevation data from CRMS0164 and CRMS0175.

Table 7: Average Existing Marsh Elevation Survey Results

Location	Elevation (ft. NAVD88 GEOID12B)
Site #1	0.72
Site #2	0.48
Site #3	0.74
Site #4	0.45
Site #5	0.74
Average	**0.64**

6.0 GEOTECHNICAL EXPLORATION AND ENGINEERING ANALYSIS

The geotechnical subsurface investigation and geotechnical engineering analyses were conducted by GeoEngineers, Inc. (GeoEngineers). CPRA's Project Engineer provided guidance to GeoEngineers, as well as reviewed portions of the analyses as described below. GeoEngineers was tasked with the following data collection efforts:

- Perform Cone Penetrometer Tests (CPTs) and soil borings within the borrow and fill areas;
- Perform laboratory classification and strength testing to determine soil characteristics;
- Perform a column settling test to determine the settling characteristics of the slurry;
- Perform low pressure consolidation tests in order to aid in the settlement determination of the slurry, and;
- Perform standard consolidation tests in order to aid in the settlement in the marsh creation area and beneath the containment dikes.

In addition to data collection, GeoEngineers was also tasked to perform the following geotechnical engineering analyses:

- Perform a detailed slope stability analysis of the proposed earthen containment dikes and gap closure features;
- Provide estimates of total settlement of the proposed earthen containment dikes and marsh creation areas, and;
- Determination of adequate cut-to-fill ratios for dredging and dike fill operations.

The geotechnical data collection reports can be found in Appendices G and H, while the engineering analysis report can be found in Appendix I.

6.1 Existing Geotechnical Data Review

An existing geotechnical data desktop analysis was performed in 2017 by GeoEngineers as part of Sigma's Feasibility Study. Soil data from the LA 1 expansion project, vibracore sampling performed in Lake Jesse, and geology maps published by the USACE and the

USGS revealed deltaic marsh deposits consisting of “cyclically interbedded interdistributary peat and clay, natural levee silt and clay, distributary sand, and mud and clay” (Sigma 2017). Important findings from GeoEngineer’s desktop analysis included:

- The proposed 3H:1V slope for the containment features may be difficult to achieve based on the existing geotechnical data. Containment features may require several lifts as well as time between lifts to allow for consolidation of the material.
- There are deep channels in some areas along the boundary of the cell alignments, which may make construction of containment features more difficult. In these areas, sheet pile features may be necessary.
- Sand and silt layers were encountered in the previous explorations, which would increase the rate of consolidation and provide stability to the containment features.
- Some marsh creation areas may contain a thick surficial layer of peat, thereby increasing the magnitude of settlement of containment features and increasing the amount of required dredged material.

By utilizing the existing geotechnical information, GeoEngineers generated a recommended field exploration plan, which aided in the development of the geotechnical permit layout.

6.2 Marsh Creation Area Subsurface Investigation

Soil conditions were evaluated in the marsh creation area by performing twenty-five (25) cone penetration tests (CPTs) to depths of approximately forty (40) feet below the existing mudline (or shallower if refusal was met) and advancing eleven (11) soil borings to depths ranging from approximately forty (40) to sixty (60) feet below the existing mudline. Water depths at the boring and CPT locations within the MCAs ranged from 0.5 feet to 5.5 feet, while mudline elevations ranged from -0.91 feet to -3.36 ft NAVD88 (GeoEngineers 2018). The approximate sampling locations are shown in Figure 12.

The soil borings were performed using a drill rig mounted on either an airboat or pontoon boat depending on the water depth at each location. Borings were sampled continuously in the upper twenty (20) feet of the soil and on (five) 5-foot centers thereafter to the completion depths denoted on the boring logs. Cohesive and semi-cohesive samples were collected with (three) 3-inch Shelby tubes utilizing an Osterberg piston sampler. Those samples unable to be collected using Shelby tubes were collected using the Standard Penetration Test (SPT) method with split-barrel sampling spoons. All samples were then classified, stored, and transported to the laboratory. Upon completion of the soil borings, CPTs were then performed using an airboat-mounted rig. All soil borings and CPTs within the marsh creation areas were completed in April 2018.

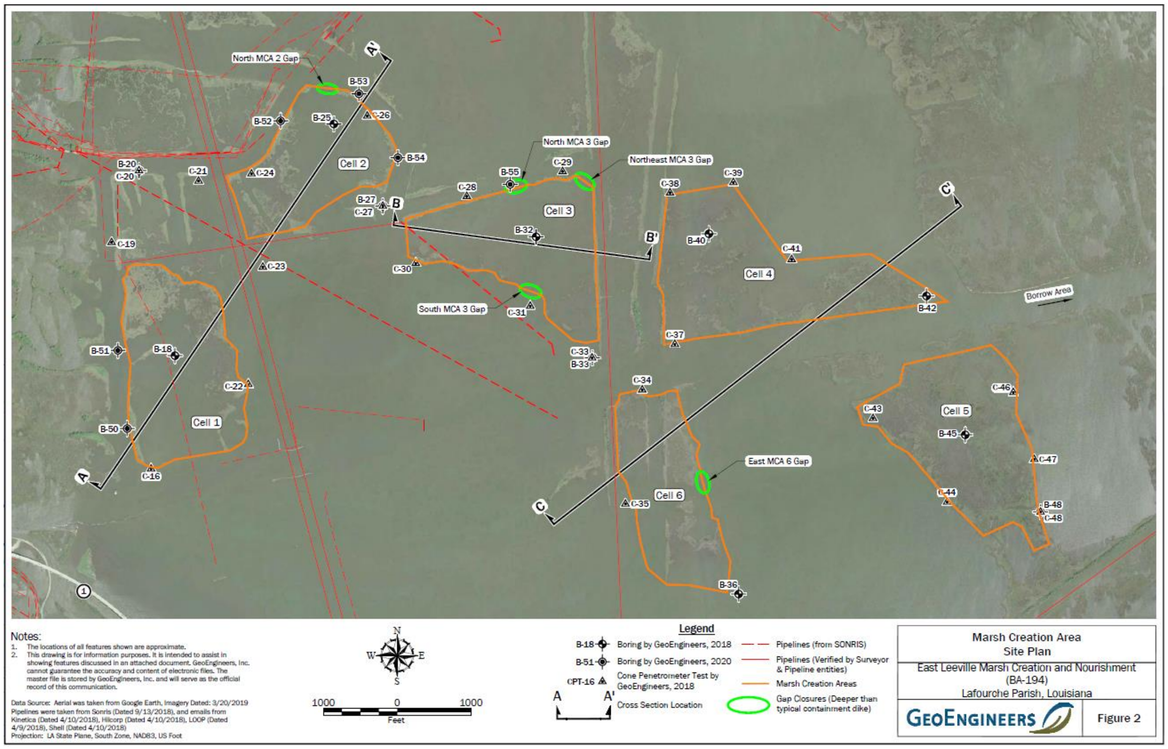


Figure 12: Soil boring and CPT locations within the MCAs.

After the soil samples were transported to GeoEngineers' laboratory, Shelby tube samples were tested for miniature vane shear strength and extruded from their tubes in order to modify or confirm the field classification. Upon review of the boring and extrusion logs, laboratory testing was assigned, which included soil compressive strength, moisture content, unit weight, organic content, grain size analysis, specific gravity, consolidation with rebound, and Atterberg limits. Locations and relevant data for both the soil borings and CPTs can be found in Appendix G.

Subsurface soils within the marsh creation areas consist primarily of very soft to soft clays with interbedded layers of silt and sand. A predominately silty layer was encountered ranging from approximately El. -20 feet to El. -30 feet across all cells (GeoEngineers 2018). Using the data gathered from field exploration and lab testing, three (3) subsurface design profiles were generated by GeoEngineers to characterize and design the project, as shown in Figure 13. Cross section A-A' characterizes MCA-1 and MCA-2, while cross sections B-B' and C-C' characterize MCA-3 and MCA-4 (MCA-6 in Figure 12), respectively.

The subsurface soils encountered in MCA-1 and MCA-2 generally have a higher shear strength than the other two cells. A thin layer of organic material overlays predominately cohesive materials encountered to approximately El. -25 feet. Interbedded layers of silts and sands are scattered throughout this interval of cohesive material, generally becoming thinner and appearing nearer to the surface when moving west to east along cross section A-A'. The presence of these silty and sandy materials are likely to increase the rate of consolidation and provide stability to the containment features of these two cells. Beginning near El. -20 feet to El. -25 feet, coarse-grained materials are encountered to the completion depth of the borings and CPTs in this area. Subsurface materials of MCA-3 are the weakest across the project site, mainly due to the presence of a 3- to 4-foot layer of peat and organic materials. Additionally, there are less coarse-grained materials present to aid in consolidation and stability as compared to section A-A'. Areas near the western alignment of MCA-3 may experience difficulty in containment construction due to the large quantity of silty materials near the surface, which typically do not hold a slope as well and may erode more easily as compared to clays. Containment features in this area may require more maintenance throughout construction. Subsurface exploration and laboratory testing within MCA-4 reveals predominately clayey material with interbedded silty materials near the surface, and granular materials encountered near El. -30 feet and extending to approximately El. -50 feet. Boring B-36 extends to an elevation of El. -63 feet, and reveals clay materials.

6.3 Subsurface Investigation of External Borrow Sources for ECD Construction

Six (6) additional borings to depths of approximately twenty (20) feet below the existing mudline were performed in the oil and gas exploration canals adjacent to MCA-1, MCA-2, and MCA-3 in February of 2020. These additional borings were performed in order to assess the suitability of external materials for use in the construction of earthen containment features. The locations of the additional borings are denoted as B-50 through B-55 in Figure 12. Locations and relevant data for the soil borings performed in the existing canals can be found in Appendix H. In general, the subsurface soils encountered in the channels around the perimeters of the marsh creation areas were similar to what was encountered in the borings and CPTs in performed in the adjacent cells (GeoEngineers 2, 2020).

The borings performed in the canal to the west of MCA-1 (B-50 and B-51) revealed that the materials in the canal are similar to the materials found within the marsh area (B-18, CPT-16, and CPT-19). However, in some areas of the canal, greater amounts of organic clays and peats are present than in the marsh creation area. GeoEngineers recommends that these materials should still be used to construct containment (11, 2020). The area near B-51 (western portion of the cell alignment) appears to have been open to the adjacent canal since around 1990, according to available Google Earth imagery. It is possible that organic materials may have washed out of the marsh area and into the canal, resulting in the increased thickness of the organic materials discovered during exploration.

On the northwest side of MCA-2, boring B-52 does not reveal the same 4-ft layer of silty sand near the surface as seen in boring B-25 performed within the marsh area. The materials in the canal are predominately clays and silty clays, with shear strengths similar to the materials found within the marsh area. On the northeast side of MCA-2, the borings performed in the external areas (B-53 and B-54) show a thin layer of peat near the surface, as well as layers of silt and sand similar to the borings performed inside of the cell alignment (B-25, B-27, CPT-26, and CPT-27). However, the layer of surficial sand inside the alignment of the cell appears in a thicker layer, nearer to the surface as compared to the layers found in the adjacent canal.

The boring performed in the canal north of MCA-3 (B-55) generally exhibits the same trends in terms of material types and strengths as the exploration performed within the marsh area (B-32, CPT-28, and CPT-29). However, the thickness of the surficial peat and organic clays is slightly less in the canals than what was discovered within the cell. This thinner layer of organics was taken into account during the evaluation of containment strategies for MCA-3 (GeoEngineers 2, 2020).

6.4 Borrow Area Subsurface Investigation

Soil conditions were evaluated in the proposed Caminada Bay borrow area by advancing eight (8) soil borings to a depth of approximately twenty (20) feet below the existing mudline (Figure 13). The borings were performed in approximately five (5) to six (6) feet of water using a pontoon mounted drill rig and a piston sampler.

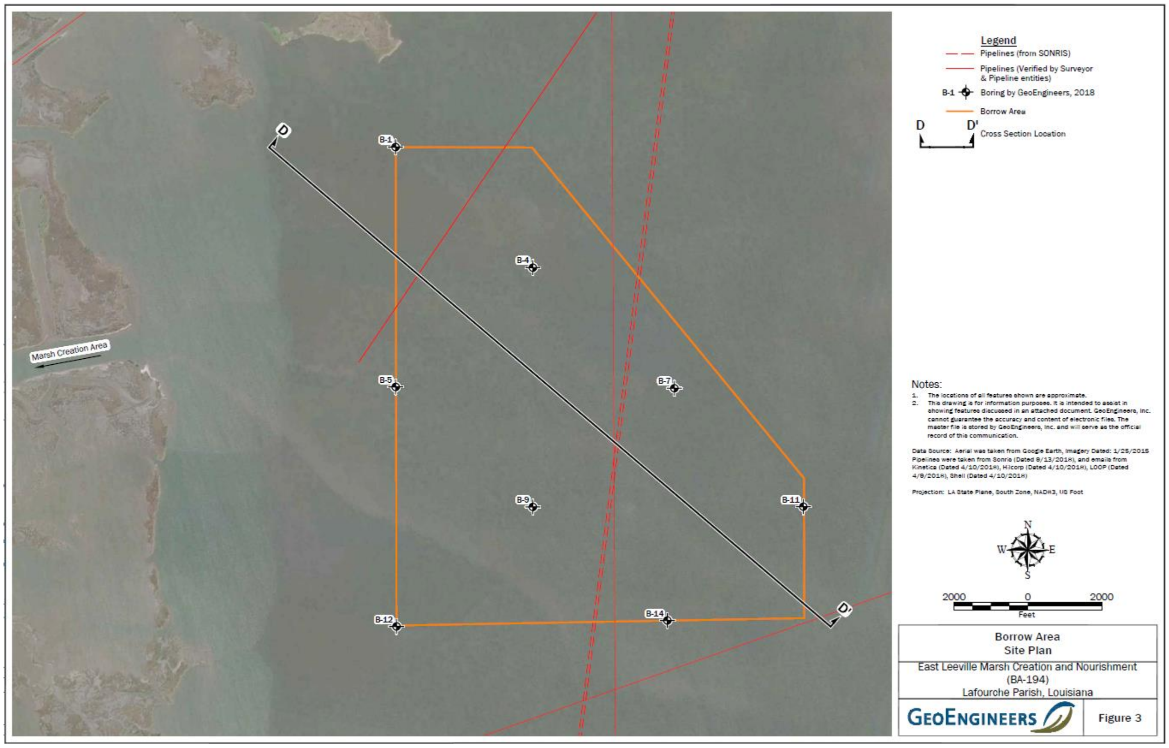


Figure 13: Soil boring and CPT locations within the borrow area.

Index properties observed during drilling and laboratory test results are located on the boring logs in Appendix G. Subsurface soils within the borrow area primarily consist of very soft clays and silty clays, with some granular material denoted at the bottom of the borings (El. -23 feet).

Low-pressure consolidation tests were performed on four (4) separate composite samples by mixing equal portions from each (two) 2-foot sample interval to approximately sixteen (16) feet in order to provide information on specific portions of the borrow area, should further delineation be necessary. The boring composite samples were then mixed with other boring composite samples as shown below:

- Composite No. 1: Borings B-1, B-4, and B-5
- Composite No. 2: Borings B-5, B-9, and B-12
- Composite No. 3: Borings B-7, B-11, and B-14

- Composite No. 4: Borings B-1, B-4, B-5, B-7, B-9, B-11, B-12, and B-14

A column settling test was performed on the composite of all the borings (Composite No. 4) in accordance with the CPRA *MCDG1.0*: Appendix B: Geotechnical Standards. The column settling test was performed using a target initial solids content of 13.0%. Soil properties and construction considerations for the borrow material are discussed further in the following section.

6.5 Marsh Creation Area Settlement Analysis

Marsh creation area settlement analyses were performed to determine the construction marsh fill elevation (CMFE) of the marsh creation areas and the total volume of fill material required for construction. The final elevation of the marsh creation area (at TY20) is governed by two forms of settlement: (1) the self-weight consolidation of the dredged material, and (2) the settlement of the underlying soils in the marsh creation areas as a result of the load exerted by the placement of the dredged fill material. Data from index testing, a column settling test, and low-pressure consolidation tests were used to estimate the magnitude and time-rate of settlement of the dredged slurry and of the underlying soils of the marsh creation areas.

The index properties of the in-situ borrow materials can impact several aspects of the construction of a marsh creation project including the time rate of settlement, the magnitude of self-weight consolidation, and the flowability of the dredged materials. Index testing of the borrow area materials – moisture content (w), Atterberg Limits, fines content, and organic content – can be used to assess these properties. The results of the Atterberg limits testing provide the liquid limit (LL), the plastic limit (PL), and the plasticity index (PI) (denoted as the distance between the LL and PL on Figure 14).

The results of the moisture content and Atterberg limits testing can also be used to determine the liquidity index (LI) of a soil sample, as shown by the following formula:

$$LI = \frac{w - PL}{LL - PL} = \frac{w - PL}{PI}$$

The liquidity index of a soil provides an assessment of the stress history of the in-situ materials and the viscosity of the material, of which both properties are useful for predicting the behavior of the dredged materials when dredged and pumped into the marsh creation areas. Soils that are overconsolidated may have a moisture content less than the plastic limit ($LI < 0$) (Das and Sobhan 109).

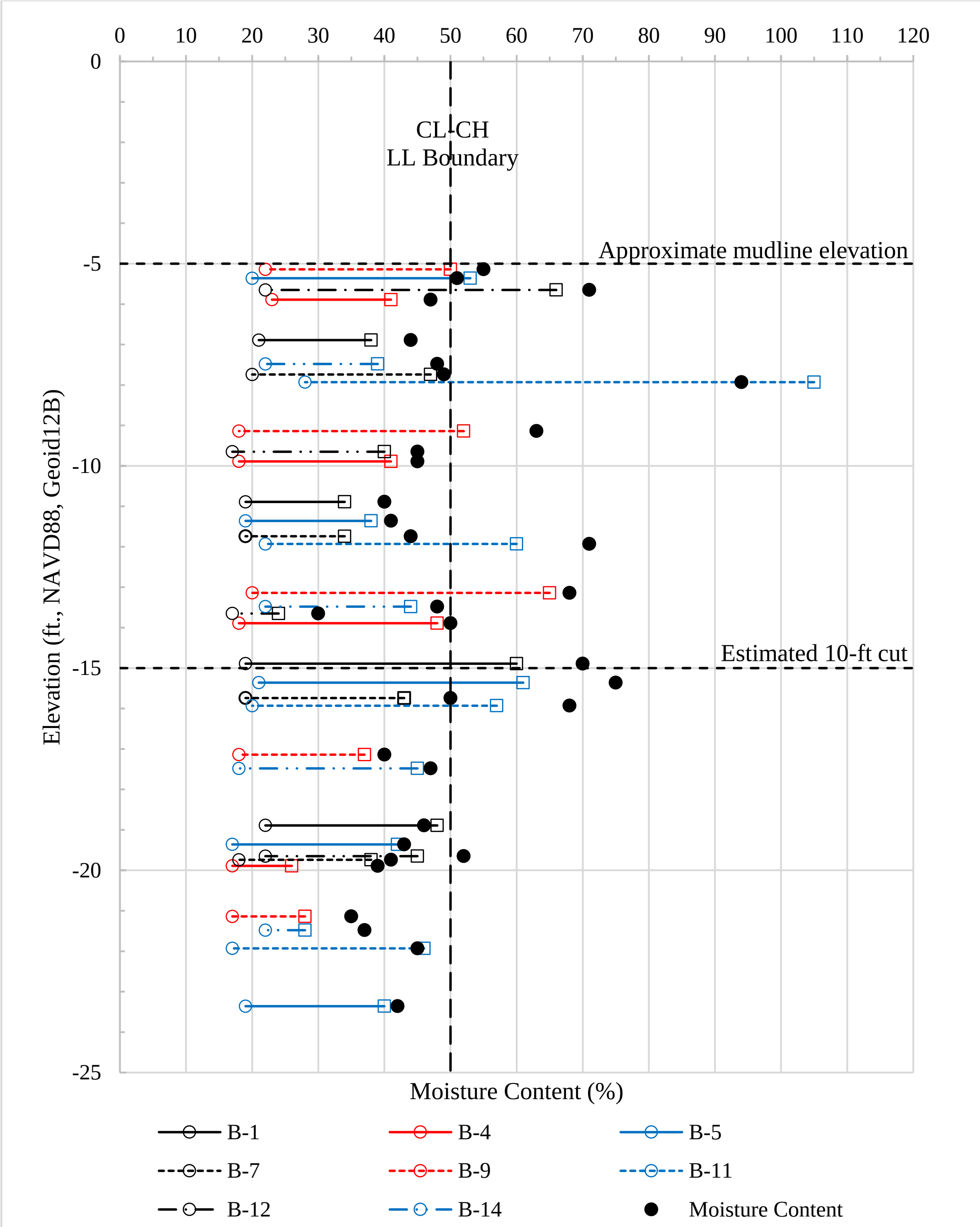


Figure 14: Evaluation of LL, PL, PI, and MC for BA samples.

Figure 14 shows a visual representation of the liquidity index, where the results of the Atterberg limits and moisture content testing plotted are against elevation. For samples where the moisture content is greater than the *LL*, the *LI* is greater than one. Samples with a moisture content greater than the *LL* are likely to be underconsolidated soils and more prone to flowing like a fluid (Das and Sobhan 109). The nature of the underconsolidated soils may cause the dredged slurry to settle more slowly during the flocculent and zone settling processes. On average, the *LI* of the borrow area materials within the upper ten (10) feet is 1.26, and the entire profile (20-ft section) is 1.30.

In order to further understand the settling processes and properties of the dredged slurry, a column settling test was performed by Ardaman & Associates, Inc. (Ardaman), in accordance with the method specified in the USACE Engineering Manual No. 1110-2-5027. Additionally, low stress consolidation tests were also performed to analyze the self-weight consolidation of the dredged material (EM 1110-2-5027) after sedimentation. The column settling tests provide an insight into the sedimentation behavior of the marsh fill when placed within the marsh creation area, while low stress consolidation tests are used to measure the consolidation properties of the dredged material under increasing low-magnitude loading conditions. Together, the results of these tests are used to determine an initial void ratio of the dredged material, e_0, taken as the point when sedimentation stops and consolidation begins. The initial void ratio and the consolidation properties determined in these tests are used to estimate the magnitude and time-rate settlement of the dredged material using the Primary Consolidation, Secondary Compression, and Desiccation of Dredged Fill (PSDDF) program developed by Dr. Timothy D. Stark. Settlement of the subgrade materials was estimated using SETANL, a program developed by GeoEngineers.

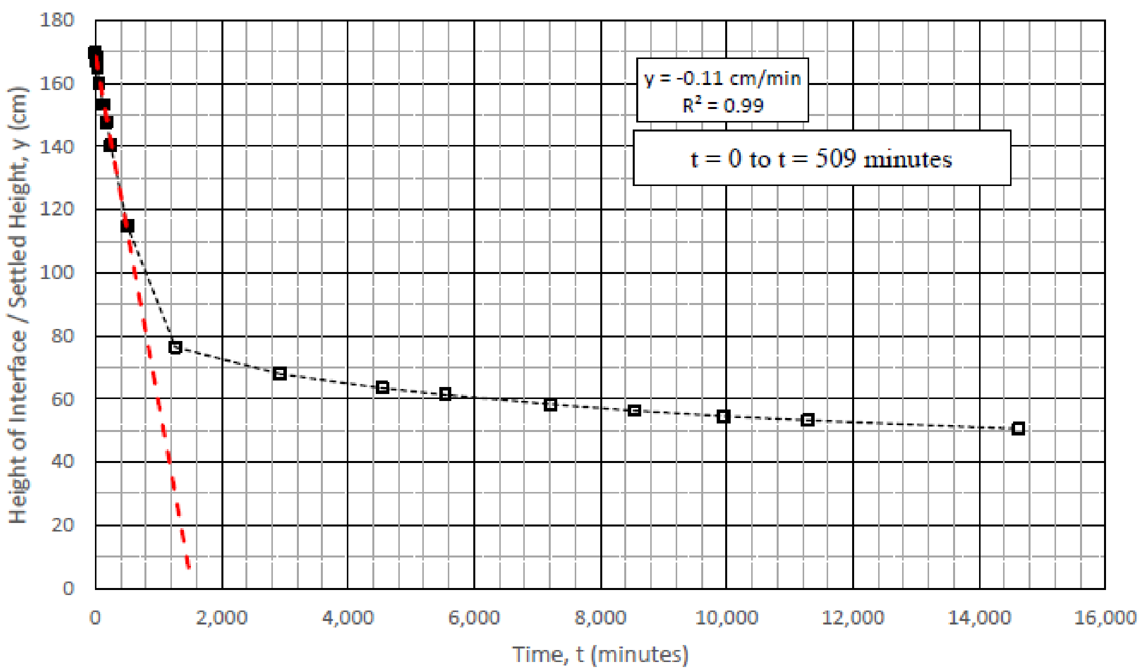
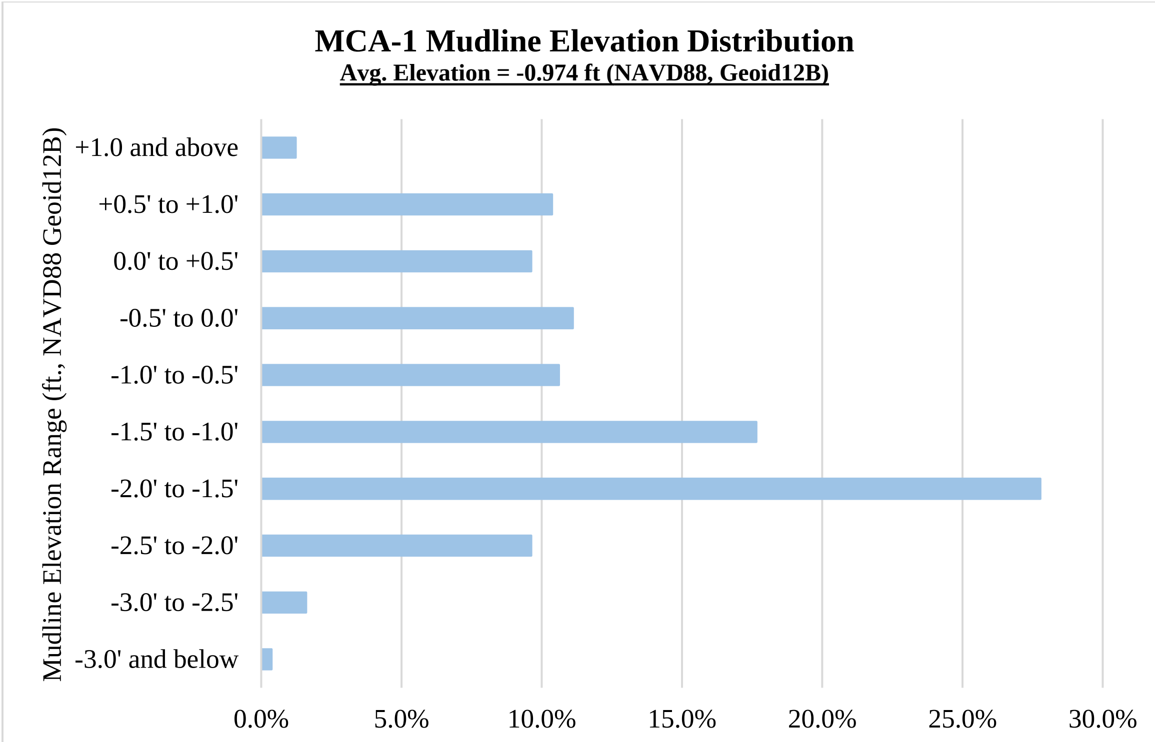
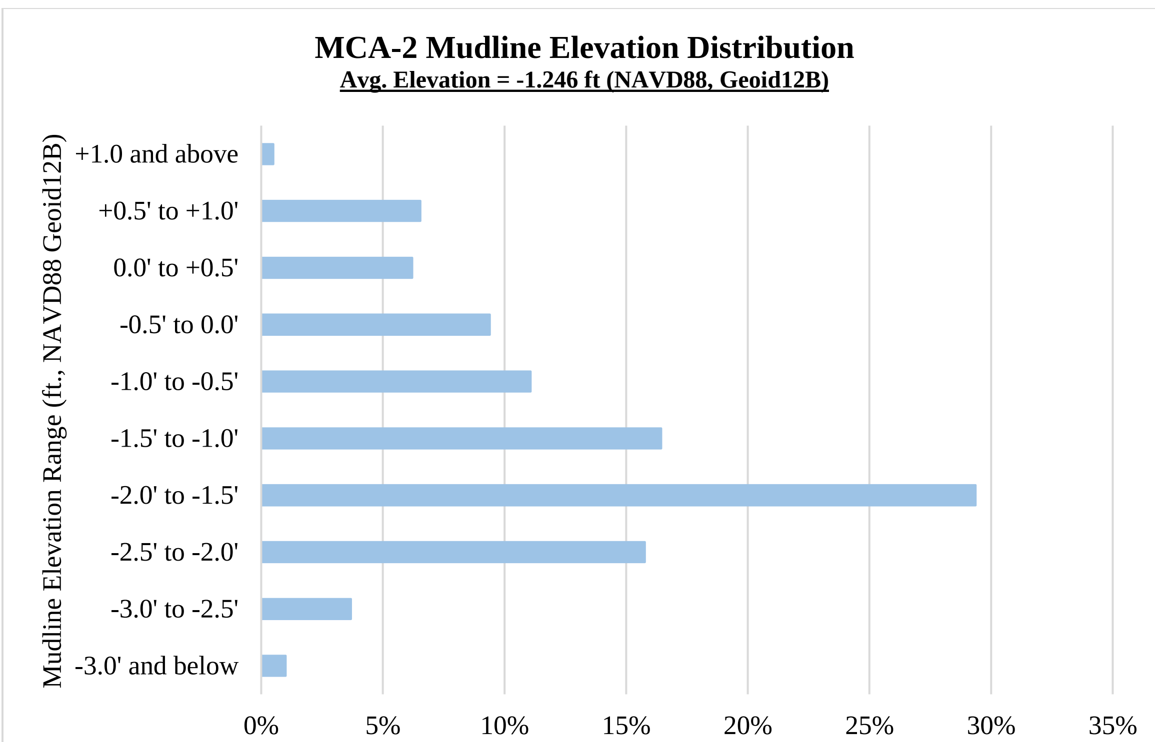
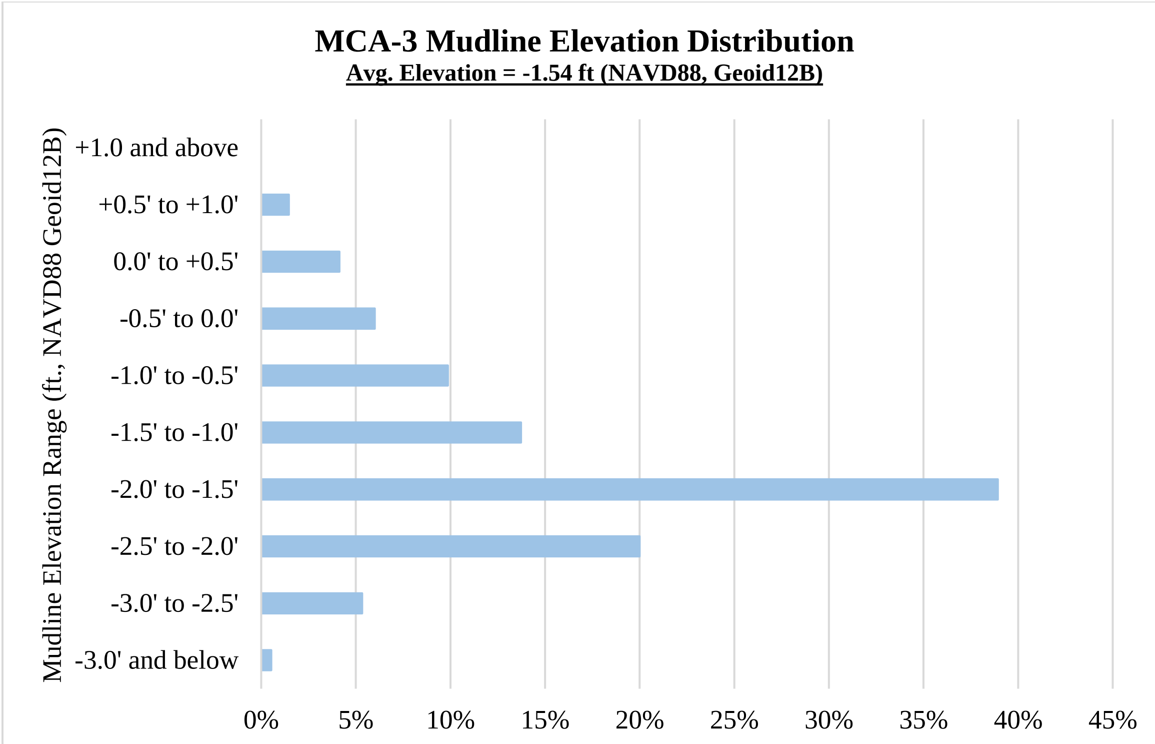


Figure 15: Zone and compression settling results of the column settling test.

The existing mudline elevations assumed for marsh fill settlement analysis can greatly affect the required construction elevation to achieve TY20 elevations. The goal is to find an elevation that is representative of the entire marsh creation area while still accounting for deeper areas within the cell. Determining an existing mudline elevation for each marsh creation area involves analyzing the survey data within each individual MCA. From Figure 16, the predominant range of mudline elevations (and the average value) can be seen for each area.


MCA-1 Mudline Elevation Distribution
Avg. Elevation = -0.974 ft (NAVD88, Geoid12B)
Mudline Elevation Range (ft., NAVD88 Geoid12B)
+1.0 and above
+0.5' to +1.0'
0.0' to +0.5'
-0.5' to 0.0'
-1.0' to -0.5'
-1.5' to -1.0'
-2.0' to -1.5'
-2.5' to -2.0'
-3.0' to -2.5'
-3.0' and below
0.0%
5.0%
10.0%
15.0%
20.0%
25.0%
30.0%


MCA-2 Mudline Elevation Distribution
Avg. Elevation = -1.246 ft (NAVD88, Geoid12B)
Mudline Elevation Range (ft., NAVD88 Geoid12B)
+1.0 and above
+0.5' to +1.0'
0.0' to +0.5'
-0.5' to 0.0'
-1.0' to -0.5'
-1.5' to -1.0'
-2.0' to -1.5'
-2.5' to -2.0'
-3.0' to -2.5'
-3.0' and below
0%
5%
10%
15%
20%
25%
30%
35%



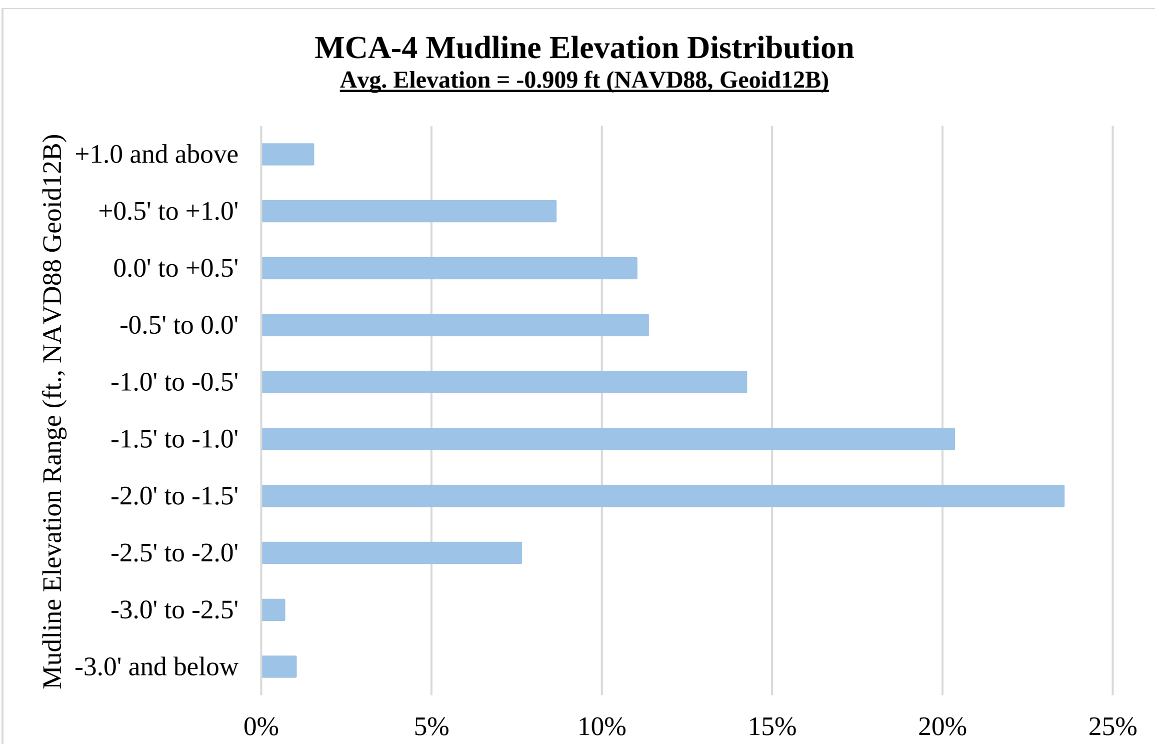


Figure 16: Elevation distributions in the marsh creation areas.

Due to the variance of the mudline elevations found within the MCAs, evaluations of total settlement over the project life at varying mudline elevations were performed, as shown in the geotechnical engineering report (GER) (Appendix I). MCA-1 and MCA-2 were analyzed with mudline elevations of -1.0 and -2.0 ft., MCA-3 was analyzed at a mudline elevation of -2.0 ft. only, and MCA-4 was analyzed at a mudline elevation of -1.0 ft. While it is acknowledged that the constructed marsh fill may behave differently for mudlines other than those analyzed, 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.

In order to determine the CMFE that would yield the most productive marsh at the end of the 20-year project life, water levels in the vicinity of the project area, ESLR, and subsidence rates for the project area were also analyzed. Evaluation of the hydrologic conditions of the site, as well as the subsidence values and ESLR rates, as recommended by the CPRA's Planning Division, are discussed in Section 4.0. Additionally, accretion rates within the Barataria Basin were investigated.

A study performed by the CPRA's Lafayette Office Operations Division evaluated elevation change and observed accretion rates in order to identify reasonable expectations for the planning of new marsh creation projects within the Barataria Basin. The study also determined the inflection point during the project life when rapid settlement of the marsh fill slowed and the surface elevation stabilized, in order to determine when natural vertical surface elevation changes began to occur. According to the information in this study, elevation data (2006-2019) from existing monitoring stations located within *created* marsh sites suggests that existing marsh in the project area has the ability to keep up with subsidence, and in many instances, result in an increase in vertical surface elevation (Sharp and Mouledous 2019). The CPRA's Lafayette Office Operations Division (based on the data presented in the study) recommend elevation change rates of 0 to +0.30 cm/year beginning between TY 5 and 8 for the BA-0194 project. While the mechanisms necessary for this positive elevation change may not be all present in the created marsh, particularly early in the project life, it is proposed that accretion will be sufficient to offset subsidence beginning eight (8) years after construction. Therefore, the rate of RSLR will be equal to ESLR begnning in TY8.

For design application, subsidence and accretion rates were applied to the marsh fill elevation (settlement curves), while ESLR was applied to the tidal datum and the inundation range. Up to five (5) CMFEs were analyzed for each marsh creation area at the aforementioned mudline elevations. The ideal final marsh platform for the BA-0194 project area would settle into the optimal range for saline emergent marsh vegetation (20%-80% inundated) shortly after construction and would remain there for the duration of the 20 year project life. GeoEngineers provided construction recommendations for each marsh creation area that would maximize the amount of time that the marsh platform would remain within the 20 to 80% inundation range.

At the 30% design level, GeoEngineers modeled construction of MCA-1 and MCA-4 with a single 30-day fill period. Analysis of single-lift construction for MCA-1 and MCA-4 resulted in the marsh platform remaining within the 20 to 80% inundation range for the entire life of the project. However, for MCA-2 and MCA-3, a single lift scenario did not result in maximization of that time. MCA-2 and MCA-3 were therefore modeled in construction by applying a two-lift scenario, with the second lift being constructed over a

15-day fill period, 30 days after construction of the first lift (60-75 days after the start of construction). Even with the inclusion of a two-lift scenario of MCA-3, the potential still existed for the elevation of the constructed marsh to fall outside of the target inundation range. This is due to the presence of peat within the upper two (2) feet of the cell, as well as highly compressible organic soils below it. While the curve did show the marsh platform falling out of the inundation range between TY 17 to 18, the curve was applicable to an existing mudline elevation of -2.0 ft. (NAVD88, Geoid12B). From the mudline distribution plots presented in Figure 17, it is seen that 74% of the area of MCA-3 has a mudline shallower than -2.0 ft. Therefore, the amount of acreage that was at risk of falling below the 80% inundation line between TY 17 to 18 is only 26% of the 80.3 acres (approximately 21 acres). The WVA performed for BA-0194 at Phase 0 incorporated an anticipated overall loss of 71 acres by TY20 (2017). However, since two-lift scenarios are generally not indicative of past construction practices, a single lift scenario over a 60-day fill period was analyzed for MCA-2 and MCA-3 at the existing mudline elevation of -2.0 ft. The proposed single lift construction of each marsh area resulted in the marsh platform remaining within the 20 to 80% inundation range for the entire life of the project for all marsh creation areas.

Figure 17 depicts the design settlement curves selected for each of the marsh creation areas in order to best meet the aforementioned criteria. This data was utilized to design the marsh creation areas as specified in Section 7.1. Additional settlement curves performed for varying mudlines and subsurface profiles can be found in the GER (Appendix I).

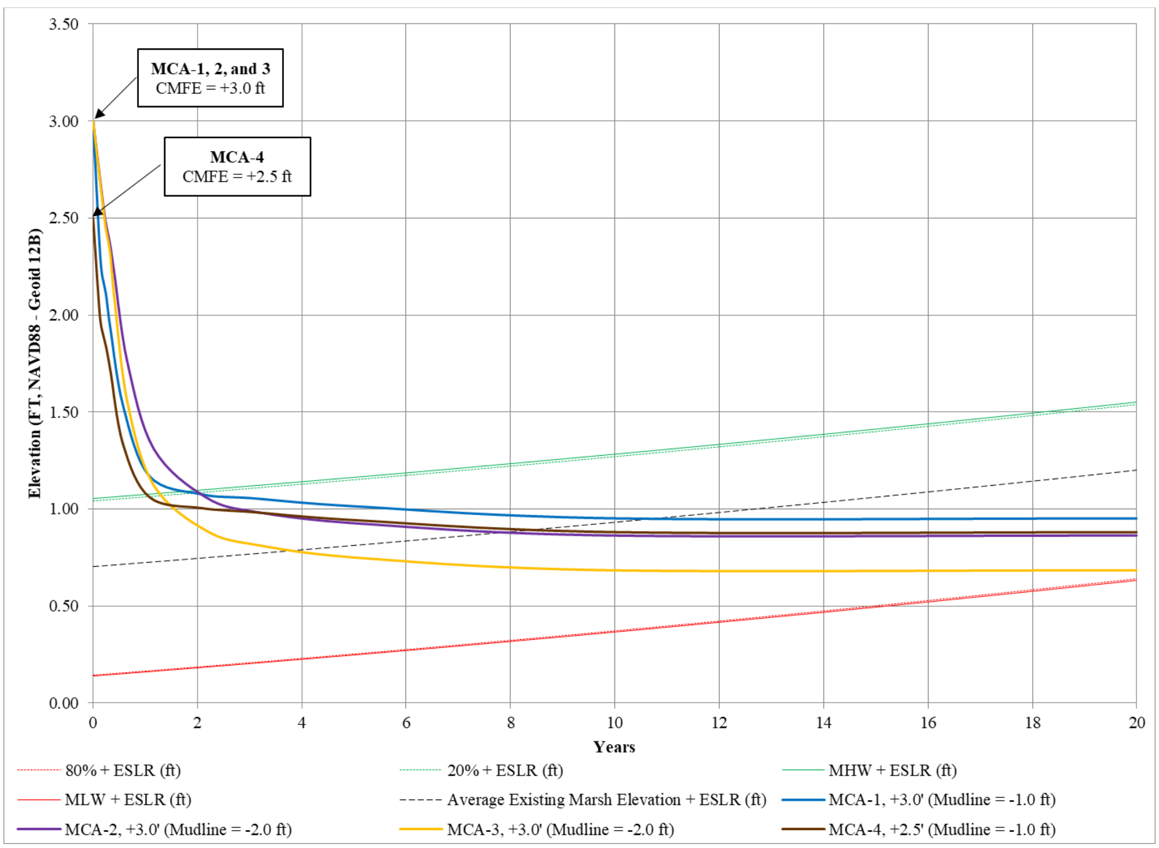


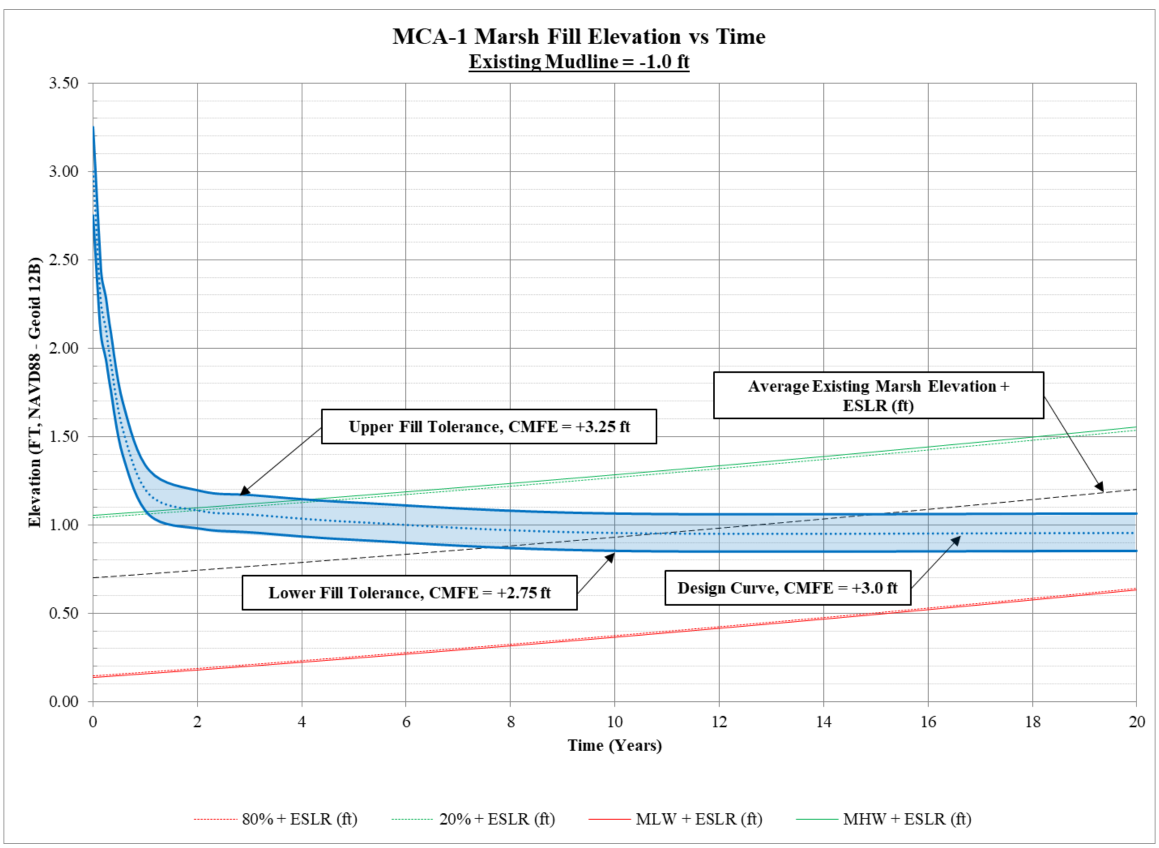
Figure 17: Estimated total settlement curves, 20% & 80% inundation, average MHW & MLW lines including ESLR, subsidence, and accretion.

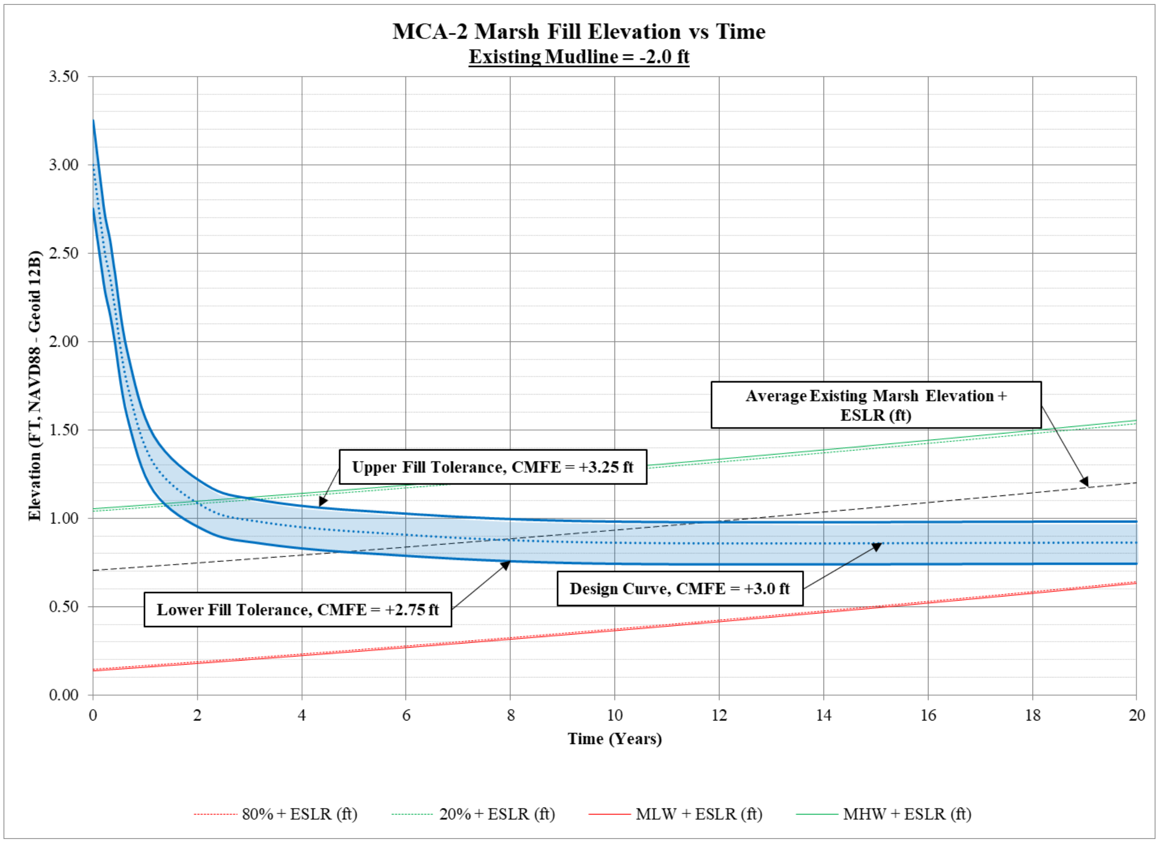
As shown in Figure 17, the CMFE was selected for each cell in order to maximize the time the marsh platform is within the 20% to 80% inundation range, while accounting for the potential variance in the magnitude of the estimated total settlement and in mudline elevation, particularly deeper areas. As such, the estimated fill elevation at TY20 for each marsh creation area falls near the lower third of the inundation range, with each curve entering the target inundation range at or just before TY2. Approximate TY20 parameters are shown in Table 8 below.

Table 8: Summary of Estimated Settlement Curve Parameters

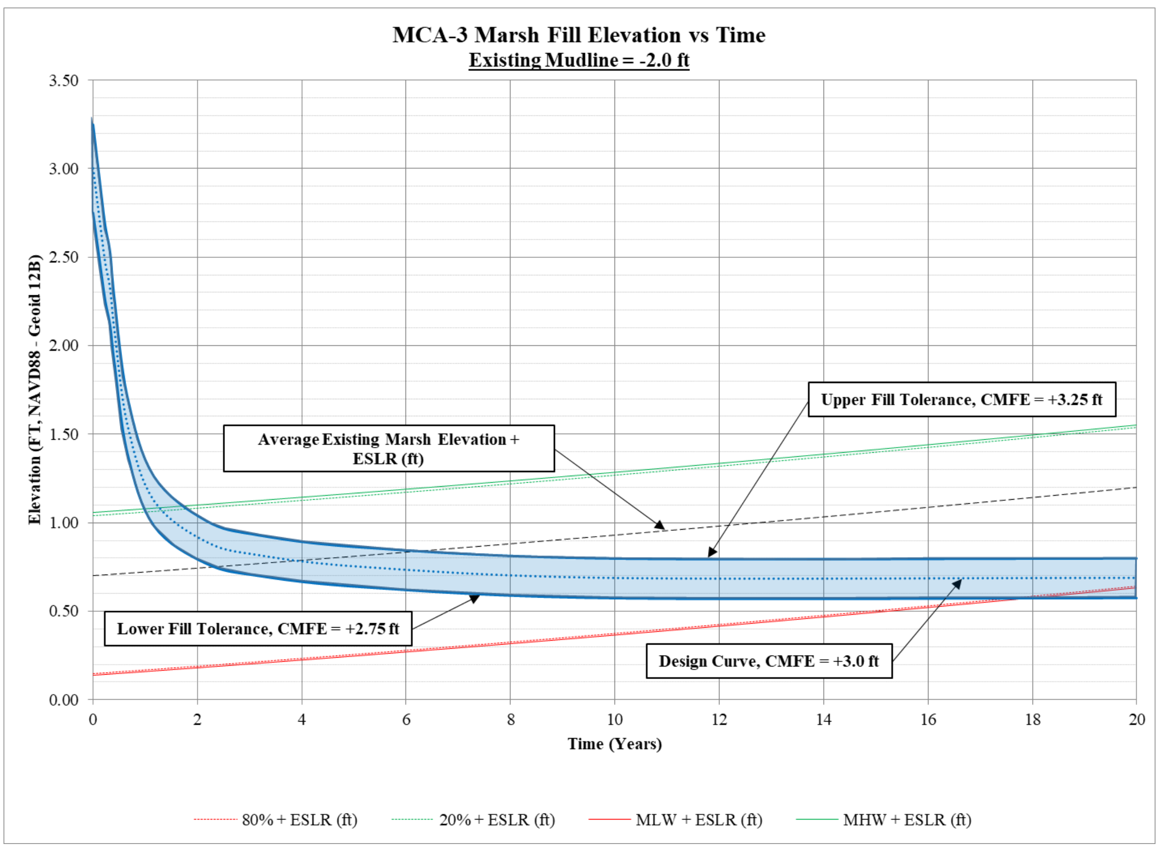
Cell	Design Mudline El. (ft. NAVD88)	Const. Fill Period (days)	Proposed CMFE (ft. NAVD88)	Time to Enter Inundation Range (years)	Estimated TY20 Ele. (ft NAVD88)
MCA-1	-1.0	30	+3.0	1.9	0.95
MCA-2	-2.0	60	+3.0	2.0	0.86
MCA-3	-2.0	60	+3.0	1.2	0.69
MCA-4	-1.0	30	+2.5	1.1	0.88

In order to account for construction tolerances, additional settlement analyses were also performed at elevations 0.5-ft higher than the design settlement curves. After a review of the settlement curves, a construction tolerance of +/- 0.25 ft was selected (see Figure 18).





MCA-2 Marsh Fill Elevation vs Time
Existing Mudline = -2.0 ft
Elevation (FT, NAVD88 - Geoid 12B)
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
2
4
6
8
10
12
14
16
18
20
Time (Years)
Average Existing Marsh Elevation + ESLR (ft)
Upper Fill Tolerance, CMFE = +3.25 ft
Design Curve, CMFE = +3.0 ft
Lower Fill Tolerance, CMFE = +2.75 ft
80% + ESLR (ft)
20% + ESLR (ft)
MLW + ESLR (ft)
MHW + ESLR (ft)



MCA-3 Marsh Fill Elevation vs Time
Existing Mudline = -2.0 ft
Elevation (FT, NAVD88 - Geoid 12B)
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
2
4
6
8
10
12
14
16
18
20
Time (Years)
Upper Fill Tolerance, CMFE = +3.25 ft
Average Existing Marsh Elevation + ESLR (ft)
Lower Fill Tolerance, CMFE = +2.75 ft
Design Curve, CMFE = +3.0 ft
80% + ESLR (ft)
20% + ESLR (ft)
MLW + ESLR (ft)
MHW + ESLR (ft)

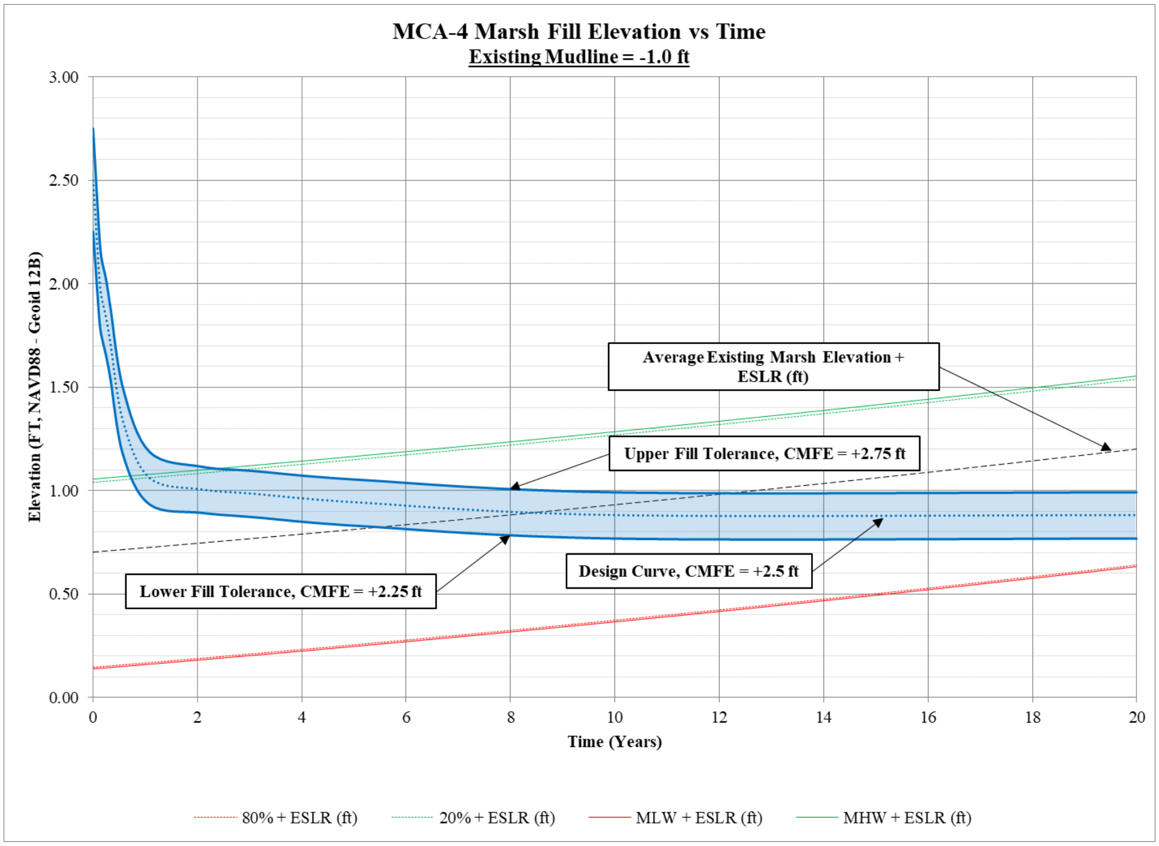


Figure 18: Estimated Total Settlement Curves including Construction Tolerances

For MCA-3, some potential exists for the elevation of the constructed marsh to fall outside of the target inundation range if fill is placed nearer to the lower tolerance elevation (+2.75 ft). The increased settlement in MCA-3 as compared to the other cells is due to the presence of peat within the upper two feet, as well as highly compressible organic soils below it. Additionally, the height of the CMFE is limited to the height of the earthen containment dike to allow a minimum of one (1) foot of freeboard. While the lower fill tolerance curve shows the marsh platform falling out of the inundation range around TY 18, this curve is applicable to an existing mudline elevation of -2.0 ft. (NAVD88, Geoid12B). From the mudline distribution plots presented in Figure 16, 74% of the area of MCA-3 has a mudline shallower than -2.0 ft. Therefore, the amount of acreage that is at risk of falling below the 80% inundation line between TY 18 is only 26% of the 80.3 acres (approximately 21 acres). The WVA performed for BA-0194 incorporates an anticipated overall loss of 71 acres by TY20 (2017). This is also an improvement from 30% design settlement calculations, where the proposed CMFE had potential to fall below the 80% inundation line between TY 17 to 18.

Table 9 summarizes the TY20 elevations for each fill area comparing the settlement curves for the CMFE and when accounting for a +0.25-ft tolerance.

Table 9: TY20 Elevations for the Proposed CMFE

Cell	Proposed CMFE (ft. NAVD88)	Estimated TY20 Elevation at CMFE (ft NAVD88)	Estimated TY20 Elevation with +0.25-ft Tolerance (ft NAVD88)
MCA-1	+3.0	0.95	1.06
MCA-2	+3.0	0.86	0.98
MCA-3	+3.0	0.69	0.80
MCA-4	+2.5	0.88	0.99

6.6 Earthen Containment Dike (ECD) Slope Stability and Bearing Capacity Analysis

Global slope stability analyses were performed on the proposed earthen containment dikes (ECDs) at different elevations and geometries. The slope stability of the ECD has two types of driving forces: (1) the forces induced by the soil weight, and (2) any seepage (pore pressure) forces, which tend to cause the soil to slide. In response to these driving forces, the subsurface soils have resistant forces in the form of shear strength and soil weight, which attempts to keep the slope from sliding. Both the driving forces and the resisting forces are dependent on the geometry of the "Failure Surface". GeoEngineers, in coordination with CPRA, performed stability analyses to evaluate ECD slope stability using optimized circular search parameters with Spencer's method in the GEO-SLOPE International Limited computer program SLOPE/W (GeoStudio 2016) that computes factors of safety against potential failure based on limit equilibrium theory. The CPRA project engineers reviewed the performed stability analyses, and made adjustments where necessary.

For this project, multiple scenarios were run based upon the alternatives analysis (see Section 7.2). Stability runs included:

1) Internal failure of containment dike, no marsh fill placed;
2) Global failure of the containment dike into the borrow channel, no marsh fill placed;
3) Failure of the borrow channel, no marsh fill placed, with construction equipment modeled, and;
4) Failure of the containment dike after placement of marsh fill (with one foot of freeboard).

Each of these runs was conducted with or without geotextile reinforcement placed as necessary and with internal and external borrow sources. All runs were conducted assuming a borrow excavation offset of twenty-five (25) feet from the toe of the ECD. As prescribed in the CPRA's *Marsh Creation Design Guidelines 1.0 (MCDG1.0)*, the ECDs were analyzed to ensure a minimum factor of safety of 1.2 against stability failure would be achieved for the selected geometry.

The ECDs were also evaluated for bearing capacity failure using the procedure outlined in the Naval Facilities Engineering Command Design Manual 7.02 *Foundations and Earth*

Structures. The minimum factor of safety against bearing capacity was determined to be 1.76, greater than the minimum requirement of 1.3 (*MCDG1.0)*.

Additional slope stability analyses were performed by GeoEngineers and reviewed by the CPRA project engineers following 30% design to evaluate the following cases:

1) Failure of the containment dike constructed with a 10-ft crown width (herein referred to as the lake dike feature) evaluated for the four (4) aforementioned cases; and
2) Failure of the containment dike overlain with articulated concreate mats (ACMs) evaluated for the four (4) aforementioned cases,

The lake dike feature and ECDs with ACMs are proposed for use along areas that experience a high energy wave environment, and thus more susceptible to erosion. The use of erosion control features is discussed further in Section 7.4.

Table 10 on the following page presents the results of the stability analyses that have been performed. Detailed results can be found in the GER in Appendix I.

Table 10: ECD Slope Stability Results

Cell	Feature	Design Mudline El. (ft. NAVD88)	Crown Width (ft.)	Estimated Dike Crest El. (ft. NAVD88)	Side Slope	Minimum Factor of Safety[1]
MCA-1 & 2	ECD	-1.0	5	+4.5	4H:1V	1.28
		-2.0		+4.5	5H:1V	1.33
		-3.0, Lift 1		+1.0	5H:1V	2.99
		-3.0, Lift 2		+4.5		1.24
		-4.5, Lift 1*		+1.0	5H:1V	2.81
		-4.5, Lift 2*		+4.5		1.48
	ECD with ACM	-1.0	5	+4.5	4H:1V	1.22
		-2.0		+4.5	5H:1V	1.26
		-3.0, Lift 1*		+1.0	5H:1V	2.99
		-3.0, Lift 2*		+4.5		1.62
	Lake Dike	-1.0	10	+4.5	4H:1V	1.26
		-2.0		+4.5	5H:1V	1.32
		-3.0, Lift 1		+1.0	5H:1V	2.99
		-3.0, Lift 2		+4.5		1.24
MCA-3	ECD	-2.0, Lift 1*	5	+1.0	5H:1V	1.79
		-2.0, Lift 2*		+4.5		1.22
		-4.0, Lift 1*		+1.0	5H:1V	2.40
		-4.0, Lift 2*		+4.5		1.30
	Lake Dike	-2.0, Lift 1*	10	+1.0	5H:1V	1.46
		-2.0, Lift 2*		+4.5		1.21
MCA-4	ECD	-1.0, Lift 1	5	+1.0	5H:1V	1.40
		-1.0, Lift 2		+4.5		1.22
		-3.0, Lift 1		+1.0		2.58
		-3.0, Lift 2		+4.5		1.19
		-4.0, Lift 1*		+1.0		3.46
		-4.0, Lift 2*		+4.5		1.64
	Lake Dike	-1.0, Lift 1	10	+1.0	5H:1V	1.40
		-1.0, Lift 2		+4.5		1.21
		-3.0, Lift 1		+1.0		2.57
		-3.0, Lift 2		+4.5		1.18

* Requires geotextile fabric
1. Includes bearing capacity analyses.

6.7 Earthen Containment Dike (ECD) Settlement Analysis

Settlement of the containment dike consists of two (2) primary factors: (1) consolidation and elastic settlement (construction settlement) of the underlying soils, and (2) shrinkage and self-weight consolidation of the fill soils. Consolidation settlement of the foundation soils beneath the earthen containment dikes were computed based on the dike geometries determined from the slope stability analyses and the properties of the underlying soils. Elastic (construction) settlement of the in-situ soils will occur quickly and will likely result in an increase in the quantity of fill required to reach the design construction elevation. The amount of settlement anticipated during construction of the earthen containment features is about 1-2.5 inches (GeoEngineers 2020). Post-construction shrinkage and self-weight settlement estimates combined will be about 15% of the fill height from the containment dike crown to the mudline in addition to consolidation settlement of the foundation soils ranging from 0.3 to 1.1 feet across the various project features (GeoEngineers 2020). Wind, rain, and wave erosion will also cause degradation of the ECDs, which will therefore require regular maintenance throughout construction of the marsh fill. Elevations of +4.0 and +4.5 feet NAVD88 were analyzed to provide a one (1) foot freeboard to the +3.0 and +3.5 foot fill elevations throughout the project life, accounting for a +0.5-ft upper construction tolerance. Settlement was analyzed for all proposed earthen containment features, including the lake dike and the ECD sections with ACMs. Table 11 below summarizes the estimated maximum settlement of the containment features over the 20-year project life. The full results of the settlement analyses can be found in Appendix C of the GER (Appendix I).

Table 11: ECD Settlement Analysis Results

Cell	Feature	Maximum Total Consolidation Settlement (ft)	Maximum Total Consolidation Settlement + Shrinkage (ft)
MCA-1 & 2	ECD	0.8	1.3
	Lake Dike	0.9	1.5
	ECD with ACM	0.9	1.5
MCA-3	ECD	1.2	1.8
	Lake Dike	1.4	1.9
MCA-4	ECD	0.5	0.8
	Lake Dike	0.5	0.9

6.8 Sheet Pile Gap Closure Features

Several tidal gaps that exist between the interior marsh and the exterior water bodies of MCA-3 are not conducive to traditional earthen containment dikes due to their depth. An additional survey effort performed on September 3rd-5th, 2019 due to data gaps in the initial survey effort, revealed three (3) areas along the alignment of MCA-3 with existing mudline elevations ranging from -4.5 to -5.0 ft NAVD88. In these areas where the existing mudline elevation is deeper than the design mudline elevation of the proposed ECDs, modified containment designs involving sheet pile were recommended by GeoEngineers in order to meet minimum factor of safety design guidelines as established in the *MCDG1.0*. The sheet pile gap closure feature would involve the construction of earthen containment to an established elevation above the water line, then sheet pile would be driven to the specified elevation through the earthen fill. A typical section and further details pertaining to the gap closure feature design can be found in Section 7.3.

Table 12 below summarizes the proposed sheet pile gap closure feature as well as the results of the stability analyses. The factor of safety shown in the table is the minimum factor of safety accounting for both pre- and post- sheet pile installation.

Table 12: Sheet Pile Gap Closure Slope Stability Results for MCA-3

Design Mudline El. (ft. NAVD88)	Estimated Top El. (ft. NAVD88)	Crown Width (ft)	Sheet Pile Tip El. (ft. NAVD88)	Dike Side Slope	Minimum Factor of Safety
-5.0	+4.5 (+1.5[1])	35	-20.0	5H:1V	1.47

1. Top of earthen backfill elevation.

The required penetration of the sheet pile sections was determined using the USACE software CWALSHT to maintain a factor of safety of 1.5 for passive pressures and 1.0 for active pressures. Design bending moment and scaled deflection were determined by running the program with equal passive and active safety factors, 1.0 (GeoEngineers 2020). A36 type steel was assumed in order to determine the sheet pile section modulus needed to select proper sheet piling by the following formula:

$$S = \frac{M_{max}}{\sigma_a}$$

where S is the sheet pile section modulus (in^3 per foot of wall), M_{max} is the maximum bending moment in the wall determined by CWALSHT (lb-ft), and σ_a is the assumed allowable stress for A36 steel (typically 25,000 psi). PZ-22 steel sheet piling was selected based on the calculated section modulus using a table of standard U.S. sheet pile sizes (GeoEngineers 2020).

6.9 Cut to Fill Ratio Recommendations

Cut to fill ratios were determined by GeoEngineers in order to account for losses due to dredging, containment, and dewatering. Due to numerous factors that are unknown until the project is awarded (such as dredge size and production rate), actual cut to fill ratios can vary greatly from project to project. Recently, constructed projects have shown that actual cut to fill ratios vary from approximately 0.8 to 1.3. Using this information, GeoEngineers recommended a cut to fill ratio of 1.2 to be applied for all hydraulically dredged marsh fill sediment.

Mechanical dredging of the containment dikes has generally yielded a cut to fill ratio approximately between 1.2 and 1.6. This value accounts for losses during construction such as material compaction, shrinkage, and foundation settlement. However due to the large number of variables involved in calculating cut to fill for mechanical dredging of the containment dikes, GeoEngineers recommends a value of 2.0.

7.0 MARSH CREATION DESIGN

The project proposes to create marsh by hydraulically dredging material from a single borrow area located in Caminada Bay into four (4) separate marsh creation areas spanning approximately two hundred ninety-four (294) acres east of Leeville, as shown in Figure 19. The Preliminary Design Drawings can be found in Appendix J. The marsh creation design was broken up in the following sections: the marsh creation area, the earthen containment dikes, the gap closure features, the dredge borrow area, dredge pipeline alignments, and equipment access dredging. An erosion reduction component along the shorelines of the various lakes and canals was included in an alternatives analysis for different methods. The design, including construction considerations due to various pipelines, is discussed in detail in the following sections.

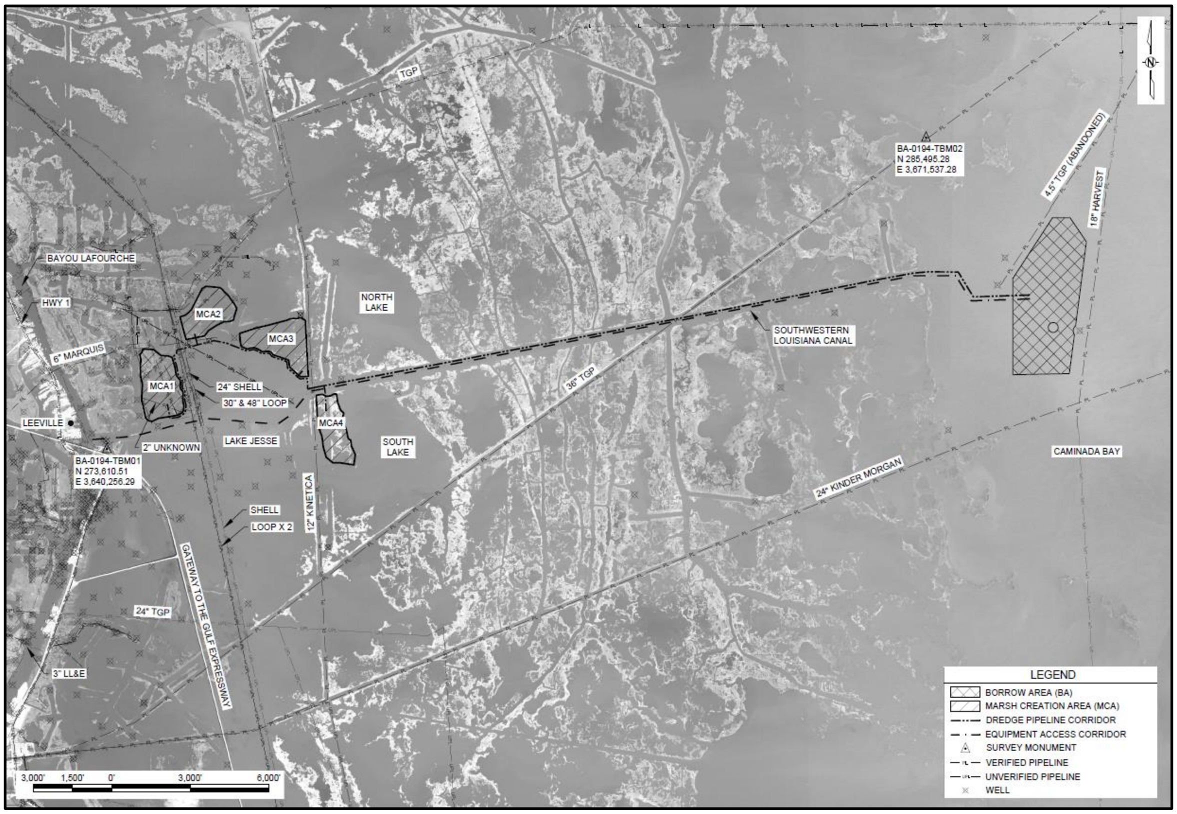


Figure 19: Plan view of the proposed marsh creation project features.

7.1 Marsh Creation Area (MCA) Design

The goal of the marsh creation area feature is to address the marsh loss in the areas east of Leeville in attempt to restore the structural framework of the marsh. The alignment of the fill areas went through several alterations from the original Phase 0 configuration before arriving at the current configuration shown in the 95% plans. The Phase 0 configuration proposed three hundred fifty-eight (358) acres of marsh creation spanning four (4) marsh creation areas and one hundred twenty-four (124) acres of nourishment with containment features traversing multiple open water segments along the rim of Lake Jesse and the SWLA Canal (Figure 1). The feasibility study performed by Sigma assessed the constructability of the proposed Phase 0 cells as well as other cells that may be practical for construction. The study revealed several features within the project area that altered the alignment of the Phase 0 cells. The LeFort Cemetery was discovered within the southwest corner of the alignment of MC-1 (Phase 0 nomenclature). In order to avoid the disturbance of this cultural resource, the cell was removed from the scope of the project. In addition, the location of the Shell MARS and Loop Pipelines resulted in MC-2 being split into two separate cells (MCA-2 and MCA-3 in Figure 20). Two additional marsh creation areas (MCA-5 and MCA-6) to the east of the final Phase 0 alignment were investigated, and MC-4 (MCA-7 in Figure 20) was reduced in size due to the increasing water depths in the southern portion of the cell. An additional cell located near the old Highway 1 and south of the mitigation area for the LA 1 Improvements project (Figure 8) was screened during the Phase 1 process, but removed from the scope due to the large number of landowners in the vicinity, as shown in Figure 20. The feasibility study resulted in the recommendation of six (6) marsh creation areas suitable for construction (all except MCA-1 in the figure below), spanning the northern shore of Lake Jesse, and bordering the SWLA Canal and North and South Lakes, as shown in the following figure.

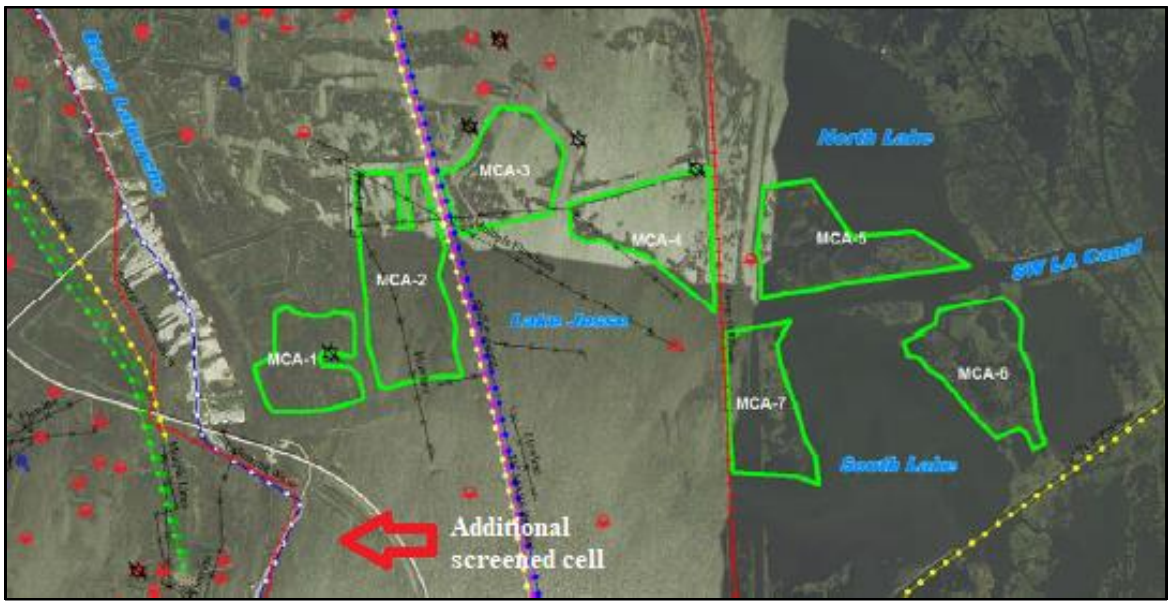


Figure 20: Alternatives analysis for cell alignments.

After completion of the survey and initial geotechnical exploration, the cell alignments underwent further adjustments. Due to the presence of an exposed gas line discovered along the northwestern boundary of MCA-2 in Figure 20, and constructability concerns of the northern portion of the cell (horseshoe shape), the northern cell alignment was shifted to the south. After a review of the available information, MCA-5 and MCA-6 were not added to the base scope of the project. The north alignment of MCA-5 is located in a deep water area that could make construction of containment features difficult. Exposure to the wave environment of North Lake may necessitate the need for some form of erosion control along the containment features. Erosion control along the lengths of the SWLA Canal may also be necessary due to vessel traffic. Moving the cell alignment inward would create a narrow marsh creation area that would also be difficult to construct. Due to these reasons, MCA-5 was removed from the base portion of the project. As for MCA-6, survey data revealed that a majority of the cell is existing marsh – therefore, this cell was also removed from the base portion of the project. The alignments of the remaining cells (MCA-3 and MCA-4, and MCA-7) were further adjusted to avoid deeper water areas and pipelines within the vicinity. From 30% design to 95% design no additional adjustments to the cell alignments were made. The proposed alignment of the cells at 95% design is shown in Figure 19. As a result of these alterations, the proposed project now spans approximately two-hundred ninety-seven (297) acres across four (4) marsh creation areas (measured to the outside toe of earthen containment features).

The next step in the marsh creation design involved determining an appropriate constructed marsh fill elevation (CMFE). CMFE is governed by several factors including the tidal range, percent inundation, existing marsh elevation, physical properties of the borrow material, and the bearing capacity of the foundation soils within the marsh creation area. Determination of the CMFE was based on consideration of the average marsh elevation over the life of the project with respect to intended functioning of the marsh from both a habitat perspective and meeting the project goals and objectives. One element of the design is to maximize the time period that the marsh platform has an elevation within the functional saline marsh inundation range, while accounting for RSLR – a function of ESLR, subsidence, and accretion. Over the 20-year project life, including ESLR as discussed in Section 4.1, the preferred inundation range is expected to rise from 0.15 ft NAVD88 and 1.04 ft NAVD88 (80% and 20% inundation levels, respectively) to 0.64 ft NAVD88 and 1.54 ft NAVD88, as shown in Figures 17 and 18. Subsidence occurs at a rate of 6.4 mm/year for the first eight (8) years of the project life, where it is proposed that accretion will begin to offset this rate through the remainder of the project life. These counteracting processes result in a total vertical surface elevation change of -0.17 feet over the 20-year life. To achieve the project goals, the dredged slurry will need to initially be placed to a constructed fill elevation above the functional saline marsh range and settle into the range over the design life. To satisfy these conditions, the marsh creation area will be pumped to an elevation of +3.0 ft NAVD88 for MCAs 1, 2, and 3 and an elevation of +2.5 ft NAVD88 for MCA-4 (as discussed in Section 6.5), and shown in Table 13 below. A +/-0.25-ft upper construction tolerance is proposed for each area that still meets the aforementioned requirements.

Table 13: Summary of Marsh Creation Area Design (with Subsidence and Accretion)

Cell	Proposed CMFE (ft. NAVD88)	Time to Settle into Inundation Range (years)	Estimated TY20 Elevation (ft NAVD88)	Estimated TY20 Elevation with +0.25-ft Tolerance (ft NAVD88)	Estimated TY20 Elevation with -0.25-ft Tolerance (ft NAVD88)
MCA-1	+3.0 (±0.25)	1.9	0.95	1.06	0.85
MCA-2	+3.0 (±0.25)	2.0	0.86	0.98	0.74
MCA-3	+3.0 (±0.25)	1.7	0.69	0.80	0.58
MCA-4	+2.5 (±0.25)	1.1	0.88	0.99	0.77

After determining the constructed marsh fill elevations necessary to meet the 20-year design life requirements, the total volume of each marsh creation area needed to be calculated. Though the final constructed fill elevation of the marsh fill area will be +3.0 ft and +2.5 ft, NAVD88, volume calculations were determined at the final settled constructed marsh fill elevation at TY20. As shown in the settlement curve in Figure 17, the fill elevation decreases at a much quicker rate within the first few years after construction as compared to the mid to later years due to the draining of excess pore water. The required amount of fill solids needed in order to meet the 20 year design requirements can be estimated using the magnitude of subgrade (and immediate) consolidation and the total settlement of the dredged slurry. Losses during dredging operations are also considered in the computation of the fill volumes (cut to fill ratios), however estimating the losses during dredging operations is difficult due to numerous factors.

Estimation of the marsh fill volumes was done by using AutoCAD Civil software that 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 was generated for the existing conditions using the 2018 survey data from MPH. In order to determine fill volumes, a second TIN surface at a specified fill elevation is needed. AutoCAD then uses the XYZ differences of each surface to calculate the volume of each marsh creation area.

In order to determine the elevation at which to generate a TIN surface and compute fill quantities, settlement plots both with subsidence and accretion and without these processes were evaluated. While the plot accounting for subsidence and accretion was used to determine which CMFE was necessary to meet the 20-year requirements, the plot without subsidence and accretion was used to determine the elevation of the TIN surface. This was done because the processes of subsidence and accretion will act after the placement of the fill volume within each fill area, and should therefore not affect the initial placement of the material. Including the subsidence rate in the TY20 elevation to determine the fill volumes would lower the TY20 fill elevation, resulting in a potential underestimate of fill quantities. In the opposite case, accretion rates would increase the TY20 fill elevation (therefore increasing volumes), despite accretion actively attempting to build land. Figure 21 on the following page shows a comparison of the settlement curves for MCA-1 both with and without subsidence and accretion. Figures for additional cells can be found in Appendix K.

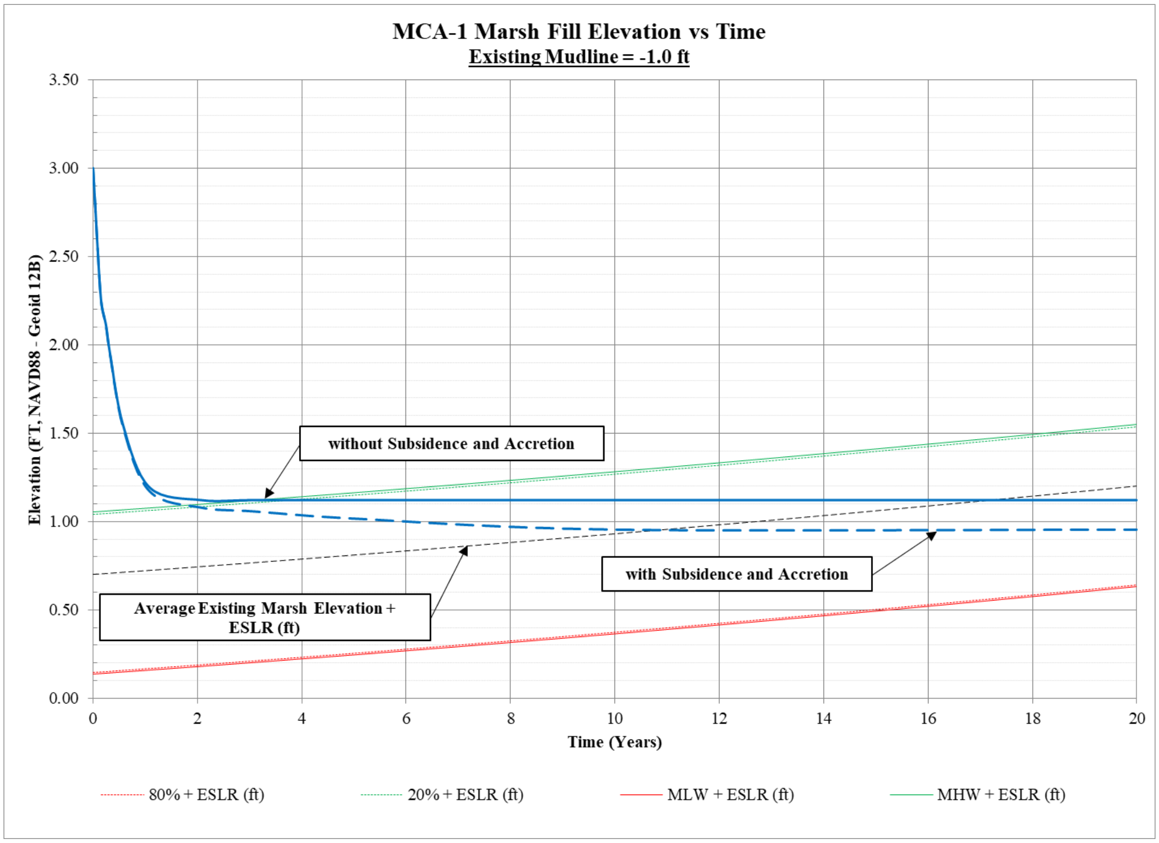


Figure 21: Impact of Subsidence and Accretion on the Computed Fill Volumes

From Figure 21 it can be seen that when a total surface elevation change of -0.17 ft occurs over the course of the 20-year project life due to the processes of subsidence and accretion, the final elevation is lower than that of the curve when these processes aren't accounted for. If the elevation of the curve accounting for subsidence and accretion were to be used to compute fill volumes, the total volume would be underestimated. Therefore, subsidence and accretion were not used to determine the TY20 elevation to compute fill volumes, but were used to determine which CMFE was the most appropriate to meet the 20-year requirements. Table 14 below shows the TY20 elevations used to compute fill volumes for the selected CMFE, the CMFE with a half-foot upper tolerance, and the elevation at the midpoint between the CMFE and the upper tolerance.

Table 14: TY20 Elevations for Computing Fill Volumes

Fill Area	Proposed CMFE (ft. NAVD88)	TY20 Elevation for Volume Calcs. at CMFE (ft. NAVD88)	TY20 Elevation for Volume Calcs. at CMFE +0.25-ft (ft. NAVD88)
MCA-1	+3.0	1.12	1.23
MCA-2	+3.0	1.03	1.15
MCA-3	+3.0	0.85	0.97
MCA-4	+2.5	1.05	1.16

In addition to the volume requirements computed between the two TIN surfaces, any ECD borrow taken from inside the marsh creation area requires additional material to be refilled. Therefore, the internal volume used to construct containment dikes plus a cut-to-fill ratio of 2.0 (ECD cut-to-fill) is then added to the volume required to fill the marsh creation areas. Finally, the cut-to-fill ratio of 1.2 for marsh fill is applied to the total fill volume, resulting in a final estimate of volumes for the marsh creation areas, as shown in Table 14. The volumes shown in Table 15 are calculated using the T20 elevation corresponding to the CMFE with a +0.25-ft tolerance.

Table 15: Marsh Creation Area Fill Volumes

Fill Area	Constructed Fill Elevation (ft. NAVD88)	Area (acres)	Cut to Fill	Volume of Fill[1] (CY)	Volume of Cut[1] (CY)
MCA-1	+3.0 (±0.25)	86.6	1.2	293,956	352,748
MCA-2	+3.0 (±0.25)	64.5		242,116	290,540
MCA-3	+3.0 (±0.25)	81.8		327,262	392,715
MCA-4	+2.5 (±0.25)	64.3		208,281	249,937
Totals		**297.2**		**1,071,615**	**1,285,940**

1. Accounting for the upper construction tolerance (+0.25 ft).
2. Total quantity rounded up in the cost estimate.

7.2 Earthen Containment Features Design

The primary design parameters associated with the earthen containment dike (ECD) design include crown elevation, crown width, and side slopes. A minimum of one (1) foot of freeboard is recommended to contain the dredge slurry within the proposed marsh creation fill area while maintaining an acceptable factor of safety of 1.2 as per the *MCDG1.0*. The ECDs are required to be maintained to the constructed elevations throughout the duration of dredging operations.

Proposed earthen containment geometries for BA-0194 vary across the project area due to varying mudlines as well as exposure to erosive conditions (discussed further in Section 7.4). Crest elevations vary anywhere from +3.5 ft to +4.5 ft with consideration for a +0.5-ft upper construction tolerance. Crown widths also vary anywhere from 5 to 10 feet depending on a particular reach of containment in relation to exposed wave fetches. Due to the poor geotechnical conditions of the site, side slopes of 5H:1V (5 feet horizontal for every foot of vertical rise) are necessary to maintain stability of the earthen features. Stability analysis performed for the earthen sections was summarized previously in Section 6.6, while Table 16 shows the summary of the features proposed on the BA-0194 project.

Table 16: Summary of Earthen Containment Features Design

Cell	Feature	Mudline El. (ft. NAVD88)	Crown Width (ft.)	Crown El. (ft. NAVD88)	Side Slope	Geotextile Fabric?
MCA-1 & 2	ECD	-3.0 and above	5	+4.0 (+0.5)	5H:1V	No
		-3.0 to -4.5				Yes
	Lake Dike	-1.0 and above	10	+4.0 (+0.5)	5H:1V	No
	ECD with ACM	-3.0 and above	5	+4.0 (+0.5)	5H:1V	Yes
MCA-3	ECD	-4.0 and above	5	+4.0 (+0.5)	5H:1V	Yes
	Lake Dike	-2.0 and above	10	+4.0 (+0.5)	5H:1V	Yes
MCA-4	ECD	-3.0 and above	5	+3.5 (+0.5)	5H:1V	No
	Lake Dike	-3.0 and above	10	+3.5 (+0.5)	5H:1V	No
		-3.0 to -4.0				Yes

Due to the erosive environment along Lake Jesse and South Lake, the crown width will be increased to ten (10) feet (discussed further in Section 7.4). Additionally, all earthen containment features will be constructed using external materials from the adjacent lakes and canals as the primary source of borrow, except in areas adjacent to existing marsh or oil and gas infrastructure. Six (6) additional geotechnical borings were performed in canals adjacent to MCA-1, 2, and 3, in order to evaluate these materials for their suitability in use to build earthen containment. Based on recommendations from GeoEngineers, the subsurface soils encountered in the channels around the perimeters of the marsh creation areas were similar to what was encountered in the borings and CPTs performed in the adjacent cells (see Section 6.3). GeoEngineers performed stability analyses modeling external borrow from the adjacent canals.

The construction of the containment features externally can utilize clamshell buckets (with a restriction on drop distance) to minimize the disturbance of the material to improve soil shear strength of the constructed ECDs, and meet the template requirements. Typical containment dikes constructed with marsh buggies produce almost fully disturbed material causing significant loss in shear strength. Clamshells allow for larger portions of material to be excavated and placed more strategically to help the material stack up without excessive lateral spread. The use of external borrow will also reduce the total fill quantity requirement of the cell. In deeper areas, double handling of material may be necessary due to a restriction on equipment reach.

As discussed in Section 6.8, sheet pile gap closure features will be required in areas along MCA-3 where existing mudline elevations are lower than the design elevations of earthen containment features. However, in order to construct the sheet pile gap closures, access dredging will be necessary for equipment access. Since external borrow is proposed in these locations already, the delineated areas for external borrow will serve a dual purpose – to allow for construction of the sheet pile gap closures as well as construction of earthen containment features by utilizing this material.

Earthen containment dikes will be constructed using clamshells and marsh buggies, and utilizing both in-situ material from inside and outside the marsh creation areas and will incorporate a 25-foot-wide construction/stability berm between the toe of the dike and the excavation pit. Some ECD reaches will also require a woven geotextile fabric (table provided on Sheet 15 of the Plans in Appendix J). Figure 22 depicts a typical ECD section for MCA-1, MCA-2, and MCA-3 utilizing an interior borrow source, while Figure 23 shows a typical ECD section utilizing exterior borrow for the same cells.

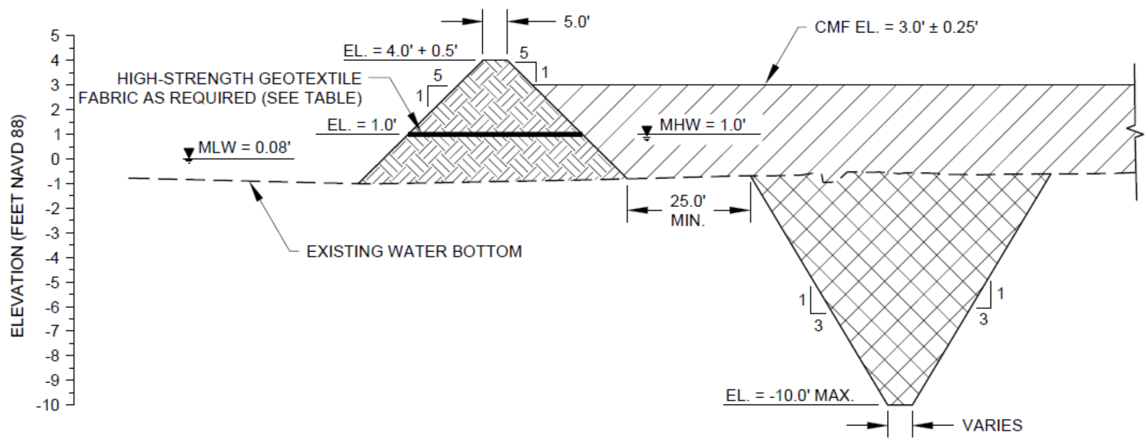


Figure 22: Typical section depicting interior borrow for MCA-1, 2, and 3.

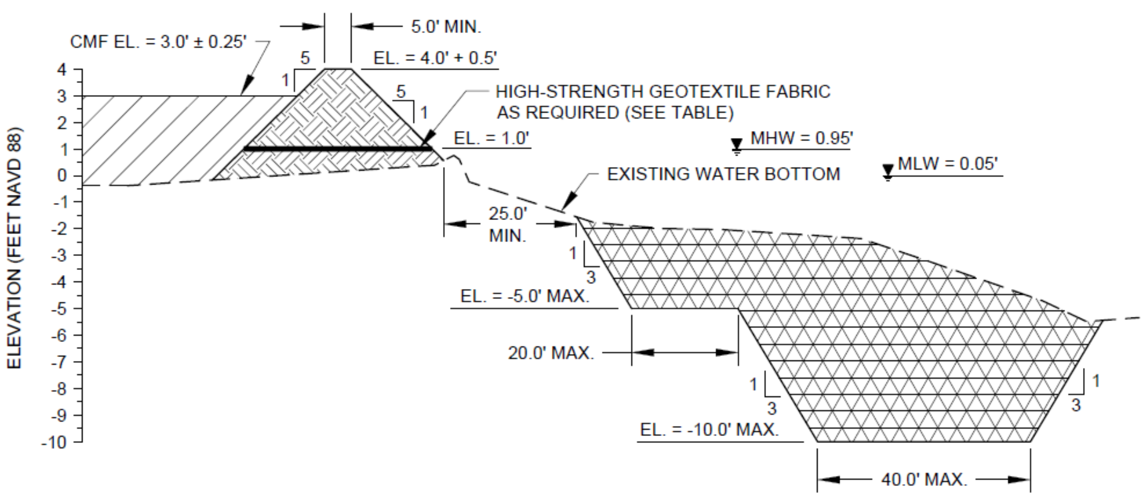


Figure 23: Typical section depicting exterior borrow for MCA-1, 2, and 3.

As discussed in Section 6.7, settlement of the soils beneath the earthen containment dikes was computed based on the dike geometries. The settlement curves for the final dike geometry and elevation are shown in Appendix C of the GER (Appendix J). The results show that a minimum of one (1) foot of freeboard will be present at all times during construction and throughout the 20-year project design life.

Tables 17 and 18 below summarize the length and fill quantities of the proposed ECDs and lake dike features for the BA-0194 project. The cut to fill for containment construction is 2:1.

Table 17: Earthen Containment Dike Quantities

Area	Length of Containment (ft)	Design Elevation (ft. NAVD88)	Side Slopes	Volume of Fill (CY)	Volume of Cut (CY)	Required Geotextile Fabric (SY)
MCA-1	6,136	+4.0 (+0.5)	5H:1V	41,694	83,388	14,365
MCA-2	6,552	+4.0 (+0.5)	5H:1V	40,948	81,896	5,504
MCA-3	4,584	+4.0 (+0.5)	5H:1V	26,080	52,160	30,754
MCA-4	2,400	+3.5 (+0.5)	5H:1V	12,451	24,902	N/A
Totals	**19,672**			**121,173**	**242,346**	**50,623**

Note: Construction tolerances were included in the volume calculations.

Table 18: Lake Dike Feature Quantities

Area	Length of Containment (ft)	Design Elevation (ft. NAVD88)	Side Slopes	Volume of Fill (CY)	Volume of Cut (CY)	Required Geotextile Fabric (SY)
MCA-1	1,518	+4.0 (+0.5)	5H:1V	9,029	18,058	N/A
MCA-3	2,842	+4.0 (+0.5)	5H:1V	20,972	41,944	20,948
MCA-4	4,884	+3.5 (+0.5)	5H:1V	38,738	77,476	6,258
Totals	**9,244**			**68,739**	**137,478**	**27,206**

Note: Construction tolerances were included in the volume calculations.

7.3 Gap Closure Features Design

In areas of MCA-3, where the existing mudline elevation is deeper than the design mudline elevation of the ECDs, a sheet pile gap closure feature will be necessary for containment in order to meet stability requirements. The sheet pile gap closure feature will consist of a sheet tip elevation of -20.0 ft (NAVD88) and a top of sheet pile elevation of +4.5 ft, backfilled with in-situ materials to elevation of +1.5 ft on both sides of the sheeting. The gap closure will be constructed by first building the earthen template to the specified elevation of +1.5 feet, with a 35-foot crown width, before installing the sheeting to the specified tip elevation. A typical section of the sheet pile gap closure is shown in Figure 24 on the following page.

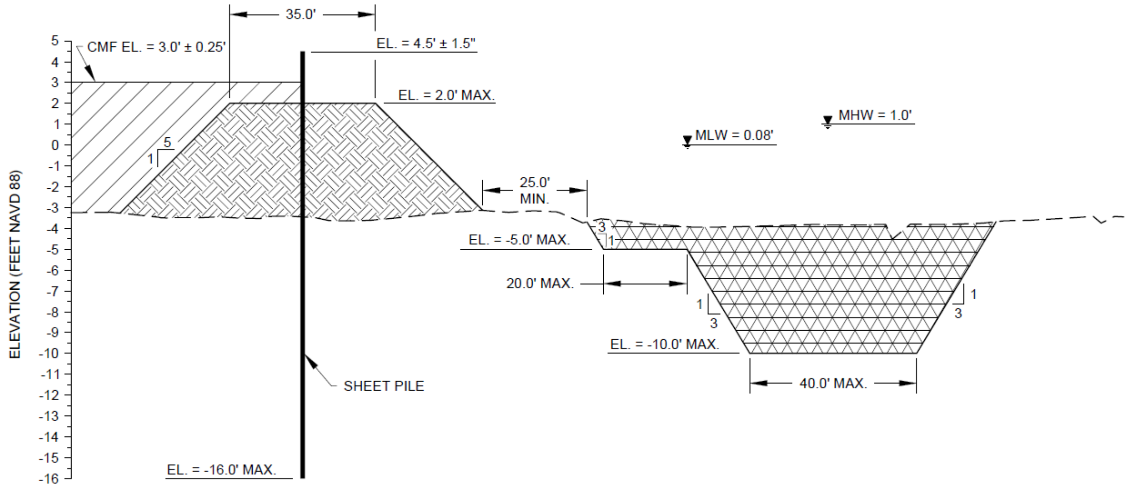


Figure 24: Typical sheet pile gap closure section with external borrow.

Due to the shallow water depths across the project site, access dredging will be necessary in order to install sheet pile. Since borrowing externally has been proposed along the areas of MCA-3 where sheet pile gap closures will be needed, the borrow pit can also be used as an access channel (see Figure 24 above).

Table 19 summarizes the length and fill quantities of the proposed sheet pile gap closure features for the BA-0194 project. The cut to fill for all gap closure features is the same as the ECDs, 2:1.

Table 19: Gap Closure Feature Quantities

Area	Length of Containment (ft)	Sheet Pile Quantity[1] (SF)	ECD Design Elevation[2] (ft. NAVD88)	Side Slopes	Volume of Fill (CY)	Volume of Cut (CY)
MCA-3	934	23,355	+1.5	5H:1V	8,979	17,958

1. Length of the feature multiplied by the 25.0-ft sheet pile section.
2. Top of sheet pile elevation is +4.5 ft.

7.4 Erosion Control Design

Due to vessel traffic and fetch conditions in Lake Jesse and South Lake, erosion of containment features during construction is a concern. As a result, a more detailed review of the earthen containment dike design was performed in areas along SWLA Canal and adjacent to Lake Jesse and South Lake. It has also been noted that portions of the Old Highway 1 project in Leeville were constructed with rock riprap in order to combat wave action along the shoreline of Lake Jesse. While there is no supporting literature to determine precisely when an erosion control system may be necessary for containment features on a marsh creation project, lessons learned on past marsh projects can be utilized to address the potential need for erosion control, and comparisons can be drawn. Erosion control features have been utilized for the protection of earthen containment features on marsh creation projects due to the presence of perpendicular wave attack generated by marine vessel or by wind-generation. Erosion of the containment features can increase construction costs and the risk of ECD failure, thus potentially affecting the ability to place marsh fill material and to allow for marsh platform development.

The Lost Lake Marsh Creation and Hydrologic Restoration Project (TE-0072) highlights the difficulties of constructing containment along areas adjacent to a lake fetch with wind-generated perpendicular wave attack. TE-0072 attempted to construct an enhanced earthen berm along Lost Lake in Terrebonne Parish, LA, with side slopes of 6H:1V, a ten (10) foot crown width, and an exterior borrow source. The contractor encountered significant issues during construction. Wave action continuously eroded the base of the berm during construction, requiring the base to be overbuilt to counteract the erosion. The wave action caused material to be further disturbed as it was eroded and washed back into the internal borrow pit. Maintenance was continuously performed on the dike section throughout construction, and the sections were ultimately built much larger than designed in order to contain the dredged slurry. The constant reworking of the material and continued wave action throughout construction resulted in increased construction time and cost.

The following sections present alternatives analysis and case studies pertaining to erosion control methods evaluated for implementation on the BA-0194 project. Five (5) alternatives were reviewed: articulated concrete mats (ACMs), enlarged earthen containment dikes (with and without the use of dredge pipeline as erosion protection), gabion mats, geotubes, and Reefblk™.

7.4.1 Articulated Concrete Mats

Articulated concrete mat (ACM) or articulated concrete block (ACB) systems are typically used to provide erosion protection to underlying soils from the hydraulic forces of moving water (NCMA 2010). ACMs have been used in a wide variety of applications related to protecting soils from flowing water, and are even appropriate for use as protection against small waves (USACE 4-38). ACM systems are generally comprised of the following:

- An armoring layer consisting of interlocked concrete blocks to resist wave action and control run up on the earthen materials (NCMA 1, Russo 17);
- A filter layer (commonly geotextile fabric) which relieves piezometric head buildup below the armoring layer and provides separation from, and retention of, the underlying soils, and;
- Anchorage to keep the system in place.

The armoring layer consists of open- or close-cell concrete blocks interlocked with or without the use of cables, geotextiles, or geogrids (NCMA 1). The open-cell systems are capable of allowing for vegetative growth (including self-vegetation) between blocks, but also serve to reduce the overall mass of the erosion protection system. The filter layer underlays the armoring component and allows infiltration and exfiltration to occur while also providing subsoil retention against the erosive forces (NCMA 1). ACM systems have been commonly used for erosion control in channel linings, spillways, levees, and stormwater control structures. More recently, ACM systems have been utilized for erosion control of containment features on marsh creation projects due to the presence of perpendicular wave attack generated by marine vessels or by wind.

The southern alignment of MCA-1 runs adjacent to the SWLA Canal and is exposed to vessel traffic. On the Cole's Bayou Marsh Restoration Project (TV-0063), articulated concrete mats (ACMs) were utilized in order to build containment along a portion of one of the MCAs adjacent to Freshwater Bayou. Perpendicular wave attack in the bayou due to vessel traffic created constructability concerns of the ECD. ACMs were utilized successfully to maintain the ECDs during construction to allow for the marsh fill to be pumped into the marsh creation areas. The areas containing the ACM system have self-vegetated since their placement. The constructed dike section had a crest width of five (5) feet with side slopes of 4H:1V, and were constructed to an elevation of +4.0 ft. The dimensions of this section are similar to the sections proposed along the shoreline of MCA-1 in BA-0194, which also has concerns with waves generated by vessel traffic.

In order to compare the sections constructed for TV-0063 and those proposed for the BA-0194 project, geotechnical conditions of those projects in those reaches with ACMs were evaluated. The geotechnical investigation performed on Cole's Bayou revealed generally very soft to soft clays and silty clays (100 to 200 psf), with organics ranging in depths from about 10 to 15 feet below the mudline, underlain by medium to stiff clay (400 to 800 psf) or silty clay soils. For comparison, the soil profiles along MCA-1 in BA-0194 reveal a thin layer (2-3 feet) of organic material overlaying predominately cohesive materials to approximately El. -25 feet, with cohesion values ranging from 100 to 150 psf in the upper 10 to 15 feet.

The BA-0194 project area geotechnical exploration revealed similar subsurface conditions to that of TE-0072 (see Section 6.2 for details on subsurface conditions present in the BA-0194 project area). TE-0072 site conditions contained very soft (less than 250 psf) cohesive soils with varying amounts of organic matter in addition to surficial layers of peat with depths varying from 4 to 6 feet below the mudline. The ECD borrow material has a similar unit weight (90 pcf vs. 85 pcf), and the subsurface materials beneath the dike sections share similar cohesion and unit weight trends. In addition, large fetch of Lake Jesse and North Lake (approximately 11,000 LF) present constant erosion concerns similar to Lost Lake (fetch length of approximately 18,200 LF).

7.4.2 Enlarged ECDs and Dredge Pipeline Erosion Protection

Enlarged earthen containment dikes along the rims of the adjacent lakes are also a potential alternative to reduce the risk of erosion failure of earthen containment features. While this alternative does not reduce the amount of erosion that occurs, it increases the time required for erosion to negatively impact the project. In other words, it increases the time available for the marsh platform to consolidate prior to erosion of the containment feature. Construction costs of this alternative would need to include maintenance to the dike during construction as wave action will continually erode the flood side of the earthen containment feature. Additionally, floating high-density polyethylene (HDPE) dredge pipe on the outside toe of the containment feature has been used in conjunction with enlarged dikes to reduce the amount of erosion.

The floating of dredge pipeline five (5) to ten (10) feet from the outside toe of the containment features has also been used to combat erosion of earthen containment features. The Lake Lery Marsh Creation Project (BS-0016) mobilized additional length of 18-inch dredge pipe to the site during construction in order to combat the erosion of the containment features along the southern rim of Lake Lery (Figure 25). 5,000 feet of dredge pipeline was placed for a period of thirty (30) days in order to determine its durability and effectiveness to protect the containment feature against erosion. At the end of the thirty (30) day period, the placement of the dredge pipeline was deemed to be an effective erosion control method for these conditions, and an additional 10,900 linear feet of pipe (for a total of 15,900 feet) was placed along the lake rim for a total duration of six (6) months to protect from erosion during construction. Figure 25 shows the minimizing effect of the floated dredge pipe on the wave action on the containment dike.

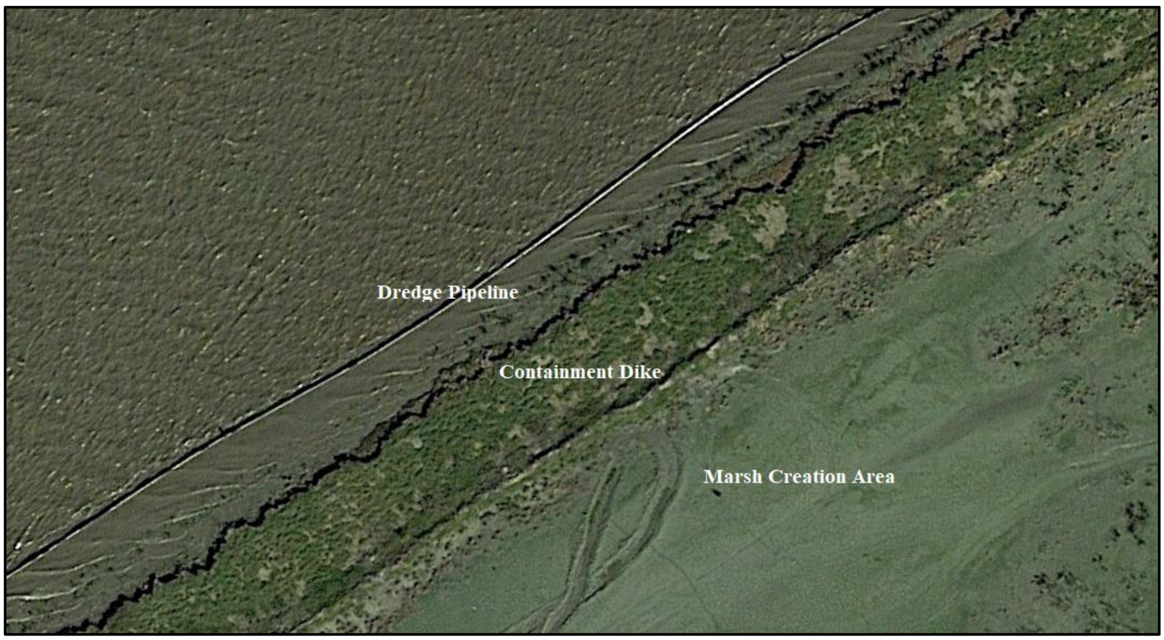


Figure 25: Aerial imagery of the dredge pipeline protection at the Lake Lery project.

The use of additional dredge pipe as a form of erosion control has potential to be a more cost-effective alternative as compared to hardened structures based on costs from BS-0016 change orders, however the BS-0016 project is the only case study. There is potential uncertainty as to the cost associated with using dredge pipe for erosion control. With a longer pump distance (such as for the BA-0194 project) the contractor may need to purchase additional pipe to meet the length requirements for erosion control. As such, the cost of purchase of new pipe would need to be included in the cost. Additionally, after demobilization, there will no longer be any erosion protection. This can potentially expose the newly placed fill material to the wave environment. Upon demobilization of the dredge pipe for BS-0016, the containment feature eroded nearly ten (10) feet from its original location in the span of a year. Therefore the ECDs located behind the dredge pipeline of the BA-0194 project would need to be enlarged to allow the dredged materials time to consolidate so that the dredged material will not flow back out of the cell in the event of a breach along the containment.

As mentioned in the previous section, the Lost Lake Marsh Creation and Hydrologic Restoration Project (TE-0072) highlights the difficulties of constructing containment along areas adjacent to a lake fetch with wind-generated perpendicular wave attack. However, the wave conditions in Lost Lake are much more severe than those seen in Lake Jesse or South Lake. The potential for erosion of the dike still exists. This alternative, if utilized, should include the cost for continued maintenance of the dike throughout construction.

7.4.3 Gabion Mats

Gabion mats (sometimes referred to as marine mattresses) are generally comprised of a geotextile or wire basket that is formed and weaved, and filled with crushed limestone or oyster shells. Gabion mats have similar uses as ACMs, including channel linings, scour aprons, and shoreline protection. The effectiveness of a gabion mat system as a shoreline protection feature was demonstrated in the Terrebonne Bay Shore Protection Demonstration (TE-0045) project funded through the CWPPRA program. As part of the TE-0045 demonstration project, gabion mats (as well as A-Jacks and Reefblk™) were constructed along northern areas of Lake Barre in Terrebonne Parish to analyze their effectiveness as shoreline protection features. Post-construction observations of the three alternatives revealed that the gabion mat treatment was the most effective of the shoreline protection alternatives (Curole and Melancon 24). A profile section of the gabion mat from the TE-0045 project is shown below.

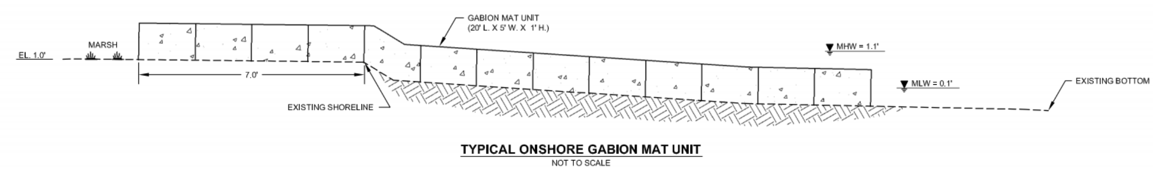


Figure 26: Typical section of the gabion mat unit utilized on TE-0045.

Since the intended use of the gabion mats for BA-0194 would be erosion control rather than shoreline protection, the use of the system required further investigation.

A known issue with a gabion mat protection system is the durability. Frequent wave attack can lead to a failure of the wire mesh due to the continuously moving grains, or due to corrosion of the mesh (Breteler et. al. 1598). Corrosion-resistant steel or specialized gabion mats (such as the HDPE bodkin rod used on TE-0045) can be used to combat this, however at an increased cost to the system. Additionally, the average weight of a gabion mat is between 10,000 to 15,000 lb (based on information from the Terrebonne Bay demonstration project). When filled with crushed limestone, the mat exerts a pressure of 100-150 pcf, approximately 1.5-2 times greater than that of an ACM. The larger pressure is likely to result in increased settlement of an earthen containment feature overlain with a gabion mat, compared to that of an ACM. Additionally, the overall stability of the containment structure would likely be reduced.

The construction of a gabion mat would require an additional staging area in order to fill the geotextile basket with the crushed limestone, unlike ACMs. ACMs come pre-fabricated, reducing construction time for the erosion control feature. The increased weight of the mats would not allow for as many mats to be placed on a lightly loaded barge to access the site. Access dredging to a deeper depth may also be needed. The increased weight would likely also require specialized equipment to place the mats on the dike, as compared to a spreader bar and marsh buggy for ACMs.

Despite the cost and duration implications, gabion mats have proven to be effective against shoreline erosion against lake fetches. However, these have not been used directly as erosion control measures as part of an earthen containment system on a marsh creation project.

7.4.4 Geotubes and Reefblks™

At the request of the federal sponsor (NOAA), CPRA evaluated the use of Reefblks™ and geotubes as an alternative erosion control feature.

Appendix I of CPRA's Marsh Creation Design Guidelines details the use of geotubes on marsh creation projects:

> *CPRA does not recommend the use of geotubes for use on marsh creation projects. An Earthen Containment Dike (ECD) is a feature used on marsh creation projects to contain the slurry during construction and is made from the lightweight in-situ soil. The adjacent soil is typically excavated with a marsh buggy excavator or small clamshell bucket and placed in multiple lifts. This equipment is readily available using South Louisiana operators, who are experienced working the Louisiana soft soil conditions, thus making this process efficient and cost effective. Geotube systems, locally referred to as "boudin bags", typically consist of expensive high-strength woven geoxtiles, which are sewn and filled with a sandy material (requires proper AOS design and drainage) that must be delivered from an approved, offsite borrow source. Clayey soils are not recommended. Because the select sandy material is off-site, it is typically more expensive and is also 30-40% heavier than the in-situ soil, thus increasing the load on the existing ground. The load increase on the foundation soil will result in an increase in foundation settlement and typically requires the use of an engineered geosynthetic mat foundation system/apron to ensure long-term stability. Specialized personnel, equipment, and processes are also required for proper installation, thus resulting in the use of a specialized Contractor. The use of granular backfilled geotubes as containment for marsh creation projects will require the use of a specialized contractor for construction, require the use of a geosynthetic mat foundation system/apron, increase the subsurface investigation costs, increase the total settlement, increase the risk to the Owner, and increase the total project costs. Therefore, due to the soft soil conditions in coastal Louisiana and as specified above, geotubes or "boudin bags" are not typically recommended for use as containment on marsh creation projects within the Louisiana Coastal Zone.*

Geotubes would require the use of specialized contractors for construction, and would require sand fill to be brought in from off-site, both increasing project costs. Secondly, the increased weight of the sand fill (typically 120-125 pcf for sand vs 80-105 pcf for in-situ materials) would result in increased settlement, and may also require the geotube to act as a foreshore structure in areas where external borrow is proposed. This offset may create a navigation hazard or require the placement over existing oil and gas pipelines, increasing project risk. Figure 27 below shows a typical section of a geotube installation.

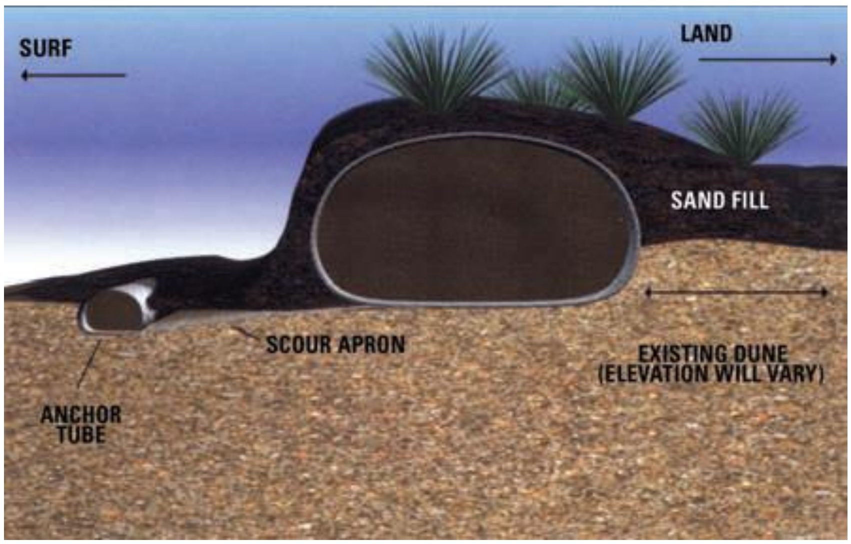


Figure 27: Typical profile view of a geotube installation (Bishop).

Similarly, Reefblks™ were also not considered for the same reasons that geotubes were not. The Reefblk™ feature was constructed and monitored as part of the Terrebonne Bay Shore Protection Demonstration (TE-0045) project. Reefblks™ consist of a pre-fabricated double-framed triangular steel unit that holds plastic mesh bags filled with oyster shells. They are generally constructed with a geogrid/geotextile and 6” crushed stone base. On average, these structures weight nearly 3,000 lb per triangular steel unit (5-ft base by 2-ft tall), not including the geotextile and base, and would also be a foreshore structure. Post-construction monitoring of the TE-0045 demonstration project revealed that Reefblks™ did not perform as well as the gabion mats (Curole and Melancon).

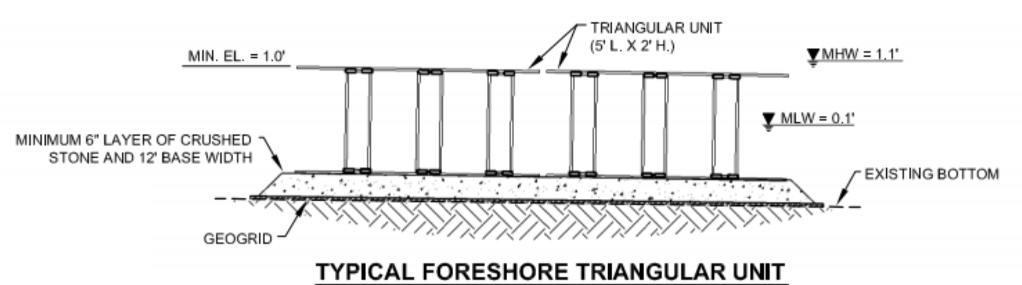


Figure 28: Typical profile view of a Reefblk system installed on TE-0045.

7.4.5 Preferred Erosion Control Alternatives

The aforementioned alternatives were reviewed for their feasibility in use on the BA-0194 project. At the request of the federal sponsor, each alternative was analyzed using the following criteria:

- The containment should be a temporary system (to the maximum extent practicable) that will afford the construction contract a high likelihood of success. The temporary nature of the containment system should extend beyond the initial construction (possibly to TY3) to allow for some time for consolidation of dredge slurry and vegetation to begin growing;
- The marsh creation areas should be contained by a system designed to retain as much solids as possible from the hydraulically pumped dredge slurry to maximize the return on the hydraulic fill placement;
- The containment system should minimize both short term and long term financial obligations (construction and O&M) and risk to the project and program to the maximum extent practicable;
- The containment system should also minimize the tort risk to the government during the 20 year life and the post 20 year life; and,
- The containment system should also seek to provide the most habitat value as determined by the project sponsors.

Ultimately, gabion mats, geotubes, and Reefblks™ were screened from the project due to the following reasons:

- **Gabion Mats** – as a result of being a higher cost alternative, with the potential for increased settlement and decreased stability, and due to its uncertainty in behavior when overlaying an earthen containment feature.
- **Geotubes** – due to the increased costs as a result of the need for specialized contractors and imported sand, a likelihood of increased settlement, and an increased placement distance from the containment feature (foreshore).
- **Reefblks™** – due to its weight and required placement as a foreshore structure, in addition to being a shoreline protection feature over an erosion control feature.

After a review of alternatives, the following is proposed for the BA-0194 project:

- Having been successfully implemented on Cole's Bayou to mitigate erosive conditions for similar soil strength and vessel-wave conditions, **ACMs** have been proposed for use adjacent to the SWLA Canal along MCA-1 (Figure 23).
- An additional length of **ACMs** has been proposed along the southern alignment of MCA-2, in an area exposed to open fetch.

- Remaining alignments along Lake Jesse, North Lake, and South Lake will be contained via the **Lake Dike** feature with dredge pipeline serving as the erosion control.

The figure below shows the proposed typical sections for the earthen containment dike protected by an ACM, proposed for use along MCA-1. The ACM will be placed along the crown of the ECD and will extend down along the flood side slope, and extending three feet past the toe. The ACM will be underlain by a non-woven geotextile separator fabric placed in the same fashion as the ACM. MCA-2 will also have reaches with ACMs, however internal borrow is proposed.

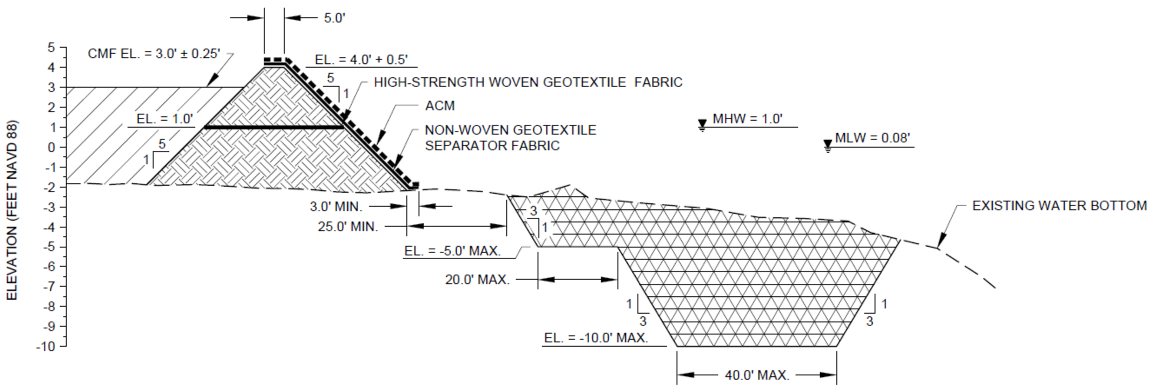


Figure 29: Typical ECD section with ACMs and external borrow.

The estimated lengths and quantities of the ACMs are shown in Table 20.

Table 20: Proposed Articulated Concrete Mat (ACM) Quantities

Area	Length of Feature (ft)	Area of Mats (SY)	Geotextile Fabric Required (SY)
MCA-1	2,146	9,798	13,465
MCA-2	517	1,938	2,433
	2,663	**11,735**	**15,898**

The Lake Dike feature is proposed for use in areas along MCA-1, MCA-3, and MCA-4, in areas exposed to potential perpendicular wave attack across the lake fetch. The Lake Dike feature will consist of a 10-ft crown width and 5H:1V side slopes, with the dredge pipeline placed 5 to 10 feet past the outside toe of the dike, as shown in Figure 30 below.

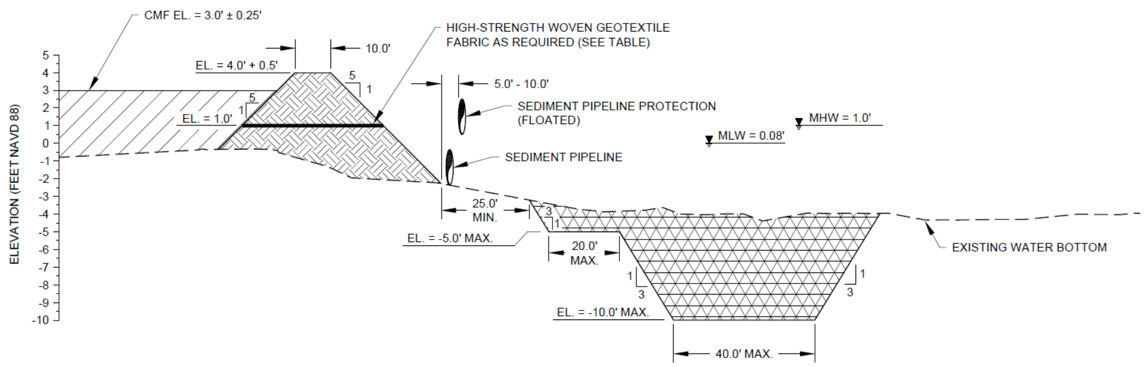


Figure 30: Typical earthen containment dike section protected by dredge pipe.

The estimated length of the Lake Dike with dredge pipe protection is shown in Table 21.

Table 21: Proposed Dredge Pipeline Erosion Control Quantities

Area	Length of Dredge Pipeline (ft)
MCA-1	1,518
MCA-3	2,842
MCA-4	4,884
Totals	**9,244**

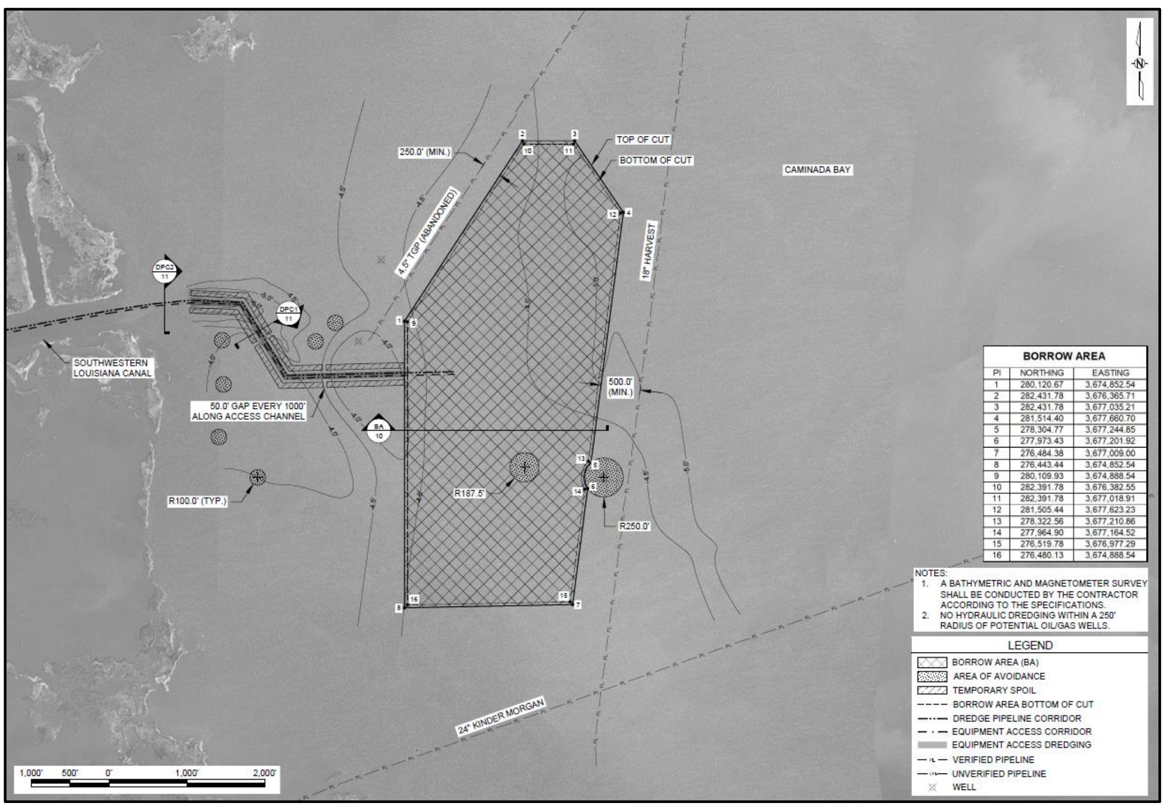
7.5 Borrow Area Design

The typical controlling factors in the borrow area design are the location, size, and available material. It is preferred that the borrow area be located in close proximity to the marsh creation area in order to minimize the pumping distance of the dredged material and reduce cost. The borrow area should be free of any existing oyster leases, critical habitat, culturally significant sites, and oil and gas infrastructure, if possible.

In the feasibility study performed in 2017 (Section 3.2), Sigma identified three (3) potential borrow areas as part of the alternatives analysis: 1) the lakes adjacent to the MCAs (Lake Jesse, North Lake, and South Lake), 2) Caminada Bay to the east, and 3) Little Lake to the west. A review of the potential factors was performed in order to determine the most suitable borrow area. The Caminada Bay borrow area provides sufficient fill material to construct the MCAs, however it will require several infrastructure and navigational crossings along 7.5 miles of DPC alignment. The Little Lake borrow area is located approximately 6 miles west of the MCAs and would also require the DPC to cross numerous pipelines, existing infrastructure, and major navigational waterways, but to a much larger extent than Caminada Bay. An extensive environmental clearance and permitting effort would be required to make use of this corridor (Sigma 2017). The borrow areas in the lakes adjacent to the MCAs would likely have needed a modeling effort in order to determine acceptable dredge depths as well as to analyze any potential impacts to the MCAs (Sigma 2017). It is likely that the allowable dredge depth would not have been deep enough to provide sufficient fill material, and the use of more than one borrow area may have been necessary.

After review of these three (3) alternatives, the borrow area in Caminada Bay was selected, with access through the SWLA Canal.

The Caminada Bay borrow area is located near two (2) oyster leases, to the north and the east, but is offset 1,500 feet to avoid any impacts to these leases. Additionally, the borrow area contains three (3) anomalies that may be cultural resources. Based on recommendations by the RPA (and concurred with by SHPO), a one hundred (100) foot buffer has been placed around these anomalies to avoid disturbance during dredging operations. Two (2) pipelines bisect the originally proposed borrow area and a third borders it to the southeast. Due to the location of the Harvest Pipeline as well as the shallow water depths within the Caminada Bay, the proposed borrow area will be restricted to the area between the Harvest Pipeline and the abandoned Tennessee Gas Pipeline, as shown in Figure 31. This will prevent the need to access dredge in the shallow water depths over the pipeline in order to reach a secondary borrow source. The borrow area was delineated to maintain a five hundred (500) foot buffer from the Harvest Pipeline and a two hundred fifty (250) foot buffer from the abandoned Tennessee Gas Pipeline during dredging operations. A dry and plugged wellhead was also discovered in the area between the delineated borrow area and the Harvest Pipeline. A two hundred fifty (250) foot radial buffer was also placed around this wellhead.



BORROW AREA		
PI	NORTHING	EASTING
1	280,120.67	3,674,852.54
2	282,431.78	3,676,365.71
3	282,431.78	3,677,035.21
4	281,514.40	3,677,660.70
5	278,304.77	3,677,244.85
6	277,973.43	3,677,201.92
7	276,484.38	3,677,009.00
8	276,443.44	3,674,852.54
9	280,109.93	3,674,888.54
10	282,391.78	3,676,382.55
11	282,391.78	3,677,018.91
12	281,505.44	3,677,623.23
13	278,322.56	3,677,210.86
14	277,964.90	3,677,164.52
15	276,519.78	3,676,977.29
16	276,480.13	3,674,888.54

Figure 31: Borrow Area plan view.

A cut depth of ten (10) feet (to elevation -15.0 ft.) was determined to be sufficient to ensure adequate volume would be available, however the total quantity for a thirteen (13) foot cut (to elevation -18.0 ft.) was also determined. The total volume of available borrow material was calculated using AutoCAD Civil software using the same procedure described in

Section 7.1. The available volume of material within the borrow area can be found in Table 22.

Table 22: Proposed Borrow Area Volume and Dredge Requirements

Cut Elevation (ft. NAVD88)	Borrow Area Acreage	Available Volume (CY)	Required Cut Volume (CY)	Percent Usage of Borrow Area
-15		4,921,582		26%
-15 to -18 (Overdredge)	299.7	1,399,927	1,285,940	-
-18		6,321,509		20%

7.6 Dredge Pipeline Corridor Design

Dredge pipeline access to the MCAs will be accomplished by submerging the pipeline along the northern bank of the SWLA Canal westward from the borrow area located in Caminada Bay. The pipeline alignment will then continue along the northern shoreline of Lake Jesse to each of the MCAs, as shown in Figure 32.

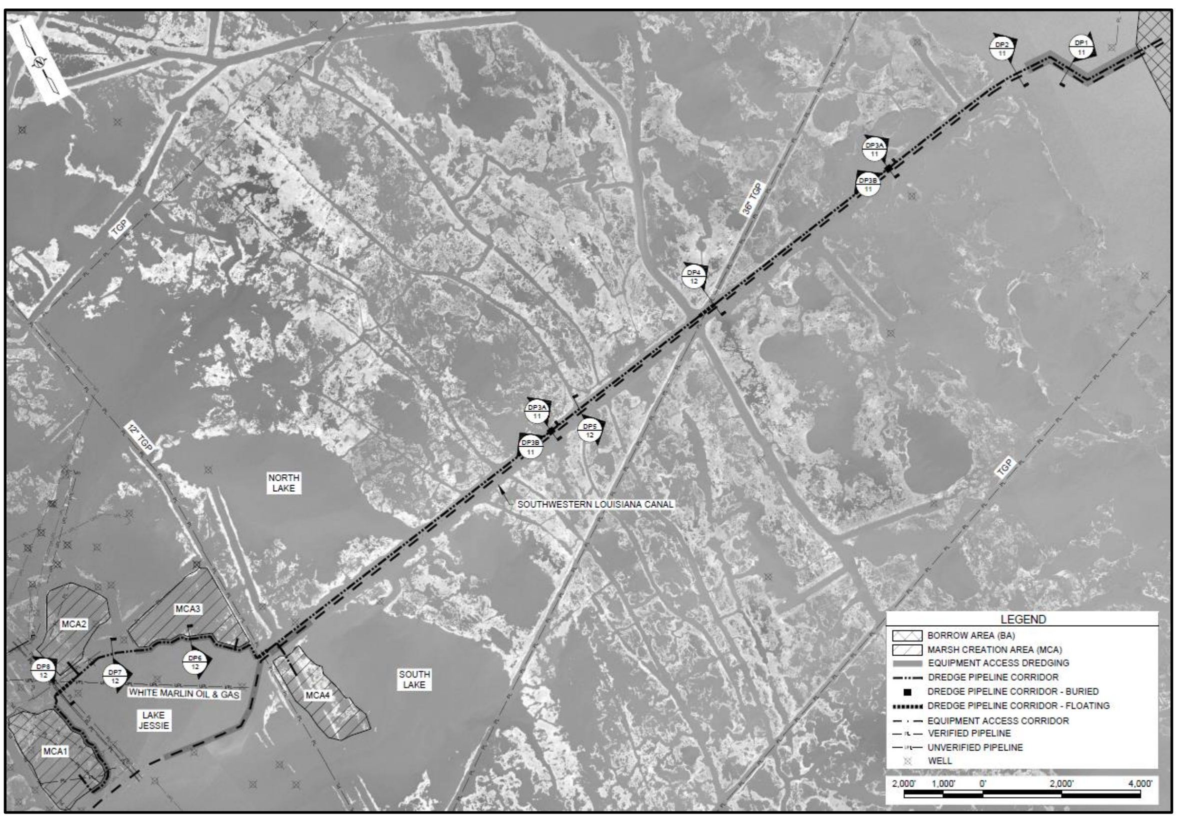


Figure 32: Proposed dredged pipeline corridor.

Surveys were performed along the dredge pipeline corridor and areas adjacent to the MCAs to optimize the alignment. The surveys revealed several pipeline Operators as discussed in Section 5.2 and 5.5. Due to the presence of these oil and gas pipelines along the DPC, the dredge pipeline will be required to float over so as to not disturb the soils above the gas pipelines. In order to accomplish this, pontoons will be used to float the dredge pipeline above the oil and gas pipelines (Figure 33). The pontoons are easily moveable allowing the contractor to move the dredge pipeline as needed throughout construction. The figure below shows a detail of the proposed pipeline crossing. Anchoring of the dredge pipeline above existing pipelines or within right of way of those pipelines will not be allowed.

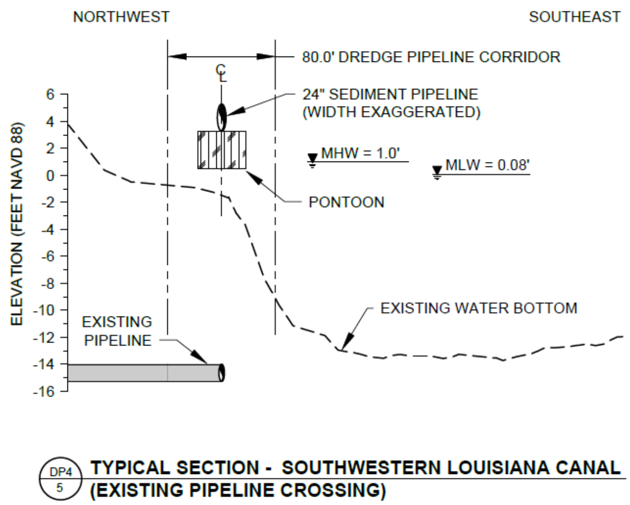


Figure 33: Proposed dredged pipeline crossing existing pipelines.

In some areas where the dredge pipeline corridor intersects navigable waterways or canals to private lands, the pipeline may need to be buried to provide undisrupted access. Figure 34 shows a detail of the proposed pipeline burial. In some of these areas, these navigable waterways contain oyster leases that will likely need to be extinguished in part or in whole in order to maintain access.

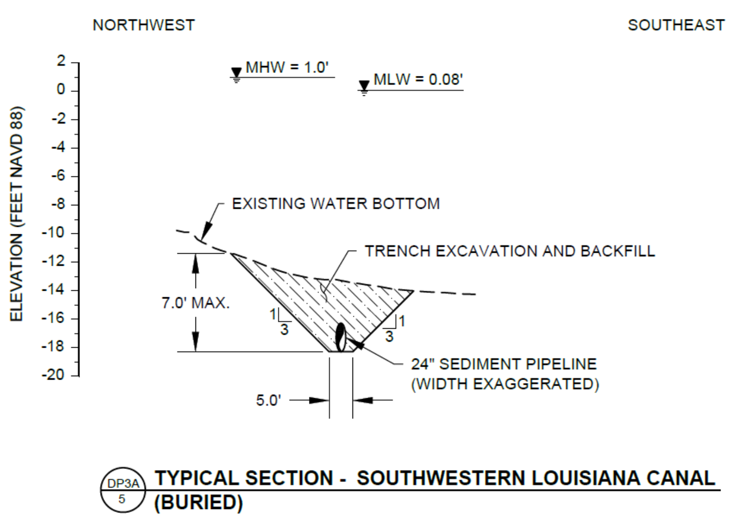


Figure 34: Proposed dredged pipeline burial at navigable waterway crossings

Table 23 summarizes estimated quantities of DPC required for the BA-0194 project.

Table 23: Proposed DPC Quantities

Type	Length (LF)
Submerged	38,546
Buried	120
Pipeline Crossing	1,331
Total	39,997

7.7 Equipment Access Dredging and Considerations

Equipment access to the borrow area will be achieved via the SWLA Canal from Bayou Lafourche. Survey data reveals that the depths of SWLA Canal range from El. -5 to El. -17 ft. Shallow areas (above El. -8.0 ft) along the canal will require access dredging to allow for barge and tug transit. All access channels along SWLA Canal shall be excavated to a maximum base width of 80 feet and a maximum cut elevation of -8.0 ft (similar to the section shown in Figure 34).

The access corridor extending through Southwest Louisiana Canal requires the crossing of the LOOP and Shell Mars pipelines just east of Leeville. On the northern boundary of the canal, the depths of cover are much lower than the southern boundary. Depths of cover for these lines on the northern section of the canal range from 1.7-5.1 feet. Care should be taken when navigating through these areas, however vessel traffic through this area is quite common.

As discussed in Sections 7.2 and 7.3, access dredging will also be necessary in order to construct the sheet pile gap closures along areas of MCA-3. In these areas, external borrow is already proposed. These areas will make use of the proposed external borrow areas for equipment access. Should additional dredging be necessary for access after construction of the ECD template, the excess material shall be placed in the marsh area.

External borrow areas (and equipment access corridors) will be stepped to allow for lightly loaded barges to access the area to construct the ECDs and to install sheet pile. Access areas in Lake Jesse or SWLA canal will not be stepped, and will have a bottom elevation of -8.0 ft. A stepped section serving as external borrow and an access corridor is shown in Figure 23, and the access only channel through Lake Jesse and the SWLA Canal is shown in Figure 35.

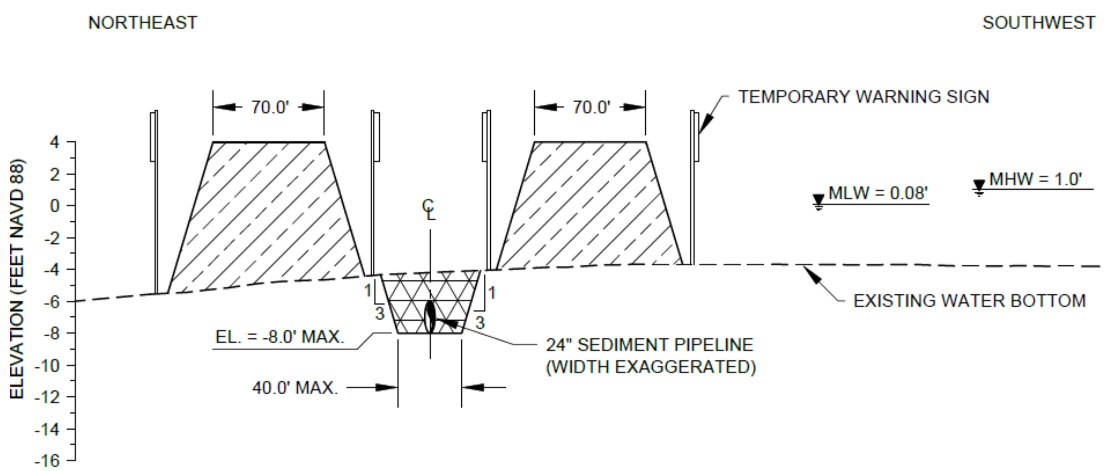


Figure 35: Proposed access corridors adjacent to MCAs 2 and 3.

Estimated access dredge quantities and the volume of external material for adjacent containment features are shown in the following table. Fill volumes rather than cut volumes were considered over required cut volumes (cut to fill of 2:1) for conservative estimates of dredge quantities.

Table 24: Access Dredge and External Borrow Quantities

Area	Total Volume of Floatation Dredge (CY)	Required Fill Volume of Adjacent Containment Features (CY)	Volume Remaining for Floatation Dredge (CY)
MCA-1	53,798	42,826	10,972
MCA-2	36,566	31,437	5,129
MCA-3	53,993	38,571	15,422
MCA-4	32,940	38,738	0
Lake Jesse	30,645	0	30,645
Borrow	28,680	0	28,680
	236,622	**151,572**	**90,848**

Floatation dredging volumes were computed assuming a stepped section, and a 5-ft bottom width at El. -10.0 ft. This will provide for a total width of 40-ft across the bottom of the section for equipment access. For the instances where required fill volumes of the adjacent earthen features are greater than the total volume of floatation dredging, the contractor will still have additional area to borrow externally. Should the contractor need further access dredging, any additional spoil can be placed within the marsh creation areas.

7.8 Pipeline Considerations and Coordination

Table 25 presents information pertaining to the known pipeline within the BA-0194 project area, their relative locations, depths of cover, and construction buffer requirements. At this time, all pipeline owners/operators have been contacted and provided with information pertaining to anticipated construction activities on or near their pipelines. If Phase II funding is received, an extensive pipeline investigation will be necessary due to the large number of pipelines as well as abandoned flowlines.

The access corridor through SWLA Canal requires the crossing of the Shell Mars pipeline. On the northern boundary of the canal, the depths of cover are much less than the southern boundary. Depths of cover for these lines on the northern section of the canal have approximately 4.7-5.3 feet of cover. Care should be taken when navigating through these areas. No access dredging will be necessary within the vicinity of these lines.

Table 25: Summary of Pipelines within the BA-0194 Project Area

Pipeline/Flowline	Ownership Details	Location Description	Depth of Cover (ft)	Minimum Construction Buffer (ft)
Loop Pipeline (48" Crude Oil)	Loop, L.L.C.	MCA-1 and MCA-2/ DPC	9.5-11.2	100/ Float DPC
Loop Pipeline (30" Brine)	Loop, L.L.C.	MCA-1 and MCA-2/ DPC	9-10.2	100/ Float DPC
Shell MARS (24" Crude Oil)	Shell Pipeline Company, L.L.C.	MCA-1 and MCA-2/ DPC	2.6-16	150/ Float DPC
4" PPC Natural Gas Flowline	Marquis Resources	MCA-1	No Cover	150
Kinetica 524A-100 (12" Natural Gas)	Kinetica Midstream Energy	MCA-3 and MCA-6/ DPC	7.2-13.6	100/ Float DPC
TGP 500-2 (36" Natural Gas)	Tennessee Gas Pipeline Company	DPC	7.3-13.0	Float DPC
TGP 524H-100 (4.5" Natural Gas)	Kinder Morgan (Abandoned)	BA	4.6-8.3	250 (25*)
Harvest Pipeline (18" Crude Oil)	Harvest Midstream	BA	8-9.5	500
KEE 500-1 (24" Natural Gas)	Kinetica Energy Express, LLC	BA	Not Surveyed	500

* Denotes a buffer provided by the pipeline company
** Items in red denote an increased construction risk.

In addition to the pipelines discussed above, twelve (12) 2-6" flowlines (including one unverified pipeline) lacking current ownership claims were discovered during the survey within and around MCA-1, 2, and 3. At this time, it is proposed for complete or partial removal of some of these flowlines by the contractor during construction via funding through either the Louisiana Site Restoration Program orphaning process, or through the allocation of Phase II funds. The Louisiana Site Restoration Program created in 1993 by the Department of Natural Resources (DNR) addresses the problem of unrestored orphaned oilfield sites across the state. Orphaned wells are abandoned oil and gas wells for which no owner can be located or the owner has failed to maintain the wellsite in accordance with state rules and regulations. Connecting flowlines, such as those found throughout the BA-0194 project area, are also a part of the abandonment process. The program has allocated funds for the removal or restoration of these wellheads and connecting flowlines, however the amount of funding this program receives is typically low. Therefore, the removal of these flowlines is included as an incurred project cost in the construction estimate.

Approximately 18,804 linear feet of flowlines will need to be removed from MCA-1, 2, and 3 in order to safely construct the project.

7.9 Additional Alternative Bid Items

Two areas identified in the feasibility study performed by Sigma (and screened in Section 7.1), are being considered as potential additional alternative bid items, should bids on the base portion of the project come in lower than the engineers' estimate of probable cost (see Section 8.2 for the engineers' estimate). These additional areas are shown in pink in Figure 36 below. These additional areas are not shown in the 95% drawings (Appendix J).

Figure 36: Layout of potential additional alternative marsh creation areas.

As discussed in Section 7.1, these marsh creation areas (MCA-5 and MCA-6 in Figure 20) were removed from the base portion of the project. However, this section will provide a preliminary evaluation of these potential alternate areas in terms of volume and cost. These areas were included within the scope of the survey and geotechnical services, therefore estimates of the total volume can be made.

The alternate areas were analyzed using the geotechnical subsurface profile and properties from cross section C-C', the same profiles used to evaluate MCA-4 (see Section 6.2). A review of the survey data collected shows that the settlement case analyzed at a -1.0 ft mudline is also applicable to these areas. Therefore, the estimated settlement curve of MCA-4 can be applied to Alternate Areas 1 and 2 (see Figures 17 and 18). Containment strategies for these areas were also evaluated and investigated in the GER. Due to Alternate Area 1 being adjacent to South Lake, erosion control features will be necessary. Area 2 lies along the SWLA Canal as well as North Lake, which may also create erosion concerns due to vessel traffic and wind-generated waves. No evaluations of ACMs along the southern edge of Area 2 was analyzed within the geotechnical report, and floating dredge pipeline within the canal may create navigation hazards. However, unlike MCA-1 where the southern alignment along SWLA is open water, Area 2 has existing remnant marsh which could aid in the reduction of erosion for any earthen containment features. Areas along the northern and eastern alignment of Area 2, and the western and eastern boundaries of Area 1 will require additional erosion control measures, likely in the form of the Lake Dike feature with floated dredge pipe used as erosion control. A summary of preliminary containment features for the two areas is shown in Table 26 below.

Table 26: Preliminary Containment Strategies for Alternate Marsh Creation Areas

Feature	Mudline El. (ft. NAVD88)	Crown Width (ft.)	Crown El. (ft. NAVD88)	Side Slope	Geotextile Fabric?
ECD	-3.0 and above	5	+3.5 (+0.5)	5H:1V	No
Lake Dike	-3.0 and above	10	+3.5 (+0.5)	5H:1V	No
	-3.0 to -4.0				Yes

Tables 27 and 28 below summarize the length and fill quantities of the proposed ECDs and lake dike features, respectively, for the additional areas. Volumes were computed using the same methods discussed in Section 7.2. The cut to fill for containment construction is 2:1.

Table 27: Earthen Containment Dike Quantities for Alternate Areas

Area	Length of Containment (ft)	Design Elevation (ft. NAVD88)	Side Slopes	Volume of Fill (CY)	Volume of Cut (CY)	Required Geotextile Fabric (SY)
1	2,872	+3.5 (+0.5)	5H:1V	10,646	21,292	N/A
2	3,145	+3.5 (+0.5)	5H:1V	11,908	23,816	N/A
Totals	**6,017**			**22,554**	**45,108**	

Note: Construction tolerances were included in the volume calculations.

Table 28: Lake Dike Feature Quantities for Alternate Areas

Area	Length of Containment (ft)	Design Elevation (ft. NAVD88)	Side Slopes	Volume of Fill (CY)	Volume of Cut (CY)	Required Geotextile Fabric (SY)
1	4,975	+3.5 (+0.5)	5H:1V	29,257	58,514	N/A
2	2,808	+3.5 (+0.5)	5H:1V	17,256	34,512	N/A
Totals	**7,783**			**43,513**	**93,026**	

Note: Construction tolerances were included in the volume calculations.

Based on the geotechnical recommendations discussed in Section 6.0, the estimated quantities for the proposed containment features is shown in Table 29. Marsh fill volumes were calculated using the same methods discussed in Section 7.1.

Table 29: Marsh Creation Area Fill Volumes for Alternate Areas

Fill Area	Constructed Fill Elevation (ft. NAVD88)	Area (acres)	Cut to Fill	Volume of Fill (CY)	Volume of Cut (CY)
1	+2.75	67	1.2	239,228	287,074
2	+2.75	42		161,242	193,490
Totals		**109**		**400,470**	**480,564**

These alternate areas will require further evaluation upon Phase II authorization in order to be included in a bid package.

8.0 CONSTRUCTION

8.1 Duration

An approximate construction duration was developed using the CDS Dredge Production and Cost Estimation Software and Microsoft Project. Assuming a 24-inch hydraulic cutter head dredge and incorporating weather days, a total construction time from mobilization to demobilization is approximately six hundred fifty (650) days.

8.2 Engineers' Estimate of Probable Construction Cost

An Engineer's Estimate of Probable Construction Costs (including contingency) was prepared for this project using the CWPPRA PPL 30 spreadsheet and historic bid data. The estimated construction cost has been provided to the CWPPRA Engineering Workgroup in the PPL 30 spreadsheet. The spreadsheet also includes a separate cost estimate for the two (2) potential additional alternative marsh creation areas discussed in Section 7.9.

8.3 Risk

Engineering Design Documents and Plans were prepared by or under the direct supervision of a licensed professional engineer and registered in the state of Louisiana following professional engineering standards as per La. R.S. Title 37, and Louisiana Administrative Code Title 46, Part LXI, Professional and Occupational Standards, as governed by the Louisiana Professional Engineering and Land Surveying Board. The engineering analyses effort completed for this preliminary design report provides guidance and insight pertaining to the construction of the proposed project features based on the data acquired to date, and shall not be used for bidding. These documents are not to be used for construction, bidding, recordation, conveyance, sales, or as the basis for the issuance of a permit. Additional risks pertaining to oil and gas infrastructure, containment construction, and potential erosion of containment features are discussed throughout the report.

9.0 MODIFICATIONS TO APPROVED PHASE 0 PROJECT

As a result of Phase I activities, the features originally approved in Phase 0 have been modified to present a more constructible project for consideration of Phase II funding. Specific modifications detailed throughout the report are summarized below:

- Phase 0 MCA-1 was removed from the scope due to cultural resource concerns (reduction of 62 acres);

- Phase 0 MCA-4 was reduced in size due to deep water conditions (mudline elevations deeper than -3.0 ft.) in the southern portion of the cell (reduction of 93 acres);

- Erosion protection measures were included in order to maintain the earthen containment features throughout construction in order to allow the dredged material time to consolidate (approximately $2.5 million);

- Geotextile fabric is proposed around the entire perimeter of MCA-3 in order to meet the minimum factor of safety (approximately $465,000), and;

- The cost of removal of numerous abandoned oil and gas flowlines within in the project area (approximately $1.3 million) was included.

Table 30 shows the reduction in acreage from the Phase 0 proposal.

Table 30: Summary of Acreage Change from Phase 0

Alternative	Acreage[1]	Acreage Change
Phase 0 Alignment	484	-
30% Alignment	293.5	-39%
95% Alignment	297	-39%

1. Measured from the outside toe.

10.0 REFERENCES

Applied Coastal Research and Engineering (ACRE), 2018. *Determining Recent Subsidence Rates for Barataria Basin, Louisiana: Implications for Engineering and Design of Coastal Restoration Projects*. Final Report prepared for Louisiana Coastal Protection and Restoration Authority. Contract 4400009020, Task 3. 70p.

Bishop Water Technologies. *How long can a Geotube shoreline protection system last?*. July 2019.

Breteler, M. Klein, et al. *Design of Alternative Revetments*. 1998, pp. 1587–1600.

Coastal Environments, Inc. *Remote Sensing Survey and Archival Research of the East Leeville Marsh Creation and Nourishment (BA-194) Project, Lafourche Parish, Louisiana*. March 2019.

Coastal Protection and Restoration Authority of Louisiana. *Bayou Bonfouca Marsh Creation Project PO-104 Final Design Report*. Baton Rouge, LA. October 2012.

Coastal Protection and Restoration Authority of Louisiana. *Cole's Bayou Marsh Restoration Project.* Baton Rouge, LA. November 2017.

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. *Lost Lake Marsh Creation and Hydrologic Restoration Project.* Baton Rouge, LA. October 2012.

Coastal Protection and Restoration Authority of Louisiana. *Louisiana's Coastal Master Plan 2017*. 2017.

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

Coastal Wetlands Planning, Protection, and Restoration Act. *East Leeville Marsh Creation and Nourishment (BA-0194) Project Fact Sheet*. March 2017.

Curole, Glen, and Dr. Earl Melancon. "Evaluating the Shoreline Protection Functioning of Three Divergent Constructed Oyster Reef Structures in Terrebonne Bay, Louisiana." Coastal Protection and Restoration Authority, 18 Mar. 2014.

Das, Braja M. *Geotechnical Engineering Handbook*. Cengage Learning, 2014.

Das, Braja M., and Khaled Sobhan. *Principles of Geotechnical Engineering*. 8th ed., Cengage Learning, 2010.

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.

Doiron, Linda N. and Whitehurst, Charles A. *Geomorphic Processes Active in the Southwestern Louisiana Canal, Lafourche Parish, Louisiana*. Louisiana State University. National Aeronautics and Space Administration. October 1974.

Earth Search Inc. *DRAFT Negative Findings Report for the Phase I Cultural Resources Investigations for East Leeville Marsh Creation and Nourishment Project (BA-194), Lafourche Parish, Louisiana.* May 2018.

GeoEngineers, Inc. *Geotechnical Data Report.* October 2018.

GeoEngineers, Inc. *Geotechnical Engineering Report.* October 2018.

“How Long Can a Geotube Shoreline Protection System Last?” Bishop Water Technologies, 2 July 2019, bishopwater.ca/geotube-longevity/.

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

Morris P. Hebert, Inc. (MPH). *Final Report*. January 2019.

“New Tidal Datum Updates - NOAA Tides & Currents.” NOAA/CO-OPS ODIN - NOAA Tides & Currents, tidesandcurrents.noaa.gov/press/tidaldatum.html.

Project Delivery Team for the LCA Mississippi River Hydrodynamic and Delta Management Feasibility Study (MRHDM), 2015. *Proposal for Addressing Relative Sea Level Rise in the LCA Mississippi River Hydrodynamic and Delta Management (MRHDM).* 20 pp. 26 March 2015.

GCR, Inc. *SONRIS Coastal Permit Lines as of December 5, 2018 – Limited Pipeline and Utility Report*. 28 December 2018.

National Concrete Masonry Association. Design Manual for Articulating Concrete Block (ACB) Revetment Systems. 2nd ed., NCMA Articulated Concrete Block Subcommittee, 2010.

National Oceanic and Atmospheric Administration, National Marine Fisheries Service, 2015. *East Leeville Marsh Creation and Nourishment, Final Project Information Sheet for Wetland Value Assessment (WVA).* October 2015.

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.

Russo, Edmond Joseph, "Stability of Articulated Revetments Against Wave Attack on Shallow Soft Soil Slopes" (2009). LSU Doctoral Dissertations. 3003.

Sharpe, L.A. and Mouledous, M. *Guidance for Using CRMS Surface Elevation Change and Accretion Data for Planning Marsh Creation Projects*. Coastal Protection and Restoration Authority of Louisiana, Lafayette, Louisiana. 8 March 2019.

Sigma Consultants, Inc. *Feasibility Study Technical Report*. August 2017.

Sigma Consultants, Inc. *LA1 Improvements Golden Meadow to Fourchon Route LA 1 Lafource Parish*. January 2016. Revised May 2016.

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.

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

United States Army Corps of Engineers (USACE). Hurricane and Storm Damage Risk Reduction System Design Guidelines. Chapter 4. pp 4-37–4-40.

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.

Appendices A-K See Link Below:

ftp://ftp.coastal.la.gov/BA-0194%20East%20Leeville/95%25%20Design%20Package/