Long Point Bayou Marsh Creation Project (CS-0085)

Coastal Wetland Planning, Protection, and Restoration Act PPL 28

Draft (95%) Design Report

State Project Engineer:
Kazi Sadid, P.E.

State Project Manager:
Renee Bennett, P.M.P.

Federal Project Manager:
Brad Crawford, P.E.

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List of Acronyms

BU	Beneficial Use
CMFE	Constructed Marsh Fill Elevation
CPRA	Coastal Protection and Restoration Authority
CPT	Cone Penetration Test
CRMS	Coastwide Reference Monitoring System
CS	Calcasieu/Sabine
CSC	Calcasieu Ship Channel
CSD	Cutterhead Suction Dredge
CSI	Chustz Surveying Inc.
CWPPRA	Coastal Wetlands Planning, Protection and Restoration Act
CY	Cubic Yard
DMMP	Dredged Material Management Plan
DPC	Dredge Pipeline Corridor
DOE	Department of Energy
ECD	Earthen Containment Dike
EM	Engineering Manual
ENCOS	ENCOS Environmental & Coastal Services, Inc.
EPA	Environmental Protection Agency
ESLR	Eustatic Sea Level Rise
FOS	Factor of Safety
FT	Foot
FY	Fiscal Year
GER	Geotechnical Engineering Report
GIS	Geographic Information System
GIWW	Gulf Intracoastal Waterway
HDPE	High-density polyethylene
IDIQ	Indefinite Delivery/Indefinite Quantity
ITD	Internal Training Dike
LF	Linear Foot
LiDAR	Light Detection and Ranging
LL	Liquid Limit
MCA	Marsh Creation Area
MCDG	Marsh Creation Design Guidelines
MCY	Million Cubic Yard
MHW	Mean High Water
MLW	Mean Low Water
MLLW	Mean Lower Low Water
MTL	Mean Tide Level
NAD83	North American Horizontal Datum of 1983
NAVD88	North American Vertical Datum of 1988
NDVI	Normalized Difference Vegetation Index
NGS	National Geodetic Survey
NRHP	National Register of Historic Places
NWR	National Wildlife Refuge
OPUS	Online Positioning User Service

PI	Plasticity Index
PL	Plastic Limit
PPL	Project Priority List
PPT	Parts per Thousand
PSDDF	Primary Consolidation, Secondary Compression, and Desiccation of Dredged Fill
PSI	Professional Service Industries, Inc.
RCG&A	R. Christopher Goodwin and Associates, Inc.
RPA	Registered Professional Archeologist
RSLR	Relative Sea Level Rise
RTK	Real-time Kinematic
SLR	Sea Level Rise
SONRIS	Strategic Online Natural Resources Information
SOP	Standard Operating Procedure
SPT	Standard Penetration Test
TBM	Temporary Benchmark
TIN	Triangulated Irregular Network
TY	Target Year
USACE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Service

Executive Summary

The Long Point Bayou project area is in Cameron Parish, Louisiana. The Calcasieu/Sabine (CS) Basin lost approximately 200 mi^2 of its coastal wetlands from 1932 to 2016, based on land area analyses of using historical U.S. Army Corps of Engineers (USACE) land loss data, aerial photography data, and satellite imagery data (Couvillion et al., 2017). Persistent flooding of marshes from sea-level rise, combined with saltwater intrusion from the Gulf of Mexico through the Calcasieu River and subsidence in the basin, is deteriorating wetlands and causing land loss. The solution to the flooding problem involves raising the marsh elevation with dredged sediment so that the marsh can support healthy marsh vegetation for the 20-year project design life.

The specific goals of the project are to:

- Create and/or nourish approximately 392 acres of saline marsh in shallow open water.
  - Hydraulically dredge and transport sediment to the project area from the Calcasieu Ship Channel (CSC).
  - Construct a marsh platform to an elevation that is intertidal throughout the design life of the project.
  - Create eight (8) acres of tidal creeks at approximately TY3 by strategically gapping the containment dike and reestablishing tidal exchange.

This project will be designed by CPRA and bid and constructed by the USACE as part of their maintenance dredging event for the lower CSC. The material removed from the CSC will be beneficially used to meet the CS-0085 project goals. The USACE will credit the cost of the project up to the Federal Standard, defined as the least costly dredged material disposal or placement alternative (or alternatives) that is consistent with sound engineering practices and meets all federal environmental requirements. The probable construction cost for the project, assuming no credit from the USACE, is approximately $14,466,008. The estimated incremental construction cost to CWPPRA program (i.e., costs outside of the federal standard) is approximately $6,091,896.

1.0 Introduction

The Long Point Bayou Marsh Creation and Nourishment project is located in the Calcasieu/Sabine Basin shown in **Figure 1**. In 2019, the Louisiana Coastal Wetlands Planning, Protection and Restoration Task Force designated CS-0085 as part of the 28th Priority Project List (PPL28). The Environmental Protection Agency (EPA) was designated as the lead federal sponsor with 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 of the State of Louisiana. The Louisiana Coastal Protection and Restoration Authority (CPRA) is serving as the local sponsor and will provide engineering and design services.

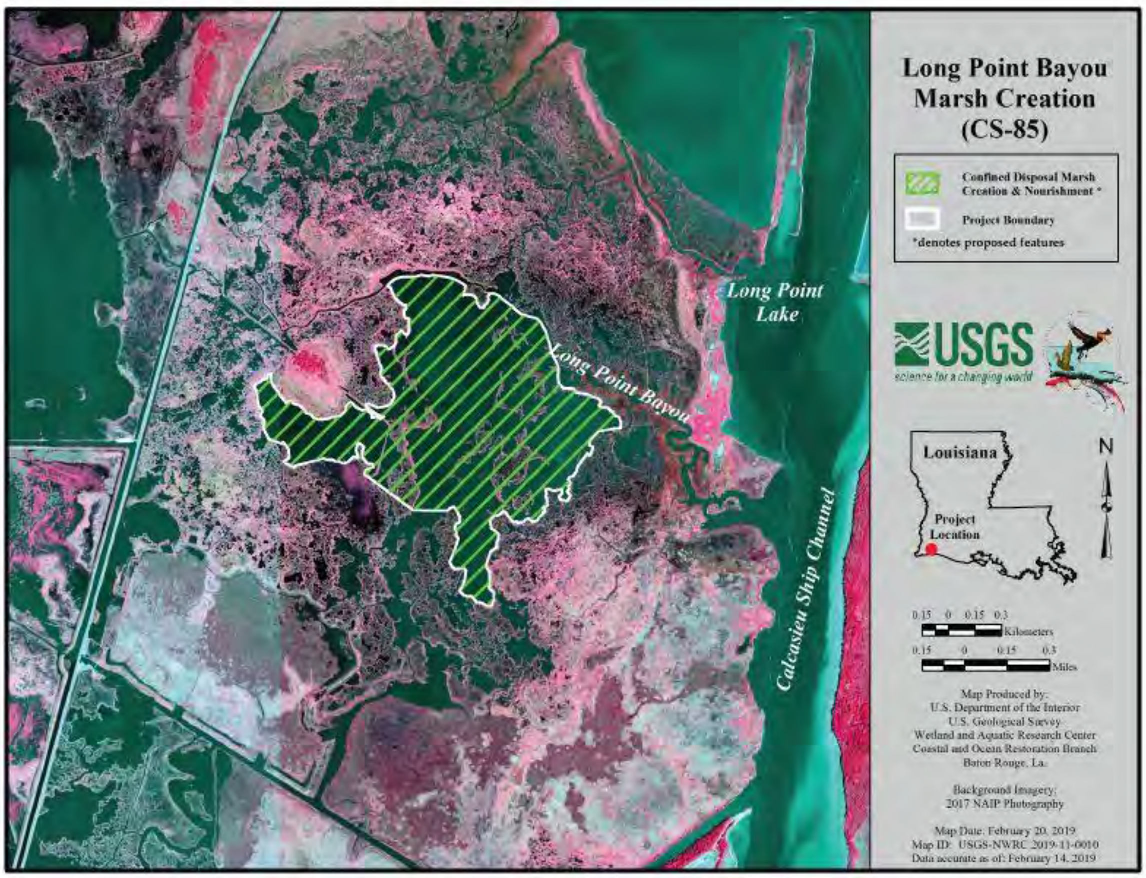

Figure 1: Phase 0 Project Area (CWPPRA 2019)

1.1 Project Consultant Team

The CPRA Engineering Division has been tasked with providing the professional engineering and drafting services for the proposed project and the USACE will develop the project bidding documents. To complete these technical tasks, several professional services were utilized from the approved CPRA Indefinite Delivery/Indefinite Quantity (IDIQ) contracts. The project's consulting team included CE Hydro, LLC (CE Hydro), R. Christopher Goodwin and Associates, Inc.

(RCG&A), ENCOS Environmental & Coastal Services, Inc. (ENCOS), Professional Service Industries, Inc. (PSI), Chustz Surveying Inc. (CSI), and C.H. Fenstermaker & Associates, L.L.C (Fenstermaker). CE Hydro had their subcontractor, RCG&A, perform a cultural resources investigation within the project area, and their other subcontractor, ENCOS, collected vibracores in the area. PSI performed geotechnical exploration and engineering services for the project, including the analysis of project features. CSI worked with PSI to provide survey and magnetometer services for geotechnical sampling locations. Fenstermaker collected topographic and bathymetric elevations and completed a magnetometer survey for the project area.

The CPRA Project Management Division has been tasked with leading the land rights and the CPRA Planning and Research Division was tasked with the environmental work. In order to complete these tasks, several land services were required. Independent Land Services LLC provided land rights services, researching ownership information in the tax assessment records, preparing a tax assessment report, chain of title report, and pipeline report for the project.

1.2 Project Area History

A combination of human induced and natural processes has contributed to land loss in the project area. These factors include saltwater intrusion, hydrologic modifications of the Calcasieu basin, oil and gas extraction and infrastructure, storm-driven erosion, subsidence, and sea level rise.

Two major navigation channels constructed in the 20th century, the Gulf Intracoastal Waterway (GIWW) and the Calcasieu River Ship Channel (CSC), altered the hydrology of the marshes in the area. These large navigation channels along with smaller channels, bayous, and oilfield canals, form a hydrologic connection with the Gulf of Mexico and Calcasieu Lake that allows higher salinity water to circulate through to interior marshes. This resulted in marsh loss and an overall shift to more saline marsh habitats in the region. The Calcasieu Sabine Basin Report published in 2019 identified the primary cause of marsh loss in the region is due to flooding and impoundments. Persistent flooding weakens the root systems of marsh vegetation making it vulnerable to removal by hurricanes (McGinnis et al., 2019).

While land loss in the region has been exacerbated by the storm surge of Hurricanes Rita (2005) and Ike (2008), the Long Point Bayou project area does not appear to have been significantly affected. Examining satellite imagery dating back to 1998 shows the amount of marsh in the area has been consistent. Recently, Hurricanes Laura and Delta made landfall in Cameron Parish on August 27, 2020, and October 10, 2020, respectively. Based on site visits to other nearby projects and satellite imagery showing portions of the project area post-storm, the marsh in the project area was not severely affected by the storms.

Natural gas exploration and drilling is also evident within the basin but there is no sign of significant activity within the project area. Some other marsh creation projects and confined disposal facilities were built surrounding the project area, mostly by maintenance dredge disposal from the CSC, including a beneficial use project built by the USACE in 1999 just south of the project area (**Figure 2)**.

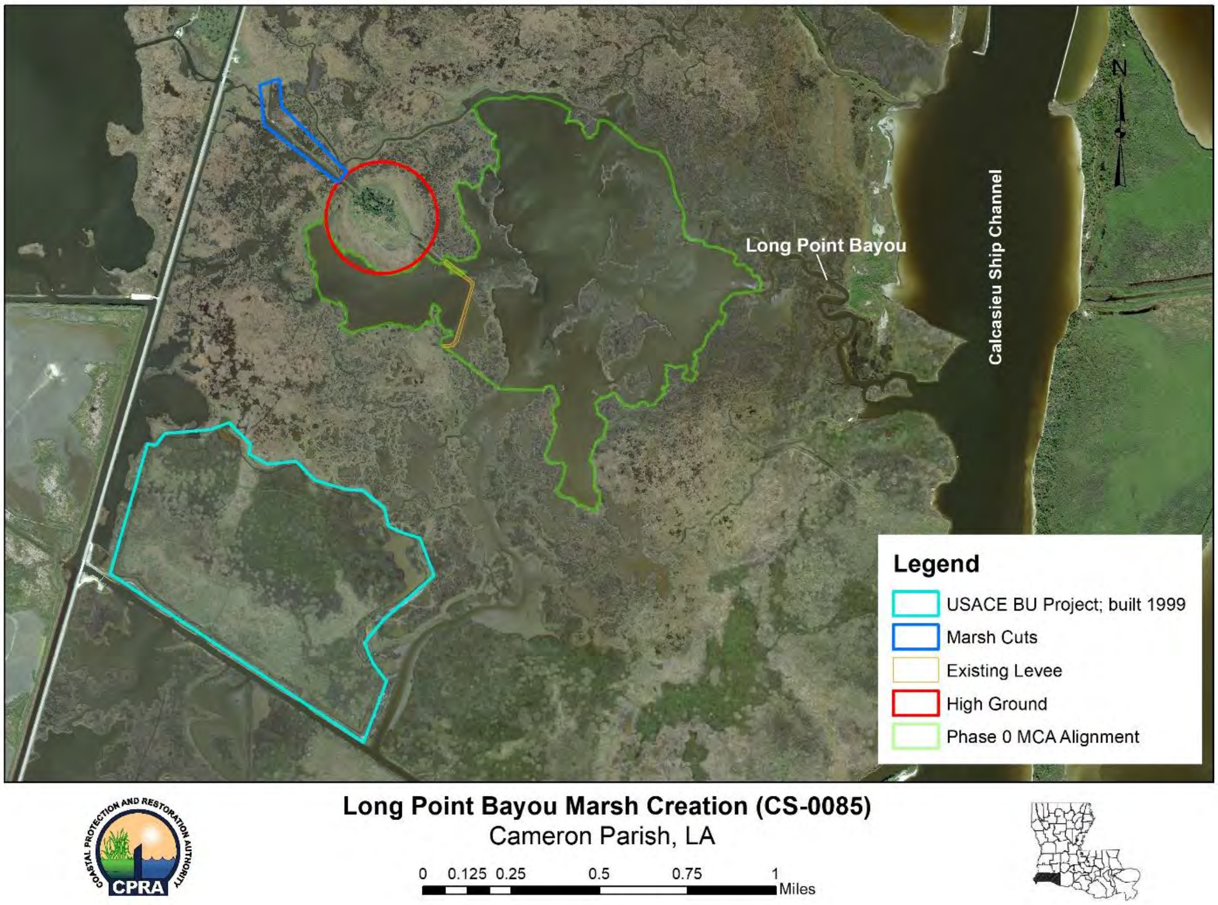

Figure 2: Features from unidentified projects and nearby Beneficial Use (BU) project

1.3 Project Goal

The goal of the CS-0085 Long Point Bayou Marsh Creation Project is to restore degrading marsh. Historical maps show that the area was nearly all land in 1955 (Osowski, 2021). The project area has been influenced by saltwater intrusion, increased water fluctuations and erosion, which has led to a conversion from intermediate and brackish marsh to saline.

The specific goals of the project are to:

- Create and/or nourish approximately 392 acres of saline marsh in shallow open water.
  - Hydraulically dredge and transport sediment to the project area from the Calcasieu Ship Channel (CSC).
  - Construct a marsh platform to an elevation that is intertidal throughout the design life of the project.
  - Create eight (8) acres of tidal creeks at approximately TY3 by strategically gapping the containment dike and reestablishing tidal exchange.

2.0 Existing Conditions

2.1 Neighboring Projects

Sabine National Wildlife Refuge Beneficial Use Cycles

Two CWPPRA projects, CS-0028 and CS-0081, have previously been authorized and are ongoing in the region to utilize material dredged from the CSC to create marsh on the Sabine National Wildlife Refuge (NWR). These projects, known as the Sabine Refuge Marsh Creation Cycles, are a series of marsh creation projects sponsored and designed by the USACE (**Figure 3**). The implementation is an effort between United States Fish and Wildlife Service (USFWS), USACE, and CPRA. The Sabine Refuge Marsh Creation Cycles are part of a larger CWPPRA programmatic effort intended to beneficially utilize USACE maintenance dredging material from the CSC.

CS-28 Cycles 1-5 began construction in 2001 with Cycle 1 and completed construction in 2015 with Cycles 4 & 5. Cycle 1, Cycle 2-Permanent Pipeline, and Cycle 3 remain under USACE sponsorship. In 2012, the Cycles 4 & 5 marsh creation cycles were transferred to U.S. Fish and Wildlife Service (USFWS) as the lead Federal Sponsor. Cycle 1 was dredged during January 2001 maintenance dredging from River Mile 8.3 to River Mile 10.4 and placed approximately 1,000,000 cubic yards of material. This cycle created about 200 acres of vegetated marsh. Cycle 2 was constructed in May 2010 to transport material from the CSC to the marsh creation cells. Cycle 3 was completed using the May 2007 maintenance dredging of the ship channel with material from River Mile 9 to River Mile 12. The material was pumped into a 230-acre containment area. Cycles 4 and 5 were completed by February 2015 using material from River Mile 10.5 to River Mile 15 placed via the permanent pipeline. Cycles 4 & 5 marsh creation cells were 230 and 232 acres, respectively. During this dredging cycle, a supplemental area referred to as Unit 1a North and South were constructed, consisting of 250 and 194 acres, respectively. For each cycle, material was placed up to +2.26 ft. NAVD88 with a final target elevation of +0.26 ft. NAVD88 after initial consolidation (5 years).

The goal of the CS-0081 Cycle 6 & 7 project is to create approximately 900 acres of marsh and nourish about 29 acres of marsh over the course of two maintenance dredging events. As was done for CS-0028, the dredged material will be transported via the permanent pipeline into the area and placed to an elevation of +1.76 ft. to +2.26ft. NAVD88.

Figure 3: CS-81 Sabine Marsh Creation Cycles 1 to 7.

2.2 USACE Maintenance Dredging

The CSC is a 68-mile-long deep draft federal navigation channel spanning Cameron and Calcasieu Parishes and connecting the Gulf Intracoastal Waterway (GIWW) with the Gulf of Mexico. The channel is split into reaches: upper (River Mile 23 to River Mile 36, including Clooney Island and Devil's Elbow), lower (River Mile -1 to River Mile 22), and bar (River Mile -2 to River Mile -32) (**Figure 4**). The upper and lower reaches are dredged in alternating years. This project includes use of dredged material from the lower reach since it is closest to the project site. The USACE is responsible for keeping the channel at the authorized dimensions.

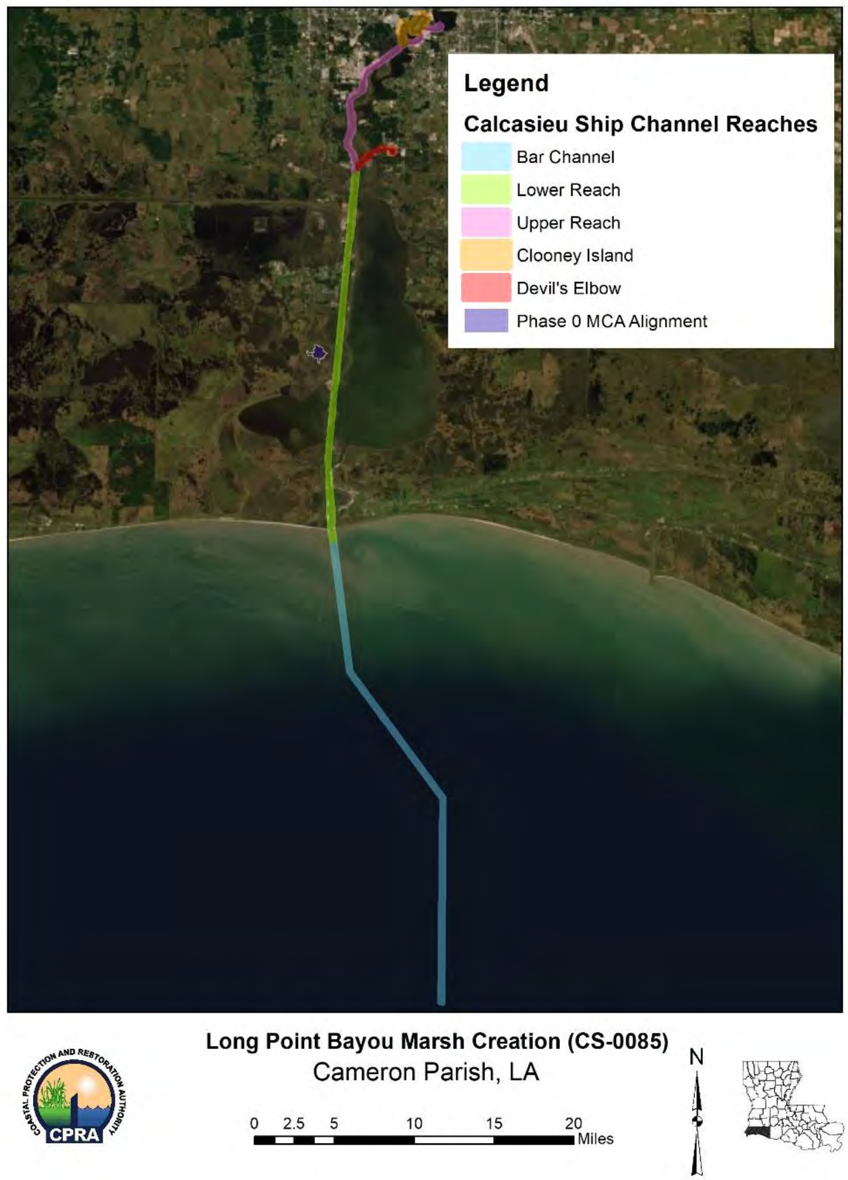

Figure 4: Calcasieu Ship Channel Reaches

2.3 Land Ownership

A land rights investigation was conducted in accordance with the CWPPRA Standard Operating Procedures (SOP) and implemented as per CPRA's *Marsh Creation Design Guidelines* (MCDG1.0). The investigation revealed approximately 16 different tracts of land in the project area (**Figure 5**). The southern tip of the project area is part of the Sabine National Wildlife Refuge (NWR).

Mr. Glenn Harris is the temporary acting Refuge Manager for the Sabine NWR owned by the U.S. Federal Government.

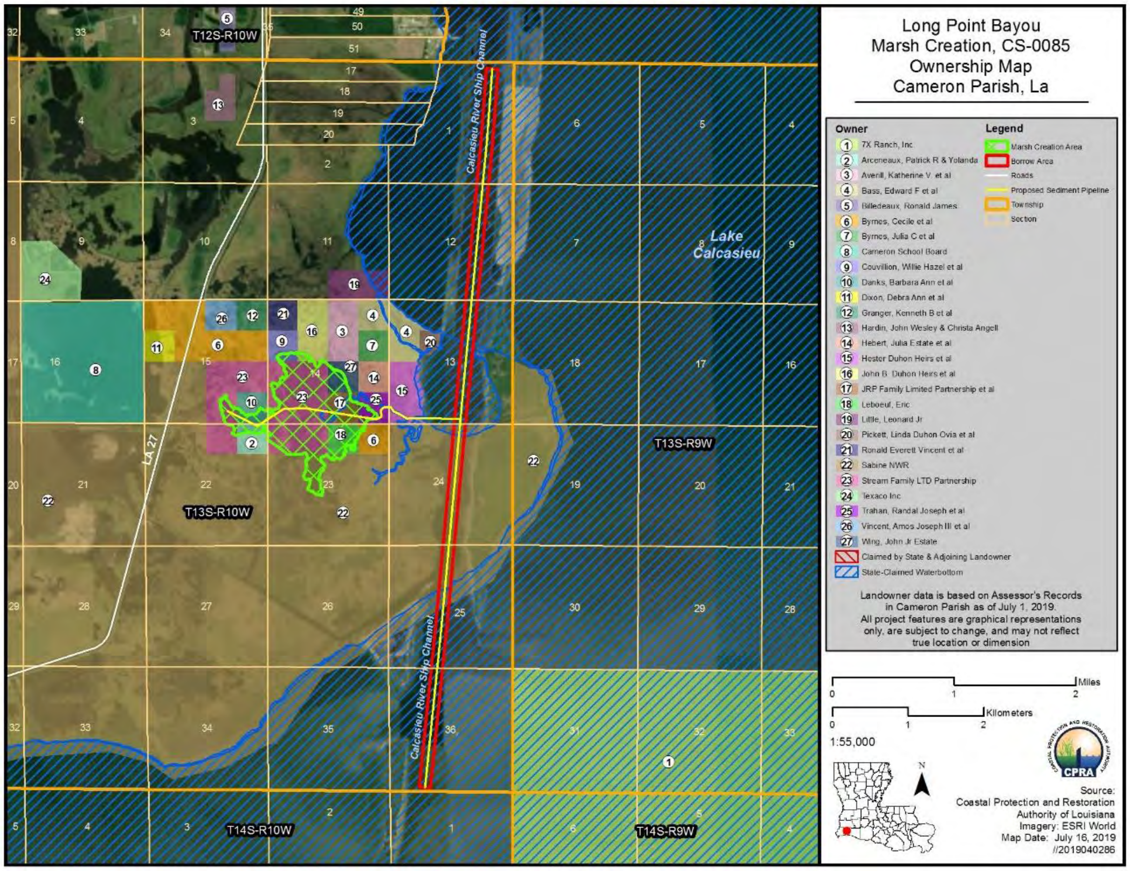

Figure 5: CS-0085 Land rights map (CPRA 2019)

2.4 Cultural Resources Assessment

CPRA contracted CE Hydro to perform a cultural resources survey on the proposed marsh creation area (MCA) and on two proposed dredge pipeline conveyance corridors. A Registered Professional Archeologist (RPA) was involved for the efforts. No evidence of cultural resources was identified within the two dredge pipeline corridors. Since there was a previously identified site within the marsh creation area, two auger tests were done within the boundary of previously identified Site 16CM147, the Long Point Bayou Pirogue Site. This site was previously determined to be ineligible for listing in the NRHP. No evidence of cultural material or features was identified in the MCA.

A copy of the cultural resource investigation report for the marsh creation area and the dredge pipeline corridor can be found in **Appendix A**.

2.5 Oyster Lease Assessment

Based on SONRIS database, no oyster leases have been identified within or near the marsh fill, dredge pipeline conveyance corridor, or borrow area.

2.6 Hydrologic Conditions

2.6.1 Sea Level Rise and Subsidence

In order to properly design the CS-0085 project and ensure it is built and performs according to the objectives of 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 0.31 to 1.98 meters of sea level rise by 2100 and are bracketed in lower-bound and upper-bound scenarios to account for uncertainty. The CPRA Planning and Research Division recommends using the one (1.0) meter scenario for the purposes of design of marsh creation projects. This accounts for approximately 6 inches of sea-level rise over the 20-year project life.

Subsidence is defined as the rate of local vertical land movement. Natural causes of subsidence include plate tectonics and Holocene sediment compaction. Anthropogenic causes of subsidence include drilling and removal of subsurface fluids. Local subsidence rates in this region are approximately 4.3 mm per year (0.17 inches/yr.) (Reed and Yuill, 2016). This equates to a decrease in the project area mudline elevation of 3.4 inches over the 20-year project design life.

2.6.2 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 optimal marsh elevation range that maximizes the duration that the restored marsh will be at intertidal elevation throughout the 20-year project life.

A tidal datum is referenced to a fixed-point known as a benchmark and is typically expressed in terms of mean high water (MHW), mean low water (MLW), and mean tidal levels (MTL) over the observed period. 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 station CRMS0687 located at 29.9405823°, - 93.35432° was selected as the control station because of its proximity to the project area (**Figure 6**) (**Appendix B**). The period of record used was May 1, 2015, to May 1, 2020, a five-year period as per CPRA's MCDG 1.0. The results of the tidal datum determination for the CS-0085 project area are as follows:

- MHW = +1.05 ft., NAVD88
- MLW = +0.06 ft., NAVD88
- MTL = +0.56 ft., NAVD88

The MHW at CRMS 0687 during the past five (5) years was +1.05 ft. NAVD88 and the MLW was +0.06 ft. NAVD88. This would suggest a mean range in the tide of 0.99 ft.

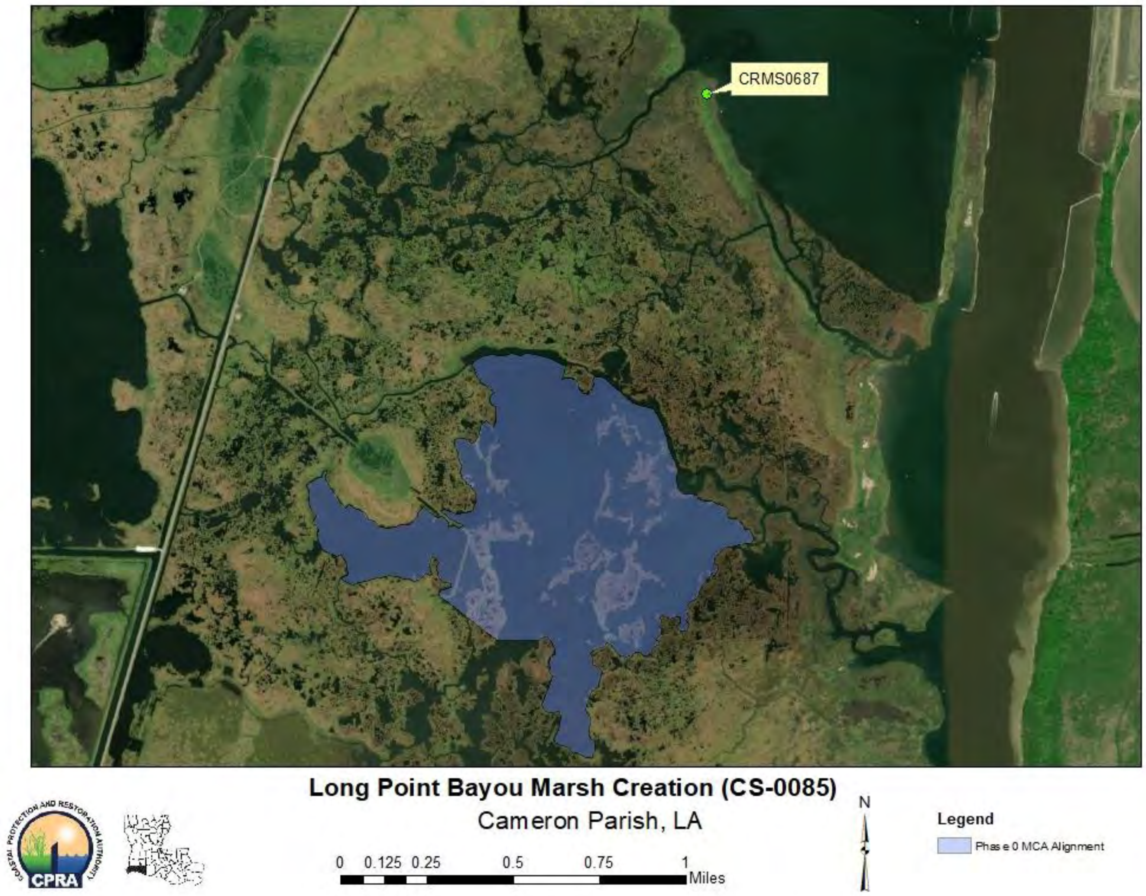

Figure 6: CRMS0687 Location

2.6.3 **Percent Inundation Determination**

The vertical positioning of marsh platforms and the frequency with which the marsh floods strongly influence plant communities and marsh health (Visser et al., 2003; Mitsch, 1986). Historically, the tidal range between MHW and MLW has been the accepted range for healthy marsh. 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. Percent inundation refers to the percentage of the year a certain elevation of land would be flooded. Therefore, using percent inundation rather than tidal range as a proxy for marsh health can give a more accurate representation of the water levels found in the area.

To determine percent inundation, the percentiles were calculated based on data gathered from the CRMS0687 station for the period from May 1, 2015, to May 1, 2020. **Table 1** presents the percent inundation results with eustatic sea-level rise applied for the duration of the project life. Based on salinity recordings from nearby CRMS site CRMS0687, peak levels can reach between 20-30 parts per thousand (ppt) sporadically throughout the year with the yearly average around 10 ppt. The 2019 mean growing season salinity (March 1 - October 31) was 7.22 ppt. Freshwater marshes have salinity levels less than 0.5 ppt, intermediate marshes have a salinity range of 2±10 ppt, brackish marshes are around 10±20 ppt, and saline marshes are higher than 20 ppt. While the salinity in the project area varies over the year, the marsh type that would ensure the long-term success of the CS-0085 marsh creation project was determined to be saline based on the latest salinity, marsh type classification and vegetative community data for CRMS 0687, as well as the data taken on the field trip (Osowski, 2021). Saline marshes are most productive when flooded between 20% and 80% of the time (Snedden and Swenson, 2012).

Table 1 : Percent Inundation Elevations with ESLR

Percent Inundation Elevations with ESLR		
Percent Inundated	**TY0 Marsh Elevation (ft. NAVD88)**	**TY20 Marsh Elevation (ft. NAVD88)**
1%	2.082	2.586
10%	1.422	1.926
20%	1.172	1.676
30%	1.002	1.506
40%	0.852	1.356
50%	0.722	1.226
60%	0.572	1.076
65%	0.492	0.996
70%	0.412	0.916
80%	0.202	0.706
90%	-0.088	0.416

*Highlighted rows represent the optimal inundation range for saline marsh

3.0 Surveys

Survey data obtained for the project includes the following:

- Topographic, bathymetric, and magnetometer surveys of the marsh creation area and dredge pipeline corridors;
- Bathymetric data of the Calcasieu Ship Channel.

Fenstermaker completed topographic/bathymetric, Light Detection and Ranging (LiDAR), and magnetometer surveys from April – June 2020, and a probing investigation in the marsh creation area.

Bathymetric survey data in the CSC was collected by the USACE in August 2020 for the lower CSC, from River Mile 5 to River Mile 17, as part of its recurring survey efforts that occur every 3-4 months.

3.1 Survey Datum

The survey datum used for horizontal coordinates was NAD83 (2011). NAVD88 GEOID18 was used for vertical control in the marsh creation area. Other data sets in the marsh creation area, such as the survey for the soil borings as well as the CRMS station data were converted from GEOID 12A to GEOID18 for consistency. The conversion between GEOID 12A and GEOID18 is as follows:

0 ft. NAVD88 GEOID12A = -0.14 ft. NAVD88 GEOID18

The USACE uses the Mean Lower Low Water (MLLW) datum to survey the CSC for navigational dredging, so MLLW was used for referencing the borrow area elevations in the CSC.

3.2 Horizontal and Vertical Control

The survey control point for the topographic and LiDAR survey was at survey monument TT-147. In addition, the survey crew performed a quality control check of TT-147 at deep rod monument CS23-SM-01. Both survey monuments are located along LA Hwy-27 and are shown on the project layout sheet in the design drawing. A temporary benchmark (TBM) was installed along an existing earthen dike to provide a central location for performing RTK survey quality control checks. The field survey was accomplished utilizing real time kinematic (RTK) surveying procedures and checked using National Geodetic Surveying (NGS) Online Positioning User Service (OPUS). The data sheet for the survey monument can be found in **Appendix C**.

3.3 Marsh Creation Area Surveys

3.3.1 Topographic Survey

Fenstermaker began surveying the marsh creation area on April 27, 2019. Survey transects were collected approximately every 250 ft. Transects were taken across open water areas, broken marsh, and across pipeline canals. Position, elevation, and water depths were recorded every 25 ft. along each transect or where elevation changes were greater than 0.5 foot. In addition to the survey transects across the marsh fill area, a profile and transects were also taken along Long Point Bayou in the north and an existing earthen dike in the western portion of the cell.

Topographic and bathymetric surveys in the marsh creation area were obtained in a manner consistent with CPRA’s MCDG 1.0. The survey was conducted by airboat using a 2-meter pole with the RTK rover unit attached. A fixed height aluminum rod with a 6-inch diameter metal plate as the base of the rod was used to prevent the rod from sinking into the water bottom. The topographic portions were merged with the bathymetric portions at the land/water interface and were separated by no more than 50 ft.

LiDAR data was also collected by Fenstermaker using a drone and multi-spectral camera. Images were corrected, rectified, and used to produce a normalized difference vegetation index (NDVI) map to reflect areas of healthy and distressed marsh (see **Appendix C**). This information helped determine areas to collect surveys for the determination of healthy marsh elevation, as discussed in **Section 3.6**.

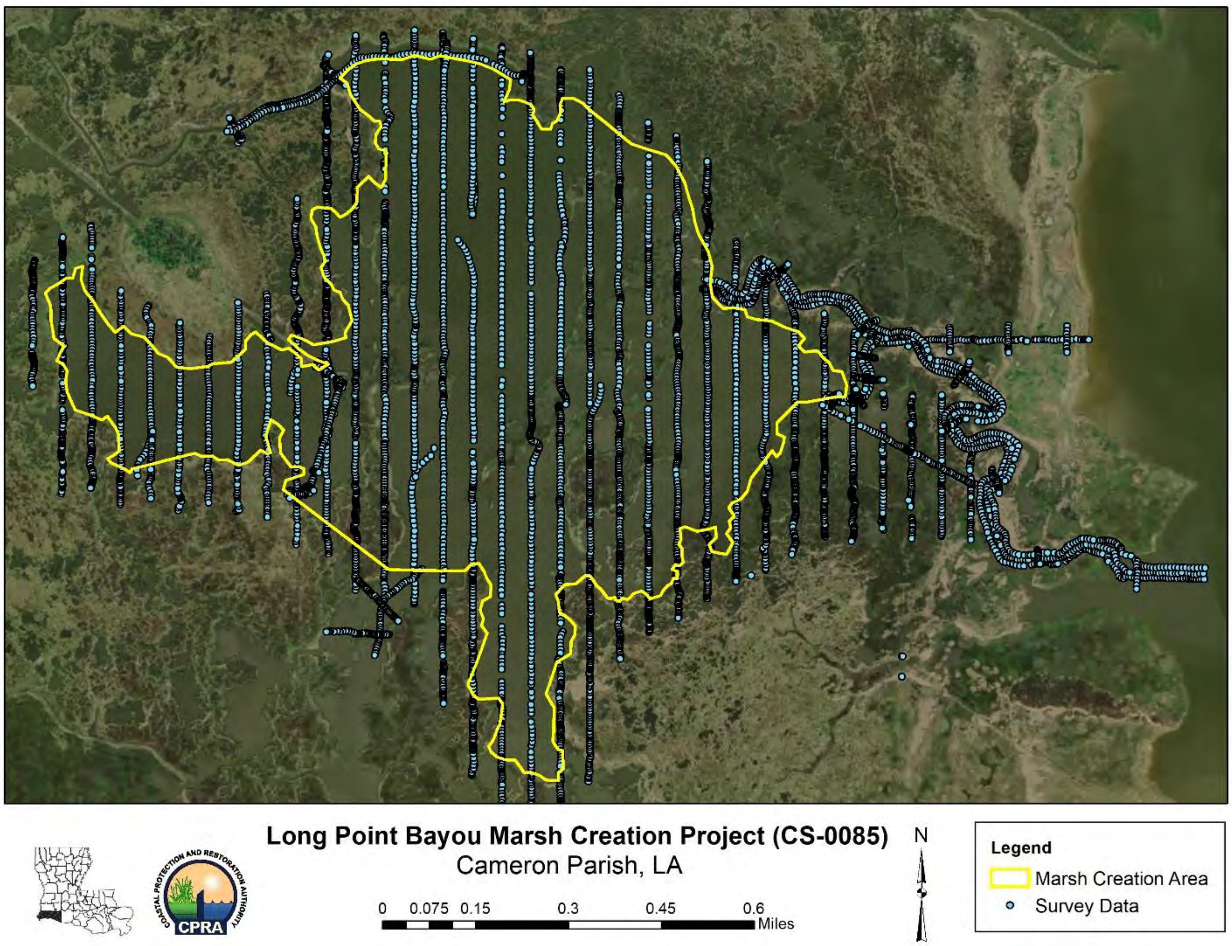

Figure 7: Survey points collected by Fenstermaker

3.3.2 **Magnetometer Survey and Pipeline Probing Investigation**

A magnetometer survey was also taken along all transects as shown in **Appendix C** in order to locate any pipelines or other infrastructure in the fill area. The magnetometer survey detected 107 magnetic anomalies in the marsh creation area and the access route. These anomalies ranged in amplitude from 36 to 2988 gamma, and in duration from zero (0) to 32 ft. The magnetic hits in the area allowed the surveyor to identify a Strategic Petroleum Reserve Pipeline running north to south through the access route in the Long Point Bayou. The USACE previously identified this pipeline as a 36-inch Department of Energy (DOE) brine pipeline. As part of this project, Fenstermaker probed along this pipeline at 16 locations spaced approximately 200 ft. apart and found the depth of cover ranged from 4 ft. to 11 ft. A map of the magnetic anomalies and probing survey is shown in **Figure 8** and a summary of the information collected on this pipeline is shown in **Table 2** and **Figure 9**.

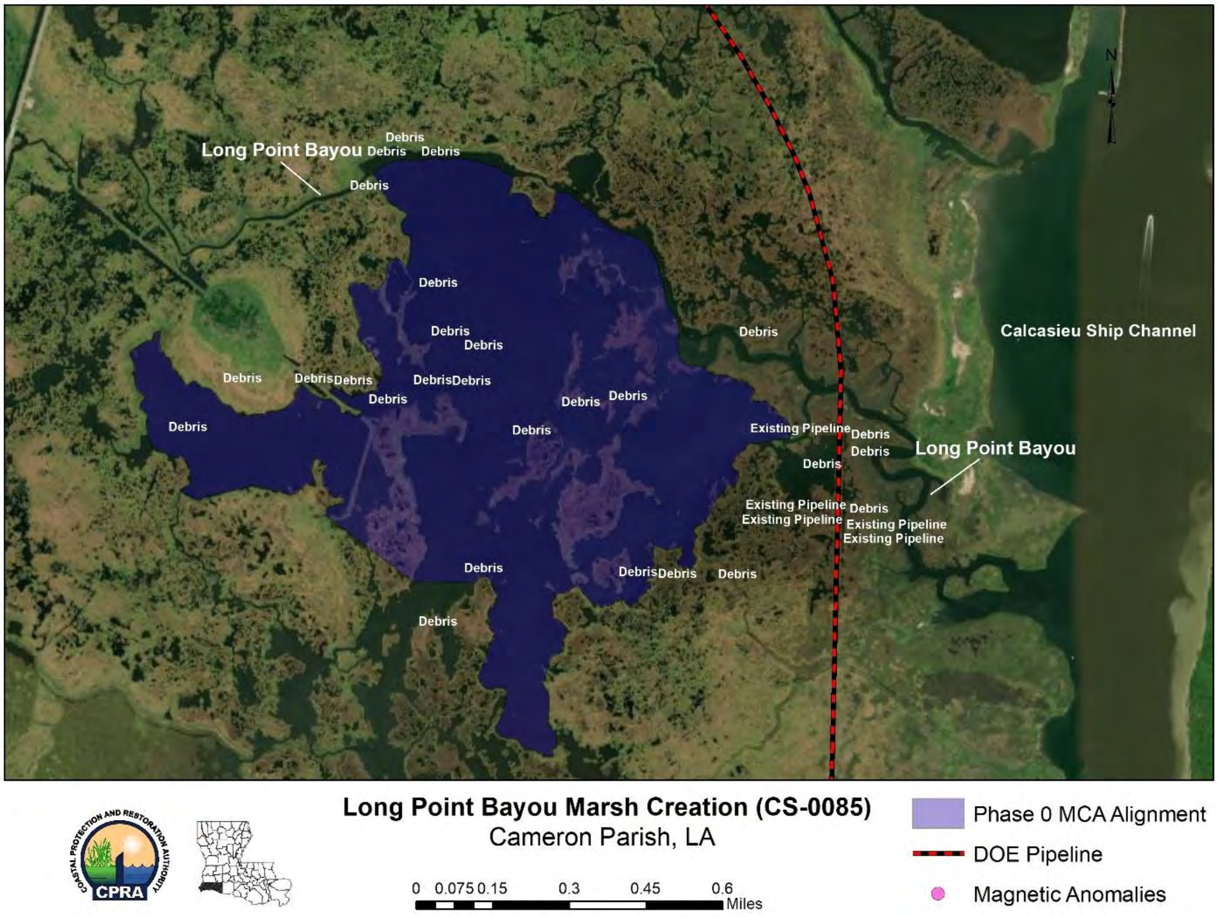

Figure 8: Magnetic Anomalies

Table 2: DOE Brine Pipeline Probed Locations

Point_Num	Northing	Easting	Elevation* Natural Ground	Description	Depth of Cover	Elevation* at Top of Pipe
134-300	523539.69	2641993.39	0.56	PL_EX	8.8	-8.2
134-301	523482.71	2641996.51	0.49	PL_EX	9.0	-8.5
134-302	523410.89	2641999.43	0.40	PL_EX	10.0	-9.6
134-303	523387.34	2642000.60	0.28	PL_EX	11.0	-10.7
134-304	523129.05	2641998.86	0.26	PL_EX	10.0	-9.7
134-305	522915.60	2641996.93	0.31	PL_EX	10.0	-9.7
134-306	522763.57	2641994.37	0.44	PL_EX	8.0	-7.6
134-307	522593.72	2641990.42	0.36	PL_EX	6.5	-6.1
134-308	522410.71	2641985.87	0.37	PL_EX	5.0	-4.6
134-309	522409.81	2641988.54	1.85	PL_EX	5.0	-3.2
134-310	522240.09	2641981.55	0.17	PL_EX	4.5	-4.3
134-311	522049.00	2641978.19	0.18	PL_EX	5.0	-4.8
134-312	521788.56	2641973.45	0.26	PL_EX	4.0	-3.7
134-313	521590.62	2641969.07	0.26	PL_EX	4.0	-3.7
134-314	521352.38	2641965.07	0.38	PL_EX	5.0	-4.6
134-315	521145.14	2641964.01	0.36	PL_EX	7.0	-6.6
134-316	520943.37	2641962.74	0.60	PL_EX	7.0	-6.4

**Elevations are in ft. NAVD88*

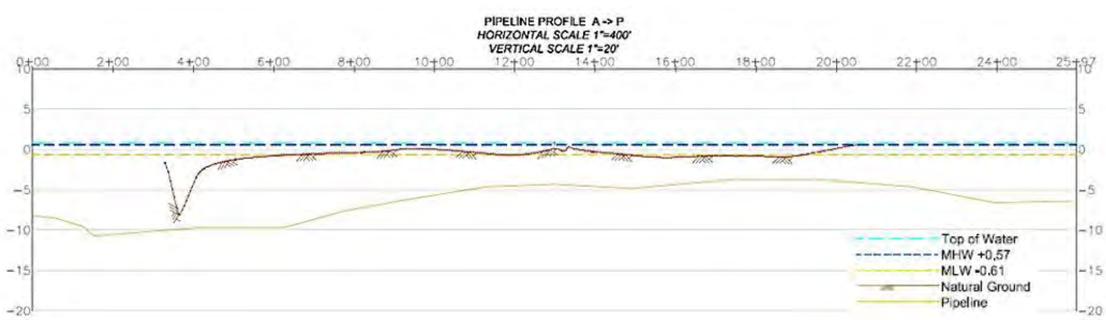

Figure 9: Pipeline profile from north to south provided by Fenstermaker

3.4 Borrow Area Survey

The CSC is surveyed by the USACE quarterly. Survey transects in the CSC are taken every 600 ft. perpendicular to the channel centerline. Position, elevation, and water depth are recorded every 30 ft. along each transect referencing the MLLW Datum. At the time of this report, the most recent data available were collected in Spring 2021.

No magnetometer survey was performed in the borrow area other than at the geotechnical sampling locations. Since the channel is regularly dredged, pipelines in the CSC are known to the USACE and were provided to CPRA.

Table 3: Borrow Area Pipelines

Pipeline Owner	Pipeline Size	EL. (MLLW)	Location
Natural Gas Pipeline Co. of America	36" Natural Gas Pipeline	-51 MLLW	Mile 8 to 8.5
Natural Gas Pipeline Co. of America	30" Natural Gas Pipeline	-56 MLLW	Mile 8 to 8.5
Columbia Gulf Transmission Co.	12" Gas Pipeline	-51 MLLW	Mile 7.5

3.5 Dredge Pipeline Corridor Alignment Survey

Two routes were surveyed as options for dredge pipeline corridors (DPC) for the project. One route was north of Long Point Bayou, coming in from Long Point Lake in the east and into the access route. The other potential route for the DPC extends off the access route below the curves in Long Point Bayou and extends through broken marsh to the marsh creation fill cell (**Figure 7).** The surveys showed that the southern dredge pipeline corridor had more degraded marsh and open water and was therefore selected as the preferred route. As discussed in Section 3.3.2, a magnetometer survey was performed along the potential dredge pipeline alignments to check for any anomalies. A DOE brine pipeline was previously identified by the USACE in this region and the magnetometer survey verified the pipeline extending perpendicular to the eastern half of Long Point Bayou. Fenstermaker later probed along this line to determine the depth of cover for the pipeline. In the DPC, there is approximately 4.5 to 6 ft. of cover over the pipeline. A detailed survey report can be found in **Appendix C**.

3.6 Average Marsh Elevation Survey

On May 23, 2020, an aerial drone survey was done using a multi-spectral camera. Images were then corrected, rectified and used to produce normalized difference vegetation index (NDVI) map. **Figure 10** shows the NDVI map that reflects the areas of healthy and distressed marsh in the project area. The CPRA Lafayette field office then reviewed the NDVI map and provided Fenstermaker five locations where the healthy marsh elevation surveys were to be performed (**Figure 11**). Based on observations from site visits, the dominant marsh in the project area is smooth cordgrass (*Spartina alterniflora*). The results from the marsh elevation survey are shown in **Table 4.** According to this survey, average marsh elevation near the project area is approximately 0.71 ft., NAVD88. At this elevation, the marsh surface is estimated to be inundated between 40-50% of the time.

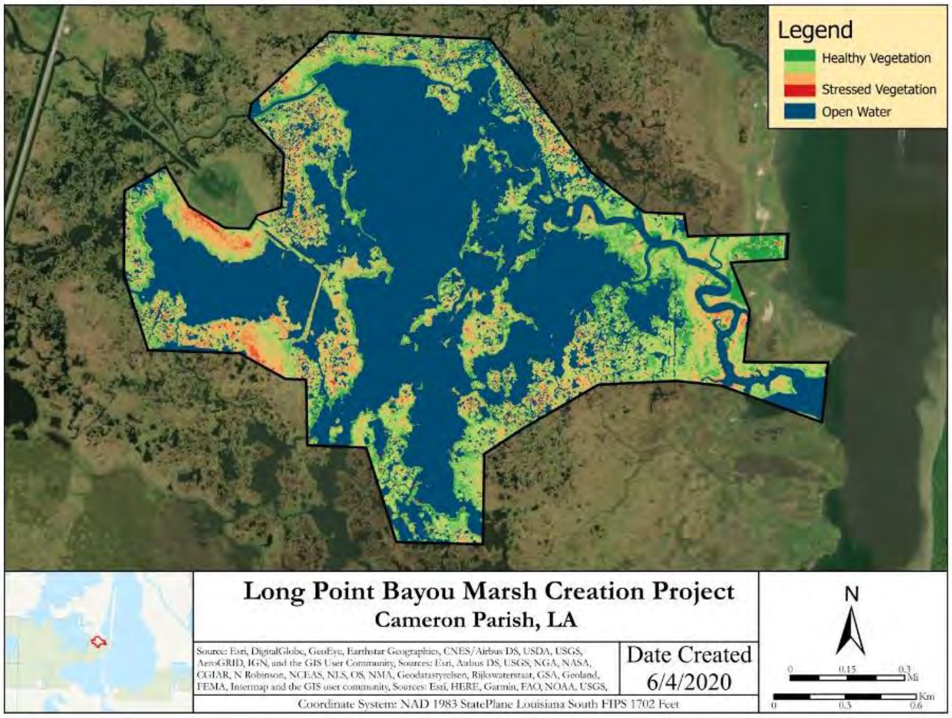

Figure 10: NDVI Map by Fenstermaker

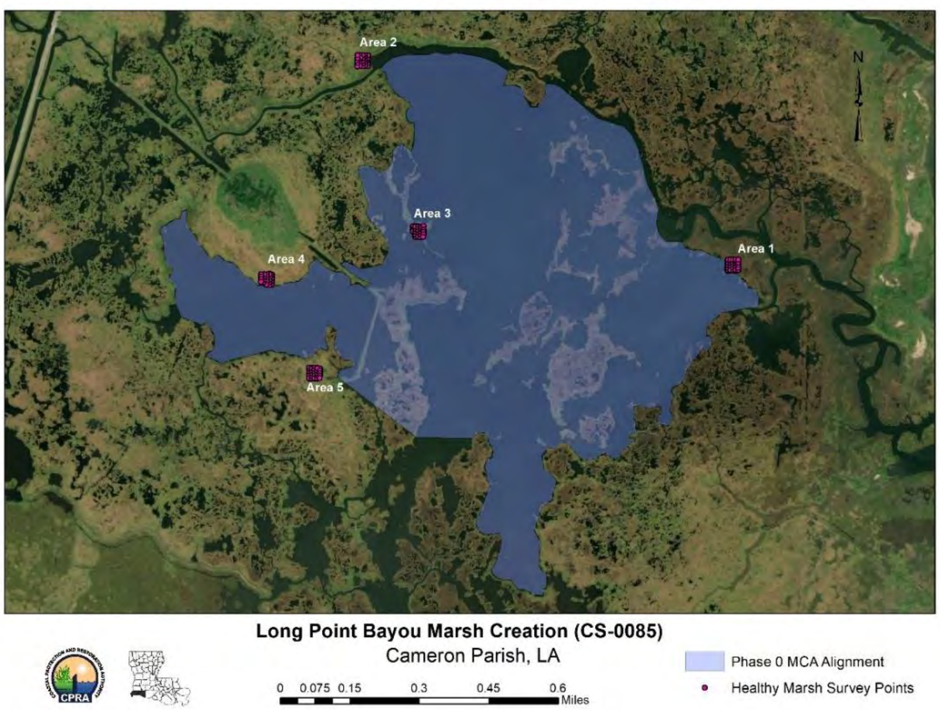

Figure 11: Healthy Marsh Elevation Survey

Table 4: Average Marsh Elevation Results

Location	Description	Average Top Elevation (ft. NAVD88)
Area 1	Smooth Cordgrass *(Spartina alterniflora)*	0.51
Area 2	Smooth Cordgrass *(Spartina alterniflora)*	1.01
Area 3	Smooth Cordgrass *(Spartina alterniflora)*	0.58
Area 4	Saltmarsh Cordgrass *(Spartina patens)*	0.47
Area 5	Saltmarsh Cordgrass *(Spartina patens)*	0.99
Average		**0.71**

4.0 Geotechnical Investigations

PSI was tasked to explore and evaluate the subsurface soil conditions and guide the geotechnical aspects of the design and construction of CS-0085. Field explorations began on May 26, 2020 and lasted until June 30, 2020. PSI was tasked with the following data collection efforts:

- Collect seven (7) borings in the borrow area to approximately elevation -45 MLLW of the channel.
- Collect five (5) soil borings in the fill area.
- Perform 12 Cone Penetrometer Tests (CPTs) soundings along the proposed containment dike.
- Perform laboratory classification and strength testing to determine soil characteristics.
- Perform two composite low pressure consolidation tests, and
- Perform two column settling test on selected composite sample.

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

- Slope stability analysis of the proposed earthen containment dikes (ECDs).
- Total settlement estimates of the proposed ECDs and marsh creation area, and
- Determination of an adequate cut to fill ratio for the ECDs and MCA.

The geotechnical data collection and data analysis reports can be found in **Appendix D** and **Appendix E**, respectively.

4.1 Existing Geotechnical Data Review

Prior to conducting the field subsurface investigation, a search of any historical data on the area was conducted. This included looking at prior subsurface investigations that occurred in the area as well as reviewing historical geological maps. Some historic data was provided by the USACE in the form of maintenance dredging reports. Soil boring logs and geotechnical analysis for the CS-0085 project were reviewed by the USACE.

The proposed fiscal year (FY) 2020 and 2021 Maintenance Dredging Activities Report described the sediment in the CSC as 12% sand, 35% silt, and 53% clay (USACE, 2019). In addition, the Calcasieu River and Pass Dredged Material Sedimentation Study performed sediment analysis using bulk samples taken in the ship channel between River Mile 11 and River Mile 30 (USACE, 2004). These samples were identified as primarily fat clay with some sand and silt. The 2004 Sedimentation Study lists the following as the general trend in material along the channel bottom:

- Bar channel: Silty to Highly Plastic Clay (generally fat clay, CH)
- Mile 0 to Mile 6: Silty Clay (CL) to Low Plasticity Silt (generally silt, ML)
- Mile 6 to Mile 9: Silty Clay (CL) to Low Plasticity Silt (generally silt, ML)
- Mile 9 to Mile 11: Silty Clay (CL)
- Mile 11 to Mile 13: Silty Clay (CL) to Highly Plastic Clay (generally fat clay, CH)
- Mile 13 to Mile 22: Silt (ML), with some sandy silt (SM) and silty clay (CL)
- Mile 22 to Mile 30: Fat clay (CH)
- Mile 30 to Mile 36: Sands and clays

The geology in the vicinity of the site is predominantly Holocene coastal marshes. The area is part of the Mermentau Alloformation that consists of marine muds, sandy and shelly beach deposits, organic marsh clays, and lacustrine and bay muds that bury the surface of the Prairie and Deweyville Allogroups. (Heinrich et al., 2005)

The geotechnical subsurface investigation and geotechnical engineering analysis for CS-0085 was conducted by PSI with guidance provided by the CPRA's Project Engineer and as per the MCDG1.0, **Appendix B**, Geotechnical Standards.

4.2 Marsh Creation Area Geotechnical Subsurface Investigation

Five (5) subsurface borings were taken in the MCA by PSI to approximately 30 ft. below the existing mudline. The soil borings were performed using an airboat with mounted drilling rig. The mudline ranged from elevations of 0.2 ft. to -0.89 ft. NAVD 88.

Samples were collected with a piston sample in Shelby tubes continuously in the upper 10-12 ft. of the soil and standard penetration tests (SPTs) were performed for the cohesion-less soils and semi-cohesive soils to the boring completion depths at 30 ft. All samples were then classified, stored, and transported to the laboratory. Shelby tube samples were tested for shear strength using a hand penetrometer and torvane. Laboratory tests included soil compressive strength, moisture content, organic content, grain size analysis, specific gravity, consolidation with rebound, and Atterberg limits. Soil conditions were also evaluated in the marsh creation area by performing 12 CPTs using an airboat-mounted rig at depths ranging from 10 to 15 ft. below the existing mudline. A summary of the geotechnical investigation is shown in **Table 5**.

Subsurface soil conditions at the center of the MCA (B-1, B-5, CPT-1, CPT-8) consisted of organic clay up to about seven (7) ft. below the mudline, followed by soft lean clay with sand that becomes stiffer around 12 ft., and hard and sandy around 24 ft. below the mudline. Subsurface conditions along the edge of the cell alignment (B-2, B-3, B-4) showed layers of soft fat clay with intermittent organics and trace sand up to 12 ft., followed by stiff lean clay with sand that transitioned to dense silty sand at around 20 ft. below the mudline. The CPTs also verified stiffer material found around 12 ft. below the mudline.

The approximate sampling locations are shown in **Figure 12**. The CPT data and boring logs can be found in **Appendix D**.

Table 5: Optimized Subsurface Investigation Plan Borings and CPTs Marsh Fill Area

ID	Northing	Easting	Mudline Elevation (ft. NAVD88)	Water Surface Elevation (ft. NAVD88)	Depth (ft.)
B-1	521,980.30	2,638,801	0.2	2.3	2.1
B-2	523,622.40	2,634,884	0.64	2.4	1.8
B-3	519,709.80	2,638,823	0.36	2.4	2
B-4	523,168.50	2,640,983	0.14	2.4	2.3
B-5	523,527.00	2,638,397	-0.89	2.3	3.2
CPT-1	522,619.70	2,635,615	-0.09	2.5	2.6
CPT-2	521,553.60	2,637,073	0.44	2.5	2.1
CPT-3	521,172.00	2,638,107	0.03	2.5	2.5
CPT-4	520,971.80	2,639,657	1.82	2.5	0.7
CPT-5	522,485.70	2,640,097	-0.11	2.5	2.6
CPT-6	524,712.50	2,639,962	0.02	2.4	2.4
CPT-7	525,528.60	2,637,538	-0.51	2.5	3
CPT-8	522,298.00	2,637,720	-0.16	2.4	2.6
CPT-9	523,168.50	2,640,983	0.14	2.4	2.3
CPT-10	523,622.40	2,634,884	0.64	2.4	1.8
CPT-11	519,709.80	2,638,823	0.36	2.4	2
CPT-12	525,466.70	2,638,445	-0.72	2.3	3

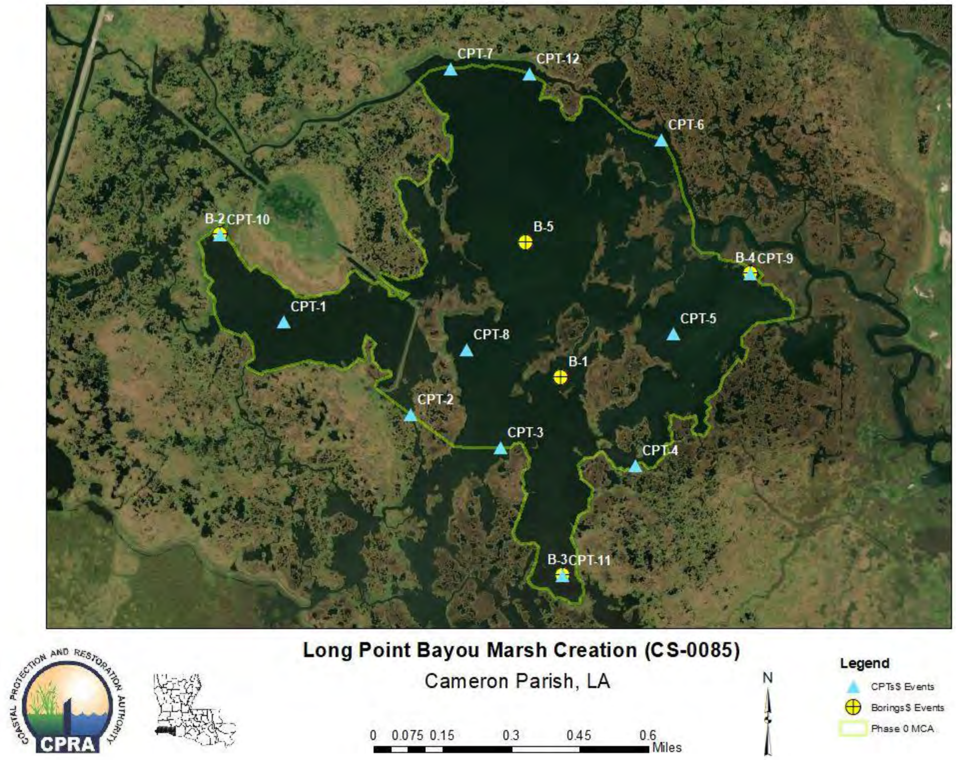

Figure 12: CS-0085 Fill Area Geotechnical Sampling Locations

4.3 Borrow Area Subsurface Investigation

Soil conditions were evaluated in the CSC borrow area by taking seven (7) borings to approximately five (5) ft. below the existing mudline (**Figure 13**). The mudline ranged from elevations of -38.90 ft. to -43.54 ft. NAVD 88 (**Table 6**). The soil borings were performed in approximately 40 ft. of water using a five (5) inch diameter and five (5) ft. long piston sampler. Since the channel was dredged recently before the geotechnical investigation, the 5 ft. long sample was sufficiently close to the environmentally cleared masimum depth for maintenance dredging. Index properties observed during drilling and laboratory test results are located on the boring logs in **Appendix D**.

Table 6: Optimized Geotechnical Investigation Plan Soil Borings Borrow Area

ID	Northing	Easting	Mudline Elevation (ft. NAVD88)	Water Surface Elevation (ft. NAVD88)	Depth (ft.)
B-6	502,413.50	2,643,251	-43.54	1.4	44.9
B-7	506,467.20	2,643,634	-42.24	1.5	43.7
B-8	514,945.20	2,644,471	-38.90	1.5	40.4
B-9	520,923.90	2,644,780	-40.17	1.6	41.8
B-10	525,073.50	2,645,166	-40.60	1.6	42.2
B-11	529,408.90	2,645,624	-41.76	1.7	43.5
B-12	536,575.50	2,646,292	-40.49	1.7	42.2

The seven (7) borings indicate a predominantly fat clay with silt pockets from the mudline to a depth of five (5) ft. with water contents ranging from 66% to 185%. A sieve analysis was performed on each sample and showed high percentages of clay and silt with 2.5% to 15% sand. The highest percentage of sand was found in B-12 north of the project area near River Mile 13. These results are in line with the samples collected in the Calcasieu River and Pass Dredged Material Sedimentation Study as part of the Dredged Material Management Plan (DMMP), (USACE, 2004). The average water content and specific gravity were used to determine an average in-situ void ratio of 3.11. The material in the CSC is newly deposited sediment since maintenance dredging takes place every two years. So, the in-situ void ratio is slightly higher than other projects in this area that used non-navigation borrow material sources.

The geotechnical behavior of clay material during the dredging process is particularly important for estimating the difficulty of transporting sediment. Dredging cohesive soils and hydraulically transporting via pipeline can be an inefficient process depending on the material's geotechnical properties. Data from index testing of the borrow materials – moisture content (w) and Atterberg Limits 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).

The liquidity index (LI) of a soil sample, as shown by the following formula, provides an assessment of the stress history of the in-situ materials and the viscosity of the material:

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

Soil boring samples with a LI greater than 1.0 are likely to be under-consolidated soils and more prone to flowing like a liquid (Das and Sobhan, 2014). The LI is greater than 1.0 for all samples collected from the borrow area. The plasticity index is a good measure to determine whether a soil exhibits plastic properties. The average plasticity index in the top five (5) ft. of the borrow material is 63, a value associated with very high plasticity and susceptible to remain bulked post construction. Post-construction containment dike degradation and gapping will aid this highly plastic material to drain and further consolidate in the marsh area.

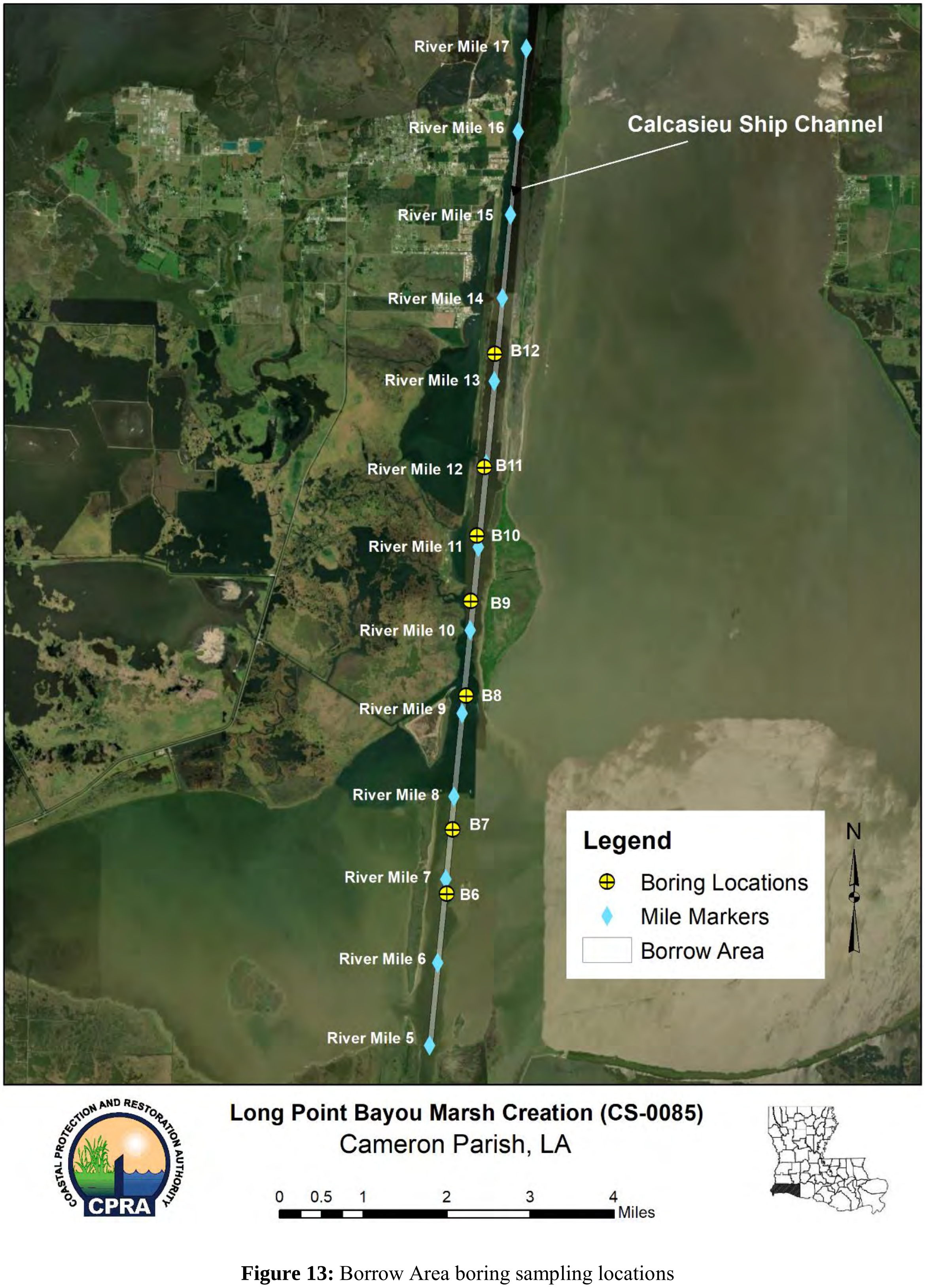

Figure 13: Borrow Area boring sampling locations

5.0 Project Design

This project proposal includes marsh creation and nourishment by hydraulically dredging material from the Calcasieu Ship Channel into the marsh creation area as shown in **Figure 14** and the 95% Design drawings located in **Appendix F**. To achieve the project goals, the dredged slurry will need to be placed to a constructed fill elevation above the saline marsh inundation range and will settle into the range over the 20-year project design life. The marsh creation design was broken up into the following sections: the marsh creation area, ECDs, dredge borrow area, and pipeline corridor.

5.1 Marsh Creation Area Design

The alignment of the MCA was changed from the original Phase 0 configuration as shown in **Figure 14** below. The Phase 0 configuration had a small portion on the southern end and very jagged edges along the containment. The alignment was changed for ease of construction, containment dikes will be easier to build in straight segments and the dredge pipe will not need to be moved to fill in the southern portion, originally included in the Phase 0 alignment. Total acreage increased slightly from 392 to 395 acres.

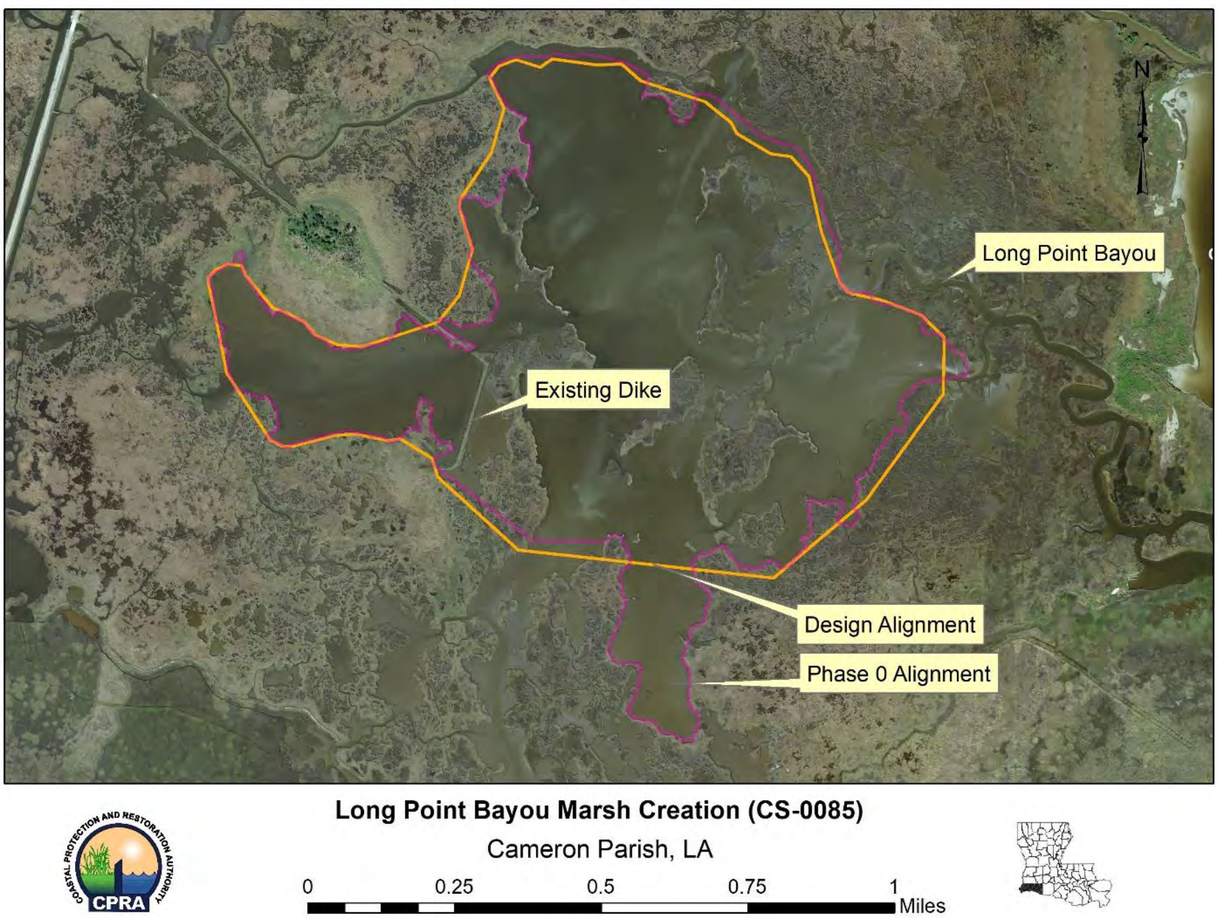

Figure 14: 95% Marsh Creation Design Plan View of CS-0085

There is an existing earthen dike in the western portion of the marsh creation area as shown in **Figure 14**. Survey points taken along the existing dike on average were at elevation +1.6 ft. NAVD88. There is an approximate 32-foot gap in the dike that would allow a marsh buggy to bring the dredge pipeline through to fill the western area. Along the northern edge of the cell is Long Point Bayou at an average elevation of -1.6 ft. NAVD88. This historic bayou is connected with the CSC to the east side of the MCA. Containment along the northern portion of the area was aligned 25-foot south of the bayou to preserve the current alignment of the bayou. In addition, material dredged from the bayou will be used to create the ECDs in this area, which will also benefit in re-establishing better hydrology within Long Point Bayou.

5.1.1 **Preparation for Marsh Creation Area Settlement Analysis**

Parameters such as sea level rise, subsidence, target surface elevations, mudline elevations, fill volumes, and dredge fill placement rates are required to perform settlement analyses. CPRA provided these parameters to PSI for them to perform the total settlement analysis, as shown in the Geotechnical Engineering Report (GER) (**Appendix E**). CPRA design team also performed some settlement analysis after the 30% design review for further adjustment of the marsh creation area fill elevation. Marsh fill and foundation settlement analysis was run with two mudlines, -1.0 ft. and -1.5 ft. NAVD88. These values were chosen based on the mudline elevation distribution shown in **Figure 15**. Approximately half of the fill area is above -1.0 ft. NAVD88, while 27% of the area is between -1.0 to -1.5 ft. NAVD88.

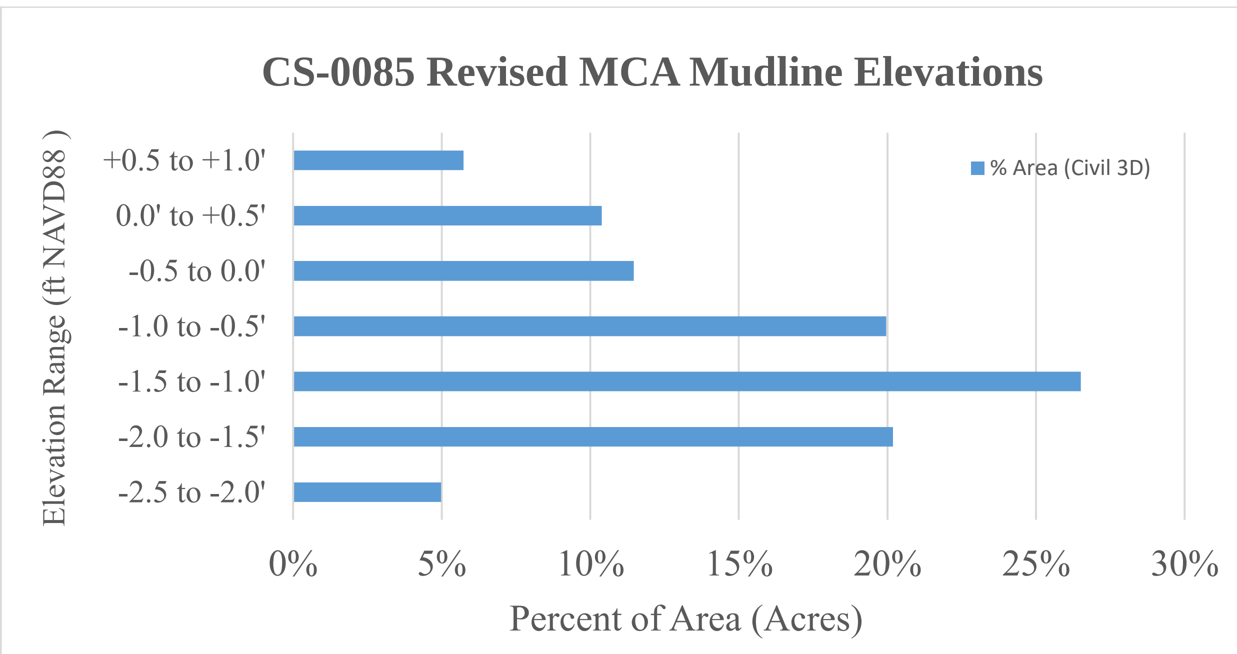

Figure 15: Histogram for 30% Cell Alignment

5.1.2 **Marsh Creation Area Settlement Analysis**

Marsh fill settlement analysis is necessary to determine the construction fill elevation of the marsh creation areas and the total volume of fill material. The final elevation of the marsh creation area (at TY 20) is governed by two forms of settlement: (1) the settlement of the underlying soils in the marsh creation areas caused by the loading exerted by the placement of dredged fill material, and (2) the self-weight consolidation of the dredged material. Data from column settling tests and low-pressure consolidation tests were used to estimate the magnitude and time-rate of settlement of the slurry, and data from traditional consolidation testing was used to determine the settlement of the underlying soils of the marsh creation areas.

A column settling test was performed by PSI, in accordance with the test method specified in the USACE Engineering Manual No. 1110-2-5027, to understand the settling processes and properties of the dredged slurry. 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 the slurry translates from zone settling to compression settling. 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 also estimated using PSDDF.

A column settling test was performed on each of two composite samples (A and B) formed by mixing material collected from seven (7) bulk samples in the CSC. These were conducted to achieve settlement curves that display zone settling and compression settling components. Zone settling is the initial settling of particles that creates a sediment water interface. As settling continues, the particles compress and are packed more tightly. The interface height does not change as significantly during compression settling. Both composite samples were created using material from all ship channel samples. The composite samples were also used for low-pressure consolidation testing. The column settling tests were performed at a concentration of 150 g/L as per the USACE EM 1110-2-5027 guideline. Results from the CS-0085 settling column test are shown in **Figure 16**. These tests were performed to gather necessary data for PSDDF inputs.

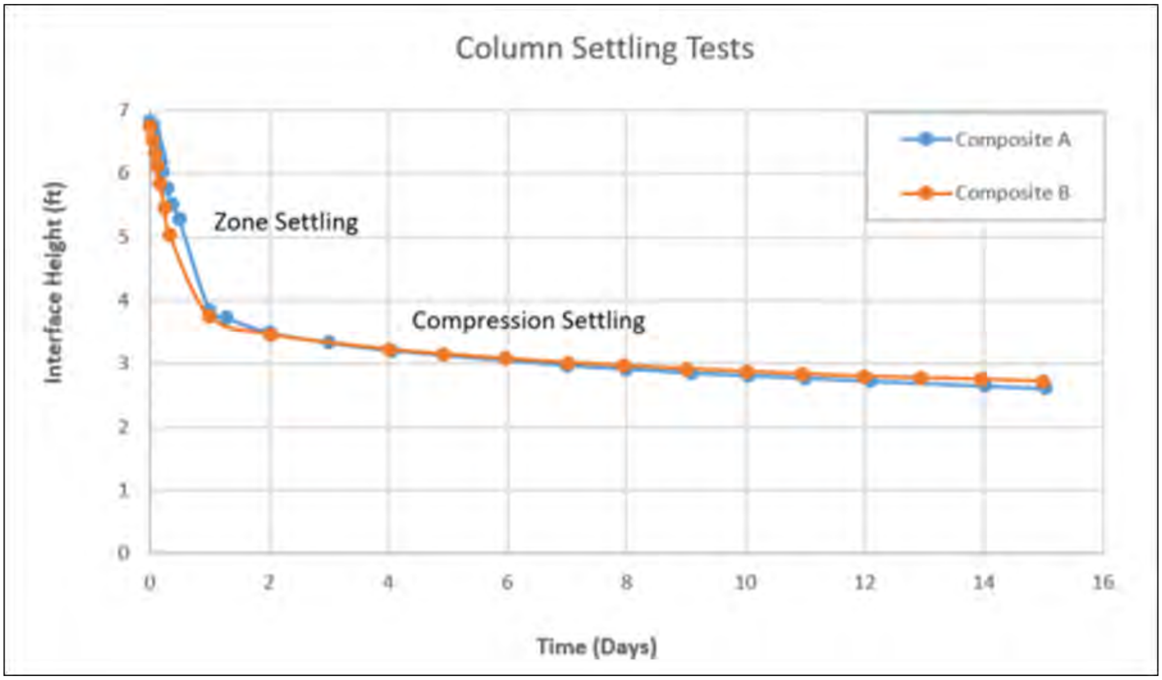

Figure 16: Zone and compression settling results from the column-settling test

The settling column test results show that compression settling occurred after 24 hours (**Figure 16**). After ten (10) days of settling, the interface height went below three (3.0) ft. from the initial height of seven (7.0) ft. Therefore, approximately 40% settlement occurred in first 10 days for both composite samples.

5.1.3 Construction Marsh Fill Elevation

The next step in the settlement analysis involved determining an appropriate constructed marsh fill elevation (CMFE) as per MCDG1.0. This elevation was governed by several factors including the tidal range, percent inundation, average existing marsh elevations, physical properties of the borrow material, and the bearing capacity of the foundation soils in the marsh creation area. Determination of the constructed marsh fill elevation 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 that the marsh platform has an elevation within the functional saline marsh inundation range (20%-80% inundated). Over the 20-year project design life, as discussed in **Section 2.6.3**, the preferred inundation range is expected to rise from 1.2 ft. NAVD88 to 1.7 ft. NAVD88 (20% inundation range), and from 0.2 ft. NAVD88 to 0.7 ft. NAVD88 (80% inundation range).

In order to determine the CMFE that would yield the most productive marsh at the end of the 20-year project life, subsidence rates were applied to the settlement curves, while ESLR was applied to the tidal datum and the optimal inundation range. The ideal final marsh platform would settle into the optimal saline marsh range (20%-80% inundated) shortly after construction and would remain there for the duration of the 20-year project life. The USACE computer program PSDDF was used to provide construction marsh fill elevation for the marsh creation area that would maximize the amount of time that the marsh platform would remain within the 20% and 80% inundation range. For a design mudline of -1.5 ft. NAVD88, three different thicknesses of dredge material (5.5 ft., 6 ft., and 6.5 ft.) were modeled in PSDDF for 60 days of dredging duration. The constructed marsh elevation after 60 days of dredging were +2.33 ft., +2.83 ft., and +3.32 ft. NAVD88, respectively. The same analysis was done assuming a design mudline of -1.0 ft. NAVD88 and for dredge material thickness of 4.5 ft., 5 ft., and 5.5 ft. In addition to the variation in existing mudline elevations of the MCA, the dredging duration varies with the dredge production rates, which can impact the overall settlement of the dredged slurry. Based on the daily logs of the CSC maintenance dredging in Spring 2021, the dredging production rate in this event was approximately 25,000 CY (gross)±3,000 CY per day. However, it may vary between 15,000 CY and 30,000 CY per day depending on the size of the dredge and other equipment used in construction. Hence, PSDDF was used to model three different dredging durations, 48 days, 60 days, and 90 days for a design mudline -1.5 ft. NAVD88 and six (6) ft. of dredge material thickness. All results are shown in **Table 7**. Based on the PSDDF results and analysis of all the settlement curves, the CMFE was selected to be +2.75 ft. NAVD88. Given the model sensitivity to the design mudline assumption, as well as the uncertainly with the dredging production rate during construction, the CMFE +2.75 ft. ensures the marsh will fall below the 20% inundation line by TY3 and will remain within the intertidal range until the end of the 20-year project life (**Figure 17 - Figure 19**). A +0.5 ft. construction tolerance will also be permitted for the CMFE.

Table 7: CMFE and TY20 Elevation for the various cases analyzed

Design Mudline (ft. NAVD88)	Dredging Duration (Days)	Dredge Material Thickness (ft.)	CMFE (ft. NAVD88)	TY20 Elevation (ft. NAVD88)
-1.5	60	5.5	+2.33	+0.59
-1.5	60	6.0	+2.83	+0.77
-1.5	60	6.5	+3.32	+0.97
-1.0	60	4.5	+1.60	+0.72
-1.0	60	5.0	+2.12	+0.85
-1.0	60	5.5	+2.83	+1.05
-1.5	48	6.0	+2.85	+0.77
-1.5	90	6.0	+2.45	+0.73

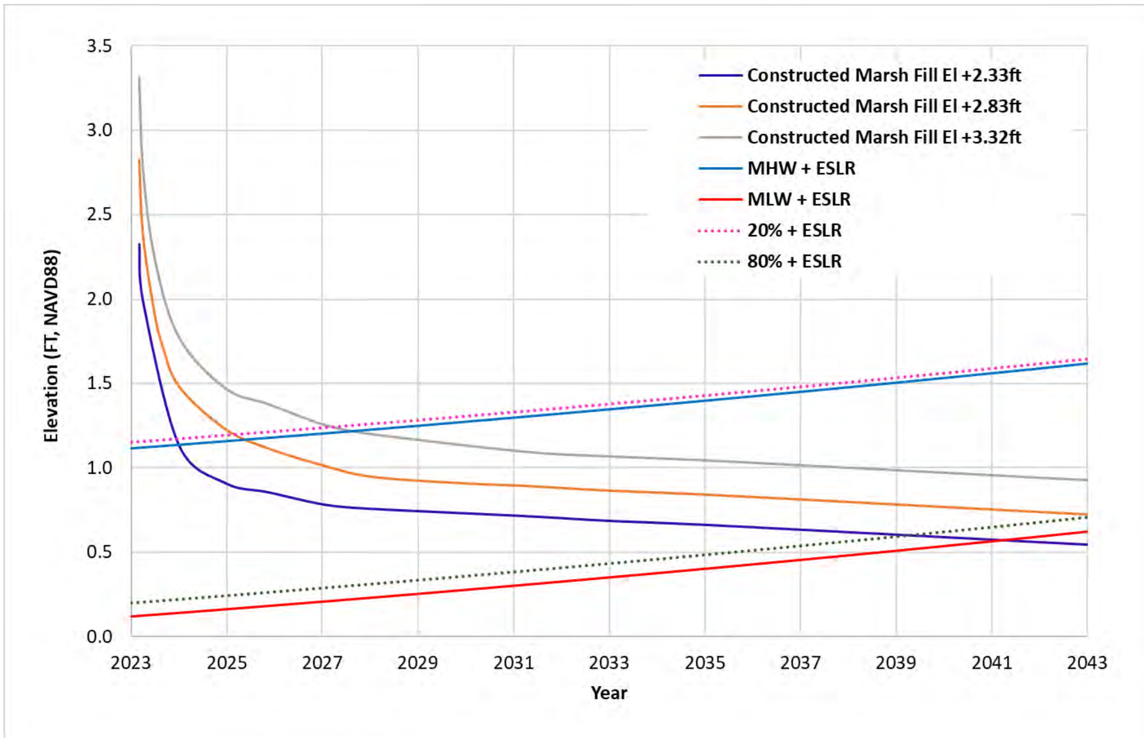

Figure 17: Estimated Total Settlement Curves for design mudline -1.5ft. NAVD88 and dredging duration 60 days

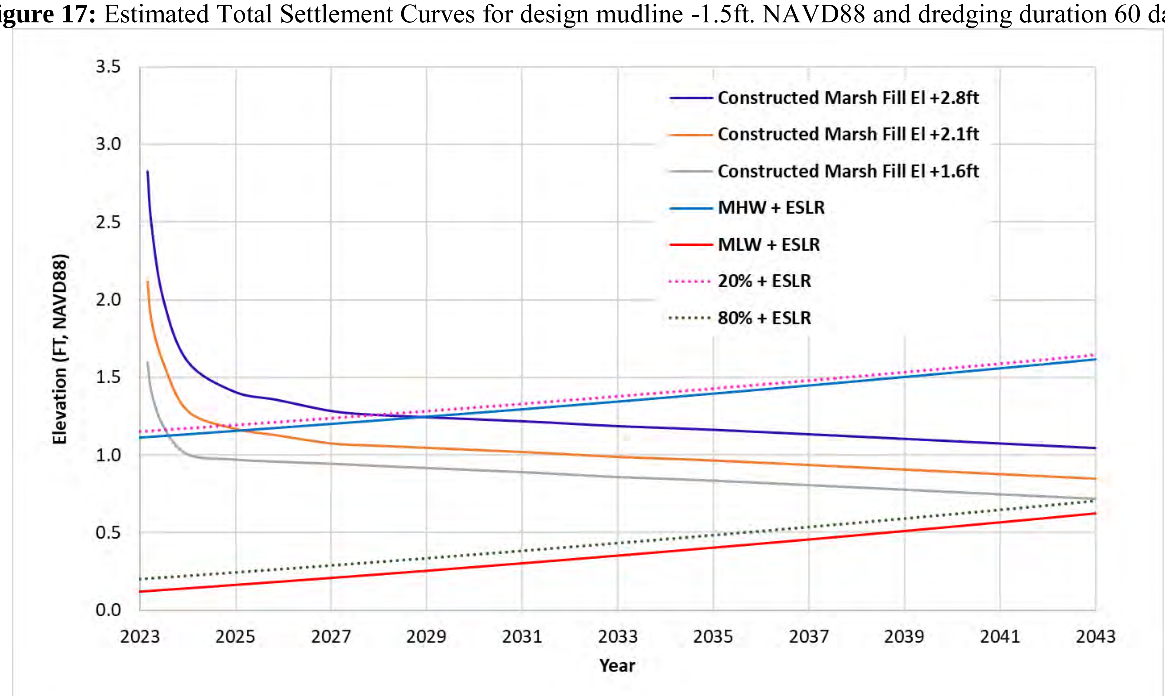

Figure 18: Estimated Total Settlement Curves for design mudline -1.0ft. NAVD88 and dredging duration 60 days

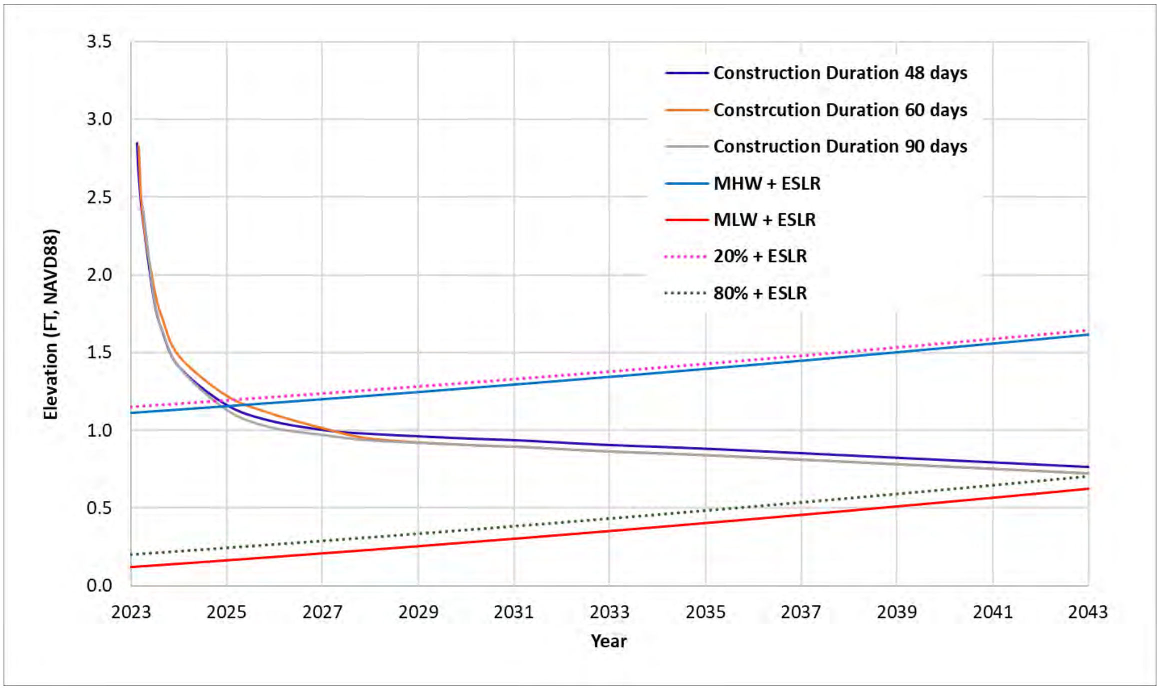

Figure 19: Estimated Total Settlement Curves for design mudline -1.5ft. NAVD88 and dredge material thickness 6.0 ft.

5.1.4 Accretion Investigation

CPRA's Lafayette Field Office performed a study based on observed organic material accretion and elevation change rates at monitoring sites in marsh creation areas. This study suggests that created marshes have the ability to keep up with subsidence, and in many instances, result in an increase in vertical surface elevation once the marsh platform falls within the target inundation range and vegetation becomes established (Sharp and Mouledous, 2019). An accretion rate of one (1) centimeter (cm)/year is expected to occur in the created marsh beginning around TY6 based on the data that were collected at monitoring sites between TY5 and TY8. The one (1) cm of accretion corresponds to about a 30% elevation gain based on observations in the study. The cumulative elevation gains from accretion over 14 years (TY6 – TY20) accounts for an increase in roughly 1.65 inches of elevation of the created marsh surface. Due to limited sampling locations and short duration of the study (TY 5 – TY 8), the elevation gain of the marsh surface was not considered in the design calculation. If organic material accumulates on top of the marsh surface and ~1.65 inches of elevation gain take place, the marsh surface will remain within the inundation range longer and the project will sustain beyond the 20-year project life.

5.1.5 Constructed Marsh Area Quantities

After determining the constructed marsh fill elevations, the total volume of the marsh creation area was calculated using AutoCAD Civil software. The software creates a three-dimensional surface based on three-dimensional coordinate data from the survey. This surface is known as the Triangular Irregular Network (TIN) model which represents a surface as a set of contiguous, non-overlapping triangles. A TIN from the 2020 survey data was created and compared with a TIN surface representing the 20-year marsh elevation created in AutoCAD. **Table 7** shows that the 20-

year marsh elevation for a CMFE of +2.75 ft. NAVD88 will vary within the fill area due to multiple factors such as the variation in mudlines, dredging duration and production rates etc. But, the 20-year design marsh elevation can safely be assumed as 0.71 ft. NAVD88. In addition, the foundation settlement and subsidence of the existing surface over the 20-year period are added to this elevation to be +1.1 ft. NAVD88. AutoCAD then uses the XYZ differences of each surface to calculate the volume of the marsh creation area. Since the containment dike borrow pits that are inside the marsh creation area must be refilled, the volume to build the containment dikes is then added to the volume required to fill the marsh area. Finally, the cut-to-fill ratio of 1.10 is applied resulting in a final estimate of volume for the marsh creation area. The determination of the cut-to-fill ratio is explained in **Section 5.6**. **Table 8** summarizes the fill volumes for the CS-0085 project.

Table 8: Summary MCA Acreage and Volume

Fill Area	Constructed Fill Elevation (ft. NAVD88)	Area (Acres)	Cut to Fill	Volume of Fill (yd^3)	Volume of Cut (yd^3)
1	+2.75	395	1.10:1	1,323,708	1,456,079

*Volume calculations shown in this table include ECD borrow quantities

Volume calculations were determined near the ultimate settled marsh elevation to allow for primary and secondary consolidation settlement of the fill to occur. This process accounts for the decrease in voids, primarily water, as the material dewaters and begins to consolidate. As shown in the settlement curve in **Figure 17-Figure 19**, 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. Near the completion of primary consolidation settlement, the material has dewatered giving a more accurate estimate of the actual volume of dredged material needed to achieve the target marsh elevation.

5.2 Earthen Containment Dike Design

The primary design parameters associated with the earthen containment dikes (ECD) design include the crown elevation, crown width, and side slopes. A minimum of one (1) foot of freeboard is required to contain the dredge slurry within the proposed marsh creation fill area while maintaining an acceptable factor of safety (FOS) of 1.2 as per the MCDG1.0. However, the USACE recommended minimum 2 ft. freeboard due to high cost of shutting the dredge down to repair the dike on a failure and to offset any settlement during construction. Therefore, the containment dike is designed with 2 ft. freeboard from the CMFE. With a CMFE of +2.75 ft. NAVD88, the design height for containment will be +4.75 ft. NAVD88. A +0.5 ft. construction tolerance will also be permitted for the containment. The crown width will be five (5) ft. and side slopes will be 3H:1V. The ECDs are required to be maintained to the constructed elevations throughout the duration of dredging operations.

The containment dike towards the southeastern and western boundary (65%) will be constructed by borrowing materials from internal borrow areas within the marsh creation area, which will be backfilled during the hydraulic dredging. The remaining portion of the containment dike (35%) towards the northern boundary of the marsh creation area will be constructed by borrowing materials externally from within Long Point Bayou. Both the internal and external borrow areas have similar design dimensions. The bottom width and elevation will be 5 ft. and -10 ft. NAVD88, respectively. The side slope of the borrow pits will be 3H:1V. The layout of the ECD and the typical sections are shown in **Figure 20** and **Figure 21**, respectively.

5.2.1 Earthen Containment Dike Stability

Slope stability analyses using SLIDE, Version 3 of Rocscience was performed on the proposed ECDs at different elevations and geometries as per MCDG1.0, **Appendix B**. Stability analyses were modeled using the Spencer's method.

The slope stability of the ECD has two types of driving forces: (1) the forces induced by the soil weight, and (2) any seepage forces, which tend to cause the soil to slide. In response to these driving forces, the subsurface soils have a resistant force in the form of shear strength, which attempts to keep the slope from sliding. Both the driving forces and the resisting forces are dependent on the geometry and soil parameters of the proposed features. PSI performed stability analyses that computes factors of safety against potential failure based on limit equilibrium theory.

In the slope stability analyses, tension cracks were also evaluated. Tension forces within cohesive soils may be observed in the upper part of the slope. A tension crack may develop in a slope when the inclination angle of the slip surface is steep and when the sliding mass is sitting on a weak foundation material. This can be modeled in SLOPE/W by creating a tension crack boundary. The tension crack boundary was created with a water-filled tension crack line to a depth of 2.5-foot below the crown of the ECD.

ECD side slopes of 3:1 was determined to meet the minimum factor of safety for stability. The unit weight and undrained shear strength profiles used for all slope stability evaluations is shown in the Geotechnical Engineering Report (GER) (**Appendix E**).

A minimum slope stability factor of safety of 1.20 is required as per the MCDG1.0, Geotechnical Standards Table B-8. A summary of the results for the slope stability analysis is shown in **Table 9**. This table shows the lowest FOS for all cases.

Table 9: ECD Factors of Safety

Mudline Elevation (ft NAVD88)	Bench Offset (ft)	Side Slope	Top of Dike Elevation (ft NAVD88)	Min FOS w/Tension Crack
-2	20	3H:1V	+4.5	1.7
-2	20	3H:1V	+5	1.6
-2	20	3H:1V	+5.5	1.5

Based on the results, the project area could be contained successfully with up to a +5.5 ft. crest dike height and side slopes of 3H:1V. The mudline analyzed for the dike stability, -2 ft., was representative of the worst-case depth along the ECD alignment in the northern part of the marsh creation area by Long Point Bayou.

5.2.2 **Earthen Dike Settlement**

Consolidation settlement of the foundation soils beneath the ECDs were computed based on the dike geometries determined from the slope stability analyses and the soil properties of the underlying soils. Total settlement factors include regional subsidence and elastic settlement of the in-situ soils. The total settlement (including subsidence) of the mudline beneath the ECD centerline is around 6-7 inches over the 20-year design life. The ECD settlement results can be found in the GER in **Appendix E**.

5.2.3 **Earthen Containment Dike Quantities**

A typical section for ECD and marsh fill is shown in **Figure 21** below. The total ECD length around the perimeter of the project is 19,680 linear ft. (LF). A summary of the ECD quantities is shown in **Table 10.**

5.3 Internal Training Dike

An internal training dike (ITD) is designed to ease the construction sequencing and dewatering of the marsh creation area. With the internal training dike, dewatering of one cell could be done in another cell within the MCA, which can reduce the potential loss of dredged slurry because of dewatering. Also, internal training dike would allow construction of the MCA in phases in case the dredge material in the CSC is limited in the next maintenance dredging event for Fiscal Year 2022. Historical map from the wetland value assessment report shows that the project area was nearly all land in 1955 with one tidal channel bisecting the fill area (Appendix J). The alignment of the ITD was chosen along the bank of the historical tidal channel and the ITD will be built by borrowing the material from within the historical channel alignment (**Figure 20**). Though the borrow area would be backfilled by the dredging material, the area may depress naturally over time due to differential settlement. This will aid the construction of the tidal creek in TY3, as well as the post-construction degradation of containment dikes for draining the marsh areas.
Like the containment dike, the main design parameters for the ITD design are the crown elevation, crown width, and side slopes. The ITD is designed with a top elevation +2.75 ft. NAVD88. The crown width and side slope will be five (5) ft. and 3H:1V, respectively (**Figure 21**). The stability and settlement analysis conducted for the ECD is applicable for the ITD. No freeboard is maintained between the CMFE and the internal dike top elevation to facilitate the dewatering of dredge material within the marsh creation area. A +0.5 ft. construction tolerance will be allowed for the internal training dike. A summary of the ITD quantities is shown in **Table 10**.

Table 10: Summary of the ECD and ITD Quantities

Marsh Creation Area	Length of Containment (ft.)	Cut to Fill	Volume of Fill (yd^3)	Volume of Cut (yd^3)
Containment Dike	19,680	1.4:1	59,923	83,893
Internal Training Dike	3,861		9,501	13,301
Total	23,541		69,424	97,194

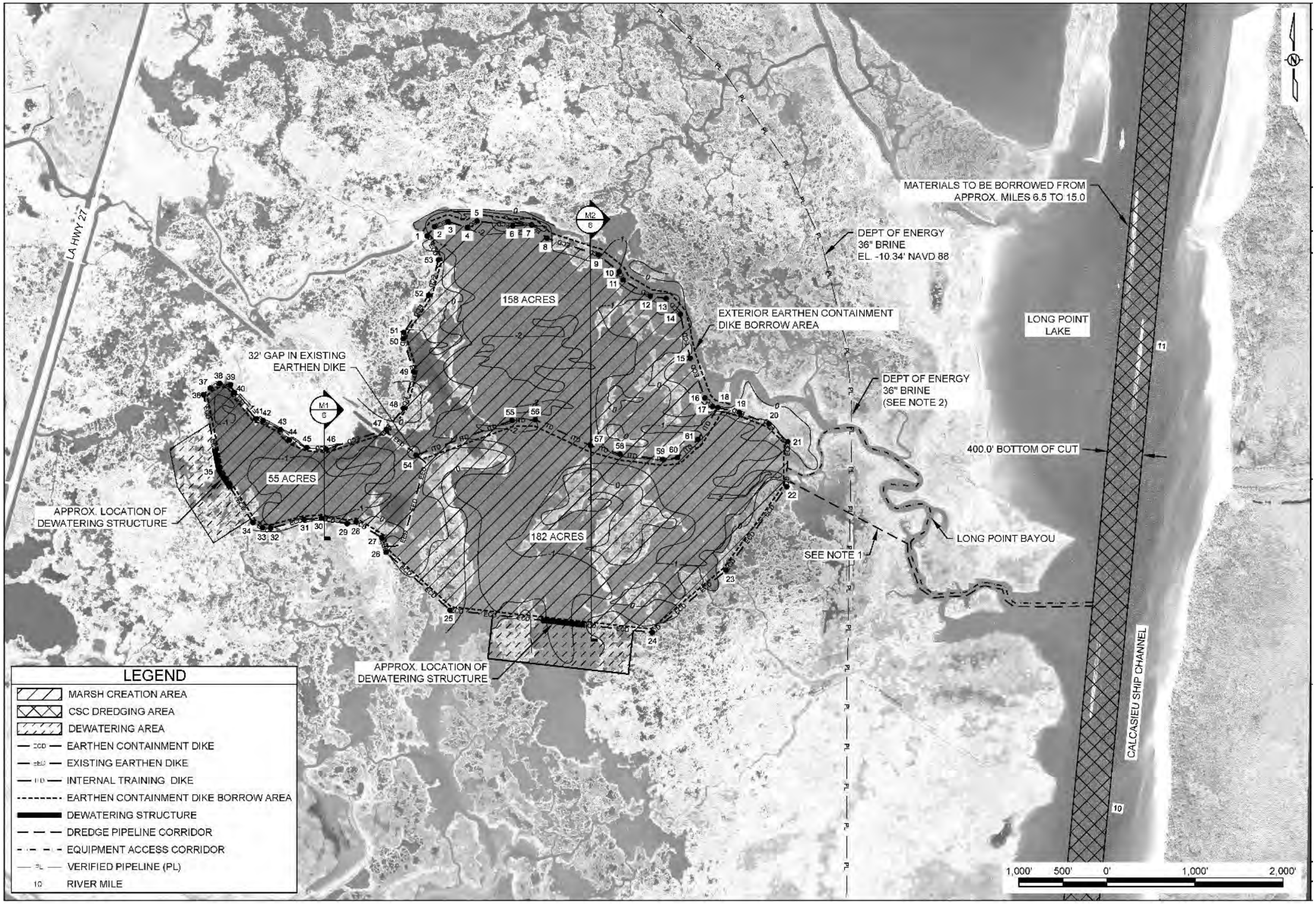

Figure 20: Plan view of the Marsh Creation Area (MCA), Earthen Containment Dike (ECD) and Internal Training Dike (ITD) Layout (95% Design)

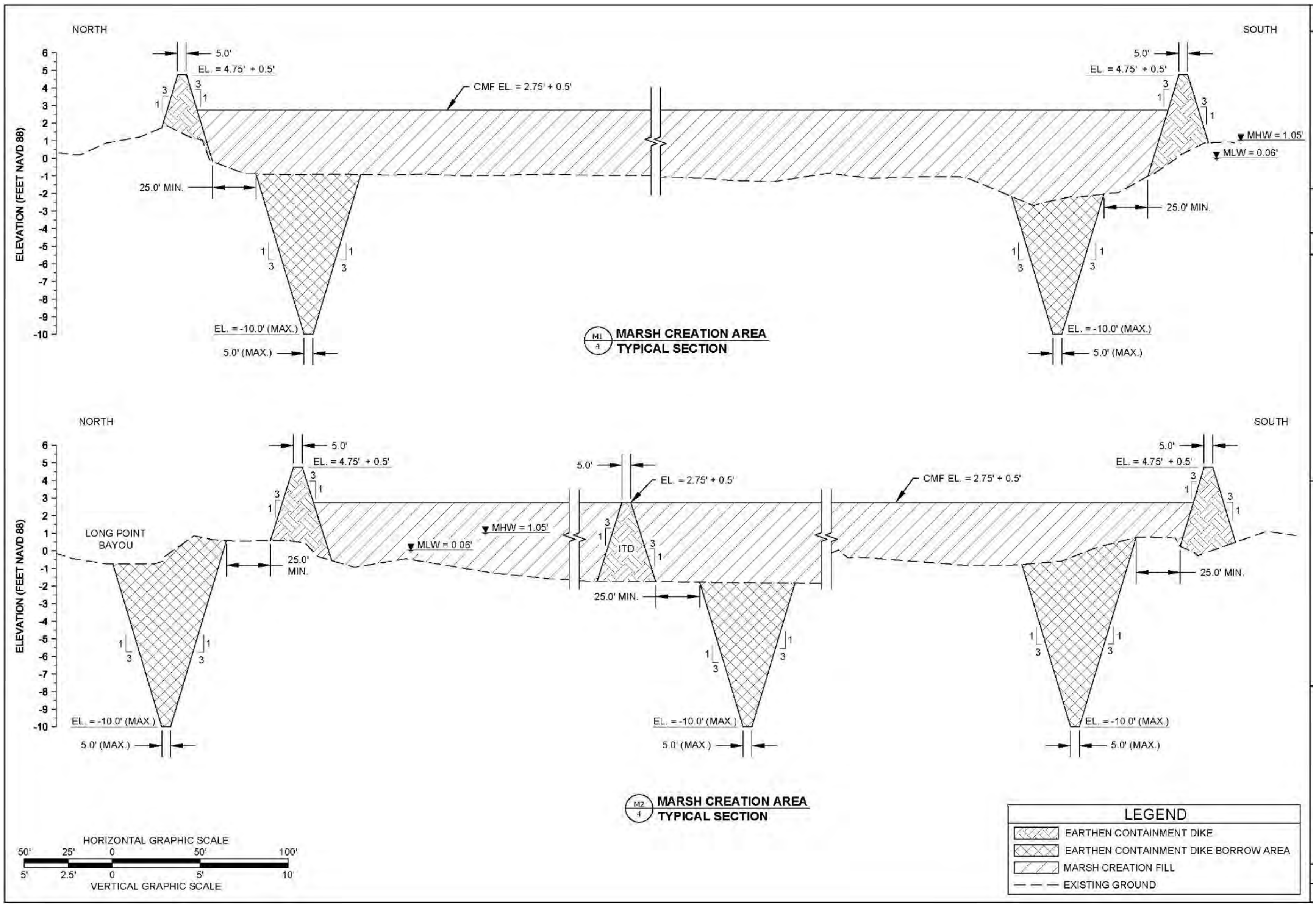

Figure 21: Typical MCA and ECD Section

5.4 Tidal Creeks

Eight (8) acres of tidal creeks will be created after the marsh has settled into the optimum inundation range in TY3. The containment dikes intersecting the creek's alignment will be gapped or degraded to provide relief for ponding and provide hydrologic exchange within the marsh creation areas. These tidal creeks will be created/restored using the Geographic Information System (GIS) water bottom data layer from the State Land Office. The internal borrow area of the training dike is strategically located following a historical tidal creek, which will likely create a natural depression over the three-year period after construction and would be a potential location for a tidal creek. In addition, tidal creeks may be added in lower elevation areas that develop naturally within three years post-construction to achieve the estimated eight (8) acres per project goals and objectives. These tidal creeks will benefit the saltmarsh topminnow and black rail, two species petitioned or proposed for listing on the Federal Endangered Species List.

5.5 Marsh Creation Borrow Area Design

The sediment for the marsh creation area will be borrowed from the lower CSC starting from Mile 5.0 to its upper limit at Mile 17.0 (**Figure 22**). Based on the historical data, the reach from Mile 6.5 to Mile 13.5 within the lower reach will likely contain the maximum available dredging quantities but considering construction flexibility for contractors and multiple candidate projects for the beneficial use of the dredge material in this region, the entire lower reach is designed as the borrow area for hydraulic dredging. Since the CSC is a federally maintained waterway, the authorized dimension for the CSC is -41 ft. MLLW x 400 ft. wide with a 2.5:1 side slope. The USACE commonly includes another two (2) ft. of dredging for advanced maintenance and allows additional two (2) ft. for allowable over dredge. In total, the CSC is environmentally cleared to be dredged as low as -45 ft. MLLW.

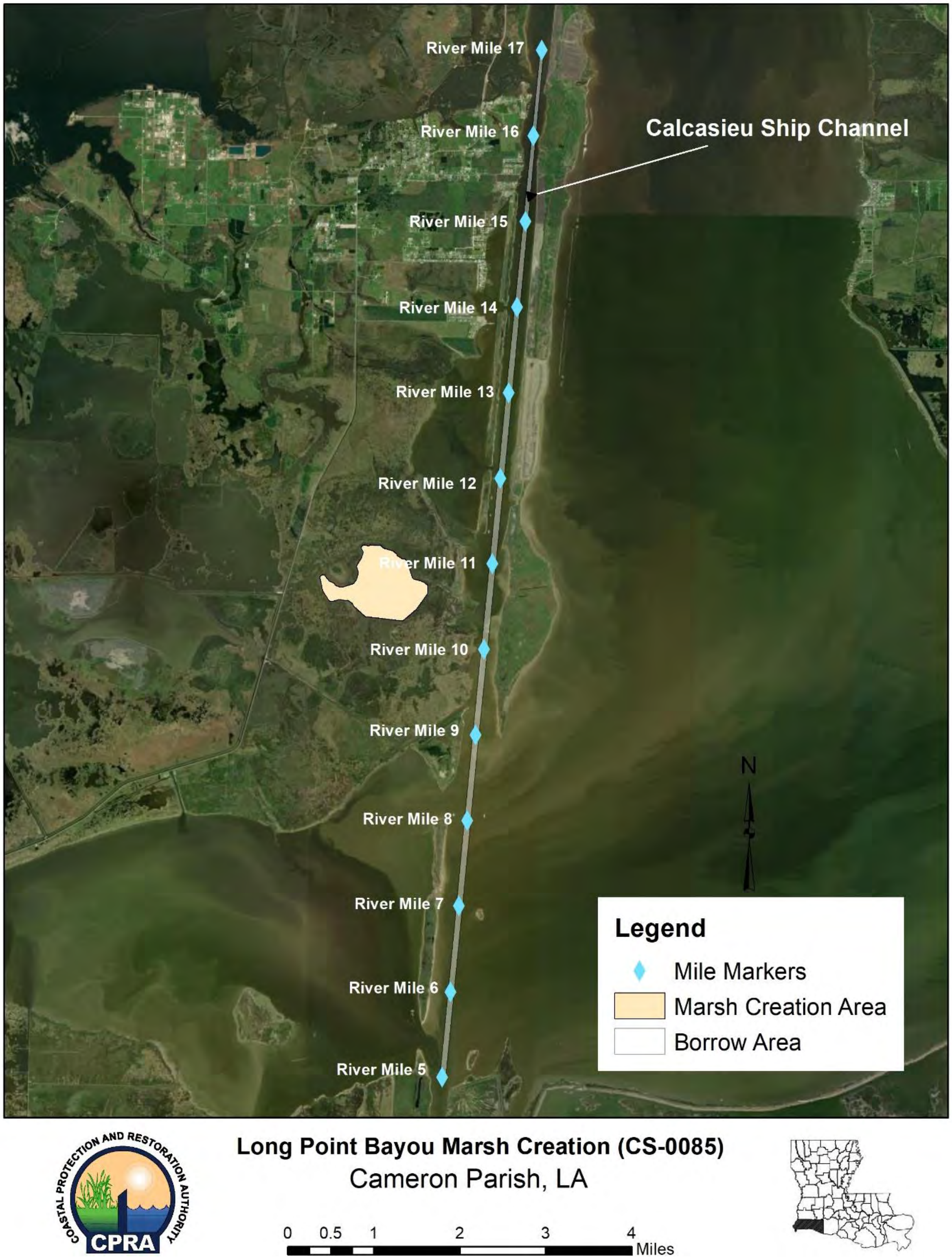

Figure 22: CS-0085 Project Area and Borrow Area

5.5.1 **Historic Dredging Timelines in the CSC**

The lower CSC, consisting of River Mile 5 to River Mile 17, is dredged every other year. The last dredge event was bid in 2018 and dredging occurred from November 2018 to January of 2020. This duration included six (6) months of no dredging due to the contractor leaving the site. The actual dredge duration for the last event was therefore around 255 days. **Table 11** below shows the bid dates, dredge start and end dates, as well as the duration of dredging for maintenance events in the lower ship channel dating back to 2010. The duration of these dredging events ranged from 137 to 304 days with some variation in the areas covered by each event. The maintenance dredging events for the lower CSC are bid in even numbered years and dredging takes place in the following year.

Table 11: Historic Dredging Durations for the Lower CSC

Project	FY	Bid Date	Project start	Project End	Duration (Days)
MILE 5 TO 22.8	2011	5/19/2009	4/8/2010	1/9/2011	276
MILE 5 TO 17	2012	5/1/2012	6/29/2012	11/13/2012	137
MILE 5.0 to 15.0, DEVIL'S ELBOW	2014	7/24/2014	9/22/2014	7/23/2015	304
MILE 5.0 TO 17.0, DEVIL'S ELBOW	2017	7/27/2016	1/31/2017	8/23/2017	204
MILE 5.0 TO 17.0	2019	9/11/2018	11/7/2018	1/16/2020	435*
MILE 5.0 TO 17.0	2020	9/28/2020	3/3/2021	8/30/2021**	180
Average					246

** No dredging for six months within the total construction duration*

*** Anticipated completion time and will be updated in the final E&D*

5.5.2 **Dredging Quantity in the CSC**

The volume of material removed from the CSC during the USACE maintenance events changes based on time between events, storm impacts, need for emergency dredging, etc. The USACE estimates volume for each cycle based on quarterly surveys and an expected shoaling rate.

The required borrow area size to achieve the project goals may vary based on yearly events and shoaling. While the entire lower CSC may be used as borrow, the goal is to utilize the dredge material from river miles closest to the project area to minimize the pumping distance and the dredging cost. The project area is located across from River Mile 11 and based on the information about material quantity, River Mile 6.5 through River Mile 15 have been selected as the borrow area for the project. **Table 12** below summarizes the material quantities listed in the USACE solicitations over the past six (6) years. On an average, 3.2 million cubic yards (MCY) are removed in every maintenance dredging from the CSC. The latest maintenance dredging event started in Spring 2021 and is currently in progress. The total bid quantity of 2.46 MCY is expected to be dredged from River Mile 5.5 to River Mile 17.

Table 12: USACE Bid Tab Quantities

Bid Year	Total Quantity in Bid Tab (CY)	First* Quantity (CY)	Solicitation
2014	3,900,000	3,900,000	W912P8-14-B-0044
2016	3,920,000	3,400,000	W912P8-16-B-0029
2018	2,600,000	2,240,000	W912P818B0022
2020	2,460,000	1,970,000	W912P820B0048**

*The USACE bid tabs have "First" and "All Over" line items for dredged material. The "First" identifies the minimum quantity expected to be removed. The "All Over" line item accounts for material that may be in the reach in addition to the "First".

** Includes Optional Work from Mile 7.5 to 12.9

5.6 Cut-to-Fill Ratios

5.6.1 Earthen Containment Dike

Mechanical excavation with a small bucket excavator will be used for construction of the ECDs. Sediment losses during excavation of ECD construction are a result of material flowing off during placement, soil shrinkage, and foundation settlement during construction. A cut-to-fill of 1.2 was recommended based on the geotechnical engineering analysis (**Appendix E**); however, this cut-to-fill was re-examined and determined to be 1.4 to account for the settlement of the dike during construction. This value will be used for the mechanical dredging of the ECDs and is accounted for in the marsh fill volume.

5.6.2 Marsh Fill

The cut-to-fill ratio for marsh fill was estimated using the following equation from EM 1110-2-5025:

$$V_f = V_i\left\{\left(\frac{e_o - e_i}{1 + e_i}\right) + 1\right\}$$

Where,

V_f = volume of fine-grained dredged material after placement (yd^3)
V_i = volume of fine-grained sediments from borrow area (yd^3)
e_i = average in-situ void ratio of the borrow area
e_o = void ratio after 20 years.

Appendix G shows how this equation is re-arranged to get the cut-to-fill ratio. Based on sampling in the borrow area, the volume of "fine-grained" or clay sediment from the proposed cut area is nearly 100%. The initial in-situ void ratio in the top five (5) ft. of the borrow area is 3.11. At 20 years, the void ratio throughout the marsh fill will decrease towards the initial void ratio of the borrow area. Based on the PSDDF output data, the average void ratio in the fill area at 20 years is 3.34. The calculated cut-to-fill ratio using the equation shown above is approximately one (1.0). Then, considering losses due to dredging and dewatering cut-to-fill ratio 1.10 is selected for this project.

5.7 Dredge Pipeline Corridor Alignment Design

Two routes were explored as options for the dredge pipeline corridor. These were reviewed as alternatives to bringing in the dredge pipe through the winding sections of the access route in Long Point Bayou. The chosen corridor is the southernmost route identified in pink in **Figure 23**.The corridor will extend to the marsh creation area across broken marsh just south of Long Point Bayou. This path was chosen rather than the northern corridor to avoid impacts to healthier marsh and high ground. The pipeline corridor width is 50 ft.

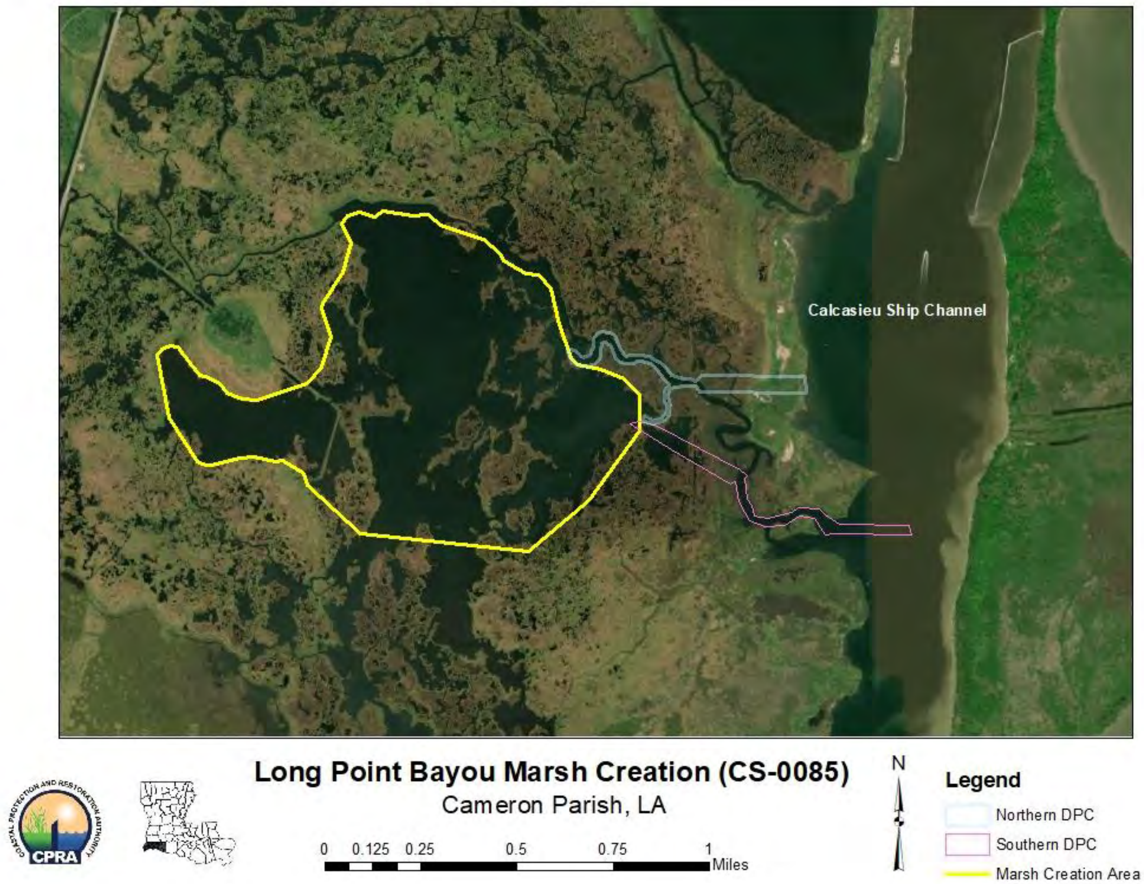

Figure 23: CS-0085 Dredge Pipeline Corridor

5.7.1 Existing Infrastructure

One existing pipeline is located in the dredge pipeline corridor. This pipeline is a Strategic Petroleum Reserve pipeline owned by the Department of Energy (DOE). More information is provided about this pipeline in Section **3.3.2**. The depth of cover over of the existing pipeline in the DPC ranged from 4.5 ft. to 6 ft. (**Figure 9**). The DOE confirmed that this 36" brine disposal pipeline to the Gulf was decommissioned in December 1995. As per the DOE, the contractor shall maintain a minimum of 3 ft. depth of cover over the pipeline during construction.

Three authorized pipelines are identified crossing in the CSC (**Table 3**). The location of the pipelines in the CSC is shown on the Plans. Since the CSC is a federally maintained channel, dredging Precautions over pipeline and utilities in the CSC shall be maintained as specified in the construction solicitation and specification of Calcasieu River and Pass Maintenance Dredging, Mile 5.0 to Mile 17.0, by USACE, New Orleans District. The USACE will ensure all pipeline and utilities have been properly identified and all the required contact information has been updated during the preparation of their operations and maintenance dredging contracts in the CSC.

5.8 Wave Model Decision

One area that is frequently of concern with marsh creation projects is the possibility of impacting wave dynamics and increasing shoreline erosion due to changing the bathymetry from dredging of the borrow areas. Since the borrow area is a portion of the ship channel that is regularly dredged, wave modeling was not needed to identify impacts caused by this project.

6.0 Construction

6.1 Equipment Mobilization

Construction will likely require hydraulic placement of sediment within the project area using a 27-inch or 30-inch cutterhead suction dredge (CSD). The Contractor should optimize the use of the lower reach of the CSC to minimize pumping distance to the site. However, in a scenario that would require material from the entire reach of the channel between River Mile 5 and River Mile 17, the max pump distance would be around seven (7) miles. Because the lower reach does span 12 miles, it is anticipated that the Contractor may need to install one or more booster pumps to get material to the project site. It will ultimately be up to the contractor to decide where the best option is to install the booster pump along the CSC based on the available dredging equipment.

Soft terrain vehicles or marsh buggies will be required to construct containment dikes and manage the slurry pipeline throughout the fill area. Spill boxes, sections of HDPE (high-density polyethylene) pipe, and steel pipe can be floated or dragged through the dredge pipeline corridor to reach the project site. Dredge pipeline/equipment access corridors must be surveyed prior to construction and returned to initial site conditions prior to demobilization.

6.2 Dike Construction

The +4.75 ft. NAVD88 dike will be constructed with in-situ material. The containment dike (6,970 LF) towards the northern boundary of the MCA will be mechanically dredged from within Long Point Bayou and will not need to be backfilled. The remaining portion of the containment dike (12,709 LF) towards the southeastern and western boundary will be built excavating material from within the MCA using marsh buggy excavators. Similarly, the 2.75 ft. NAVD88 internal training dike (3,861 LF) will be built using in-situ material within the MCA. This excavated region will later be backfilled with the marsh material pumped from the borrow source. There will be a +0.5 ft. tolerance on the containment dikes. A minimum distance of 25 ft. will be maintained between the containment dike and the borrow area in order to ensure a stable inner slope and stay within the reach of the excavator. Assuming five (5) marsh buggies can each build 65 LF of dike a day, the estimated duration for constructing total 23,541 LF of containment dike is approximately 65 days.

Once marsh fill placement of the entire marsh is complete, the dikes will either be gapped or degraded to allow tidal water exchange within the newly created marsh by TY3. Typically, 25 ft. gaps are constructed every 500 to 1,000 ft. Precise gap dimensions and spacing will be determined once hydraulic dredging operations are complete.

6.3 Construction Duration

Historic dredging events in the lower ship channel have ranged from 137 to 304 days with some variation in the areas excavated by each event. The estimated duration for the maintenance event, as listed on the dredge update on the USACE website for fiscal year 20-21, is 180 days. An estimated duration of 90 days for hydraulic dredging is presented in **Table 13** below and is lower than the historic durations for the lower CSC maintenance event.

It is estimated that 1,000 LF of pipeline can be placed per day. The maximum estimated LF of pipeline needed to reach the project area from River Mile 17 (the furthest distance) is ~44,000 LF. Therefore, maximum pipe pre-lay time is anticipated to be around 44 days. This pipeline may need to be moved to reach the lower miles in the southern section of the reach. Pipe pickup is estimated at a rate of 2,000 LF/day and 14 days for equipment demobilization/clean up/punch list items. This brings total demobilization duration to 36 days. All assumptions are based on past projects and may vary.

Table 13: Project Construction Duration

Task	**Duration (Calendar days)**
Pre-construction Meeting/Prep (includes Notice to Mariners/Aids to Navigation)	44
Pre-Construction Survey and Mobilization (includes laying dredge pipe, installment of settlement plates and staff gauges)	105
Dike Construction	65
Hydraulic Dredging	90
As-Built Survey	30
Modifications and Punch List Items	14
Demobilization (includes picking up dredge pipe)	36
Weather Days	25
Total	409

6.4 Cost Estimate

A cost estimate of Probable Construction Costs was prepared for this project using the CWPPRA PPL 31 spreadsheet and historic project bid data. For this project, the USACE will only credit the cost of the project that is within the Federal Standard. The Federal Standard is defined in USACE regulations as the least costly dredged material disposal or placement alternative (or alternatives) identified by USACE that is consistent with sound engineering practices and meets all federal environmental requirements. The total estimated construction cost including a 15% contingency is

$14,466,008. The estimated incremental construction cost (i.e. outside of the federal standard) to build the CS-0085 project as part of the USACE's lower Calcasieu River maintenance dredging event is $6,091,896. This cost is less than the Phase 0 cost estimate of $6,714,693.

7.0 Schedule

The CS-0085 project would be incorporated in the bid documents for the USACE 2023 maintenance dredging event for the lower ship channel. The USACE plans to advertise in Summer 2022 with an award in late summer/early fall. Assuming the CS-0085 project receives Phase II funding in January 2022, the CS-0085 project will be part of this advertisement and award. Dredging for this event is expected to begin around November or December 2022, with dredging completed in Spring 2023. The USACE estimated maintenance dredging bid schedule is below:

Table 14: USACE Dredge Schedule

FY 2021	
COE Dredge Advertise	August 2020
COE Dredge Award	September, 2020
COE Dredge	March 2021
COE Dredging Complete	Fall 2021
FY 2023	
COE Dredge Advertise	June/July 2022
COE Dredge Award	August/September 2022
COE Dredge	November/December 2022
COE Dredging Complete	Summer/Fall 2023

The CS-0085 project needs to progress from the 95% to the final design to meet the deadline of the USACE maintenance dredging bid in Summer 2022. A detailed final design schedule is summarized below.

Final Cost Estimate	November 15, 2021
Final Plan and Specification (P&S)	Sept. 28, 2021 – November 30, 2021
Phase II Grant Application	November 15, 2021 – March 3, 2022
Request Phase II funds	November 19, 2021
CPRA Review of Final P&S	December 1, 2021 – December 31, 2021
CPRA Revisions	January 4, 2022 – January 21, 2022
USACE Review of Final P&S	January 24, 2022 – February 28, 2022
CPRA Revisions	March 2, 2022 – March 15, 2022
USACE Acceptance of Final P&S	March 30, 2022

8.0 Risk

Engineering Design Documents, as well as the Plans and Specifications were prepared by or under the direct supervision of a licensed professional engineer 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 95% 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.

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