North Delacroix Marsh Creation and Terracing Project (BS-0041)

Coastal Wetland Planning, Protection, and Restoration Act PPL 29

95% Design Report

State Project Engineers:

Alex Holston, P.E.
Thomas McLain, P.E.

State Project Manager:

Chris Scalco, P.E.

Federal Project Manager:

Brandon Howard

Executive Summary

The North Delacroix Marsh Creation and Terracing project area is in Breton Sound Basin (in CWPPRA Region Two) in St. Bernard Parish, Louisiana. The project area is located twenty (20) miles southeast of downtown New Orleans and serves as an important buffer to Highway 300 and the Wood Lake community. The project is authorized by the Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA), and was approved for Phase I funding by the CWPPRA Task Force on January 29, 2020. The Coastal Protection and Restoration Authority (CPRA) is the local sponsor and the National Oceanic and Atmospheric Administration (NOAA) is the federal sponsor.

St. Bernard Parish is expected to see increases in wetland loss and storm surge flood depths over the next fifty (50) years (CPRA "Attachment F3", 2023). With no further coastal protection or restoration actions, the parish could lose an additional three hundred (300) square miles, or seventy-nine percent (79%) of the parish land under high environmental scenario projections (CPRA, 2024). In this area, coastal wetland loss can be attributed to drilling and dredging for oil and gas, flooding marshes from sea-level rise, storm-driven erosion from Hurricanes Katrina (2005), Rita (2005), Isaac (2012) and Ida (2021), and subsidence. The CPRA and the 2023 Coastal Master Plan (CMP) utilize two primary marsh restoration techniques, river diversions and marsh creation projects, to help offset marshland loss in the Breton Sound Basin.

Marsh creation projects involve raising the marsh elevation with hydraulically dredged sediment so that the marsh can support healthy marsh vegetation for the twenty (20) year project design life. The goal of this project is to restore marsh habitat by creating and nourishing areas to be tidal marshes for as long as possible during the twenty (20) year project life. Marsh creation projects restore landscape and ecosystem processes, enhance habitat, and provide storm surge attenuation.

The Phase 0 Project consisted of two (2) Marsh Creation Areas (MCAs) with a total area of three hundred eighty-nine (389) acres, as well as approximately 8,500 linear ft of terracing. Phase 0 also authorized data collection in additional areas that could be added to the Phase 1 Project as alternate features. The 30% Design features included three (3) MCAs (the reshaped Phase 0 cells plus an additional cell to the east) totaling three hundred seventy-one (371) acres and a reconfigured terrace field totaling 5,250 LF. Changes from the 30% Design include additional reshaping of MCAs, moving the eastern MCA to the surveyed recon area north of Jacks Canal, and adding terraces. The proposed 95% Design marsh creation project will create three (3) MCAs totaling three hundred seventy-eight (378) acres of marsh restoration. In addition, an Earthen Terrace field totaling 7,250 linear ft is being proposed to help dissipate wave energy and potentially trap sediments from MCA dewatering activities. The proposed Marsh Creation Borrow Area (MCBA) is located approximately six (6) miles southeast of the project area in Lake Amedee. A scope change request to account for increased project cost and for the changes to project layout were presented to and approved by the CWPPRA Technical Committee in March 2024 and the CWPPRA Task Force in May 2024.

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List of Acronyms

AOI	Area of Interest
APE	Area of Potential Effect
ASTM	American Society for Testing and Materials
BS	Breton Sound
BTAB	Bayou Terre aux Boeufs
CDP	Census Designated Place
CERA	Coastal Emergency Risks Assessment
CEI	Coastal Environments, Inc.
CIAP	Coastal Impact Assistance Program
CMFE	Constructed Marsh Fill Elevation
CMP	Coastal Master Plan
CPRA	Coastal Protection and Restoration Authority
CPT	Cone Penetration Test
CRMS	Coastwide Reference Monitoring System
CSD	Cutterhead Suction Dredge
CWPPRA	Coastal Wetlands Planning, Protection and Restoration Act
CY	Cubic Yard
DPC	Dredge Pipeline Corridor
DPW	Department of Public Works
EAC	Equipment Access Corridor
ECD	Earthen Containment Dike
ESA	Environmental Site Assessment
ESLR	Eustatic Sea Level Rise
ESRI	Environmental Systems Research Institute
FEMA	Federal Emergency Management Agency
FFE	Finished Floor Elevation
FT	Foot
GDR	Geotechnical Data Report
GER	Geotechnical Engineering Report
GIS	Geographic Information System
HDPE	High Density Polyethylene
HSDRRS	Hurricane and Storm Damage Risk Reduction System
HTRW	Hazardous, Toxic, and Radioactive Waste
IDIQ	Indefinite Delivery/Indefinite Quantity
LDWF	Louisiana Department of Wildlife and Fisheries
LF	Linear Foot
LiDAR	Light Detection and Ranging
MC	Marsh Creation
MCA	Marsh Creation Area
MCBA	Marsh Creation Borrow Area
MCDG	Marsh Creation Design Guidelines
MHW	Mean High Water
ML	Mudline
MLW	Mean Low Water
MNA	Marsh Nourishment Area
MTL	Mean Tide Level
NAD83	North American Horizontal Datum of 1983
NAIP	National Agriculture Imagery Program
NAVD88	North American Vertical Datum of 1988
NGS	National Geodetic Survey
NOAA	National Oceanic and Atmospheric Administration

NPMS	National Pipeline Mapping System
NRHP	National Register of historic Places
OPUS	Online Positioning User Service
PPL	Project Priority List
PSDDF	Primary Consolidation, Secondary Compression, and Desiccation of Dredged Fill
REC	Recognized Environmental Conditions
ROW	Right-of-Way
RPA	Registered Professional Archeologist
RSLR	Relative Sea Level Rise
RTK	Real-time Kinematic
SF	Square Foot
SHPO	State Historic Preservation Office
SLR	Sea Level Rise
SONRIS	Strategic Online Natural Resources Information System
SOP	Standard Operating Procedure
TBS	T. Baker Smith, LLC
TIN	Triangulated Irregular Network
TY	Target Year
UAV	Unmanned Aerial Vehicle
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
WVA	Wetland Value Assessment

1.0 INTRODUCTION

The North Delacroix Marsh Creation and Terracing project is in the Breton Sound (BS) basin, just east of Highway 300 and Bayou Terre aux Beoufs (BTAB), near Wood Lake, as shown in **Figure 1**. In 2020, the Louisiana Coastal Wetlands Planning, Protection and Restoration Task Force designated BS-0041 as part of the 29th Priority Project List (PPL29). The NOAA was designated as the lead federal sponsor. The CPRA is serving as the local sponsor and will provide engineering and design services.

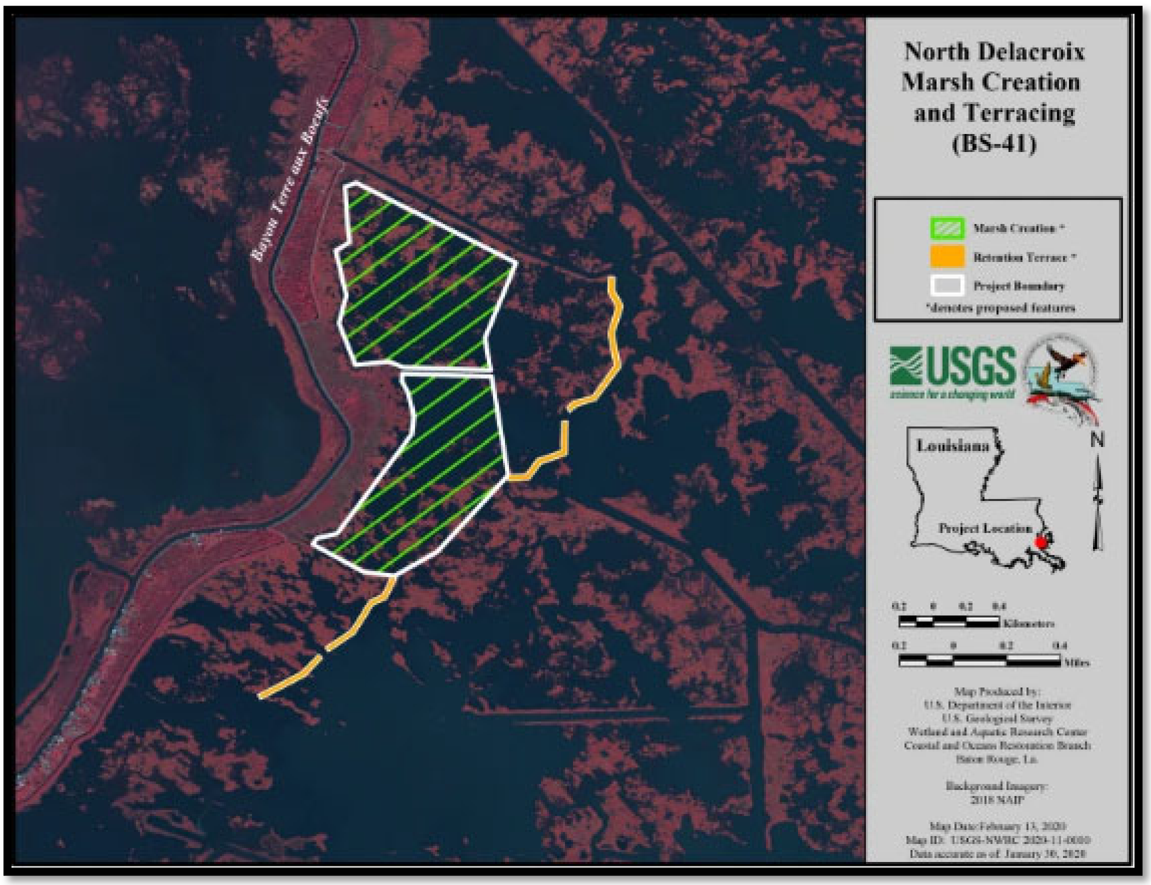

Figure 1: CWPPRA Phase 0 Project Area (CWPPRA, 2020)

1.1 Engineering and Design Standards for Marsh Creation Projects

The NOAA is serving as the federal project sponsor in addition to providing environmental compliance and coordination for cultural resources. The CPRA is both serving as the local project sponsor and providing the professional engineering and drafting services for the proposed project and the development of the project bidding documents. To complete these technical tasks, several consulting services were utilized from the approved CPRA Indefinite Delivery/Indefinite Quantity (IDIQ) Contracts. The project's consulting team included C.H. Fenstermaker & Associates, L.L.C. (Fenstermaker), TerraSond Limited (TerraSond), Eustis Engineering, and T. Baker Smith, LLC (TBS). Fenstermaker provided surveying services for the project area and collected MCBA bathymetry, geophysical, and magnetometer survey data. TerraSond assisted the Fenstermaker survey crew with sub-bottom profile surveys and a Phase I marine cultural resource investigation in the MCBA. Fenstermaker also performed the topographic survey for the marsh creation areas (MCAs) and consolidated all of the survey data for the survey report. Eustis Engineering performed geotechnical exploration and engineering services for the project, including the analysis of project features. TBS provided surveying services for Eustis Engineering to gather elevations and magnetometer data for the proposed boring locations.

The CPRA Project Management Division has been tasked with leading the required land rights services while the CPRA Planning and Research was tasked with environmental services. To complete these tasks, several consulting services were required from Timbalier Resources, LLC (Timbalier), Moffat & Nichol, Coastal Environments, Inc. (CEI), and Providence Engineering and Environmental Group LLC (Providence). Timbalier provided land rights services, including researching ownership information in the tax assessment records, preparing a tax assessment report and chain of title report. CEI conducted a Phase I terrestrial cultural resources survey in the MCAs as part of the Moffat & Nichol team. APTIM Environmental & Infrastructure, LLC performed a Hazardous, Toxic, and Radioactive Waste Investigation (HTRW) and Phase I Environmental Site Assessment (ESA).

1.2 Project Area History

The proposed MCAs are located just east of BTAB, approximately 2 miles north of Delacroix, LA. The first known settlers of Delacroix along BTAB were the Canary Islanders (often referred to as Los Isleños). In the 1780s, Governor Bernardo de Galvez settled a group of Spanish Canary Islanders along the stream's banks where they lived a coastal life hunting and fishing. Today, the area still supports commercial and recreational anglers, fishing docks, tourist fishing businesses, boat launches, and related facilities. Delacroix, LA was first listed as a census designated place (CDP) in the 2020 census with a total population of 48 (U.S. Census Bureau, 2020).

1.3 Landforms and Waterways in Project Area

The project area is located within the Breton Sound Basin, which is a remnant of the Mississippi River delta lobe and the abandoned St. Bernard Delta (**Figure 2**). The principal hydrologic features of the Breton Sound Basin include the Mississippi River and its natural levee ridges, the flood protection levee, abandoned delta distributaries, Lake Lery, Grand Lake, other interior lakes, and the freshwater diversions at Caernarvon, White Ditch, Bohemia, and Bayou Lamoque. The barrier islands, which make up the Breton National Wildlife Refuge are offshore and thus provide minimal protection to the project area.

The Mississippi deltaic plain formed over the last 10,000 years as the Mississippi River flowed towards the Gulf of Mexico, depositing sediment and nutrients to coastal marshes. BTAB and La Loutre were once the primary channels of the Mississippi River during the formation of the St. Bernard Delta between 5,500 to 1,100 years ago (Saucier, 1994). The natural levee of BTAB is the highest natural landform in the project area. Since the construction of flood control levees along the Mississippi River in the 1930s to reduce floodwaters on urban areas in the Mississippi floodplain, the Mississippi River no longer provides a significant freshwater source and sediment to this region. Coastal marshland growth in the Breton Sound Basin generally ceased, resulting in a slow marsh vegetation retreat.

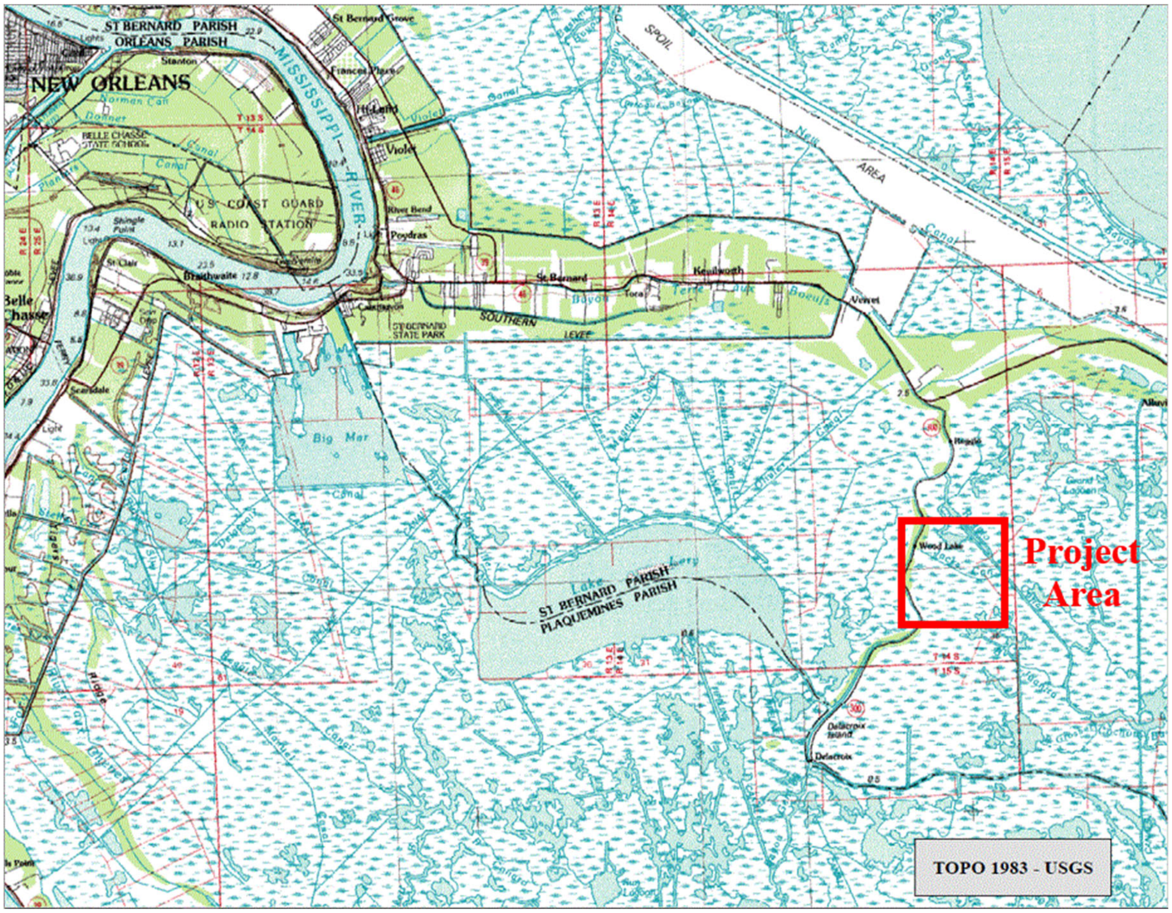

Figure 2: Project Vicinity on Black Bay, LA Topographic Map - 1983 USGS

Local topographic features include Jack's Canal, Reggio Canal, Bayou Juanita, Bayou Groscbec, Cochon Bay, Lake Amedee, Petain Lagoon, and BTAB as shown in **Figure 3**. The primary man-made landforms in the project area include Highway 300, the Wood Lake tidal levee, and the spoil banks along Jack's Canal. These natural and man-made waterways and landforms influenced the positioning of the proposed marsh restoration efforts. The proposed marsh creation project will reduce its impact on the current landscape by utilizing the existing landforms present in the project area.

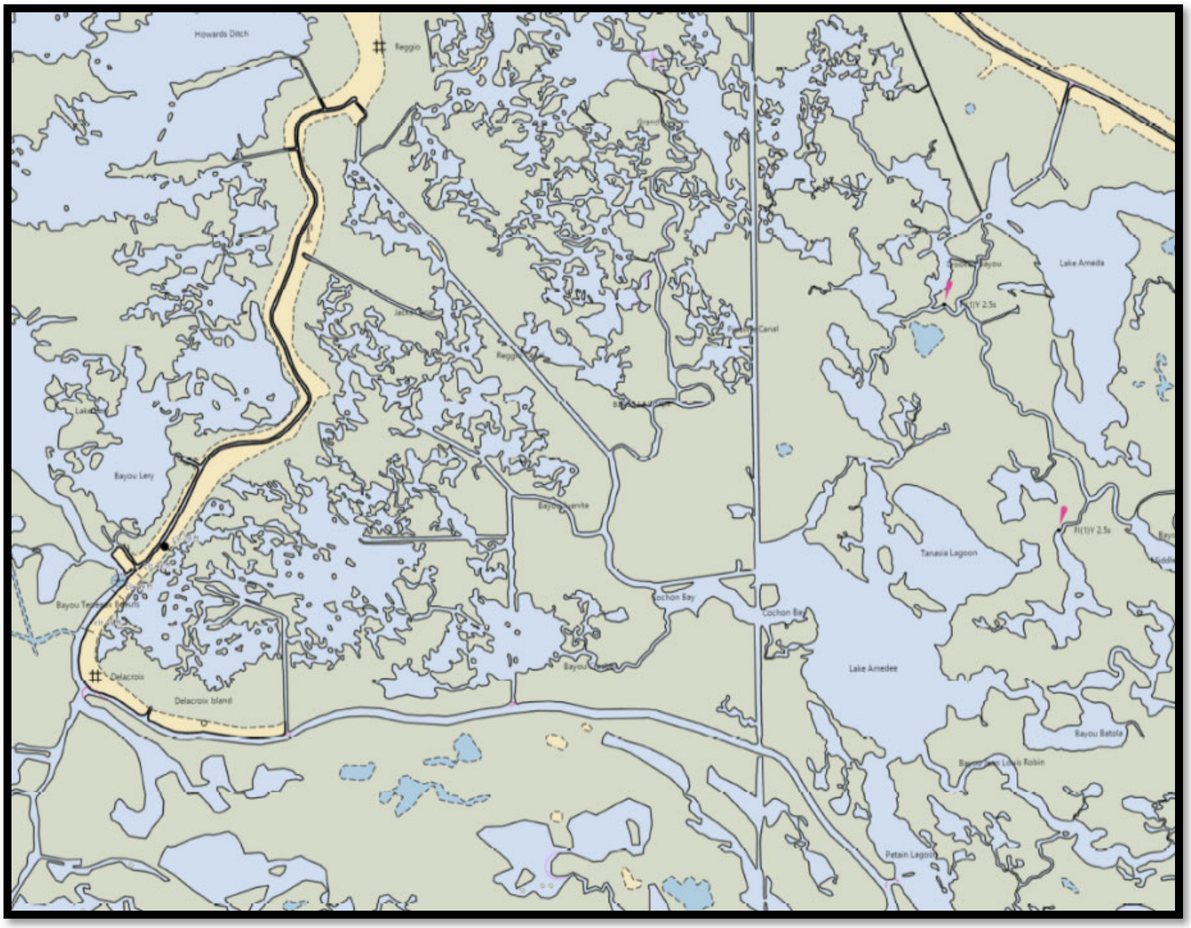

Figure 3: NOAA Navigational Chart for Area East of Delacroix Island

1.4 Land Loss in Project Area

The loss of wetlands in the project area has increased dramatically over the last several decades due to a combination of human-induced and natural processes. These factors include hydrologic modifications of the Basin, dredging for access to facilitate hydrocarbon extraction and infrastructure, storm-driven erosion, subsidence, and sea-level rise.

By the 1990s, the marsh in the project area was severely degrading with open water taking the place of marsh grass by 1998. Land loss in the project area became even more apparent following Hurricanes Katrina, Isaac and Ida's passage in 2005, 2012, and 2021 respectively. Hind cast storm surge modeling provided by Coastal Emergency Risks Assessment (CERA), estimates the maximum water height in Delacroix, LA on August 29, 2005 was 15.6 ft NAVD88 due to hurricane Katrina. Inundation of high saline water from surrounding saline waterbodies and wind-induced scour, from Hurricanes Katrina, Isaac, and Ida increased land loss within the project area.

USGS calculated historical rates of land change for the BS-0041 Wetland Value Assessment using an experimental land loss analysis and found that from 1984-2018 the land loss rate was -1.41% per year (-47.55 ac/yr) for an extended project boundary totaling 4,149 acres (**Figure 4**). This land loss trend is represented in **Figure 5**. Without further action, land loss will continue to occur in the project vicinity without sediment reintroduction into the system. The wetland loss in the area is shown in aerial photography taken in 2004 and 2024 (Error! Reference source not found. and **Figure** 7).

Figure 4: PPL29 North Delacroix Marsh Creation & Terracing Extended Project Boundary (USGS)

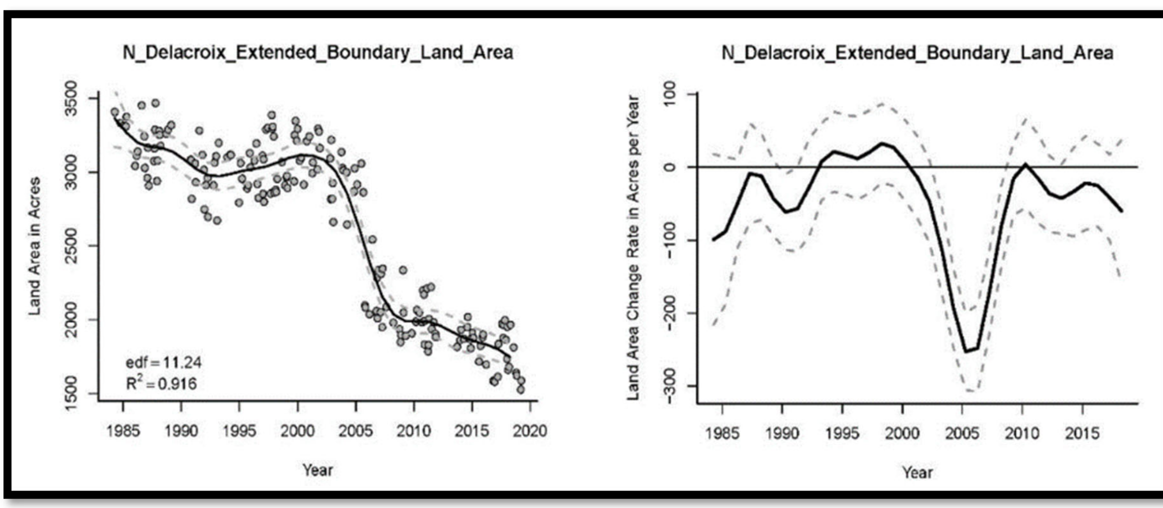

Figure 5: Land Area Change Rate for BS-0041 (extended boundary)

Figure 6: 2004 Imagery of Wood Lake (Google Earth)

Figure 7: 2024 Imagery of Wood Lake (Google Earth)

1.5 Project Goals

As established in Phase 0 and as stated on the CWPPRA PPL 29 Project Fact Sheet, the primary goals of BS-0041 were to create three hundred twenty-two (322) acres and nourish sixty-seven (67) acres (three hundred eighty-nine (389) acres total) of marsh in two (2) confined disposal areas by hydraulically dredging material from Lake Lery. Approximately 8,548 ft of earthen terraces were to be constructed and planted on the sides and crown with appropriate bare root vegetation.

Throughout the Engineering and Design (Phase 1) process, adjustments were made to the configuration and location of the MCAs and the MCBA to minimize cost and risk for the State and CWPPRA program. Earthen containment dikes (ECDs) and earthen terraces were re-aligned based on hydrographic survey collected to avoid deeper areas, which could cause stability issues for construction. Additional terraces were added and one of the MCAs was moved to the surveyed recon area between the Reggio Marsh Creation (BS-0043) and BS-0041 projects. The naming of the MCAs was updated with the new alignments: the cell in the surveyed recon area north of Jacks Canal is now MCA-1; the 30% Design MCA-1 is now named MCA-2; the 30% Design MCA-2 was removed; and the 30% MCA-3 kept its naming (**Figure 8**). The MCBA was relocated from Lake Lery to Lake Amedee to eliminate the need for installing a casing pipe underneath Highway 300.

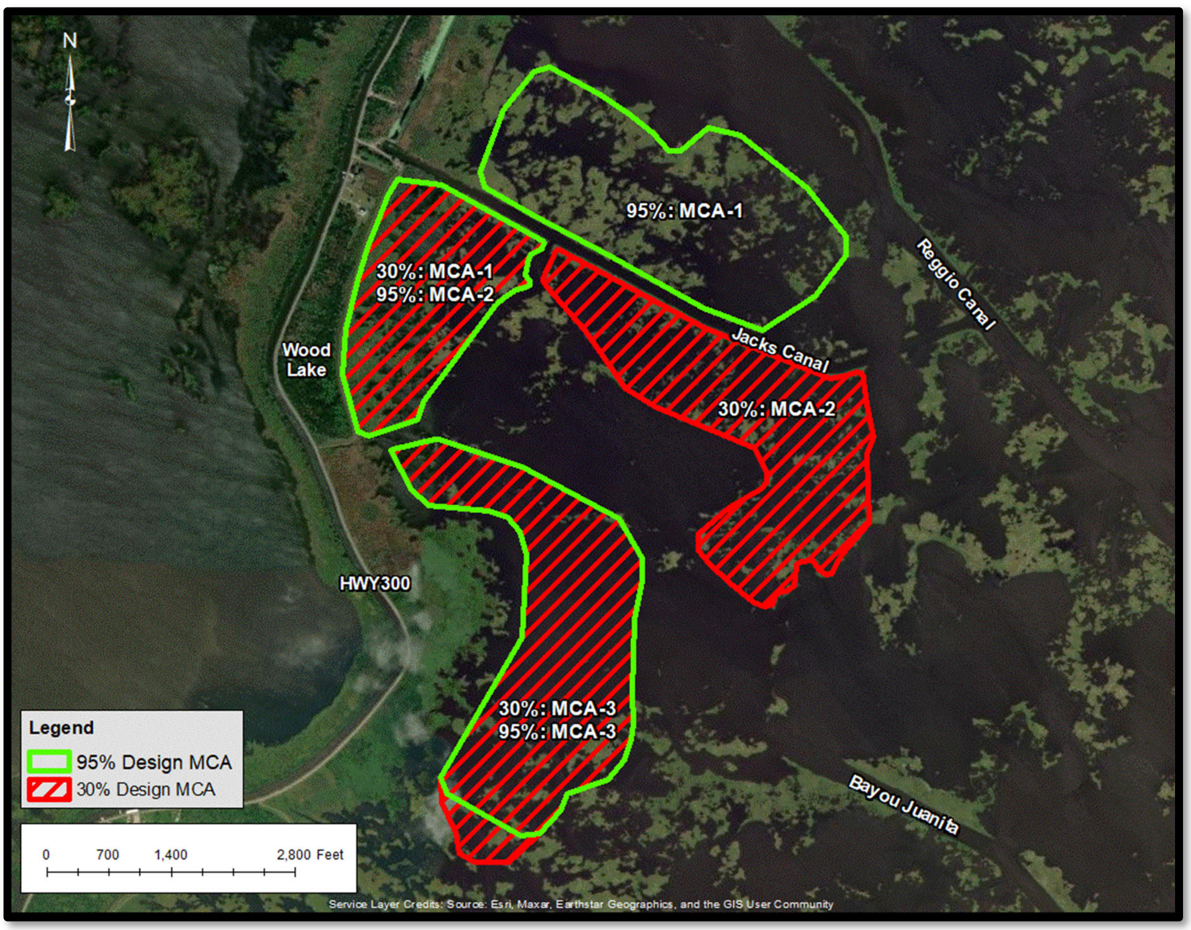

Figure 8: BS-0041 30% & 95% Design MCA Naming

The total acreage of the marsh creation and nourishment areas decreased from three hundred eighty-nine (389) acres to three hundred seventy-eight (378) acres. Additionally, the location of the borrow area shifted from utilizing Lake Lery as a borrow source to Lake Amedee. Adjustments were also made to the area and configuration of the earthen terraces which would change the total length from 8,548 linear ft to 7,250 linear ft. All project features are shown in **Figure 9** and discussed in further detail in the **Project Design** Section (see Section 5.0).

The project goals for the North Delacroix Marsh Creation and Terracing project are to:

- Restore marsh habitat via marsh creation and nourishment, ensuring tidal influence as early as possible and for as long as possible during the twenty (20) year project life, taking into consideration elevations and ecological performance of existing marsh habitats.
- Create terraces that serve as a buffer to protect from the erosive potential of wind-generated waves, to reduce wave fetch, to create habitat for fisheries, and for sediment retention during construction dewatering efforts.

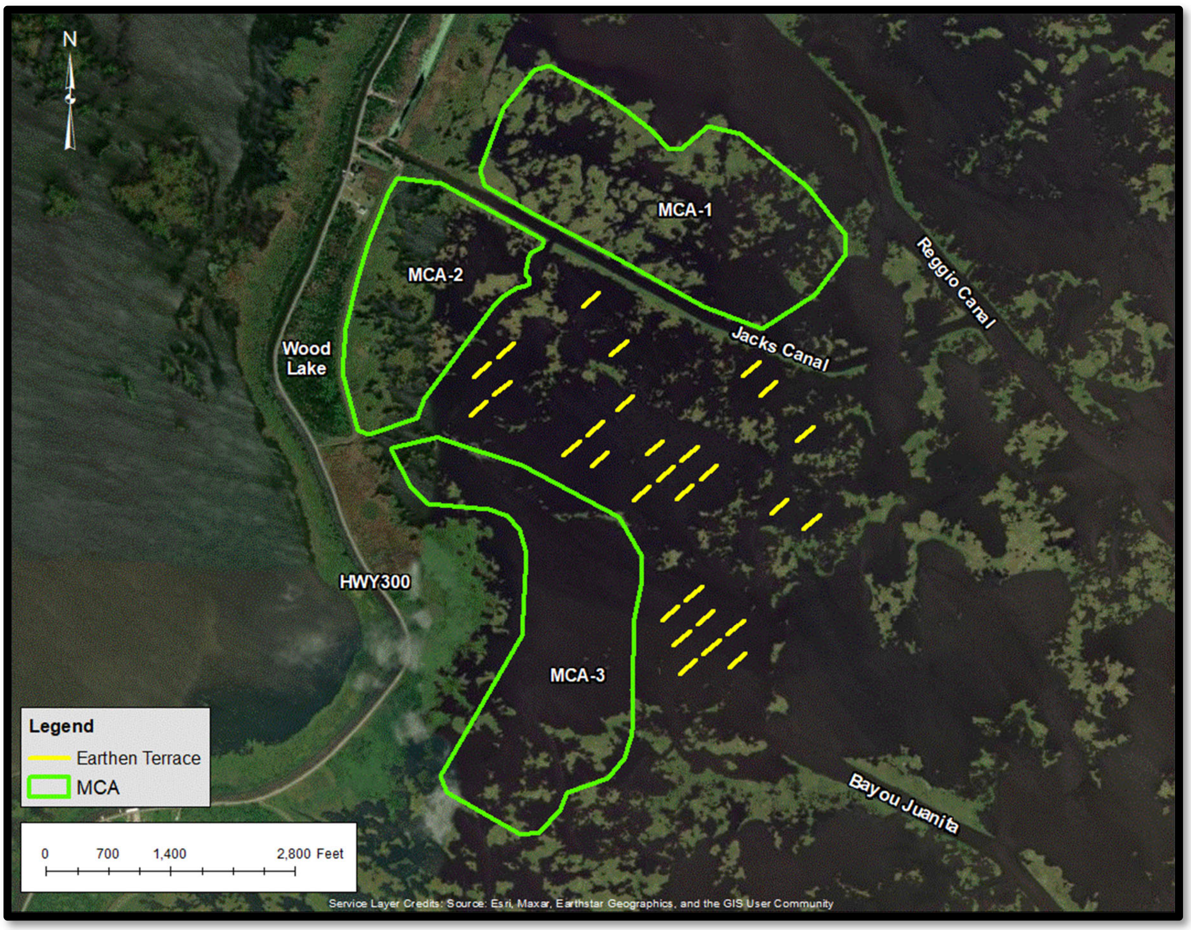

Figure 9: North Delacroix Project 95% Features

1.6 Existing Project Area Features

The community of Wood Lake is situated on the BTAB ridge bounded by an earthen embankment on the east and Highway 300 on the west. These two topographical features form a tidal ring levee system protecting Wood Lake from moderate tidal flooding. Storm water from rainfall and overtopping is stored in the drainage canals next to the tidal levee until the water can be hydraulically removed from the area. The Delacroix, Wood Lake, and Reggio communities are currently vulnerable to high tide flooding and the probability of these flooding events occurring more frequently in the near future is increasing due to several factors including sea-level rise, land loss, and subsidence.

Wood Lake also has a pump station maintained and operated by the St. Bernard Parish Department of Public Works (DPW). This pump station removes water from the drainage canals and delivers it to Jacks Canal. Following Hurricane Katrina, in 2009, significant modifications occurred to the community of Wood Lake's pump station. This Federal Emergency Management Administration (FEMA) Public Works project included raising the diesel engines to a finished floor elevation (FFE) of twenty (20) ft above sea level and increasing the station’s capacity. The community pump station has a single twelve-inch (12”) diameter discharge line capable of pumping up to 4,750 gallons per minute. This pump station's primary purpose is to remove storm water from the drainage canals that serve as a retention area for Wood Lake, which receives an annual average rainfall of approximately sixty (60) inches. The proposed marsh creation layout is delineated to minimize impact to emergency dewatering operations of the island’s drainage canals when required.

1.7 Breton Sound Marsh Creation Projects

The North Delacroix Marsh Creation and Terracing Project (BS-0041) is one of several marsh creation projects within the Breton Sound Basin that are currently in either the Phase 1 (engineering & design phase) or pending construction and are planning to use either Lake Amedee, Lake Lery, Grand Lake, Petit Lake, the Mississippi River, or Lake Ameda as a borrow source. These projects are summarized in **Figure 10** and **Table 1**.

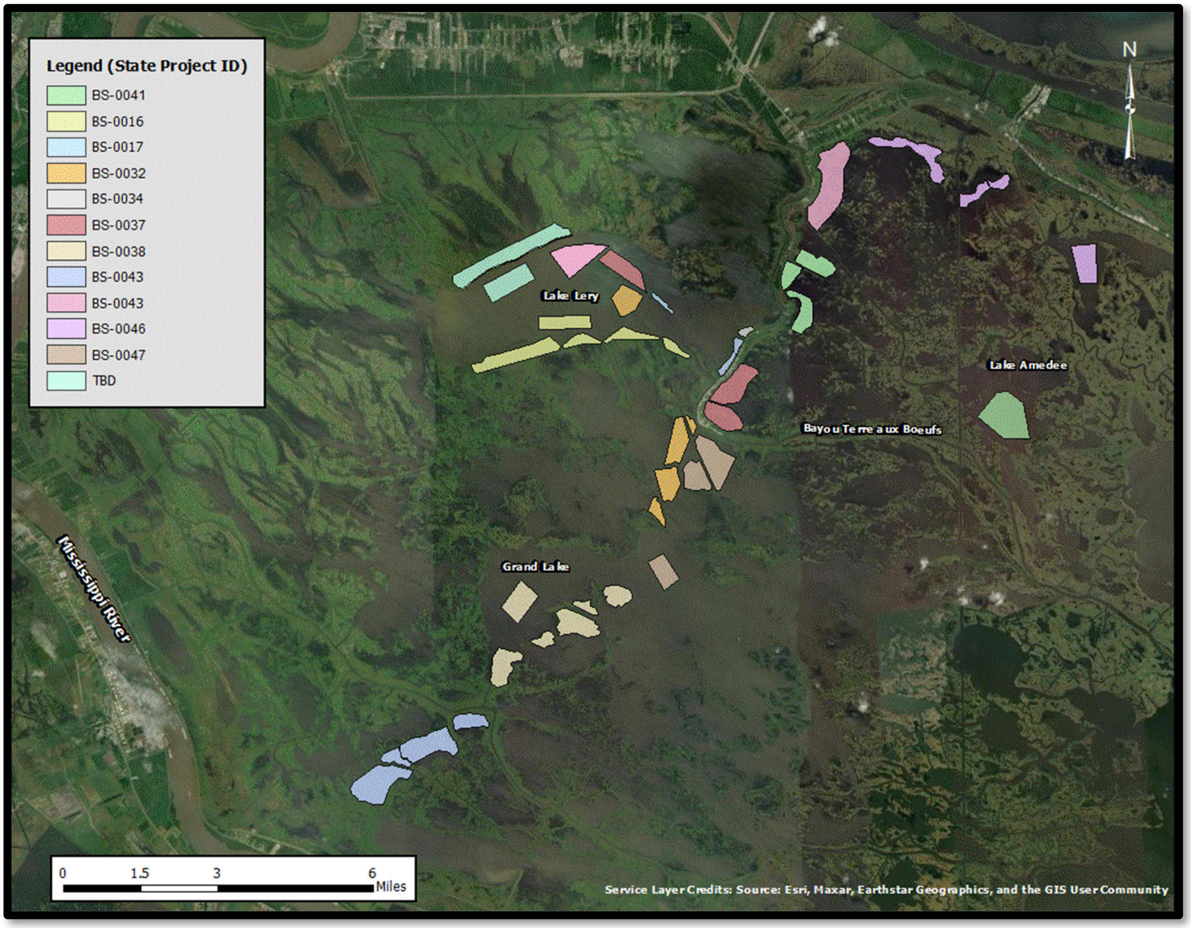

Figure 10: Map of the Planned MCAs & MCBAs in the Breton Sound Basin

<u>**Table 1:** Restoration Projects in the Breton Sound Basin</u>

Project ID	Project Name	Status	Funding Source	Borrow Source
BS-0032	Mid-Breton Landbridge MC and Terracing	Awarded Phase II Construction Funding	CWPPRA	Lake Lery
BS-0016	South Lake Lery Shoreline and Marsh Restoration	Constructed	CWPPRA	Lake Lery
BS-0017	Lake Lery MC Phase 1	Constructed	CIAP	Lake Lery
BS-0034	Lake Lery MC Phase 2	Active Construction		
TBD	Lake Lery MC Phase 3	PPL33		
BS-0037	East Delacroix MC and Terracing	Awarded Phase II Construction Funding	CWPPRA	Lake Lery
BS-0038	Mid-Breton (West) MC	Awarded Phase II Construction Funding	CWPPRA	Grand Lake
BS-0042 & BS-0044	BS-0042 Phoenix MC - East & West Increment	Phase I E&D Funding	CWPPRA	Mississippi River
BS-0043	Reggio MC and Hydrologic Restoration	Phase I E&D Funding	CWPPRA	Lake Lery
BS-0046	Yscloskey	Phase I E&D Funding	CWPPRA	Lake Ameda
BS-0047	South Delacroix Marsh Creation	Phase I E&D Funding	CWPPRA	Petit Lake

1.8 Land Ownership

A land rights investigation was conducted by CPRA's Land Rights Division following the CWPPRA Standard Operating Procedure (SOP) and implemented as per the Marsh Creation Design Guidelines Version 1.0 (MCDG 1.0 Section 3.4). This included a tax assessment report and title research.

The project area contains sixty (60) tracts of land, consisting of approximately two hundred twenty (220) undivided landowners (**Figure 11)**. The MCBA in Lake Amedee is claimed by the Office of State Lands. The title research to confirm ownership has been completed.

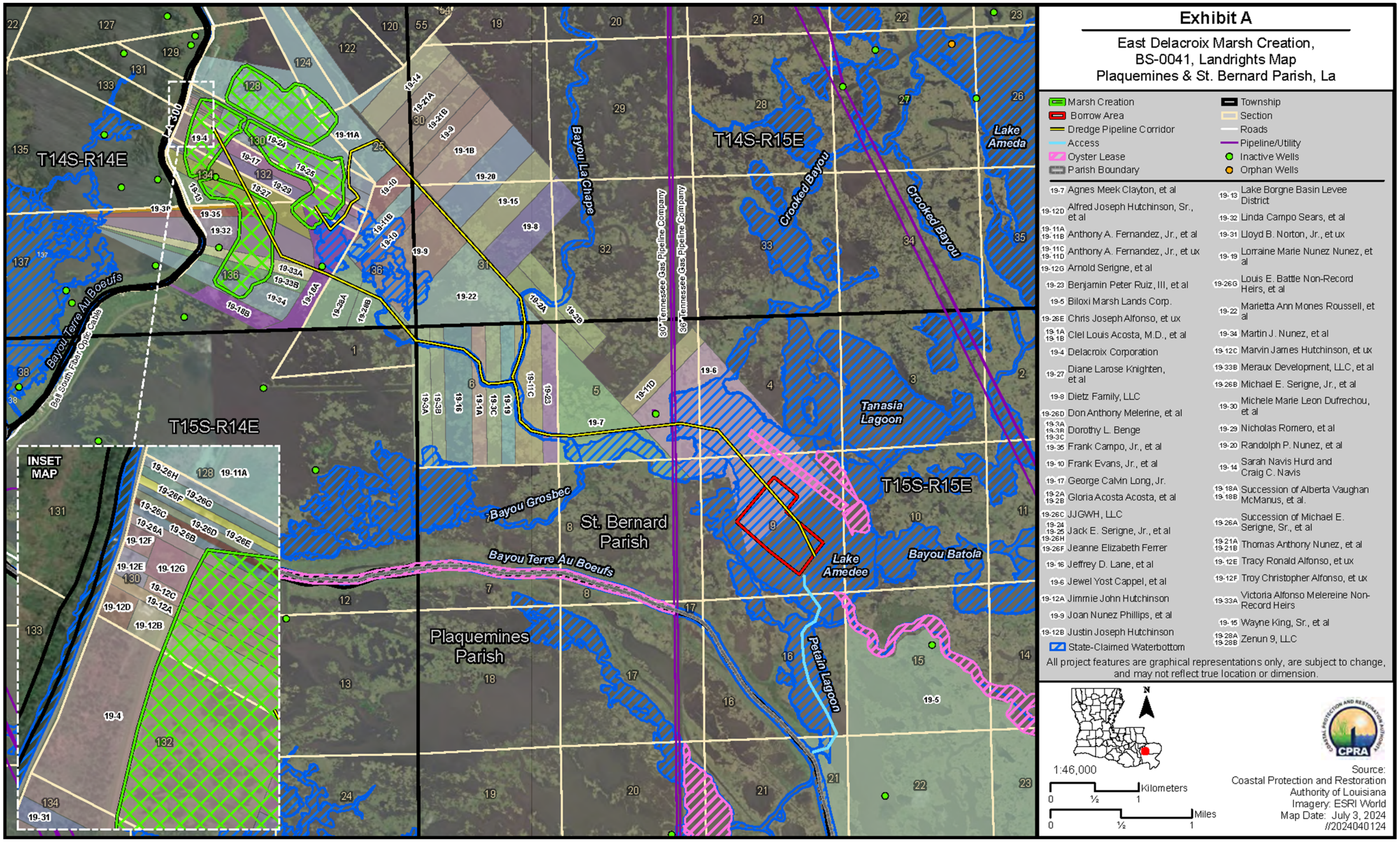

Figure 11: Land Ownership Map

1.9 Cultural Resources Assessment

Cultural resources assessments were conducted separately for the MCAs, Bas, and dredge pipeline corridor (DPC) to evaluate the Area of Potential Effect (APE).

1.9.1 Marsh Creation Area

Coastal Environments, Inc. (CEI) performed a Phase I cultural resources survey on the marsh creation APE in April 2021 (**Appendix D**). The cultural resources survey of the MCAs and the terraces was conducted from an airboat and involved systematic probing of high probability areas and examination of shorelines for shell accumulations and artifacts. Findings and recommendations are contained in the *Phase I Cultural Resources Survey of the North Delacroix Marsh Creation and Terracing Project (BS-0041), St. Bernard Parish, Louisiana* (CEI, 2021). The survey located no archaeological sites or other historic properties and based on the results of this survey, the project will have no effect on historic properties. No further work is recommended.

1.9.2 Borrow Area and Dredge Pipeline Corridor

As part of the survey of the borrow area performed by Fenstermaker, a Registered Professional Archeologist (RPA) was present for the efforts in accordance with LR 20:410 of April 1994. The cultural resources survey for the proposed marsh creation borrow area (MCBA) was performed by CEI in January 2022 (**Appendix D**). Systematic coverage of the survey area was obtained by bathymetry, magnetic, sonar and sub-bottom profile survey along primary lines across the MCBA and DPCs. The survey revealed fifty-six (56) side scan sonar contacts and two hundred sixty (260) magnetic anomalies within the survey area, however only two were recommended for avoidance as potential modern debris, one as a modern shipwreck, with one hundred (100) ft buffer zones. Both of the anomalies are found in potential DPCs where dredge pipeline will be floated in and laid on the bottom. It is recommended that the pipelines are not anchored on the bottom within the one hundred (100) ft buffer of the two anomalies. No areas of high potential for archaeological significance were interpreted within the datasets.

The NOAA consulted with the State Historic Preservation Office (SHPO) regarding the BS-0041 borrow and DPC APEs. Copies of the letters sent to the NOAA by the SHPO can be found in **Appendix A**. After a review of the provided surveys, the NOAA was issued letters stating that SHPO concurred with the assessments that no archeological properties were listed in or eligible for listing in the National Register of Historic Places (NRHP) for either survey.

1.10 Oyster Lease Assessment

The State of Louisiana leases water bottoms to oyster harvesters for the production and harvesting of oysters. There are approximately 400,000 acres of state water bottoms currently under lease. CPRA Land Rights has conducted an oyster lease assessment within the study area. A review of the Louisiana Department of Wildlife and Fisheries (LDWF) oyster lease database revealed that four (4) oyster leases or oyster seed grounds are present in the study area, which is within 1,500 the access routes and borrow area (**Figure 12**). No oyster leases or oyster seed grounds are present within the one hundred fifty (150) ft direct impact area. The list of oyster lease holders can be found in **Appendix J**. The oyster lease assessment found that there were no live resources within the 150 ft buffer zone, and only some shells were found within the 1,500 ft buffer zone. An appraisal of these oyster leases shall be performed upon Phase II authorization, to determine if compensation will be needed.

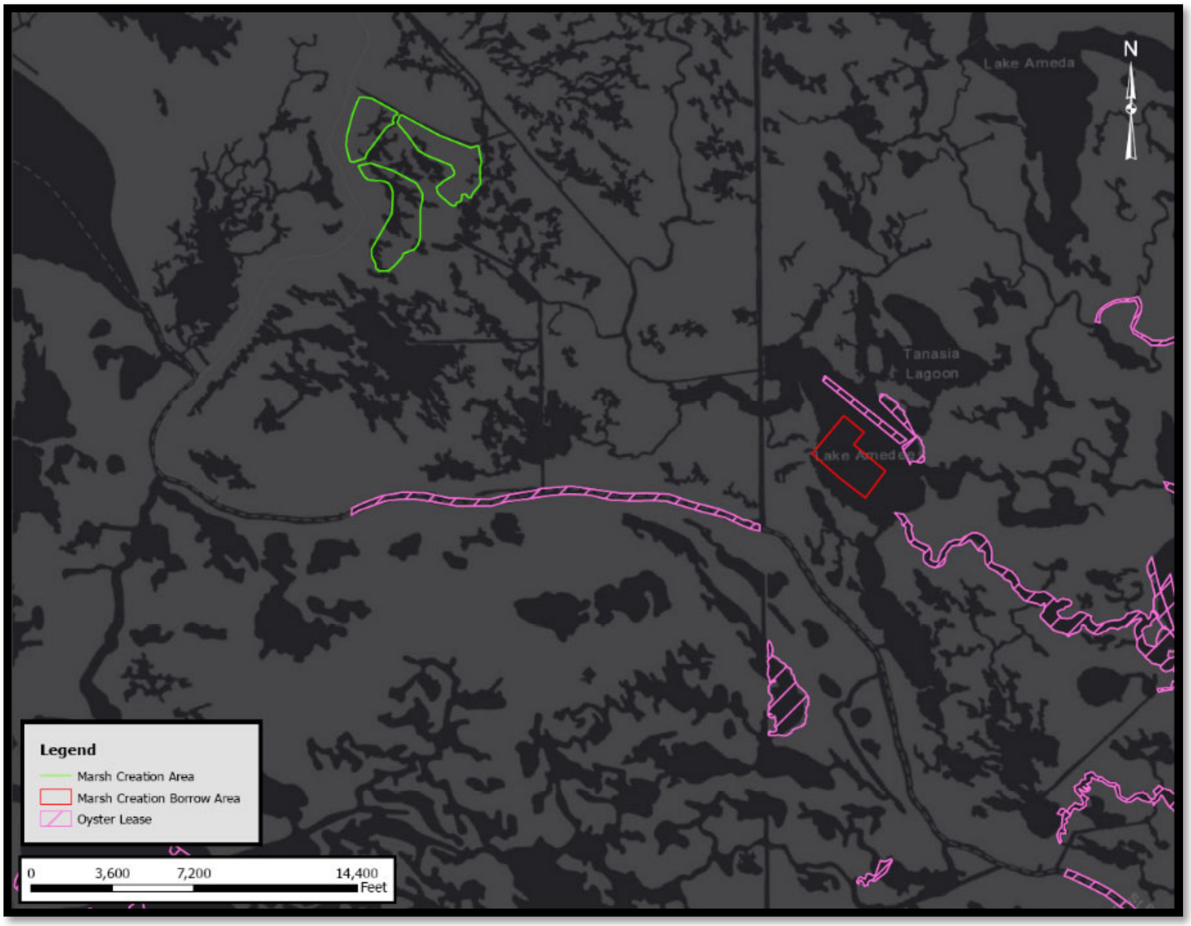

Figure 12: North Delacroix Marsh Creation Project Area & Oyster Leases (LDWF)

1.11 Phase 1 Environmental Site Assessment

Aptim performed a Phase I ESA in conformance with the scope and limitations of the American Society for Testing and Materials (ASTM) Practice E1527-13 of the North Delacroix Marsh Creation and Terracing Project Area (the “Property”). The purpose of the Phase I ESA is to identify, to the extent feasible, recognized environmental conditions (RECs) in connection with the Property. The assessment consisted of a records review, Vapor Encroachment Screening- Tier 1, site reconnaissance, and interviews. The assessment and report prepared by Aptim revealed no evidence of RECs with the Property. The ESA for the North Delacroix project is provided in **Appendix B**.

2.0 HYDROLOGIC CONDITIONS

2.1 Sea Level Rise

To properly design the North Delacroix Marsh Creation Project and ensure it is built and performs according to the objectives of the twenty (20) year project life, specific natural processes such as eustatic (global) sea-level rise (ESLR) and subsidence must be assessed. ESLR refers to a global change in water level. The value associated with ESLR is based on a global average rate of water level increase that considers several variables including ocean heat uptake and thermal expansion, loss of glaciers, and runoff from thawing permafrost. The CPRA Planning Division provided forecasted sea-level rise rates consistent with the 2023 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 one (1.0) meter scenario to design marsh creation projects (Demarco 2012). This accounts for nearly six (6) inches of sea-level rise over the twenty (20) year project design life. Details of these calculations are provided in the 95% Design Calculations Package (**Appendix H**).

2.2 Subsidence

Subsidence differs from ESLR in that it is measured locally. Subsidence is defined as the rate of local vertical land movement down or in a negative direction. Natural causes of subsidence include plate tectonics and Holocene sediment compaction. Anthropogenic causes of subsidence include drilling and removal of subsurface fluids. Recent detailed subsidence studies were completed in 2019 by Applied Coastal Research and Engineering (ACRE) and C.H. Fenstermaker and Associates in the Breton Sound and Barataria Basins. The 2019 CPRA/ACRE report determined that Holocene geology and sediment consolidation are primary factors controlling subsidence. Results from this study indicate that the subsidence rates in the Breton Sound Basin generally range from 3.0-4.0 mm per year (ACRE, 2019). The subsidence rate selected for the design of BS-0041 was 4.0 mm per year (0.16 inches/yr.). This equates to a decrease in the project area mud line elevation of 3.4 inches over the twenty (20) year project design life.

2.3 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 an intertidal elevation throughout the twenty (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 average of the MHW and MLW for that period.

Water level data was collected from nearby gauges including the Coastwide Reference Monitoring System (CRMS) monitoring station CRMS 0146 and CRMS 4355 shown in **Figure 13**. The United States Army Corps of Engineers (USACE) hardened gage was installed in March of 2022 and will provide real-time water level data in BTAB for construction oversight. This gauge is located on the Hurricane & Storm Damage Risk Reduction System (HSDRRS) gauge structure near end of Highway 300 in Delacroix and data is available at Rivergages.com. The CRMS sites 0146 and 4355 were selected as the design stations because of their long-term record of data and proximity to the project area as shown in **Appendix C** and **Figure 13:** Water Level Gauges near Project Location

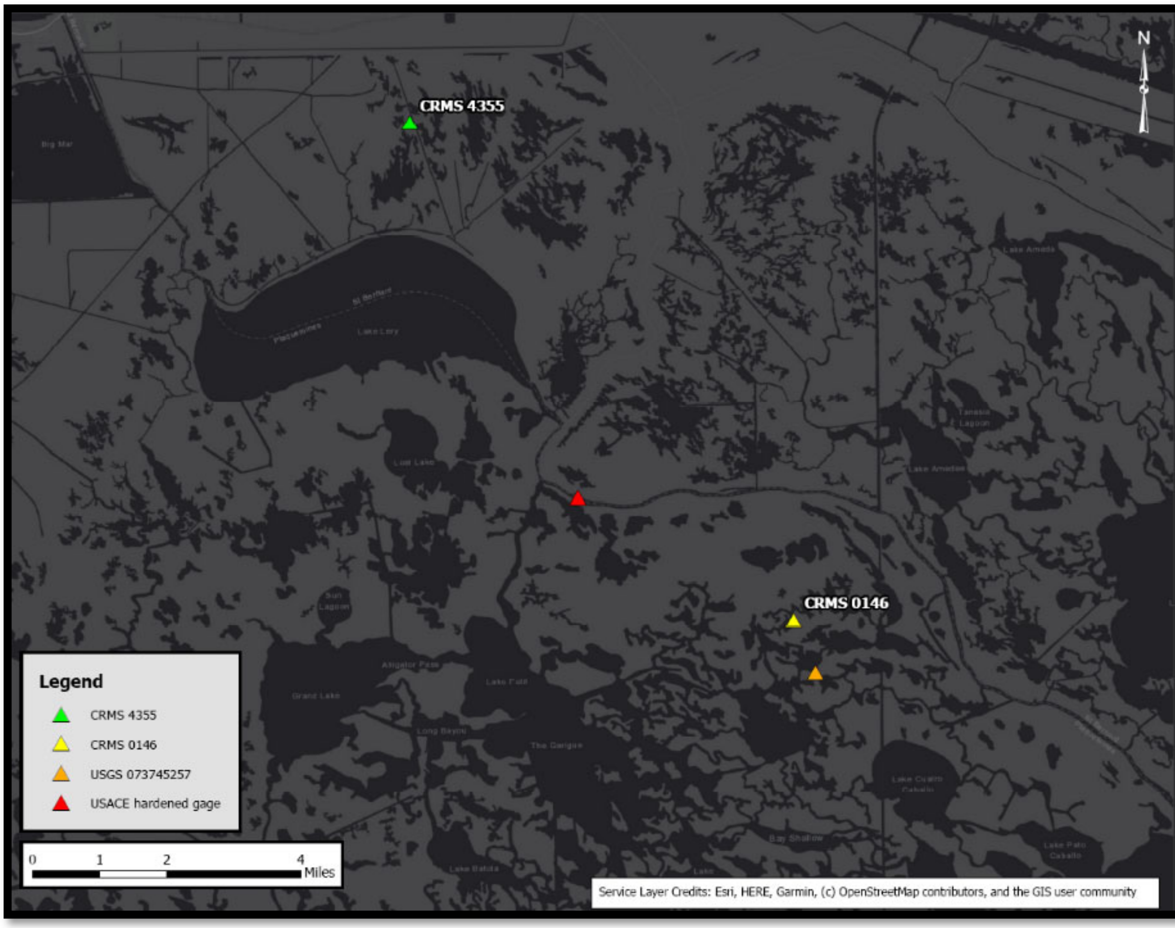

Figure 13: Water Level Gauges near Project Location

Hourly hydrographic data was collected from CRMS 0146 and CRMS 4355 for the period of record from August 17, 2017, to August 17, 2022, five (5) years as per CPRA's Marsh Creation Design Guidelines 1.0 (MCDG 1.0): Appendix D: *Marsh Inundation Methodology*.

The results of the tidal datum determination for the BS-0041 project area are shown in **Table 2**. The average MHW between CRMS 0146 and CRMS 4355 during the past five (5) years was +1.02 ft NAVD88, the MLW was +0.41 ft NAVD88, and the MTL was +0.71 ft NAVD88. This equates to a mean range in the tide of 0.62 ft.

Table 2: Tidal Conditions near Project Area

CRMS Station	MHW, ft (NAVD88, GEOID12B)	MLW, ft (NAVD88, GEOID12B)	MTL, ft (NAVD88, GEOID12B)
4355	+0.97	+0.55	+0.76
0146	+1.06	+0.26	+0.66
Average	**+1.02**	**+0.41**	**+0.71**

2.4 Percent Inundation Determination

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). Historically, the tidal range between MHW and MLW has been the accepted range for healthy marsh. Percent inundation refers to the percentage of the year a certain elevation of land would be flooded. Therefore, using percent inundation rather than MHW/MLW as a target range for marsh elevation may result in a more functional constructed marsh.

To determine percent inundation, the percentiles were calculated based on data gathered from both the CRMS 0146 and CRMS4355 stations, and averaged for the most recent five (5) year period from August 17, 2017, to August 17, 2022. **Table 3** and **Figure 14** presents the percent inundation results with ESLR applied for the duration of the project life.

Table 3: Percent Inundation Elevations with ESLR

Percent Inundation Elevations with ESLR CRMS 0146 & CRMS 4355		
Percent Inundated	**TY0 (2027) Marsh Elevation** (ft NAVD88 GEOID 12B)	**TY20 (2047) Marsh Elevation** (ftNAVD88 GEOID 12B)
1%	+3.09	+3.62
5%	+1.96	+2.48
10%	+1.65	+2.17
20%	+1.32	+1.84
30%	+1.12	+1.64
40%	+0.96	+1.49
50%	+0.81	+1.34
60%	+0.67	+1.19
65%	+0.60	+1.12
70%	+0.53	+1.05
80%	+0.34	+0.86
90%	+0.07	+0.59

*Highlighted rows represent the optimal inundation range for intermediate marsh.

Intermediate marsh vegetation is most productive when flooded between ten and ninety percent (10% and 90%) of the time (Snedden and Swenson 2012). Productivity of the marsh vegetation is based on salinity and vertical position of the marsh in relation to water levels (Snedden and Swenson 2012).

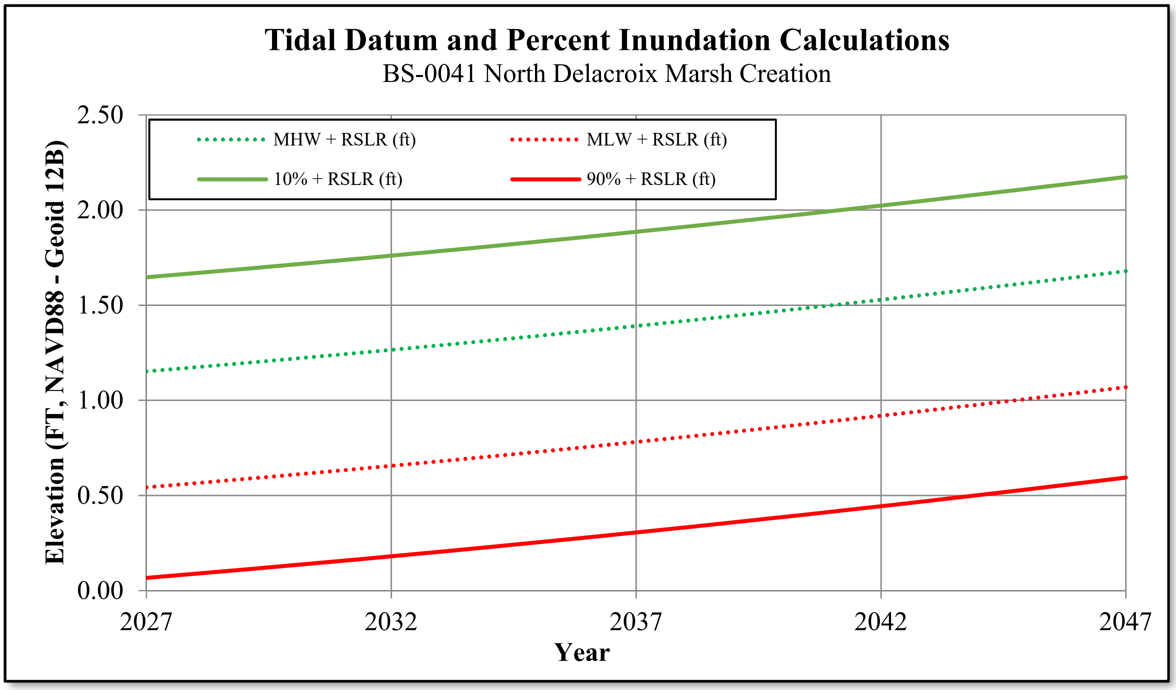

Figure 14: Tidal Datum & Percent Inundation over Project Life

The ninety percent (90%) inundation level is the elevation at which the marsh will be inundated ninety percent (90%) of the time based on the collected water level data. The ninety percent (90%) inundation level is a lower marsh elevation than the ten percent (10%) inundation level, which is the elevation that the marsh will be inundated less frequently at ten percent (10%) of the time.

For analysis and design of the MCAs over the twenty (20) year project life, the subsidence rates presented in this report will be applied to the existing mudline elevation within the project area, and ESLR will be applied to the tidal datum and optimum inundation range. This calculation process is documented in detail in **Appendix H**.

3.0 SURVEYS

The BS-0041 design surveys were performed, per CPRA Survey Standards, from April 2021 to April 2022 by C.H. Fenstermaker and TerraSond. These surveying efforts consisted of an initial design survey, a Lake Amedee recon survey, final design survey, and a Light Detection and Ranging (LiDAR) survey of the Wood Lake Levee. Topographic, bathymetric, and magnetometer survey methods were used as applicable to obtain all transects and were consistent with CPRA's MCDG 1.0*:* Appendix A: *A Contractor's Guide to the Standards of Practice.* Fenstermaker performed the topographic, magnetometer, and probing investigation within the MCA, Equipment Access Corridor (EAC) and DPC in February 2022. TerraSond conducted the bathymetric, magnetometer, side-scan, and sub-bottom (geophysical surveys) of the proposed Lake Lery MCBA, Lake Amedee MCBA, DPC, and EAC with completion in February 2022. Fenstermaker also performed a topographic survey utilizing an Unmanned Aerial Vehicle (UAV) with LiDAR surveying methods along the Wood Lake Tidal Levee in July 2022. Additionally, Chustz Surveying performed a bathymetric survey within BTAB to Black Bay for equipment access feasibility from the Gulf of Mexico as part of the Reggio Marsh Creation project (BS-0043). A summary of the surveying events for this project is provided in **Table 4**. Survey reports including the raw data of each design survey will be provided to the contractor as an Appendix to the Specifications.

Table 4: Timeline of Design Surveys

Survey Effort	Locations of Interest	Survey Type	Field Start Date	Field End Date	Report Release Date
Initial Design Survey (**Appendix D.1**)	MCAs, Recon Area, Highway 300, Wood Lake Pump Station, Jack's Canal, Lake Lery	Topo, bathymetry, magnetometer, sub-bottom, side-scan	4/29/2021	6/17/2021	9/30/2021
Lake Amedee Recon Survey	Hopedale Canal to Lake Amedee	Bathymetry & magnetometer	7/21/2021	8/17/2021	8/24/2021
Final Design Survey (**Appendix D**)	Lake Amedee, Bayou Juanita, Bayou Grosbec, and Reggio Cultural Survey	Topo, bathymetry, magnetometer, sub-bottom, side-scan	1/21/2022	2/18/2022	4/18/2022
LiDAR Delacroix & Wood Lake Levee Survey (**Appendix D.2**)	Wood Lake Tidal Levee	LiDAR	6/22/2022	6/25/2022	7/8/2022
BTAB Survey (BS-0043)	Black Bay to Bayou Terre aux Bouefs	Bathymetry	06/14/2022	07/01/2022	11/05/2022

3.1 Survey Datum

The horizontal datum is State Plane Louisiana South (NAD1983) and vertical datum is NAVD 1988 GEOID 12B.

3.2 Horizontal and Vertical Control

The surveying team set up one (1) temporary benchmark, "TBM 100", to establish horizontal and vertical control during the survey due to the location of the existing Secondary Control Monument (BS-32-SM-01). The monuments were established by performing a GPS Static Survey. The field survey utilizing real-time kinematic (RTK) surveying procedures and were checked using the National Geodetic Survey (NGS) Online Positioning User Services (OPUS). The survey monument datasheet is provided in **Appendix D**. The BS-32-SM-01 monument location is shown in **Figure 15** and **Table 5.**

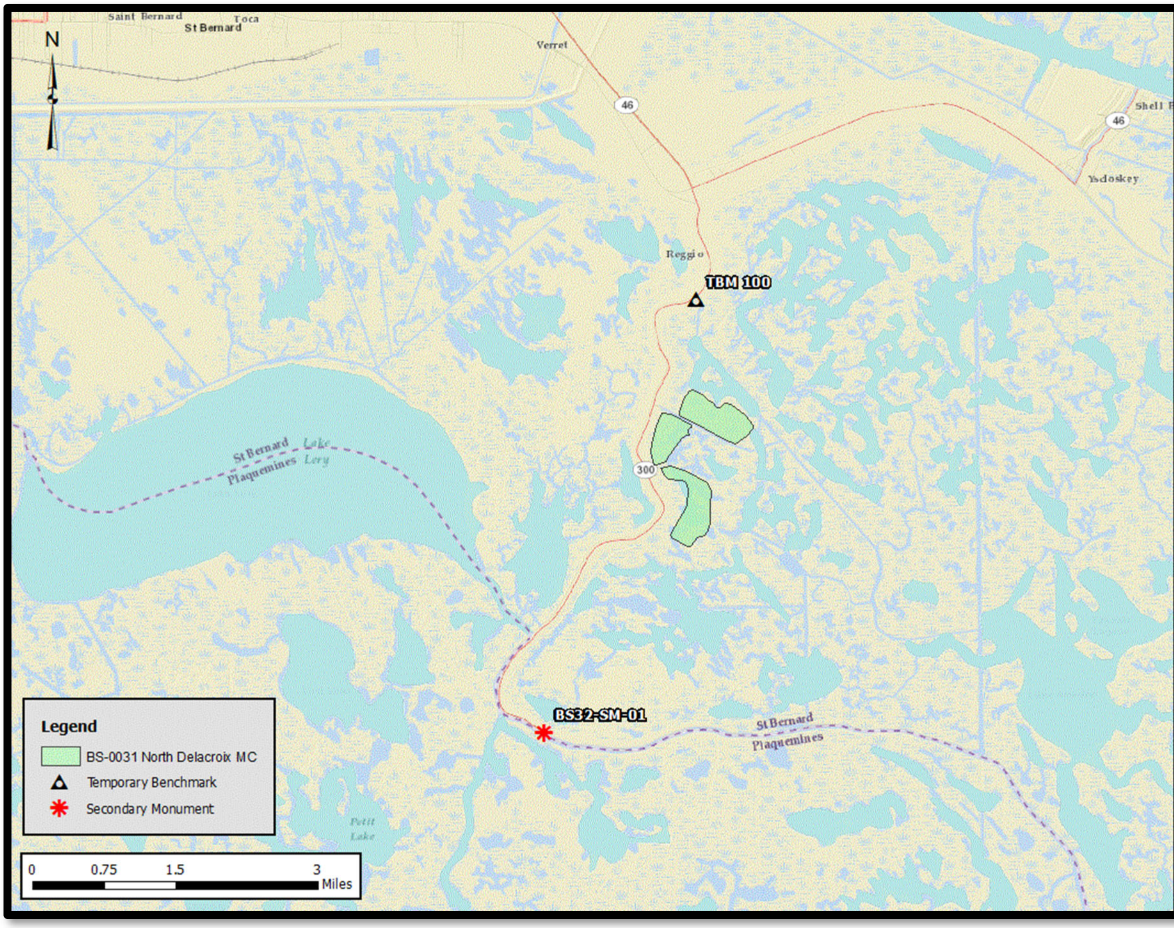

Figure 15: Secondary Monument Location

Table 5: Survey Monument & Temporary Benchmark Locations

Name	Northing (NAVD88, GEOID12B)	Easting (NAVD88, GEOID12B)	Elevation (NAVD88, GEOID12B)
TBM 100	484,922.99	3,780,837.28	+2.73
BS-32-SM-01	460,856.72	3,772,450.52	+2.64

3.3 Marsh Creation Area Survey

3.3.1 Bathymetry/Topographic Survey

Fenstermaker began surveying the MCAs on April 28, 2021. Survey transects were spaced in a grid approximately every five hundred (500) ft as shown in **Figure 16**. Transects were taken across open water areas, broken marsh, existing spoil banks, and the existing tidal levee adjacent to the MCA. A centerline profile survey was performed along the existing tidal levee and along the proposed Phase 0 ECD alignment. Additionally, an area beyond the Phase 0 project area was surveyed for project expansion feasibility. Position, elevation, and water depths were recorded every twenty-five (25) ft along each transect or where elevation changes were greater than one-half (0.5) ft.

The topographic portions of the survey were merged with the bathymetric portions at the land/water interface and were separated by no more than fifty (50) ft. Side shots were taken as necessary to pick up variations in topographic features (highs and lows) such as, meandering channels, broken marsh areas, or any other existing infrastructure such as crab traps, pipelines, wellheads, duck blinds, and warning signs, which may affect project design implementation. The use of a fixed height aluminum rod 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.

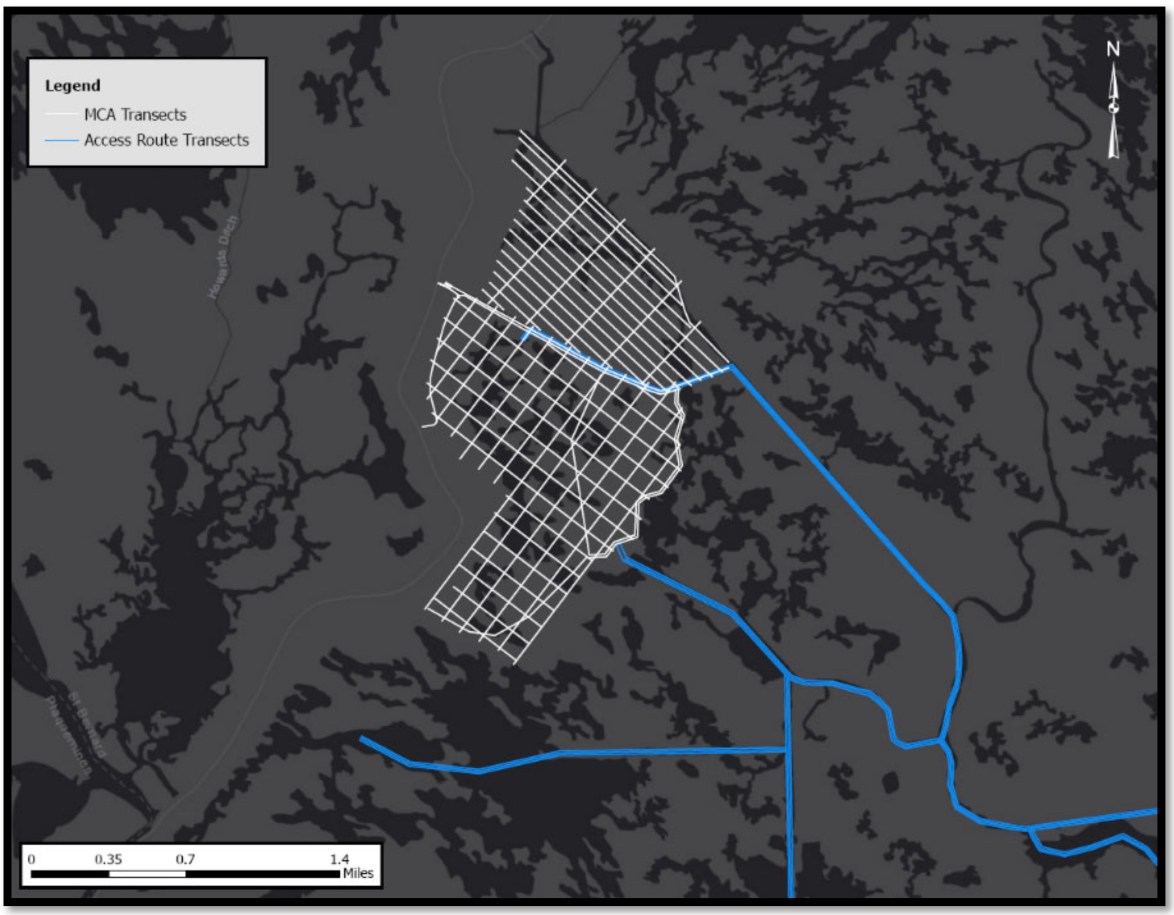

Figure 16: Topographic & Bathymetric Survey in MCA & Recon Area

3.3.2 LiDAR Survey of Wood Lake Tidal Levee

Topographic surveying efforts for the Wood Lake Tidal Levee were performed in March of 2021 in tandem with the initial MCA design survey. The initial Wood Lake Tidal Levee survey consisted of a centerline profile along the crown of the levee with transects from the MCA survey that extended across the tidal levee located approximately five hundred (500) ft apart. This initial MCA survey provided limited resolution for the Tidal Levee survey data. Due to the low quantity of material anticipated for the Tidal Levee, higher resolution survey data was required.

Fenstermaker performed additional aerial drone-based LiDAR surveys in July 2022 (**Appendix D.2**), using a Rigel miniVUX-2UAV LiDAR system with a DJI M600Pro Hex copter. In total 14 flight lines were required to cover the area of interest (AOI). Nominal flying height was 75m above ground level with a speed of 6 m/s. Ground control points were also surveyed with traditional surveying methods in order to QA/QC the LiDAR geospatial data.

The UAV LiDAR survey conducted by Fenstermaker provided a high-resolution dataset that filled in the data gap between the traditional RTK surveys. This data was incorporated into the existing Civil 3D surface providing a higher quality dataset for planning and design. A sample of the high-resolution data set is provided in **Figure 17**.

Figure 17: Sample Image of the Wood Lake Tidal Levee LiDAR Survey

3.3.3 Magnetometer Survey and Probing Investigation

A magnetometer survey was taken with a G-882 Cesium Marine Magnetometer along all design survey transects to locate any pipelines or other infrastructure in the MCAs. A hydrographic survey specialist then analyzed each file picking all magnetometer anomalies. The specialist then exported a file with all anomaly positions and amplitudes to be mapped for further investigation. For each magnetic finding greater than fifty (50) Gammas, Fenstermaker performed a closed loop path with the magnetometer. If a pipeline was detected, the crew probed the pipeline to determine the depth of cover and the elevation of the top of the pipeline.

A map of the magnetometer and probing survey conducted by Fenstermaker and permitted gas well data available through the Strategic Online Natural Resources Information System (SONRIS) database is shown in **Figure 18**. All permitted gas wells were investigated during the surveying efforts. Based on the available SONRIS documentation all wells within the project vicinity including 40660, 16263, 16267, and 40660 are plugged and abandoned.

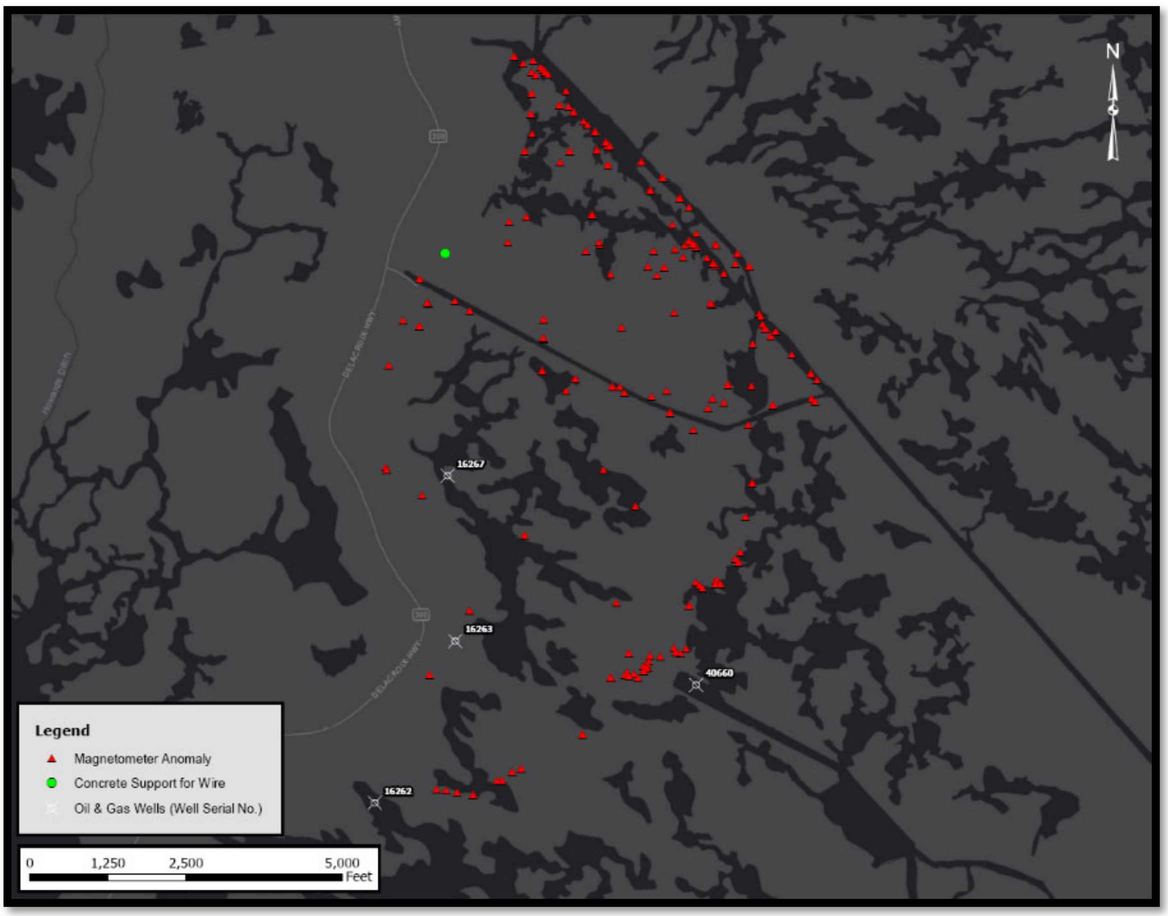

Figure 18: Magnetometer & Probing Investigation in the MCAs

The magnetometer survey detected one hundred fifty-six (156) magnetic anomalies in the MCAs. These anomalies ranged in amplitude from fifty-one (51) to 9,545 gammas, and in duration from two (2) to five hundred two (502) ft. None of these anomalies were determined to be associated with pipelines using conventional probing techniques. Most of these anomalies were determined to be consistent with targets usually associated with minor debris such as crab traps, steel cans and buckets, anchors, etc. Upon further investigations of the anomalies, crab traps seemed to be the most common debris source.

3.4 Borrow Area Survey

3.4.1 Bathymetric Survey

On June 15, 2021, Fenstermaker commenced a cultural resource geophysical survey within the proposed Phase 0 Lake Lery borrow area. This geophysical survey included bathymetry, side-scan, sub-bottom, and pipeline probing within Lake Lery. This borrow area was planned to become an expansion of the East Delacroix borrow area utilizing a sediment pipeline crossing at Highway 300. During the sediment pipeline highway crossing feasibility study conducted by the East Delacroix project team, it was determined that the cost risk to the North Delacroix project team would be reduced by relocating the Phase 0 borrow area from Lake Lery to Lake Amedee. The geophysical survey data collected in Lake Lery was provided to the BS-0043 Reggio Marsh Creation project team to avoid duplicating survey efforts in Lake Lery.

On July 21, 2021 a recon bathymetry and magnetometer survey was performed in Lake Amedee and its connecting waterways to determine construction access feasibility. This survey revealed that Lake Amedee could be safely accessed by a small hydraulic cutter suction dredge from BTAB and Petain Lagoon. Following the recon survey, an additional higher-resolution cultural survey was performed in Lake Amedee and along the proposed EAC and DPCs to determine whether any cultural significant items may be disturbed during construction activities. This final design survey of Lake Amedee was completed on February 18, 2022. Survey track lines performed in Lake Amedee and the connecting waterways can be seen in **Figure 19**.

Bathymetric survey methods consistent with the CPRA MCDG 1.0: Appendix A (*A Contractor's Guide to the Standards of Practice*) were used to obtain all transects. Survey transects of the proposed borrow area were spaced every one hundred (100) ft, as required for cultural resources surveys, oriented from west to east. Position, elevation, and water depth were recorded every fifty (50) ft along each transect or where elevation changes were greater than one-half (0.5) ft. The bottom elevation data obtained from these surveys was used for creating water depth maps for construction equipment access and determining available sediment borrow quantities. The water bottom elevation in the Lake Amedee MCBA ranges between -4.0 ft to -6.0 ft NAVD88.

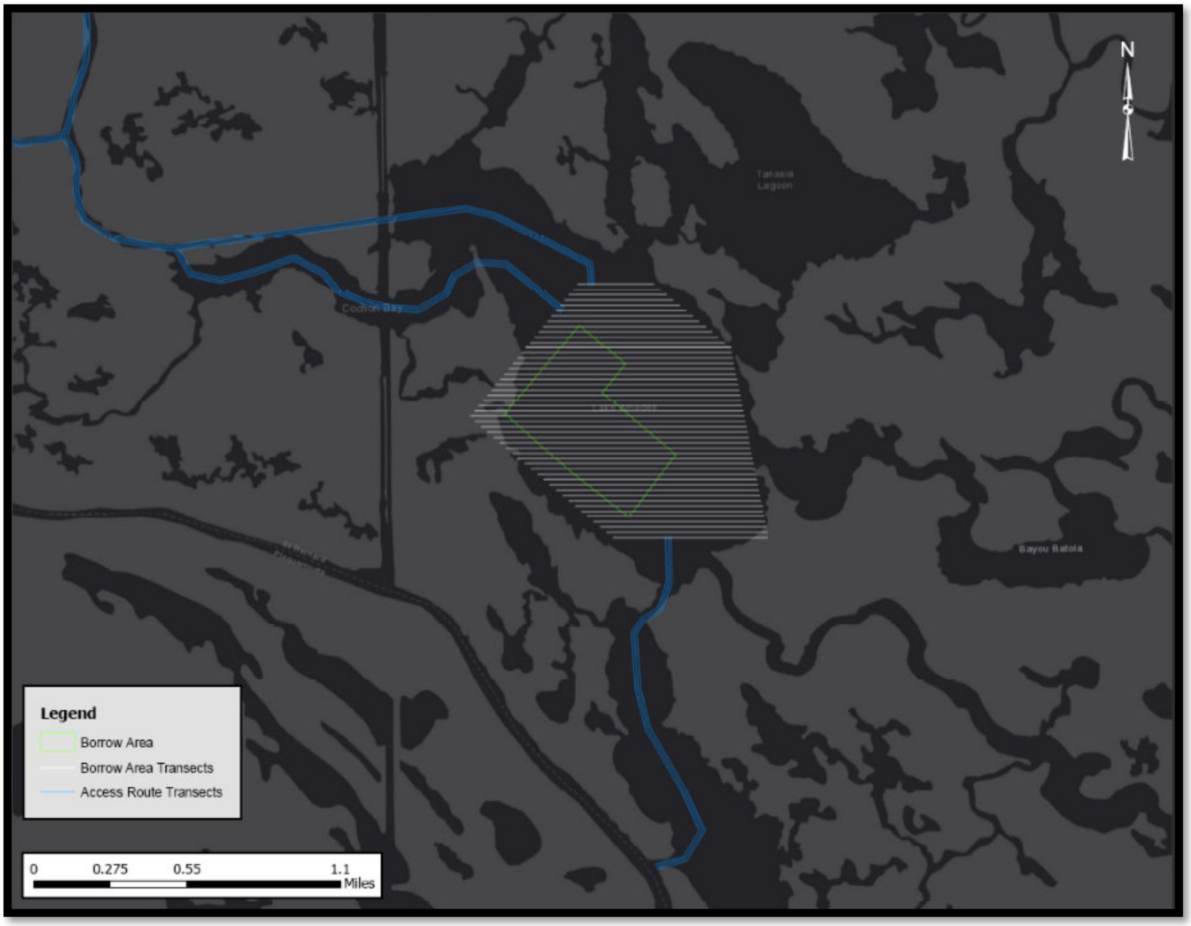

Figure 19: Lake Amedee MCBA, DPC, EAC Bathymetric Survey

3.4.2 Magnetometer Survey and Geophysical Survey

In addition to a single-beam bathymetric survey, a marine magnetometer, side-sonar, and sub-bottom profile survey was performed along the same transects as the MCBA bathymetric survey. The G-882 marine magnetometer detected nineteen (19) magnetic anomalies in the proposed 95% MCBA (**Figure 20**). All nineteen (19) magnetic anomalies could not be correlated to known features within the MCBA. The unknown magnetic anomalies have amplitudes ranging from fifty-four (54) to 2,264 gammas and durations ranging between sixteen (16) to ninety-three (93) ft (**Appendix D**). These unidentified magnetic anomalies were probed and recorded as "Nothing Found".

The sidescan survey performed in the proposed 95% Design MCBA identified four (4) sonar contacts (Contact 0004, 0010, 0011, and 0017). These contacts are described by Terrasond as being a linear feature, typical crab trap, unknown object/debris, and linear depressions, respectively. Overall, the survey area is heavily occupied by active and inactive crab pots as observed during the field survey and during office interpretation (TerraSond, 2022). No significant magnetic and side scan sonar targets were discovered within the proposed MCBA during the survey investigation.

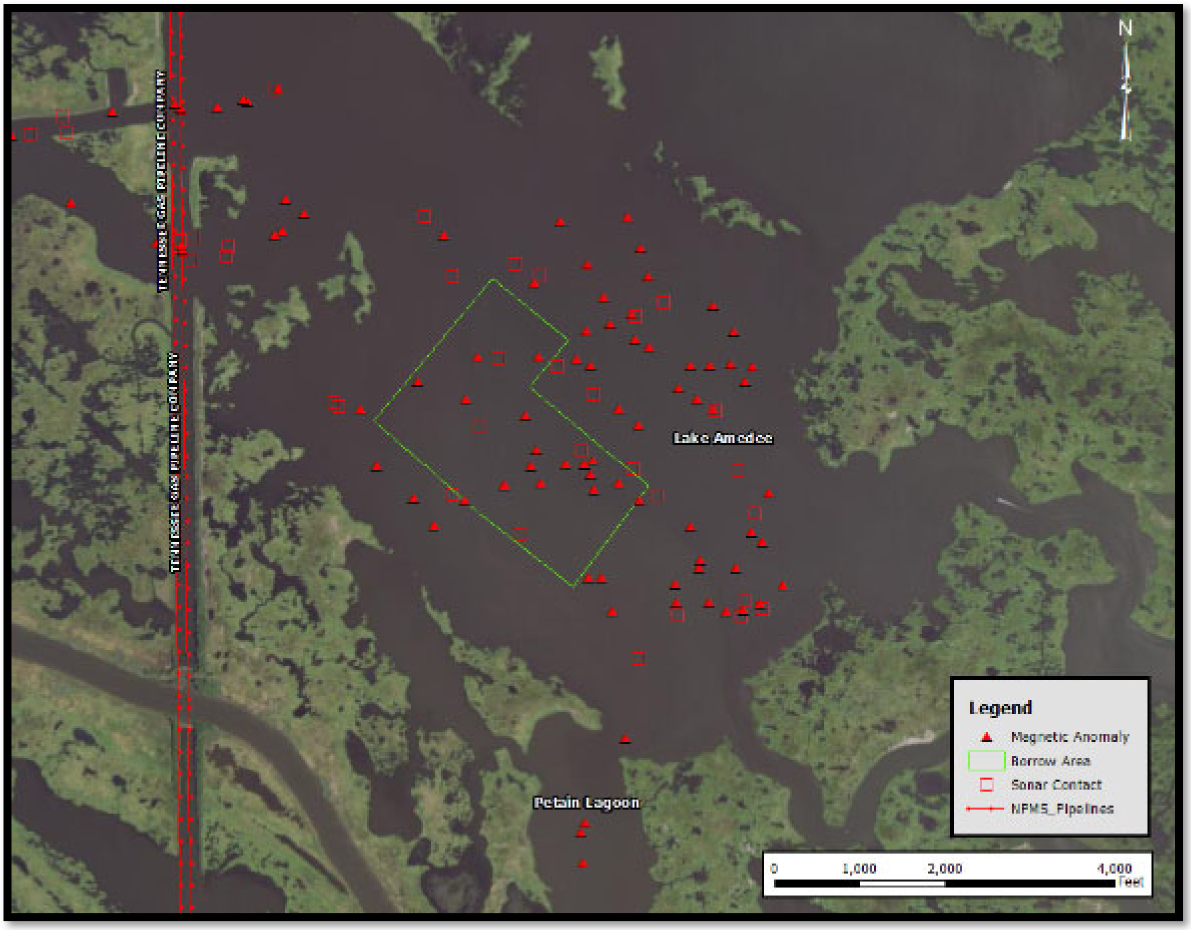

Figure 20: Lake Amedee MCBA Infrastructure

3.5 Dredge Pipeline Corridor and Equipment Access Routes

3.5.1 Geophysical Survey

Two (2) potential equipment access routes, Hopedale to Lake Amedee and BTAB to Lake Amedee, were surveyed for construction feasibility. The DPC and equipment access surveys consisted of sidescan sonar, magnetometer, single beam bathymetry, and RTK GPS data collection along three (3) profile transects spaced fifty (50) ft apart with 1,000-ft spaced cross-sections with position and elevation data collected continuously every five (5) ft.

Magnetic anomalies from the surveys were mapped and provided to the engineer and to the survey crew to facilitate marking and probing pipelines for the depth of cover, and depth of water, if submerged. Two (2) known active pipelines were identified in the National Pipeline Mapping System (NPMS) and probed by Fenstermaker near the Lake Amedee MCBA and are summarized in Error! Reference source not found. and **Figure 21** - **Figure** 23**.** Dredge pipe installed within the DPC will be required to float over the Tennessee Gas Pipelines when traveling west to reach the MCAs as shown in the 95% Design Drawings (**Appendix G**).

Table 6: Summary of Pipelines Probed near the MCBA

Pipeline Operator Name	**Depth of Cover** (ft)	**Water Depth** (ft)	**Size** (in.)	**Product**	**Status**
Tennessee Gas Pipeline	3-8	5-10	30 and 36	Natural Gas	Active

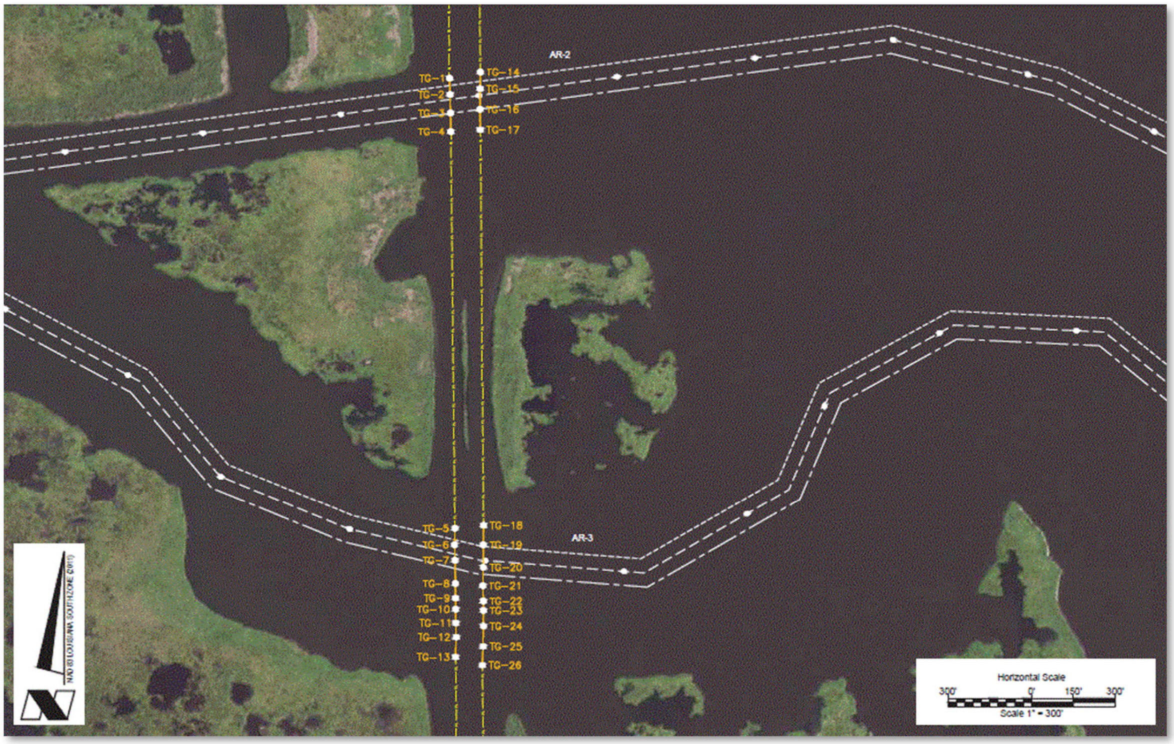

Figure 21: Pipeline Probe Hits on Tennessee Gas 36" (West) & 30" (East) Pipelines

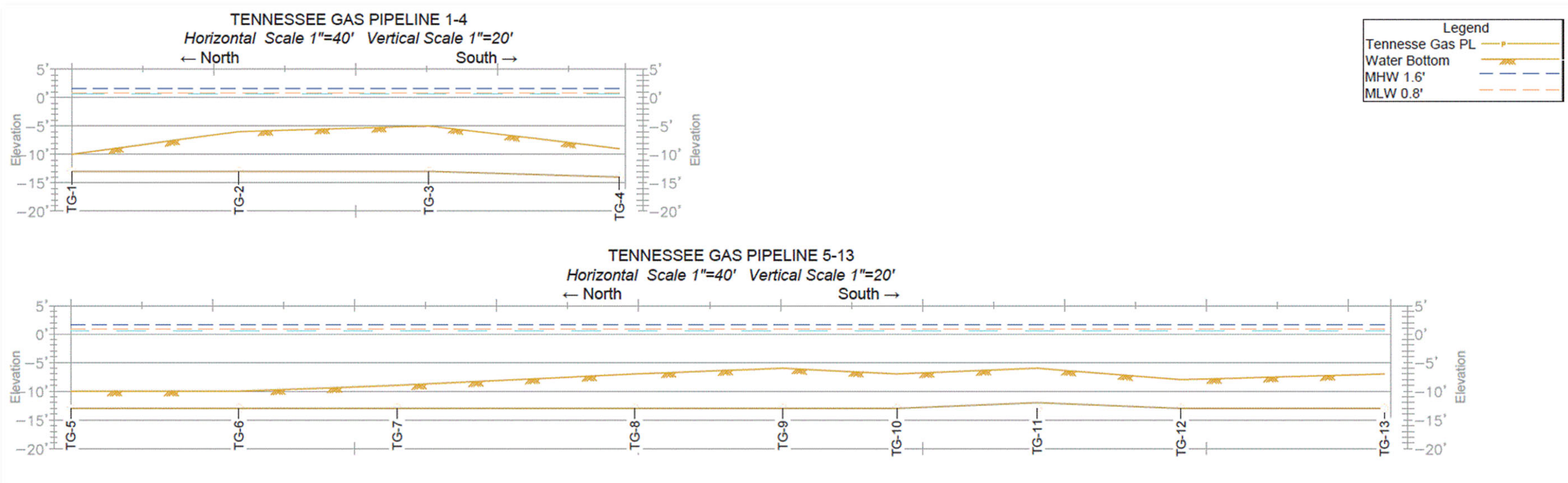

Figure 22: 36" Gas Pipeline (West) Profile

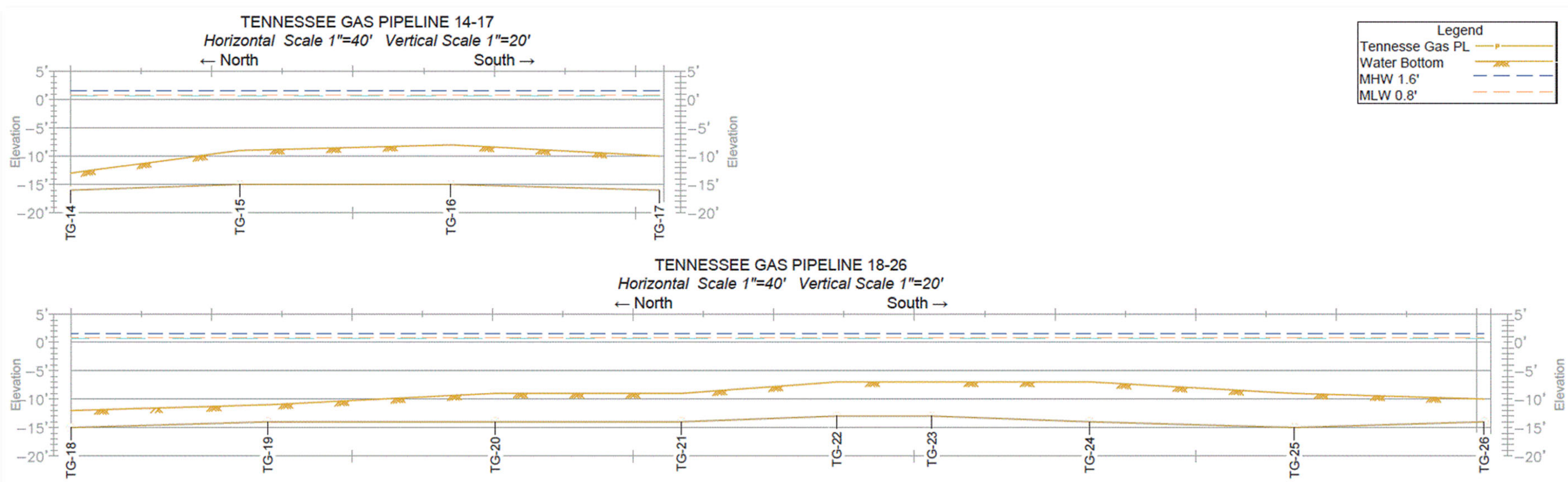

Figure 23: 30" Gas Pipeline (East) Profile

The average water depth, when measured from MLW, in Lake Amedee is six (6) ft. The average water depth along the center of Pentain Lagoon is four (4) ft. The average water depth in the center of Bayou Juanita is ten (10) ft. Small hydraulic cutter suction dredge access to Lake Amedee can be provided via Petain Lagoon as shown below in **Figure 24**.

Figure 24: Petain Lagoon Equipment Access Route

3.5.2 Highway 300 Sediment Pipeline Crossing Survey

A topographic survey was also performed at the original Phase 0 planned dredge pipeline crossing location along Highway 300, which will no longer be required due to moving the borrow area to Lake Amedee. This survey consisted of transects extending across the right of way, drainage ditch, both edges and the centerline of Highway 300, the edge and center of BTAB, and all erosion control features (riprap or bulkhead) along the highway. Topography and bathymetry was surveyed every ten (10) ft or changes in elevation greater than one-half (0.5) ft along transects. LA One Call was also notified prior to the topographic survey commencing to mark all existing utilities within each pipeline crossings' footprint. Fenstermaker surveyed visible utilities at both crossings and georeferenced the utility markings provided by LA One Call. Geographic Information System (GIS) databases provided by the St. Bernard Parish DPW also revealed a six (6) in. waterline along the northbound side of Highway 300. A summary of the preliminary utility investigation based on existing records and visible utility surveys of all subsurface and above-surface utilities identified along Highway 300 are provided in **Table 7**.

Table 7: Summary of Utilities Identified along Highway 300

Utility	Owner	Size (in.)
Waterline	Parish	6
Fiber optic	AT&T	3/8
Power Pole	Entergy	n/a
Drainage Ditch	Parish	n/a

Based on the visual site inspections and surveys conducted by Fenstermaker, Highway 300 is a two-lane undivided highway that provides single access to and from the community of Delacroix. The highway centerline elevation was found to be at +4.0 ft NAVD88. Highway 300 is bordered by a roadside drainage ditch to the east and BTAB to the west. Additionally, there is a subsurface waterline, fiber optic cable, and an aboveground power line that runs along the east side of Highway 300 as shown in **Figure 25**.

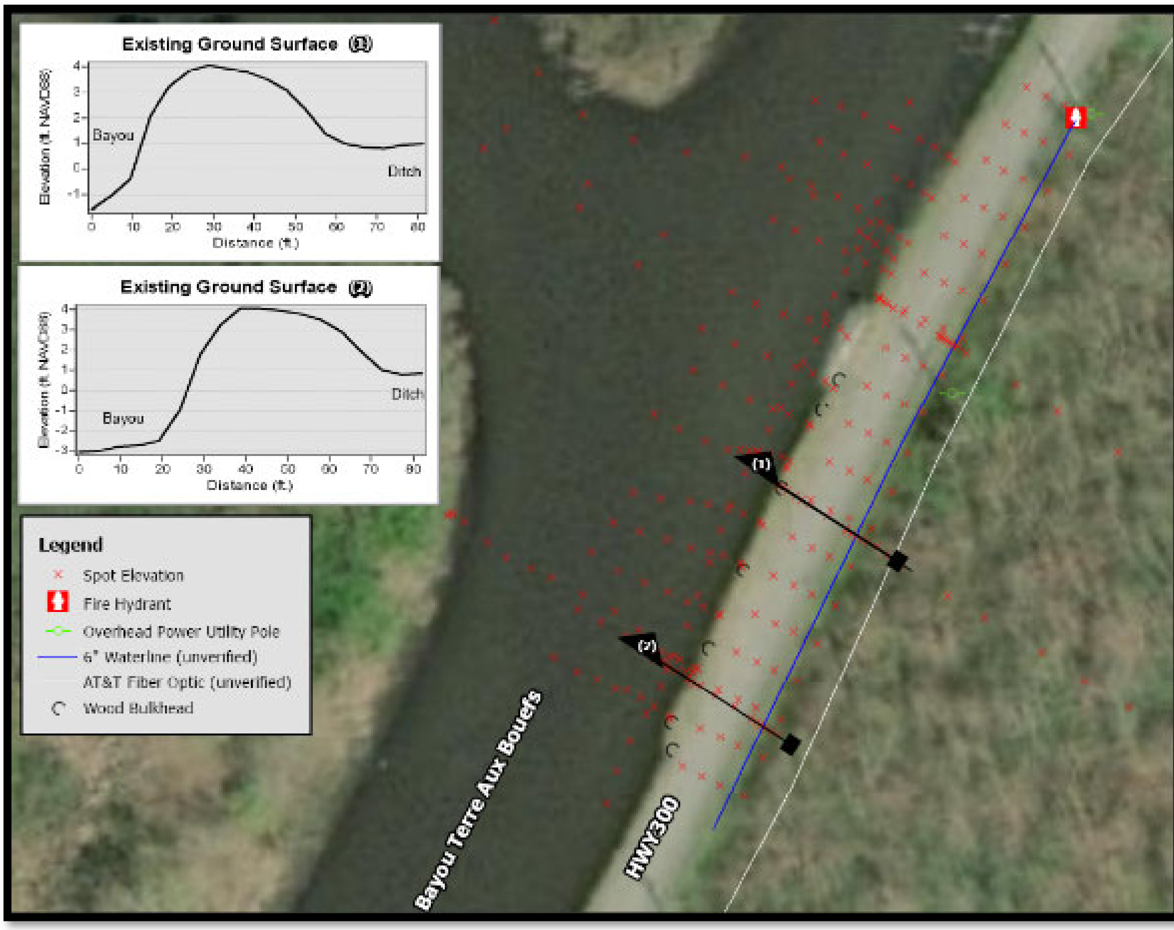

Figure 25: Highway 300 Survey

3.6 Project Feature Survey Analysis

The topographic, bathymetric, and LiDAR survey data provided by Fenstermaker was imported into the Environmental Systems Research Institute (ESRI)'s ArcGIS and AutoCAD Civil 3D for site analysis. A boundary line was created in Civil 3D around the extents of all survey data to begin the analysis. Existing topographic features that would be utilized as part of the design of the marsh creation project were then delineated with break lines. Triangulated Irregular Network (TIN) surface models, contours, and histograms were generated with the merged bathymetric and topographic survey data to create maps for features of the project including the ECD, tidal levee, MCAs, and terrace field area.

3.6.1 Earthen Containment Dike

Topographic survey shots and bathymetry data were spatially selected by using the boundary of each MCA and applying a search distance around the boundary to determine the existing mudline along the proposed ECD alignment. Survey shots selected were then sorted by elevation and reviewed spatially for construction feasibility.

3.6.2 Wood Lake Tidal Levee

The existing Wood Lake Tidal Levee is proposed to be utilized as a containment feature for dredge fill placement. An elevation profile along the centerline of the Wood Lake Tidal Levee is shown in **Figure 26**. A general summary of the mean, minimum, and maximum elevation along the centerline of the Wood Lake Tidal Levee in MCA-2 is summarized in **Table 8** below. The mean elevation along the centerline of the tidal levee is +6.2 ft NAVD88. The maximum and minimum elevations along the centerline of the tidal levee are +7.1 ft and +5.1 ft NAVD88, respectively.

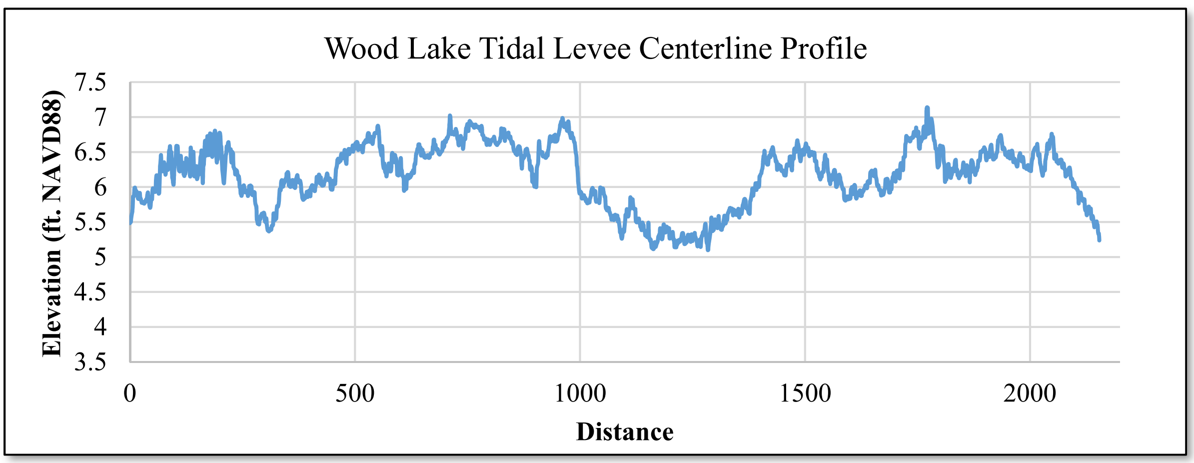

Figure 26: Wood Lake Tidal Levee Centerline Profile

Table 8: Summary of Tidal Levee Survey

MCA	Minimum Elev. (ft NAVD88)	Maximum Elev. (ft NAVD88)	Mean Elev. (ft NAVD88)
1	+5.1	+7.1	+6.2

3.6.3 Marsh Creation Area

The project layout for North Delacroix consists of three (3) MCAs. The area of MCA-1 is one hundred forty-eight (148) acres, MCA-2 is eighty-seven (87) acres, and MCA-3 is one hundred forty-three (143) acres. The total area for all MCAs is three hundred seventy-eight (378) acres. Each cell has a slightly different existing mudline. The average elevations within MCA-1, MCA-2, and MCA-3 are -1.3 ft, -0.5 ft, and -2.0 ft NAVD88, respectively. The MCA and ECD layout was delineated to avoid filling areas with a mudline below the -3.0 ft NAVD88 contour.

The results of the MCA survey analysis are shown in the TIN surface in **Figure 27** and histograms created in **Figures Figure** 28 **- Figure** 30.

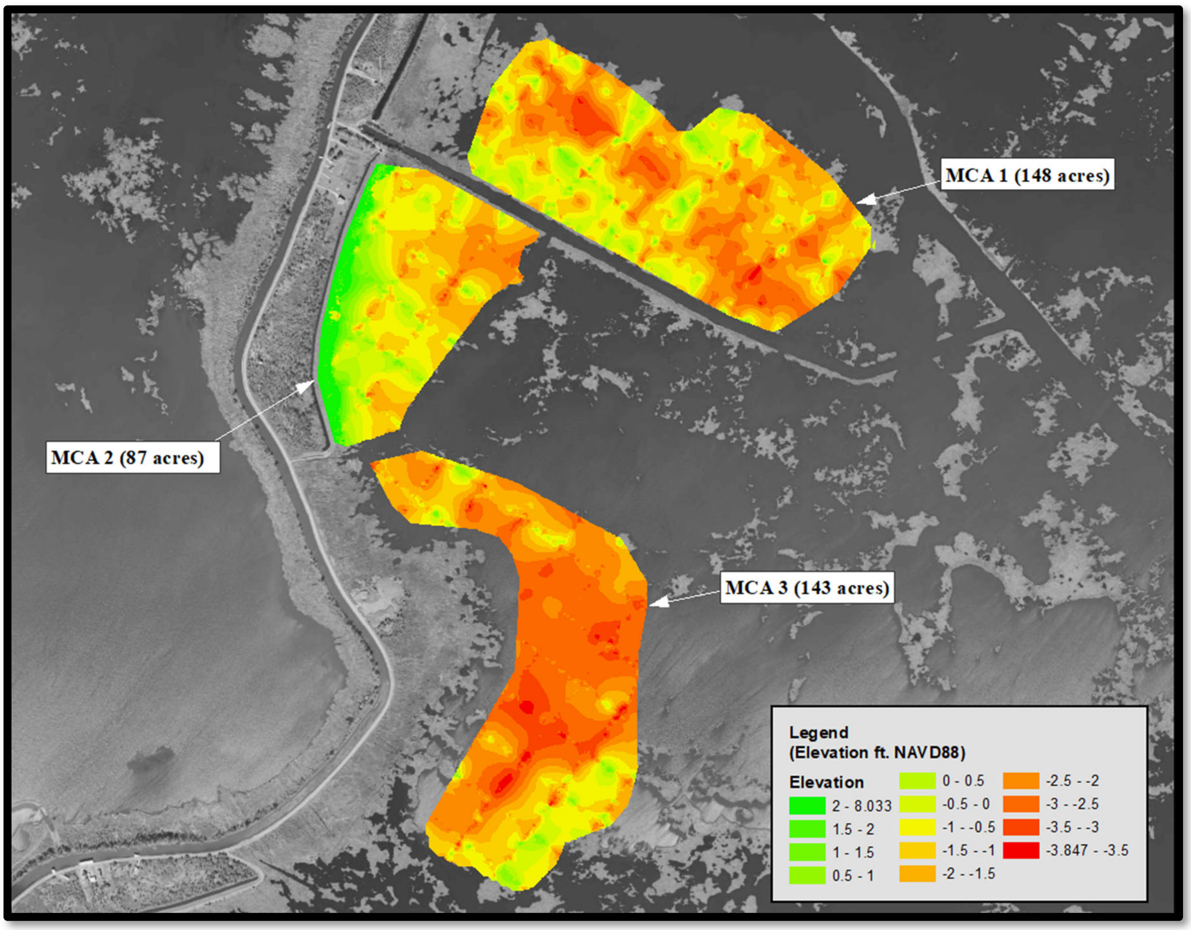

Figure 27: TIN Surface Models of the MCAs (2021 Design Survey)

The surface created in Civil 3D and the histograms in the 30% Design Report showed that two hundred eleven (211) acres or fifty-six percent (56%) of the total MCA footprint is below an elevation of -1.5 ft NAVD88. This survey analysis performed within the MCA helped select the baseline mudline elevations which was used in modeling marsh fill settlement as mentioned in **Section 5.1.1**. The updated 95% Design alignments show numbers similar to 30% Design, with two hundred seven (207) acres or fifty-five percent (55%) of the total MCA footprint below an elevation of -1.5 ft NAVD88.

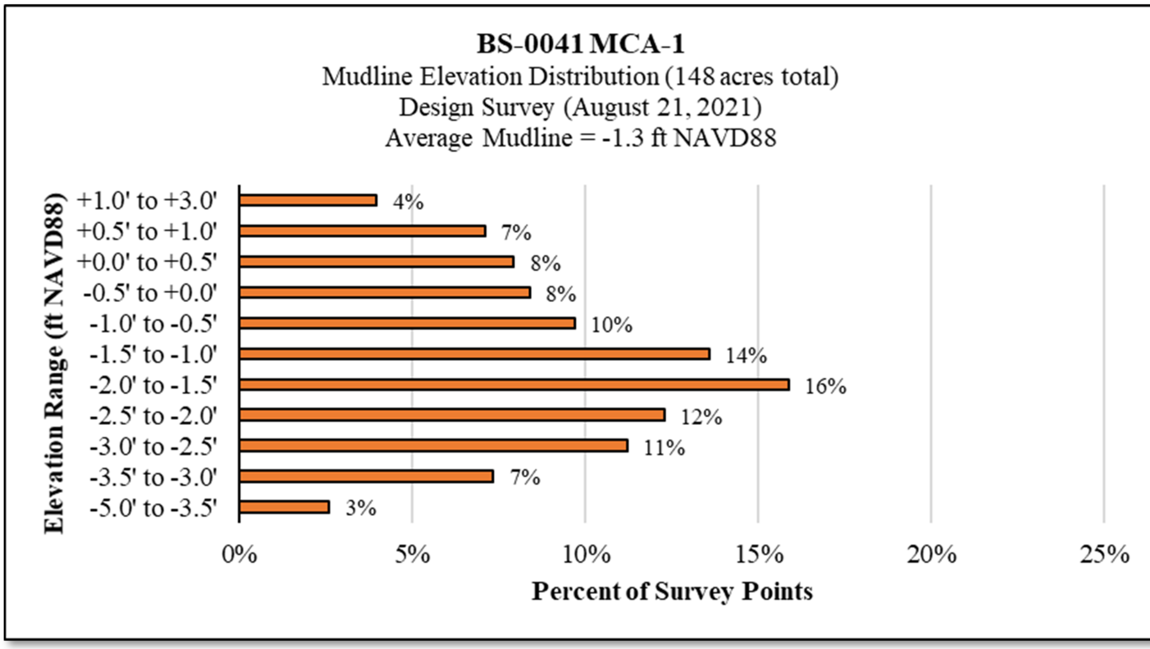

Figure 28: MCA-1 Existing Mudline Elevation Distribution

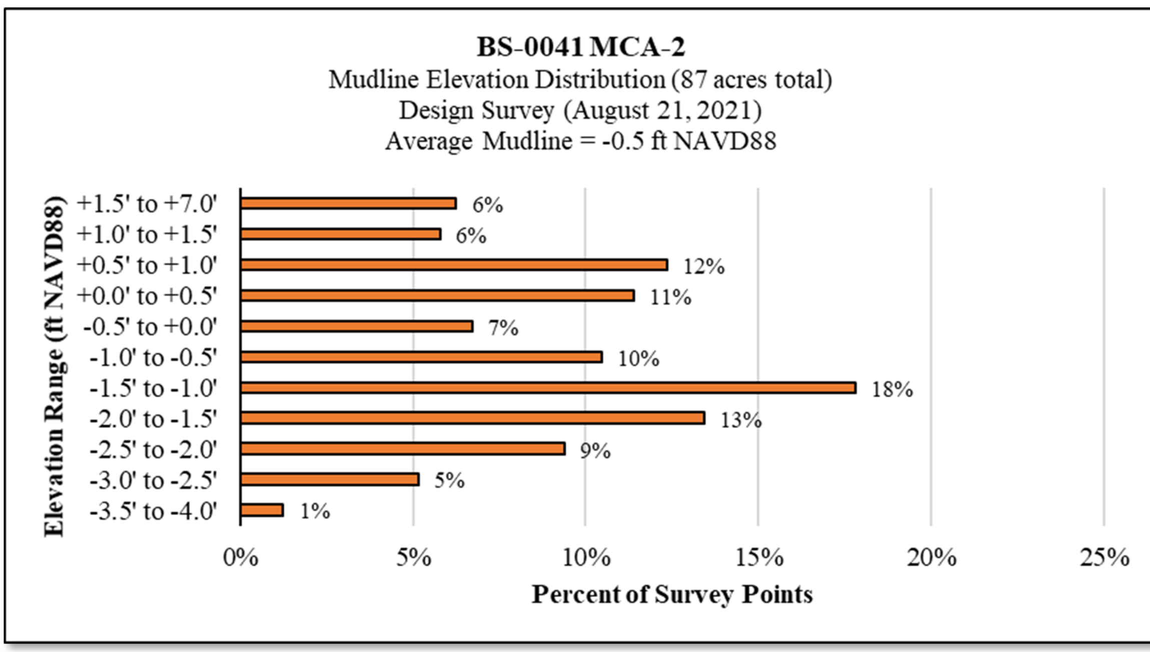

Figure 29: MCA-2 Existing Mudline Elevation Distribution

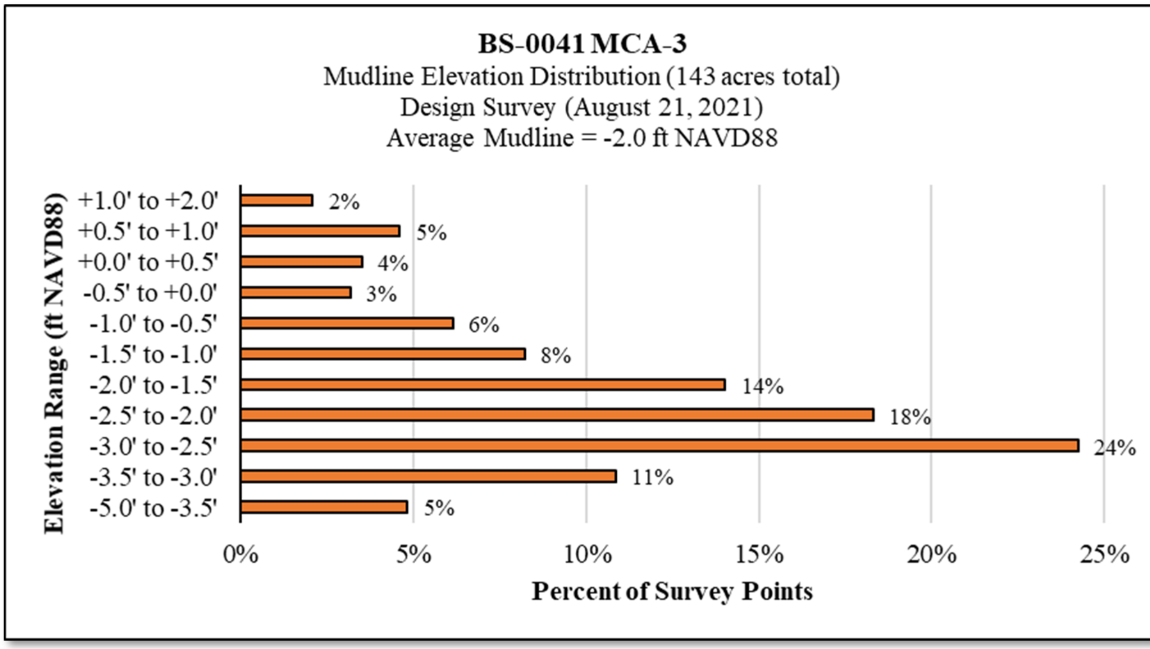

Figure 30: MCA-3 Existing Mudline Elevation Distribution

3.6.4 Existing Marsh Elevation Survey

On April 28, 2021, Fenstermaker surveyed three (3) existing marsh locations near the project area. These surveys were conducted to determine the dominant species of vegetation and to help determine an average existing marsh platform elevation for the project area. RTK surveys were taken at twenty (20) locations within each selected site, separated by twenty (20) to forty (40) ft. Elevations were recorded on a data logger at the top of the marsh root mass and top of the mudline adjacent to the root mass. Based on observations from site visits, the project area's dominant marsh is marsh hay cordgrass (*Spartina patens*).

The results from the existing marsh elevation survey conducted on April 23, 2020 and April 28, 2021 are shown in **Table 9** and **Figure 31**.

Table 9: Average Marsh Elevation Results

Project ID	Average Top of Root Mass (ft NAVD88)	Average Top of Mudline Elevation (ft NAVD88)	Name
BS-0037	+0.94	+0.55	North
BS-0037	+1.20	+0.84	Central
BS-0037	+0.98	+0.38	South
BS-0041	+0.72	-0.20	North
BS-0041	+1.15	+0.36	Central
BS-0041	+0.94	+0.15	South
Average	**+0.98**	**+0.34**	

According to this survey, the average mudline at the existing marsh near the project area is approximately +0.34 ft, NAVD88. At this elevation and with estimated sea level rise this marsh surface is estimated to be completely inundated in less than twenty (20) years.

Figure 31: Existing Marsh Survey Locations

4.0 GEOTECHNICAL INVESTIGATION

Eustis Engineering was tasked to explore and evaluate the subsurface soil conditions and provide geotechnical engineering analysis and recommendations for the design and construction of BS-0041. Eustis conducted the geotechnical subsurface investigation and geotechnical engineering analysis for BS-0041 with guidance provided by the CPRA's Project Engineer and adhering to the MCDG1.0, Appendix B, *Geotechnical Standards.* Field explorations began on May 5, 2022 and lasted until June 15, 2022.

Eustis Engineering was tasked with the following data collection efforts:

- Collect twelve (12) undisturbed soil borings in the Lake Amedee MCBA to a depth of twenty (20) ft.
- Collect nine (9) soil borings in the marsh fill and terrace areas to a depth of thirty (30) ft.
- Perform fourteen (14) Cone Penetrometer Tests (CPTs) soundings along the proposed ECD to a depth of thirty (30) ft.
- Collect two (2) soil borings and perform three (3) CPTs in the Recon Area.
- Perform two (2) CPTs soundings along the Wood Lake tidal levee to a depth of forty (40) ft.
  - Collect one (1) undisturbed soil boring using a track-mounted Geoprobe rig to a depth of forty (40) ft.
- Perform laboratory classification and strength testing to determine soil characteristics.
- Perform one (1) composite low-pressure consolidation test and a column settling test on the selected composite sample.

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

- Slope stability analysis of the proposed ECDs and terracing features.
- Total settlement estimates of the proposed ECDs, Terraces, and MCAs.

The geotechnical data report (GDR) and geotechnical engineering report (GER) can be found in **Appendices E** and **F**, respectively.

4.1 Existing Geotechnical Data Review

Before conducting the field subsurface investigation, a search of any existing 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.

Surface geology maps published by the Louisiana Geological Survey reveal that the project area is underlain by the deposits from the St. Bernard delta lobe of the Mississippi River. These deposits are composed of cyclically interbedded interdistributary peat and clay; natural levee silt and clay; distributary sand; delta front sand; and prodelta mud and clay. Delacroix Island and the adjacent tidal levee's subsurface are primarily deposits of a meander belt of the distributary course of the Plaquemines and Balize Delta lobes of the Mississippi River. These are comprised of deposits from sandy point bars and natural levees.

4.2 Marsh Creation Area Geotechnical Subsurface Investigation

Seven (7) subsurface borings were taken near the Phase 0 MCAs by Eustis Engineering to depths of thirty (30) ft below the existing mud line. Three (3) borings in the MCAs were co-located with CPT soundings in order to determine a site-specific CPT cone factor, used to estimate soil properties. An additional four (4) borings were performed in the proposed terrace field area (T-1 and T-2) and in the Recon Area (R-2 and R-4) where the 95% Design MCA-1 is located. The soil borings were performed using airboat-mounted equipment provided by Specialized Environmental Resources, Inc. (SER). The mud line ranged from elevations of -4.7 ft to -1.9 ft NAVD88. Samples were collected with a piston sampler in Shelby tubes continuously in the upper twenty (20) ft of the soil and on five (5) ft centers thereafter to boring completion depths. All samples were then classified, stored, and transported to the laboratory. Laboratory tests included soil strength, moisture content, organic content, grain size analysis, specific gravity, consolidation with rebound, and Atterberg limits. Visual classifications of the soil within the project area using the Unified Soil Classification System (USCS) with depth are provided in **Figure 32**.

Depth	B-1	B-2	B-3	B-4	B-5	B-6	B-7	R-2	R-4	T-1	T-2
0	CH	OH	CH	CH	OH	PT	PT	PT	PT	PT	PT
-1	OH	OH	OH	OH	OH	OH	OH	OH	OH	NS	OH
-2	CH	CH	OH	OH	OH	OH	OH	OH	PT	OH	OH
-3	CH	CH	OH	OH	OH	OH	OH	OH	OH	NS	OH
-4	CH	OH	OH	OH	OH	OH	OH	OH	OH	OH	OH
-5	OH	OH	OH	OH	OH	OH	OH	CH	PT	OH	OH
-6	CH	OH	PT	PT	PT	OH	OH	OH	OH	OH	OH
-7	CH	OH	PT	PT	NS	PT	OH	OH	OH	PT	OH
-8	CH	PT	CH	OH	PT	PT	OH	OH	OH	OH	PT
-9	CH	PT	CL	CH	PT	PT	CH	OH	PT	OH	PT
-10	CL	CH	CH	OH	ML	OH	CH	OH	PT	OH	PT
-11	OH	CH	CH	CH	ML	OH	OH	OH	PT	OH	PT
-12	PT	CH	CH	CH	CH	CL	CH	OH	PT	OH	OH
-13	PT	CH	NS	CH	CH	ML	OH	OH	OH	OH	CH
-14	OH	CL	CL	CH	CH	PT	CH	OH	OH	OH	OH
-15	OH	CH	CL	CH	NS	ML	CH	OH	CL	OH	OH
-16	OH	CH	CL	CH	CH	CH	CH	OH	CH	OH	CH
-17	CH	CH	SM	NS	CH	CH	OH	OH	ML	CH	CH
-18	CH	CH	CH	CH	CH	PT	OH	OH	CH	CH	CH
-19	NS	CH	CH	CH	CH	CH	OH	OH	SM	CH	CH
-20	NS	NS	CH	CH	CH	CH	OH	OH	SM	CH	CH
-21	NS	NS	CH	CH	CH	CH	OH	OH	SM	CH	CH
-22	NS	NS	CH	CH	CH	CH	OH	OH	SM	CH	CH
-23	CH	CH	SM	CH	CL	CH	OH	CH	CH	CL	CH
-24	CH	CH	SM	ML	CL	CH	ML	CH	CH	ML	ML
-25	CH	NS	SM	ML	CL	CH	ML	CH	CH	ML	ML
-26	CH	CH	SM	ML	CL	CH	ML	CH	CH	ML	ML
-27	CH	CH	SM	ML	CL	CH	ML	CH	CH	ML	ML
-28	CH	CH	ML	CH	CH	CL	SM	OH	SM	CL	CH
-29	CH	CH		CH	ML	ML		OH		ML	SP
-30											

*CH- fat clay, OH- organic clay, PT- peat, ML- silt, SM- silty sand, CL- lean clay, SP- poorly graded sand, NS-not sampled

Figure 32: Project Area Soil Boring Visual Classification with Depth

Soil conditions were also evaluated in the MCAs by performing eight (8) CPTs using an airboat-mounted rig at depths ranging from twenty-seven (27) to thirty (30) ft below the existing mud line. Soil borings B-3, B-5, and B-7 were co-located with CPT soundings in order to determine a site-specific CPT cone factor and to estimate soil properties. Three CPTs (RCPT-1, RCPT-2, and RCPT-3) were performed in the Recon Area as well.

Subsurface soil conditions encountered at marsh creation soil boring locations generally consist of extremely soft-to-soft gray and brown humus, peat, and organic clay to approximate depths of zero (0) to fifteen (15) ft below the mudline. The boring R-2 showed this layer extending deeper to approximately twenty (20) ft below the mudline. These organic clays were underlain by extremely soft to soft gray clay and silty clay with interbedded strata of very loose to loose gray silty sand, clayey sand, and fine sand and very loose to medium compact silt to boring termination depths of 30 ft below the mud line (Eustis, 2022). A map of the geotechnical sampling layout in the project area is shown in **Figure 33**. All CPT data and soil boring logs can be found in **Appendix E**.

4.3 Tidal Levee Geotechnical Subsurface Investigation

One (1) subsurface soil boring (L-1) and two (2) CPTs (LCPT-1 & LCPT-2) were performed with a track mounted Geoprobe rig and a track mounted cone rig through the existing tidal levee. This subsurface investigation was performed in order to select soil design parameters for stability analysis. A review of the soil boring data by Eustis Engineering indicates that approximately five to eight (5-8) ft of existing levee fill. Beneath these stiffer fill materials, Eustis encountered soft gray and brown lean clay and fat clay.

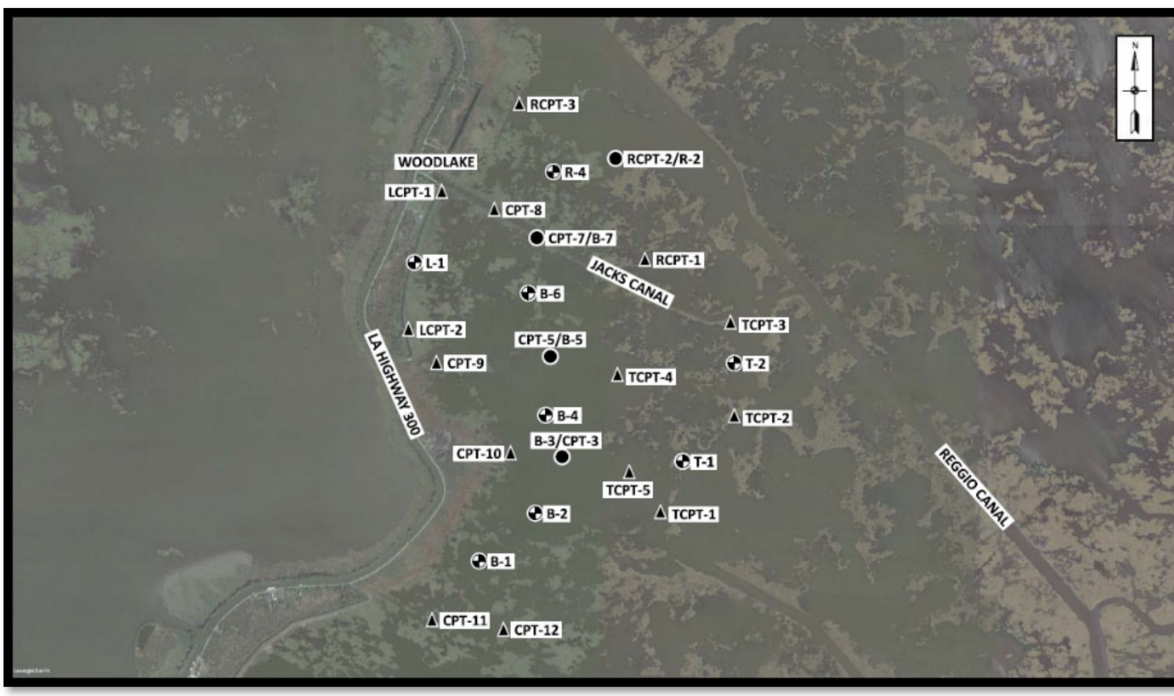

Figure 33: MCA Geotechnical Data Collection Layout

4.4 Borrow Area Geotechnical Subsurface Investigation

Soil conditions were evaluated in the Lake Amedee MCBA by advancing twelve (12) cores to twenty (20) ft below the existing mud line. Locations of the soil borings within the Lake Amedee MCBA are shown in **Figure 34**. Index properties observed during drilling and laboratory test results are located on the soil boring logs in **Appendix E**. The twelve (12) soil borings indicate a general stratigraphy of alternating stratum of extremely soft to soft dark gray, gray, and brown humus/organic clay and extremely soft to soft gray clay (Eustis, 2022). Some interbedded strata of very loose gray silty sand and gray silt were also encountered in some of the borrow area borings. Pockets of shells and shell fragments were encountered in all soil borings in the borrow area (Eustis 2022). The proposed fifteen (15) ft cut depth in the borrow area extends from about -5.0 ft to -20.0 ft NAVD88.

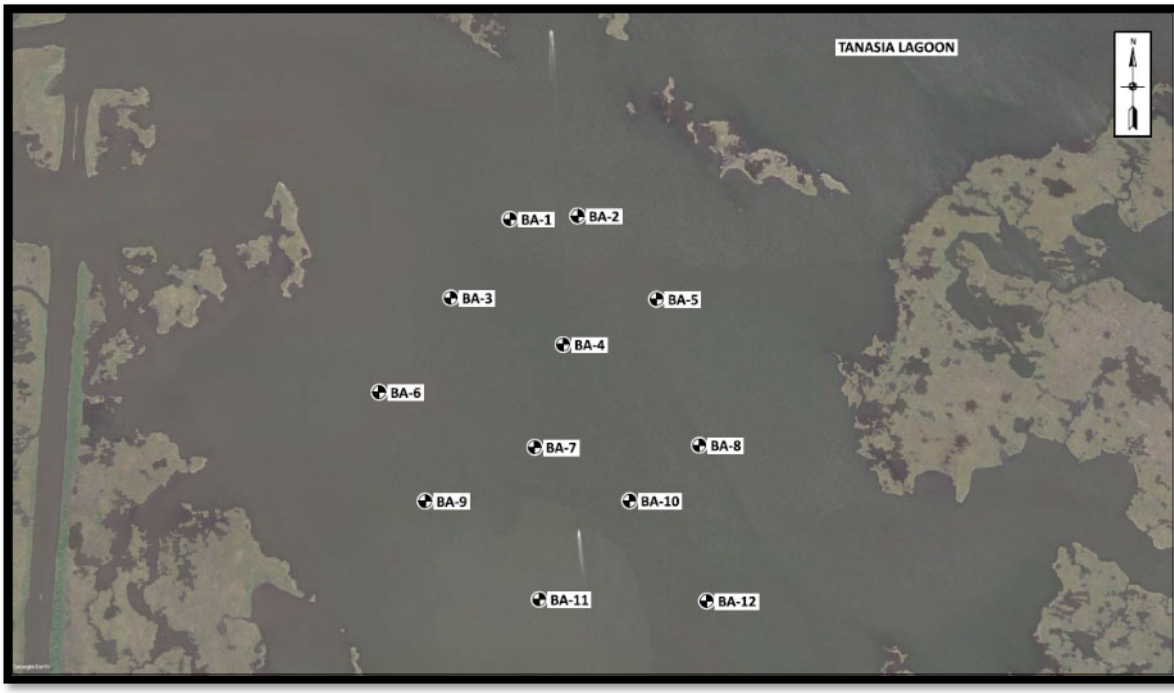

Figure 34: MCBA Geotechnical Data Collection Layout

5.0 PROJECT DESIGN

This project proposes to create and nourish three hundred seventy-eight (378) acres of marsh by hydraulically dredging material from Lake Amedee into three (3) MCAs as shown in **Figure 35**. The proposed fully confined MCA-2 will utilize the existing Wood Lake Tidal Levee embankment and proposed ECDs to contain the hydraulically dredged marsh fill placed in the MCA. To achieve the project goals, the dredged fill will need to be placed to a constructed fill elevation above the selected intermediate marsh inundation range so that the marsh platform will settle into the optimum inundation range over the twenty (20) year design life. The project design section of this report is broken up into the following sections: MCAs, ECDs, ET, MCBA, EAC, and DPC design. The 95% Design Plan views and Typical Sections of the proposed project features are provided in the 95% Design Drawings (**Appendix G**).

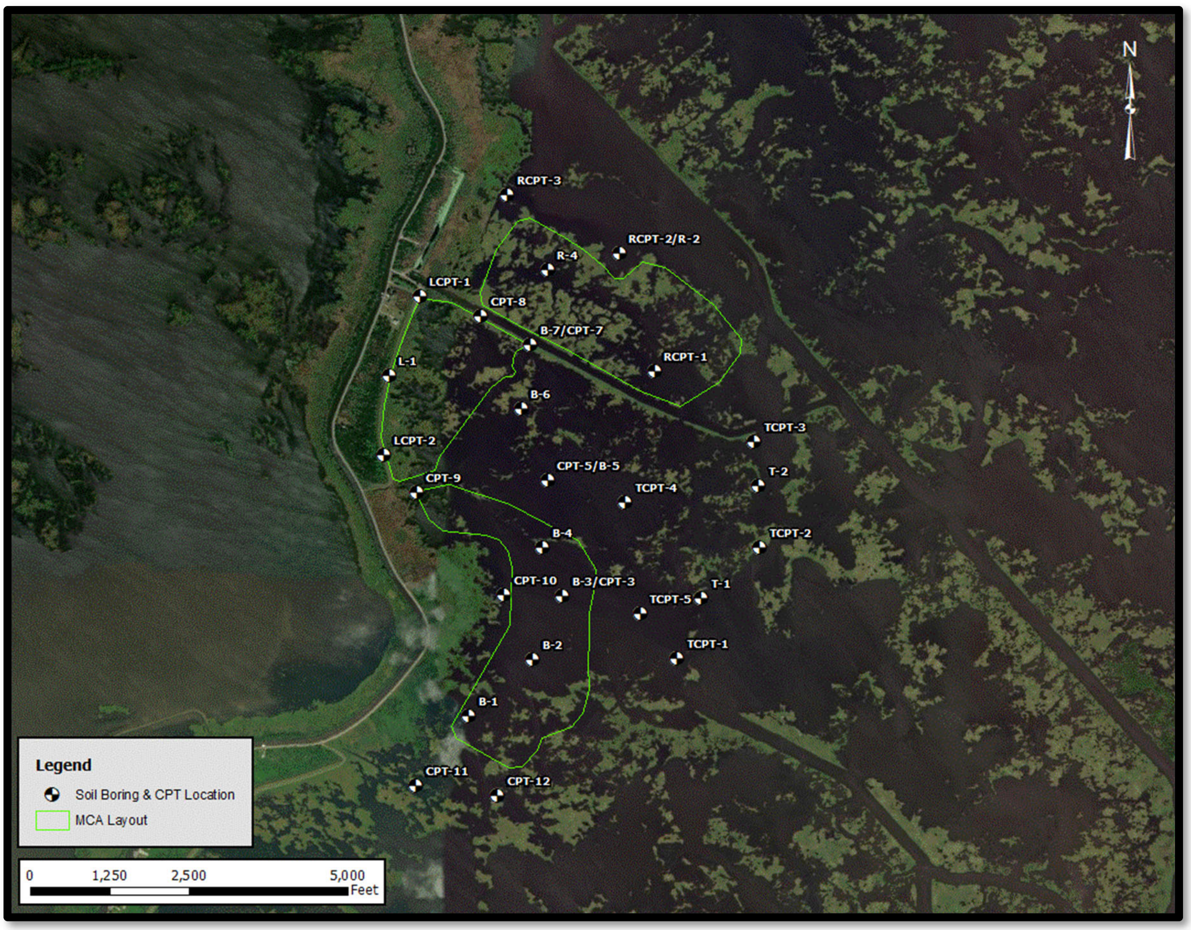

Figure 35: MCA Layout with Geotechnical Sampling Locations

5.1 Marsh Creation Area Design

Marsh fill settlement analysis was performed to determine the construction marsh fill elevation of the MCAs and the total volume of marsh fill material needed for construction. The final elevation of the MCA (at year twenty (20)) is governed by two forms of settlement: (1) the settlement of the underlying soils in the MCAs caused by the loading exerted by the placement of dredged fill material, and (2) the self-weight consolidation of the dredged material. Additionally, the natural process of subsidence plays a role in determining the final settled twenty year (20) elevation of the MCA as mentioned previously in **Section 2.2**.

5.1.1 Preparation for Marsh Creation Area Settlement Analysis

PSDDF is a program developed by the U.S. Army Corps of Engineers (USACE) Waterways Experiment Station (WES) that accounts for the Primary Consolidation, Secondary Compression and Desiccation of Dredged Fill. PSDDF calculates the total settlement of dredge fill and the compressible foundation based on the consolidation characteristics of each. This settlement is then accumulated for each compressible layer within the area and a cumulative settlement for all dredged fill and compressible foundation layers is calculated (Stark, 2014). Data from settling column, traditional consolidation testing and low-pressure consolidation tests were used to estimate the magnitude and time-rate of settlement of the dredge fill.

To perform the marsh fill settlement analysis in PSDDF, parameters such as sea level rise, subsidence, target marsh creation surface elevations, existing mudline elevations, fill volumes, and dredge fill placement rates are required. The primary inputs required by PSDDF include the void ratio versus effective stress and void ratio versus permeability relationships for dredged fill and foundation materials. Additional inputs include the specific gravity of solids, initial void ratio and the desiccation characteristics of dredged material.

Marsh fill and foundation settlement analysis was modeled with an existing mudline of -3.0, -2.0, and -1.0 ft NAVD88. These mudlines represent the prevailing existing mudline elevations throughout all MCAs. Mudline elevations selected for settlement analyses are based on the histograms presented in **Section 3.6.3**, and summarized in the table below. The representative mudlines analyzed were -1.0 ft for MCA-2 and -3.0 feet for MCAs 1 and 3.

5.1.2 Assumed Filling Sequence for PSDDF

In order to model fill placement in PSDDF, a hydraulic fill placement lift schedule must be determined. The dredge production rate determines the lift schedule, which can vary widely depending on dredge size and contractor means and methods. Based on the shallow water depths in Lake Amedee and the minimum operating depths for cutter suction dredges, mobilization of a sixteen (16) to eighteen (18) inch cutterhead suction dredge (CSD) is anticipated. The estimated time to fill each MCA is based on a production rate of 10,000 cubic yards per day**.** The construction duration for each MCA varies from thirty (30) days to one hundred ten (110) days. Eustis Engineering considered four (4) assumed filling durations in PSDDF to account for self-weight settlement during construction to capture the potential filling rates for each MCA and their respective mudline.

5.1.3 Foundation Settlement

The top five (5) to ten (10) ft of foundation material in the MCA is predominantly organic clay underlain primarily by soft and fine-grained clays. This weak foundation material will experience significant initial consolidation due to dredged material placement, followed by continuing settlement over long periods of time at a diminishing rate (Eustis, 2023).

Settlement analysis of the foundation soils within the MCA was modeled using PSDDF. Void ratio-effective stress and void ratio-permeability relationships were developed for each layer of the foundation. PSDDF calculates the total settlement of dredge fill and the compressible foundation based on the consolidation characteristics of each. This settlement is then accumulated for each compressible layer within the area and a cumulative settlement for all dredged fill and compressible foundation layers is calculated (Stark, 2014). The design water level for the marsh creation cells was set to the estimated year twenty (20) elevation of +1.0 ft NAVD88 to account for buoyancy over the design life of the project. Results of the MCA foundation settlement analysis from dredge fill placement are summarized in **Table 10**. The analysis presented in the GER (**Appendix F**) refers to the 30% Design layout of the MCA as shown in **Figure 8**. The 30% Design MCA-2 assumed a representative mudline elevation of -2.0 ft NAVD88 for settlement analysis. In the 95% Design, forty-two percent (42%) of the MCA-1 mudline distribution falls within the elevation range of -1.0 to -2..5 ft NAVD88 as shown in **Figure 28**. For design purposes, the 95% Design MCA-1 uses the settlement assumptions of the 30% Design MCA-2, whose representative mudline of -2.0 ft NAVD88 is appropriate for the 95% Design MCA-1.

Table 10: Marsh Creation Area Foundation Settlement Results (95% Design MCAs)

Model	Mudline Elevation (ft NAVD88)	Estimated Construction Settlement (ft)	Estimated Post-Construction Settlement (ft)	Total Estimated Foundation Settlement (ft)
MCA-1	-2.0	0.652	0.260	0.912
MCA-2	-1.0	0.555	0.272	0.827
MCA-3	-3.0	0.661	0.281	0.942

To account for the long-term predicted foundation settlement, each MCA is assigned a value for foundation settlement based on the corresponding PSDDF model output. The respective foundation settlement value for each of MCA will be added to the elevation used for calculating volumes. The foundation settlement thickness, along with the previously mentioned subsidence estimate of 3.6 inches of fill, will be added together to the target twenty (20) year surface elevation to be used in volume calculations as shown in the calculations package (**Appendix H)**. A summary of the foundation settlement analysis conducted by Eustis Engineering is provided in the GER (**Appendix F**).

5.1.4 Self-Weight Settlement

The other settlement required for marsh creation settlement analysis is self-weight settlement. A column settling test was performed by Eustis Engineering to understand the settling processes and properties of the dredged slurry, by the test 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. Column settling tests provide an insight into the sedimentation behavior of the marsh fill when placed within the MCA, 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. Dredge material test results from the column settling test, low-stress consolidation test, and the selection of the initial void ratio determined by Eustis are shown in Appendix II of the GER (**Appendix F)**.

5.1.5 Constructed Marsh Fill Elevation

The next step in the settlement analysis involved determining an appropriate constructed marsh fill elevation (CMFE). One element of the design is to maximize the time that the marsh platform has an elevation within the selected intermediate marsh inundation range (ten to ninety percent (10%-90%) inundated). To determine the CMFE that would yield the most productive marsh at the end of the twenty (20) year project life, water levels in the project area, ESLR, subsidence rates, and foundation settlement estimates for the project area were determined. For design application, subsidence, and foundation settlement estimates were applied to the marsh fill elevation (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 intermediate marsh range (ten to ninety percent (10%-90%) inundated) shortly after construction and would remain there for the duration of the twenty (20) year project life.

Eustis Engineering provided construction marsh fill settlement recommendations for each MCA that would maximize the amount of time that the marsh platform would remain within the ten to ninety percent (10% to 90%) inundation range. Eustis Engineering modeled the compression settlement of the dredge fill for each MCA with the goal of achieving an elevation above the 90% inundation of +0.60 ft NAVD88 at TY20 (2044). The actual elevation at the end of dredge fill placement will depend on contractor equipment size, means and methods of fill placement, dewatering operations, as well as the initial concentration of dredged material. Field sampling and quality control during construction may be utilized by CPRA to calibrate and verify settlement modeling to reduce uncertainty once in construction. The results of the estimated marsh fill settlement in MCA-1, MCA-2, and MCA-3 are presented in **Figures Figure** 36, **Figure** 37, and **Figure** 38, respectively. Generally, the maximum elevation at the start of compression settlement and the final twenty (20) year surface elevation for all PSDDF model runs varied slightly for each MCA. Additional settlement curves for each MCA are provided in the GER (**Appendix F**).

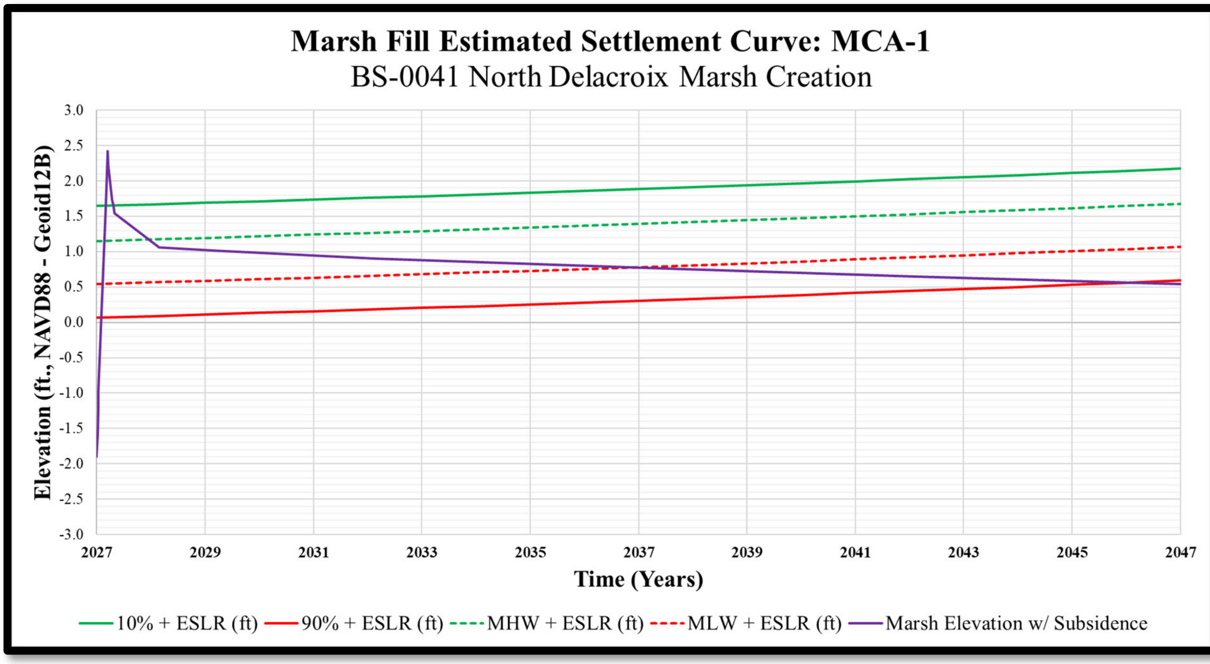

Figure 36: Marsh Fill Estimated Total Settlement Curve for MCA-1

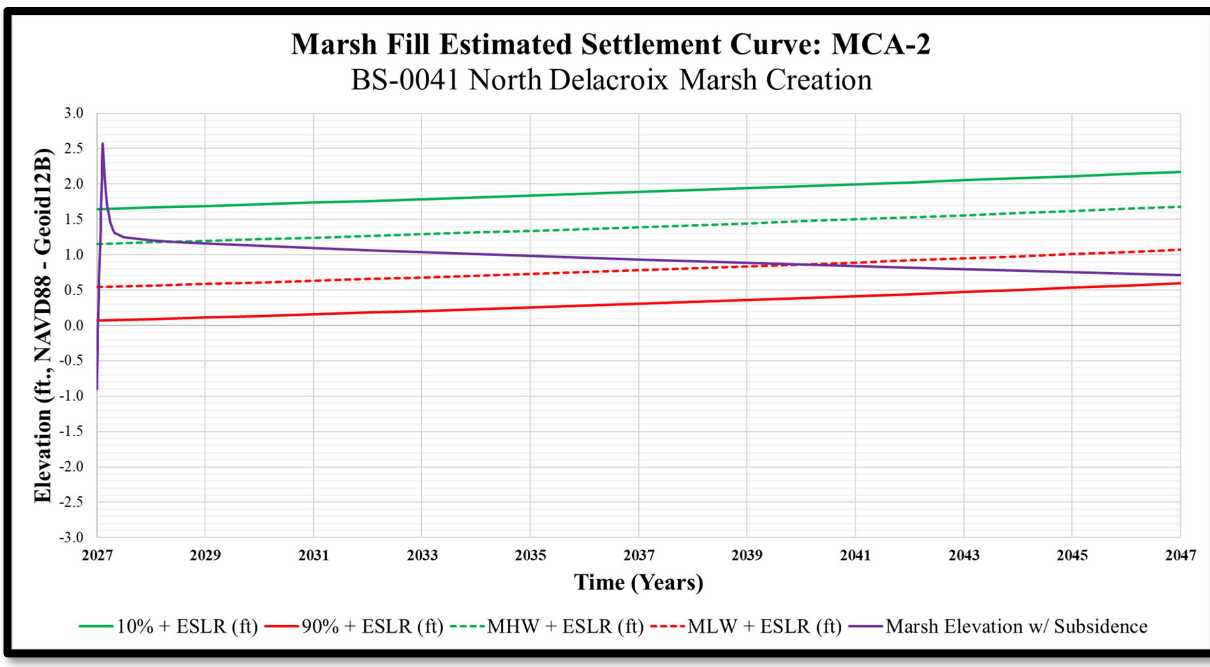

Figure 37: Marsh Fill Estimated Total Settlement Curve for MCA-2

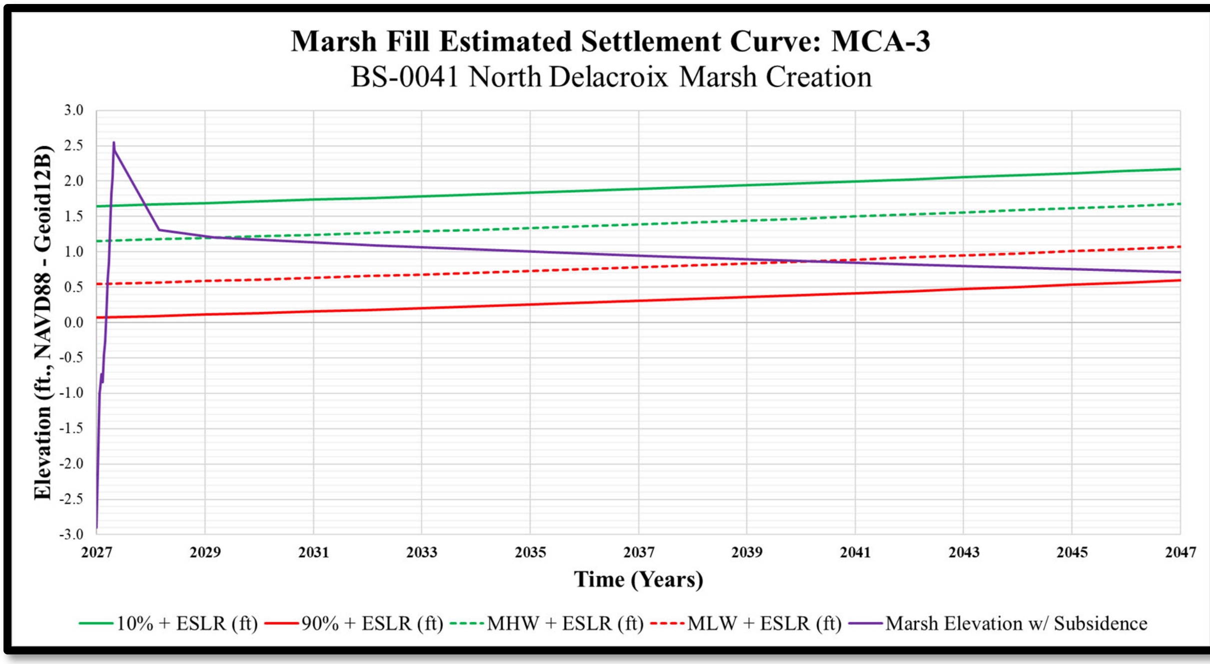

Figure 38: Marsh Fill Estimated Total Settlement Curve for MCA-3

Based on the PSDDF results presented, the recommended CMFE for all MCAs is +2.50 ft NAVD88 with a quarter-foot upper and lower tolerance (± 0.25 ft). This recommended CMFE should provide a cost and material efficient marsh platform with maximum time spent within the optimum inundation range. During construction, the CMFE may be adjusted based on field observations, sampling, and actual daily dredge production rates. The observational approach to design typically involves geotechnical monitoring of the soil behavior during the early phases of construction to verify design parameters and predict responses to inform subsequent construction (Samtani & Nowatzki, 2006).

5.1.6 Accretion

The goal of any marsh creation project is to establish a wetland ecosystem by raising the elevation of the existing mudline to an intertidal elevation that can support natural vegetative processes. Similarly to existing marsh, created marsh surfaces will begin to gain elevation once the marsh platform falls within the target inundation range, and vegetation becomes established.

CPRA's Lafayette Operations Division performed a study based on observed accretion and elevation change rates at monitoring sites in MCAs. This study suggests that created marsh can keep up with subsidence, and in many instances, result in an increase in vertical surface elevation (Sharp and Mouledous 2019). Based on the data presented in this study, an accretion rate of one (1) cm/year is expected to occur in created marsh after establishment of vegetation. Accretion rates differ from a true elevation change rate therefore an "elevation to observed accretion factor" of thirty percent (30%) is applied to the one (1) cm/year accretion rate yielding an elevation rate of +0.3 cm/year (0.11 inches/year).

Created marsh surfaces will begin to gain elevation once the marsh platform falls within the target inundation range, and vegetation becomes established. To remain conservative, volume calculations do not take into account the anticipated elevation gain from accretion.

5.1.7 Marsh Creation Area Quantities

After determining the magnitude of foundation settlement, subsidence, and the twenty (20) year settled marsh platform elevation, the total volume of the MCA was calculated using AutoCAD Civil 3D 2020 software. The software creates a 3-Dimensional surface based on three-dimensional coordinate data from design survey data. This surface is known as the base triangular irregular network (TIN). The base TIN surface from the 2021 survey data and a flat TIN comparison surface for each MCA was created by AutoCAD. AutoCAD then uses the XYZ differences of each surface to calculate the fill volume of the MCA. The flat TIN comparison surface elevation for each MCA is shown in **Table 11.**

Table 11: Elevations used for MCA Fill Volumes

Project Feature	**Year Twenty Desired Elevation** (ft NAVD88)	**Total Estimated Foundation Settlement** (ft)	**Total Estimated Subsidence** (ft)	**Comparison Surface Elevation** (ft NAVD88)
MCA-1	+0.60	0.91	0.30	+1.85
MCA-2	+0.60	0.83	0.30	+1.70
MCA-3	+0.60	0.94	0.30	+1.85

The cut-to-fill ratio for marsh fill was estimated twenty (20) years after dredging using the following equation from EM1110-2-5025:

$$V_f = V_i \left[\left(\frac{e_{20} - e_0}{1 + e_0} \right) + 1 \right]$$

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_0 = average in-situ void ratio of the borrow area
e_{20} = void ratio after twenty (20) years.

For determination of the cut to fill ratio the average void ratio for the entire fifteen (15) foot column of the proposed borrow area will be utilized for calculations. The average in-situ void ratio in the proposed borrow area is approximately 2.81. Throughout the twenty (20) year design life of the project, the void ratio throughout the marsh fill will decrease towards the initial void ratio of the MCBA. Based on the PSDDF output data, the average void ratio in the fill area at twenty (20) years is 2.95. The estimated change in void ratio from the MCBA to the final in-place void ratio at twenty years is summarized below.

$$e_0 \rightarrow e_d(varies) \rightarrow e_{20} = 2.81 \rightarrow 5.0 - 18.0 \rightarrow 2.95$$

Where,

e_0= in-situ borrow area void ratio
e_d= void ratio during dredging
e_{20}= final in-place void ratio

The calculated cut-to-fill ratio at twenty years using the equation shown above is 0.96. To account for losses (dewatering, disturbed borrow material not transported, etc.), the cut-to-fill ratio that will be utilized for design and for the hydraulic dredging bid quantity is 1.1. Since the containment borrow pits must also be refilled, the volume to build the containment dikes including a cut-to-fill ratio of 1.5 for the dikes is then added to the volume required to fill the MCAs. Finally, this project's hydraulic dredging cut-to-fill ratio of 1.1 is applied, resulting in a final estimate of fill volume for each MCA. A summary of the estimated marsh fill volume calculations is shown in the **Table 12**.

Table 12: Summary MCA Acreages & Volumes

Fill Area	**CMFE** (ft NAVD88)	**Area** (ac)	**Cut to Fill**	**Fill Volume*** (yd^3)	**Cut Volume** (yd^3)
MCA 1	+2.5 (± 0.25)	148	1.1:1	855,000	941,000
MCA 2	+2.5 (± 0.25)	87	1.1:1	324,000	356,000
MCA 3	+2.5 (± 0.25)	143	1.1:1	921,000	1,013,000
Total	-	378	-	2,100,000	2,310,000

* Volume calculations shown in this table include ALL ECD borrow quantities

5.2 Earthen Containment Dike Design

The primary design parameter associated with the ECD design is the crown elevation. The ECD crown elevation governs the maximum elevation of dredge slurry. Several factors associated with the equipment type, means of methods of the contractor, and the existing conditions of the project site drive the selection of the design crown elevation of containment dikes on marsh creation projects. These factors include but are not limited to, the dredge production rate (dredge size), the concentration of slurry (or specific gravity of the slurry), weir box management, volume of solids required to achieve the target twenty (20) year elevation, and the capacity of the fill area.

ECDs may be gapped or degraded prior to construction demobilization at the discretion of the sponsors. This will include a minimum twenty-five percent (25%) of the total linear length of ECD be degraded in a manner equivalent to one twenty-five (25) foot gap excavated at least to 0.0 feet NAVD88 every one hundred (100) feet no later than year three after completing pumping. This is to aid in establishment of tidal wetland functions and is in addition to any dike gapping to the CMFE during construction for dewatering. Use of available elevation survey data and an interagency on-site investigation will be used to refine gapping and siting needs. Gaps wider than 25 feet is an option, and may be implemented, to reduce the risk of gaps from becoming obstructed from siltation, vegetation, debris, etc. The existing tidal levee that will serve as containment on MCA-2 shall not be gapped or degraded.

5.2.1 Earthen Containment Dike Height

Marsh fill settlement calculations in PSDDF and the MCDG were used to guide the decision for determining the appropriate containment dike height required to contain the total volume of solids to achieve the target twenty (20) year elevation for this project. Given the uncertainty with the actual cutter suction dredge performance and means of methods of fill placement, the maximum extents of the ECDs were analyzed. Based on the maximum CMFE of +2.75 ft NAVD88 and the minimum one (1.0) ft of freeboard requirements outlined in the MCDG, it is recommended that the crown elevation of containment dike to contain dredged slurry for all MCAs is +3.5 ft NAVD88 with an upper half foot (+0.5) tolerance.

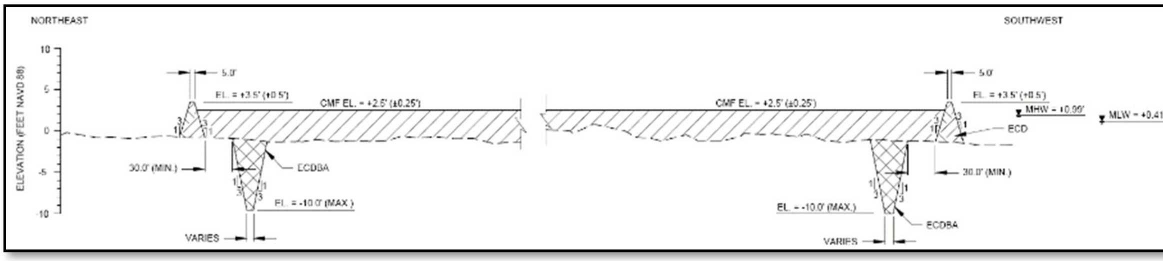

Figure 39: MCA & ECD Typical Section

5.2.2 Earthen Containment Dike Stability

Stability analyses for the ECDs were performed using Spencer's Method of Analysis and GEOSLOPE SLOPE/W. For the ECD fill material, Eustis assumed a unit weight of 80 pounds per cubic foot (pcf) and a cohesion of 100 pounds per square foot (psf) based on guidance provided in the MCDG. Eustis also performed a site-specific sensitivity analysis for weaker ECD fill materials by reducing the cohesion of the fill materials from 100 psf to 75 psf.

The maximum ECD elevation of +4.0 ft NAVD88, along with three (3) horizontal to one (1) vertical (3H: 1V) side slopes and a thirty (30) ft berm width, was selected for the ECD stability analyses. The following slope stability scenarios were run in SLOPE/W:

Case A-1) Global failure of the containment dike, no marsh fill placed.

Case A-2) Failure of the borrow channel, no marsh fill place, with construction equipment modeled (Vertical load surcharge = 260 PCF).

Case B-1) Failure of the containment dike with no marsh fill.

Case B-2) Failure of the containment dike after placement of marsh fill (no freeboard).

ECDs were analyzed to a minimum factor of safety of 1.2 as recommended in MCDG 1.0. Based on the results presented in **Table 13**, the project area could be contained successfully with a +4.0 ft crest dike height and side slopes of 3H:1V. A summary of the site-specific stability results at the -3.0 ft contour are presented in **Table 13**.

Table 13: ECD Slope Stability Results

Condition	Mudline Elevation (ft NAVD88)	Crest Elevation (ft NAVD88)	Borrow Pit Offset (ft)	Berm Side Slope	Factor of Safety (Min = 1.2)
ECD Borrow Excavation Global (A-1)	-3.0	+4.0	30	3H:1V	1.81
ECD Borrow Excavation Local (A-2)	-3.0	+4.0	30	3H:1V	1.88
Filled to CMFE of +3.5 (B-2)	-3.0	+4.0	30	3H:1V	1.29
ECD Local Stability (B-1)	-3.0	+4.0	30	3H:1V	1.30

5.2.3 Earthen Containment Dike Settlement

Consolidation settlement of the foundation soils beneath the +4.0 ft NAVD88 ECDs were computed by Eustis Engineering in Settle3 assuming instantaneous loading. Instantaneous loading of the ECD foundation will yield more conservative estimates of settlement. Eustis Engineering determined that approximately two (2) ft of settlement would occur at the centerline of the containment dike over the twenty (20) year project life. A substantial portion of the settlement occurs within the top five to ten (5-10) ft of the foundation soil due to the placement material on top of the weak foundation soils during construction. The lateral displacing or mud waving that occurs during ECD construction will occur quickly and may increase the quantity required to reach the design construction elevation. This increase in quantity from settlement and lateral displacement is accounted for in the cut-to-fill ratio for ECDs. Figures of the ECD settlement results can be found in Appendix IV of the GER (**Appendix F**).

5.2.4 Earthen Containment Dike Quantities

ECDs will be constructed using clamshells and marsh buggies, and utilizing in-situ material from inside the MCAs. ECD volumes were calculated using AutoCAD Civil 3D and in Microsoft Excel using the Average End Area Method. A crown elevation of +4.0 ft NAVD88 and side slopes of 3H:1V were used to calculate volumes to account for the construction tolerance. To account for any losses, elastic settlement, and ongoing maintenance of the ECD template during construction, a cut to fill ratio of 1.5 was applied to determine the volume of borrow required to build the ECDs. The final ECD quantities are summarized in **Table 14**. Typical Sections for the MCAs and ECDs are shown in **Figure 39** and the 95% Design Plans (**Appendix G**).

Table 14: Summary of ECD Quantities

Marsh Creation Area	Total ECD Length (ft)	Cut to Fill	Fill Volume (yd^3)	Cut Volume (yd^3)
ECD 1	10,900	1.5:1	37,000	55,500
ECD 2	5,000*	1.5:1	20,800	31,200
ECD 3	13,200	1.5:1	64,500	96,800

*MCA-2 also has an additional 3,000 ft of existing levee that will serve as containment, putting the MCA-2 total perimeter distance at 13,000 ft.

5.3 Wood Lake Tidal Levee

Based on the latest 2022 UAV LiDAR survey, existing grades of +5.0 ft NAVD88 and greater are prominent along the centerline of the Wood Lake Tidal Levee. This is higher than the recommended ECD. Additionally, the toe of the tidal levee is at an elevation of +3.0 ft NAVD88 and greater, which is higher than the CMFE with tolerance (+2.75 ft NAVD88). Therefore, a levee raise and stability analysis for additional loading on the levee will not be required.

5.4 Earthen Terrace Design

The goal of the earthen terrace is to maintain a crown elevation of one (1) foot above the twenty (20) year projected MHW level throughout the project design life. The proposed earthen terrace feature will serve multiple purposes, such as protecting the MCAs from wave erosion, potentially capturing sediment-laden water of nearby dewatering MCAs, and increasing marsh edge in the project area.

The terrace field layout shown in **Figure 40** was delineated to provide as many habitat acres as possible within the project area given the geometric and geotechnical design constraints as well as minimizing construction impacts to existing marsh in the area. Based on five (5) years of the most recent available wind speed and direction data from the New Orleans Lakefront Airport, the predominant wind direction is southeast. The Terrace Field layout is perpendicular to the prevailing wind direction associated with the site to prevent significant wave propagation. Earthen terraces will be spaced approximately three hundred (300) ft from centerline to centerline and each terrace will be two hundred fifty (250) ft long. The wind rose generated in **Figure 41** was created using the Iowa Environmental Mesonet application and the wind data is provided by the New Orleans Naval Air Station.

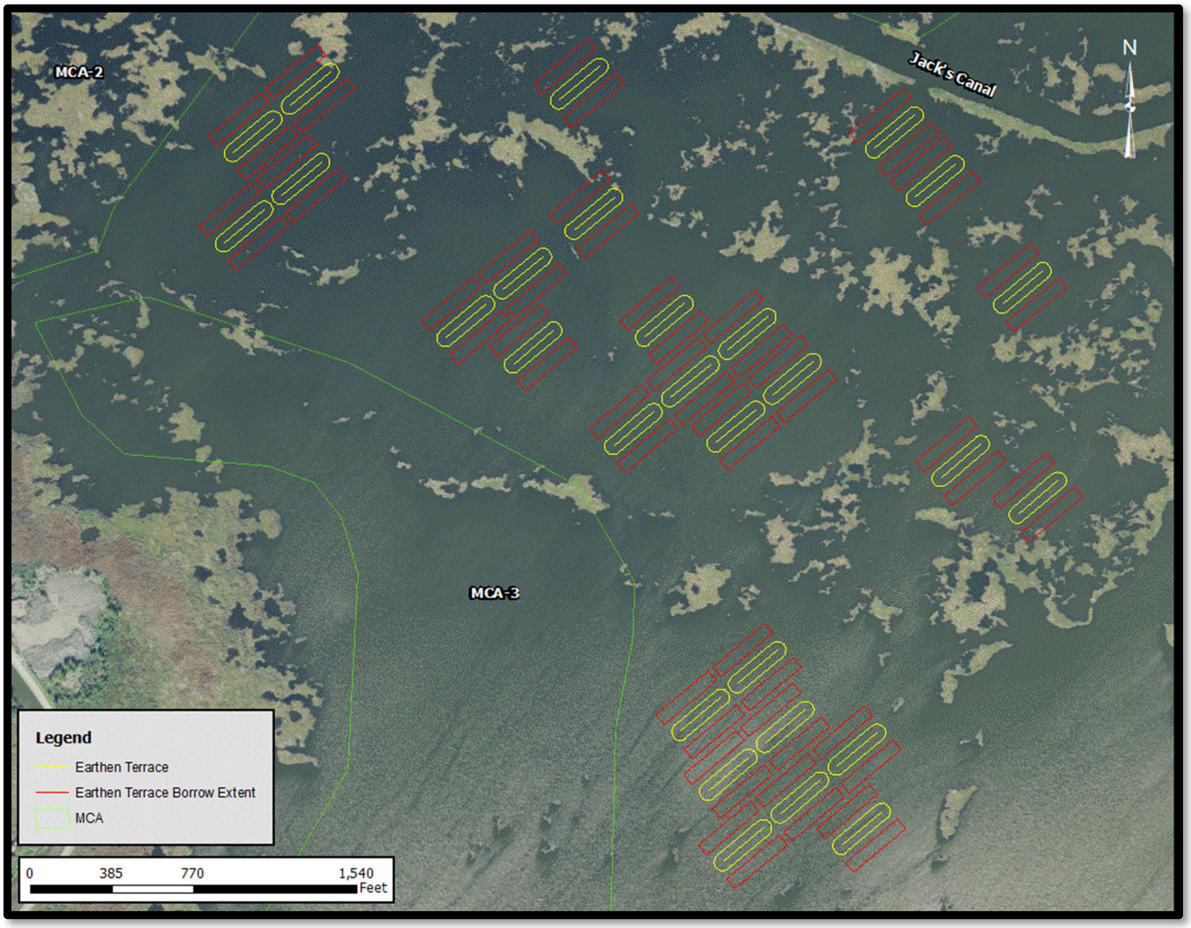

Figure 40: Earthen Terrace Field Layout

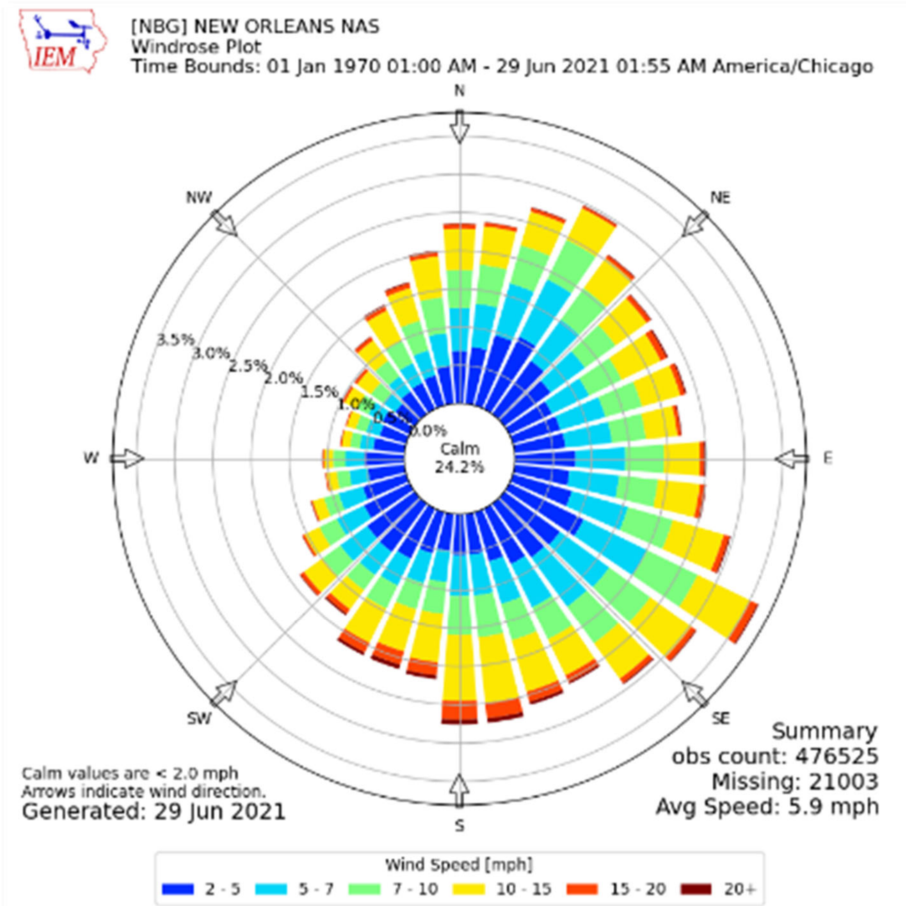

Figure 41: Wind Rose at New Orleans Naval Air Station (January 1970 - June 2021)

5.4.1 Earthen Terrace Quantities

All Earthen Terraces are proposed to have a top width of ten (10) ft and will be constructed to a target elevation of +4.5 ft NAVD88, with side slopes of 5H:1V. The Typical Section for the proposed Earthen Terrace feature is presented below in **Figure 42**. The +4.5 ft NAVD88 elevation is calculated based on a target elevation of +2.6 ft NAVD88 at year twenty (20) and an estimated settlement of approximately 1.5-2.0 ft over the twenty (20) year project life as outlined in the GER.

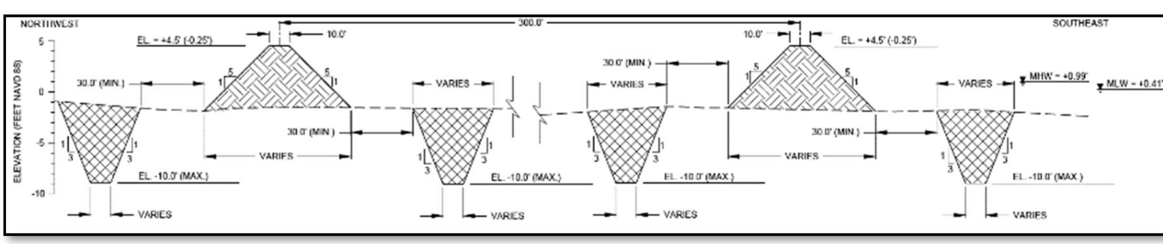

Figure 42: Earthen Terrace Typical Section

Earthen terrace fill volumes were calculated using AutoCAD Civil 3D. An earthen terrace elevation of +4.5 ft (NAVD88, Geoid 12B) was used to calculate volumes. To account for any losses, elastic settlement, mud wave action, and localized bearing capacity failures during construction, a cut to fill ratio of 1.5:1 was applied to determine the total earthen terrace cut volume. All earthen terrace quantities are summarized in **Table 15**.

Table 15: Earthen Terrace Quantities

Number of Terraces	**Length of Earthen Terrace** (LF)	**Total Length of Earthen Terraces** (LF)	**Total Earthen Terrace Fill Volume** (CY)	**C:F**	**Earthen Terrace Cut Volume** (CY)	**CY/LF**
29	250	7,250	97,100	1.5	145,700	20

5.5 Marsh Creation Borrow Area Design

The typical controlling factors in the MCBA design are the location, existing infrastructure, borrow soil properties, and quantities. It is preferred that the borrow area be located near the proposed MCAs to minimize the pumping distance of the dredged material and therefore minimize the dredging cost. The MCBA should be free of any existing oyster leases, critical habitat, culturally significant sites, and infrastructure, if possible.

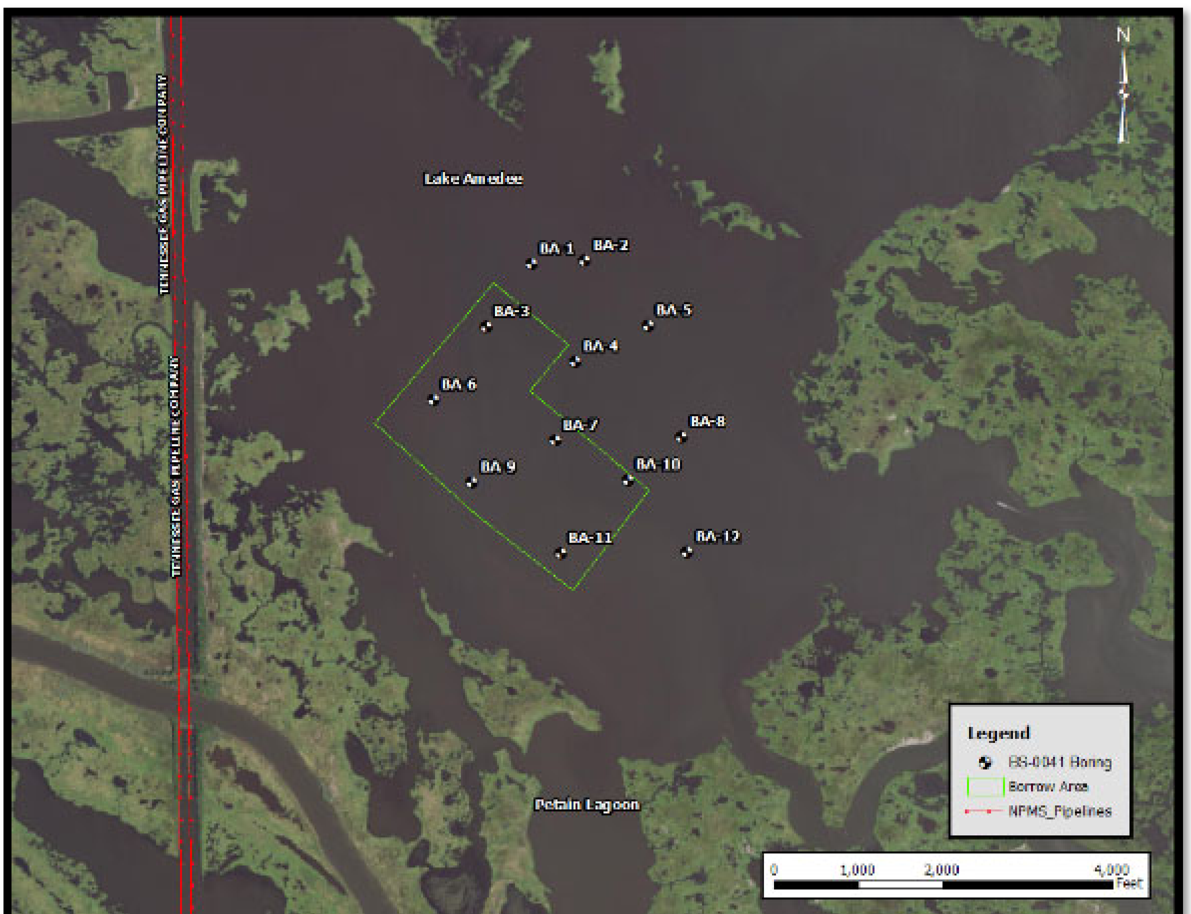

Figure 43: 95% MCBA & Geotechnical Sampling Locations

The MCBA has two distinct profiles that were identified by reviewing the visual classifications and material properties of the borrow material. MCBA Profile 1 consists of soil borings BA-3, BA-6, BA-7, BA-9, BA-10, and BA-11. MCBA Profile 2 consists of the remaining soil borings BA-1, BA-2, BA-4, BA-5, BA-8, and BA-12. These profiles consist of slightly different borrow material that are best represented visually in the summary tabulations and Figures below. The soil properties that typically influence fill suitability were averaged for each profile and are included in **Table 16**. Those properties include plasticity index (PI), liquid limit (LL), moisture content (w), unit weights (γ), and percent organics. The number of samples with each USCS classification are also included in the **Table 16**.

Table 16: MCBA Geotechnical Properties Summary

Borrow Area Profile	PI	LL	w	γ_w	γ_d	% organic	USCS Classification					
							OH	CH	PT	CL	ML	SM
1	69	95	105	94	48	6	16	98	0	0	3	1
2	91	124	145	90	41	12	53	57	6	2	2	0

Visual classifications and void ratios for all MCBA soil borings by depth are presented in **Figure 44** and **Figure 45**. MCBA Profile 2 consists of approximately fifty-three (53) organic clay and six (6) peat samples while MCBA Profile 1 consists of sixteen (16) organic clay samples. Upon review of the geotechnical boring log data, it was determined that the denser and less organic material in Profile 1 would provide a better long-term marsh platform for the project. Additionally, the proximity of the western half of the Lake Amedee MCBA to the MCAs favored the selection of MCBA Profile 1. Soil borings associated with Profile 1 were ultimately utilized for the composite sample testing. The testing of a composite sample for Profile 2 was not conducted; therefore, additional testing and analysis to determine the material's suitability for use as hydraulic dredge borrow material for future marsh creation projects should be performed.

Of the one hundred twenty (120) samples from Profile 1, three (3) were visually classified as being inorganic silts and very fine sands, one (1) silty sand, sixteen (16) organic clays, and ninety-eight (98) fat clay samples. A summary of the geotechnical properties of the composite sample from Profile 1 are listed below in **Table 17**.

Table 17: MCBA Profile 1 Composite Sample Geotechnical Properties Summary

Dredge Material	Specific Gravity	% Sand			% Fines		PL	LL	USCS	% Organic	w	γd
		Coarse	Medium	Fine	Silt	Clay						
Composite Sample (Profile 1)	2.6	0	0.5	5.9	40.1	53.5	20	83	CH	6	107	35.0

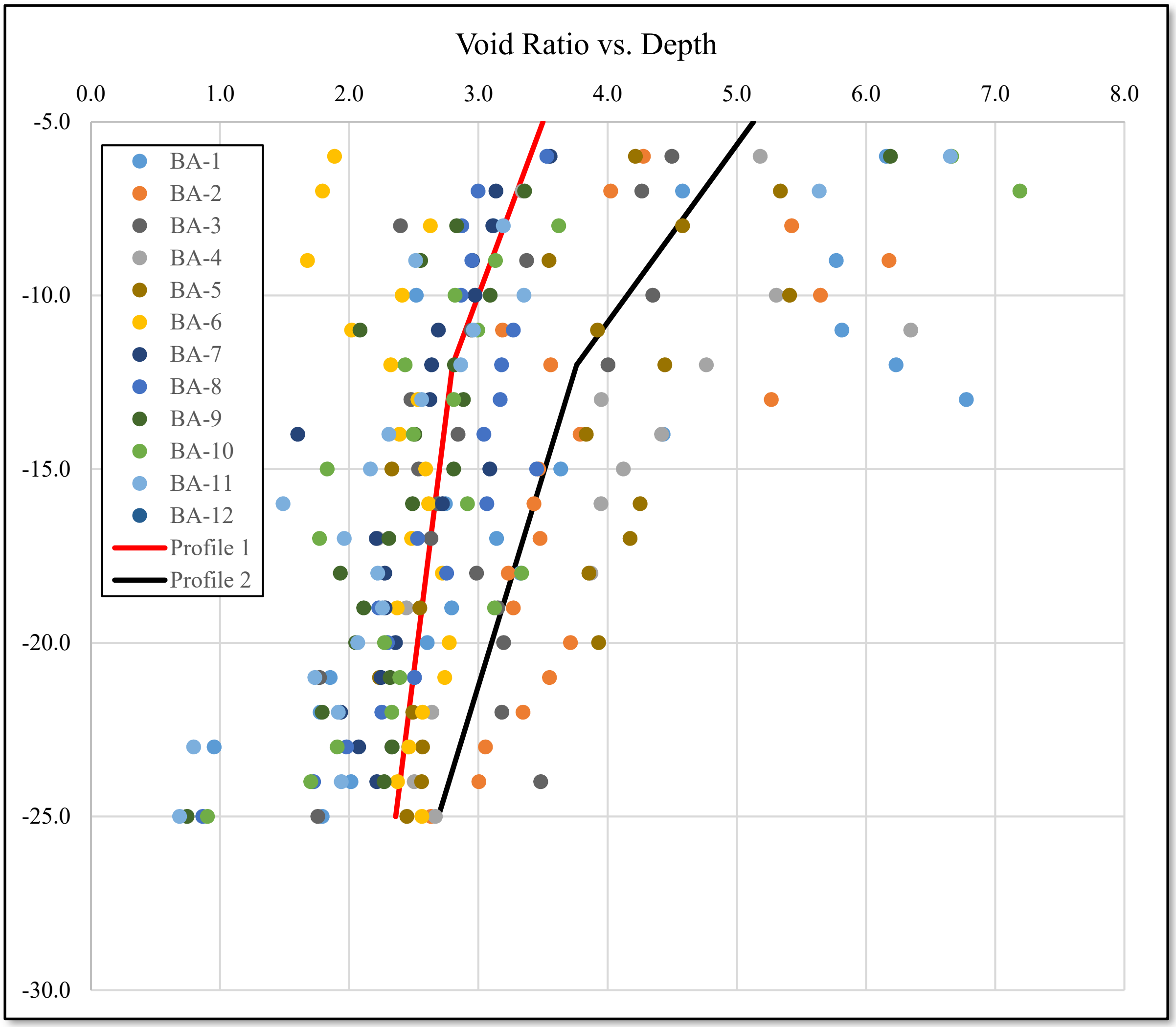

Figure 44: MCBA Design Profiles with Void Ratio vs. Elevation

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 thus 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 where the moisture content is greater than the LL are likely to be underconsolidated soils and more prone to flowing like a fluid (Das and Sobhan 109). The top fifteen (15) ft of the Lake Amedee borrow area trends to a material consisting of soft fat clays (CH) with low unit weight and water contents that exceed the liquid limit. On average, the LI of the borrow materials within the upper fifteen (15) ft is 1.37. This is an indication that the material in the top fifteen (15) ft will behave more like a fluid than solid material.

BS-0041 Marsh Creation Borrow Area Visual Classification												
	Profile 2						Profile 1					
Elev.	BA-1	BA-2	BA-4	BA-5	BA-8	BA-12	BA-3	BA-6	BA-7	BA-9	BA-10	BA-11
-5	OH	OH	OH	OH	OH	OH	OH	CH	OH	OH	OH	OH
-6	OH	OH	OH	PT	CH	OH	OH	CH	OH	OH	OH	OH
-7	OH	OH	PT	OH	OH	OH	CH	CH	CH	OH	OH	CH
-8	OH	OH	PT	CH	CH	OH	NS	CH	CH	CH	CH	CH
-9	OH	OH	PT	OH	CH	OH	OH	CH	CH	CH	CH	CH
-10	OH	OH	OH	OH	CH	OH	CH	CH	CH	CH	CH	CH
-11	OH	OH	OH	OH	CH	CH	OH	CH	CH	CH	OH	CH
-12	OH	OH	CH	PT	CH	PT	CH	CH	CH	CH	OH	CH
-13	OH	OH	OH	CH	CH	OH	CH	CH	CH	CH	CH	CH
-14	OH	OH	OH	CH	CH	CH	CH	CH	CH	CH	CH	CH
-15	CH	OH	CH	OH	CH	CH	CH	CH	CH	CH	CH	CH
-16	CH	OH	CH	OH	CH	CH	CH	CH	CH	CH	CH	CH
-17	CH	OH	CH	OH	CH	CH	CH	CH	CH	CH	CH	CH
-18	CH	CH	CH	CH	CH	CH	CH	CH	CH	CH	CH	CH
-19	CH	OH	CH	OH	CH	CH	CH	CH	CH	CH	CH	CH
-20	CH	OH	CH	CH	CH	CH	CH	CH	CH	CH	CH	CH
-21	CH	OH	CH	CH	CH	CH	CH	CH	CH	CH	CH	CH
-22	CL	CH	CH	CH	CH	ML	CH	CH	CH	CH	CH	ML
-23	CH	CH	CH	CH	CH	CH	CH	CH	CH	CH	CH	CH
-24	CH	CH	CH	CH	CL	ML	CH	CH	CH	SM	ML	ML

Figure 45: MCBA Soil Boring Logs Visual Classification with Depth

The soil boring sample locations of the proposed borrow area are shown in **Figure 43**.

AutoCAD Civil 3D was used to calculate the volume of available material in the MCBA. This resulted in a total of 2,995,000 cubic yards (CY) of material. The available volume of material within the MCBA to an elevation of -20.0 ft NAVD88 and the required cut volume for marsh creation are shown in **Table 18.** The Typical Section for the MCBA is presented below in **Figure 46**.

Table 18: Proposed MCBA Quantities

Borrow Area	**Area** (Acres)	**Cut Elevation** (ft NAVD88)	**Available Volume** (yd^3)	**Required Cut Volume** (yd^3)
BA	123	-20	2,995,000	2,310,000

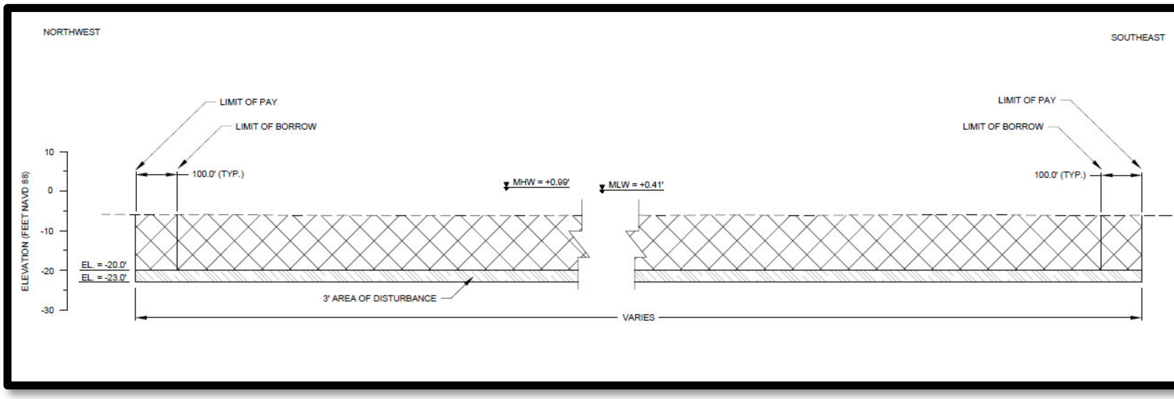

Figure 46: MCBA Typical Section

5.6 Equipment Access

All equipment required to construct the proposed project including deck barges, amphibious excavators, hydraulic cutter suction dredge, and support equipment will access Lake Amedee from BTAB and Petain Lagoon. The current design depth for equipment is approximately four (4) ft. The Petain Lagoon bathymetry shown in **Figure 24** provides sufficient draft (four and a half (4.5) ft of water) at mean high water. No equipment access dredging is proposed at this time for this project. Deck barges for storage, cargo transport, and booster pumps may access the project via Cochon Bay and Bayou Juanita as shown in **Figure 47**.

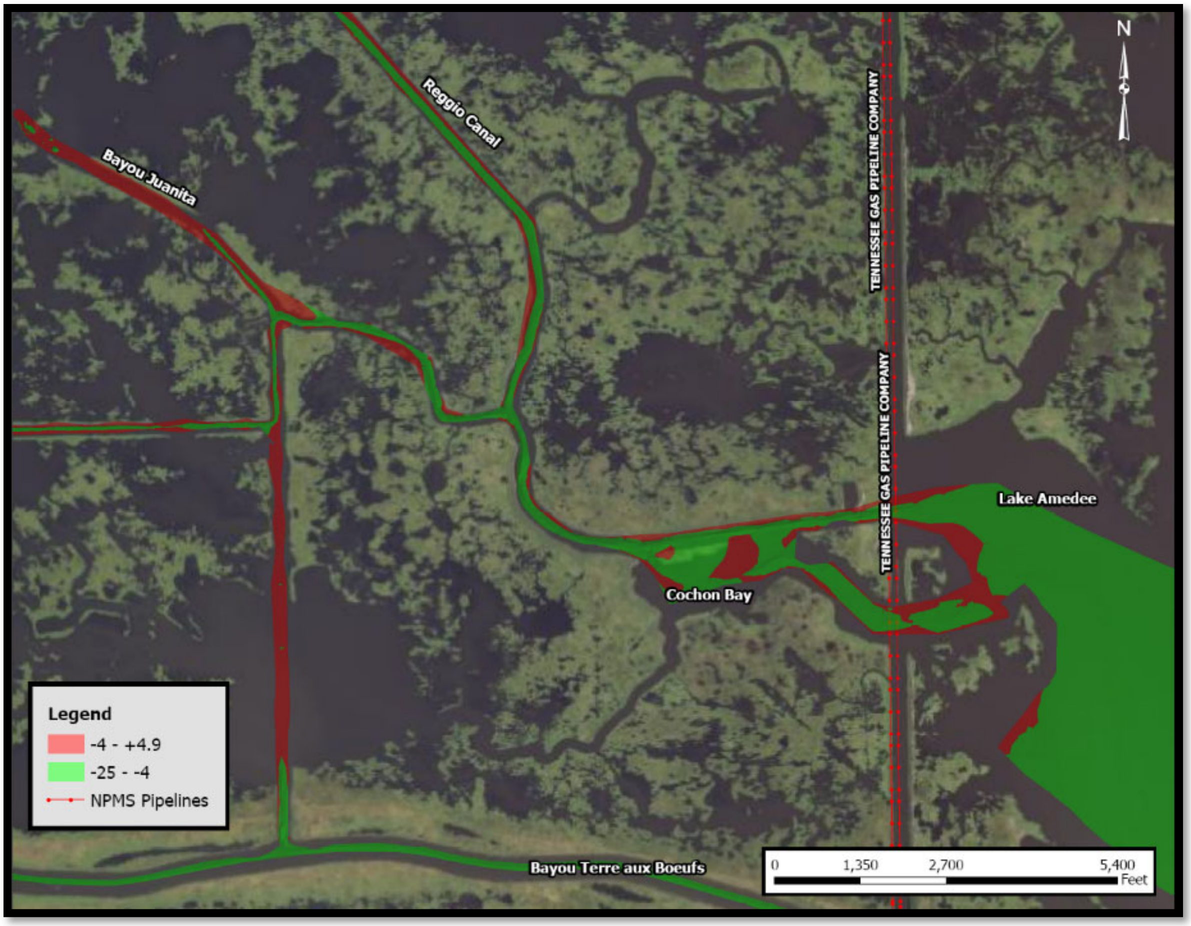

Figure 47: Dredge Pipeline Corridor Planning Map

5.7 Dredge Pipeline Corridor

The proposed DPC was determined through performing an extensive alternative analysis on several potential DPCs and MCBAs areas weighing cost and risk associated with each option. The outcome of the alternative analysis concluded that borrowing material from Lake Amedee was the best path forward for BS-0041. Additional information on the alternative analysis is summarized in **Section 5.7.1** below.

The Lake Amedee/Bayou Juanita dredge pipeline alignment generally moves from east to west following Cochon Bay and Bayou Juanita. The proposed dredge pipeline will be installed in open water along the alignment with the goal of minimizing impacts to recreational fishery access to the various marsh habitats in the area. Four (4) dredge pipeline crossings for recreational boat traffic will be required, these are shown in **Figure 48**. Additionally, the dredge pipeline will be required to cross two (2) Tennessee Gas Pipelines in Cochon Bay. Typically, this is shown in the Plans with floating dredge pipe overtop the lines, however, the Contractor will be required to work with the pipeline owners for agreements on the required method for crossing.

The total length of the dredge pipeline from Lake Amedee to the fill area is approximately five and a half to six (5.5-6) miles. Due to the long pumping distance from the MCBA to the MCAs, booster pumps will be required for conveyance of dredged slurry from the MCBA to the MCAs.

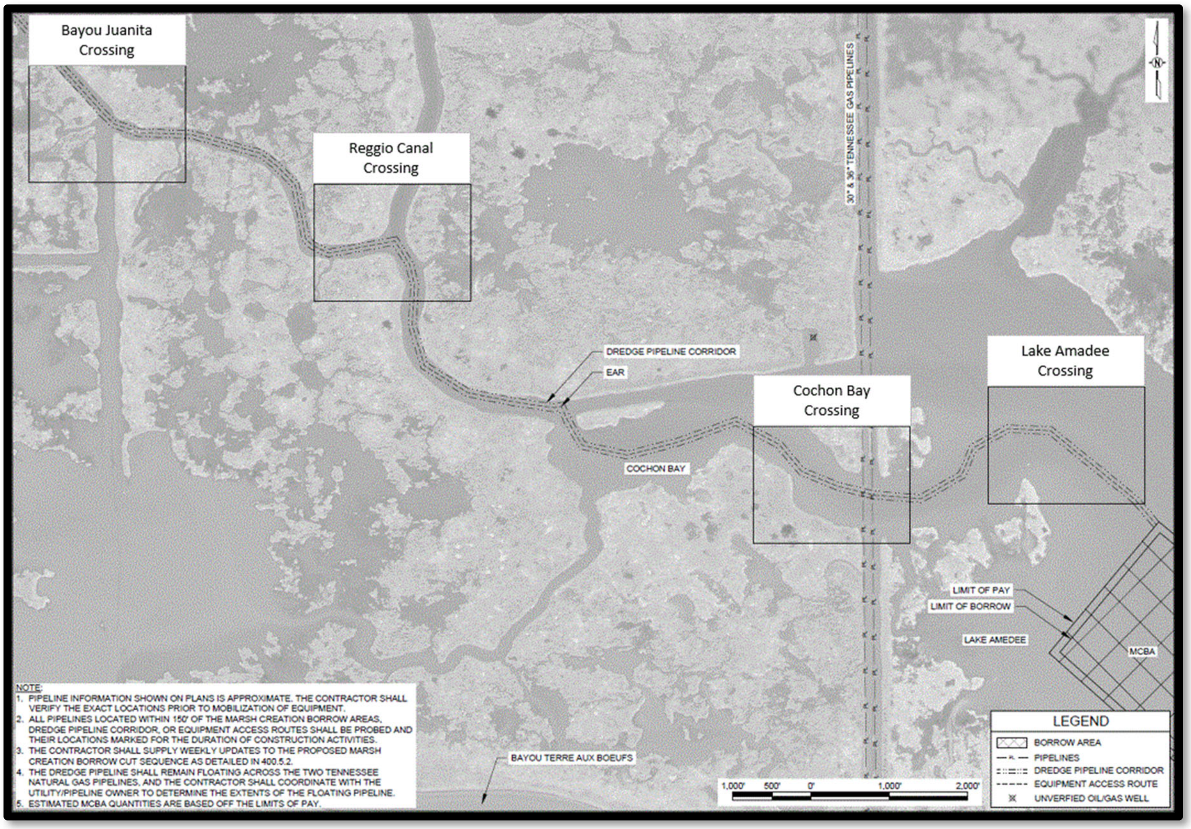

Figure 48: Locations of Navigation Crossings

The proposed DPC will consist of mostly subline from the Lake Amedee MCBA through Cochon Bay except where crossing the Tennessee Gas Pipelines. Water depths, when measured from MLW, in Lake Amedee are generally five to six (5-6) ft. Water depths in the middle of Cochon Bay are generally five to six (5-6) ft. At the confluence of Bayou Juanita & Reggio Canal water depths exceed eight (8) ft. The water depth along the centerline of Bayou Juanita continues to provide eight (8) ft of water depth and becomes shallower upon reaching the fill site as shown in **Figure 47**.

5.7.1 Dredge Pipeline Corridor Alternative Analysis

An alternative analysis was conducted as part of the East Delacroix (BS-0037) design process on the feasibility of various DPC alignments from Lake Lery and Lake Amedee to the BS-0041 project site, as shown in Figure 49. The original Phase 0 DPC alignment for both BS-0037 and BS-0041 was from Lake Lery to each project site crossing Highway 300. This Phase 0 DPC alignment was the shortest distanced borrow area for both BS-0037 and BS-0041. Upon further investigation of various sediment pipeline highway crossing methods it was determined that the estimated cost and construction risks associated with installing a casing pipe underneath Highway 300 outweighed the cost saving from having a shorter pipeline run for each project. The final proposed DPC alignments along with the original Phase 0 DPC crossing Highway 300 is shown in Figure 49. Additional information on the DPC alternative analysis is provided in the East Delacroix Marsh Creation and Terracing 95% Design Report excerpt **Appendix I**.

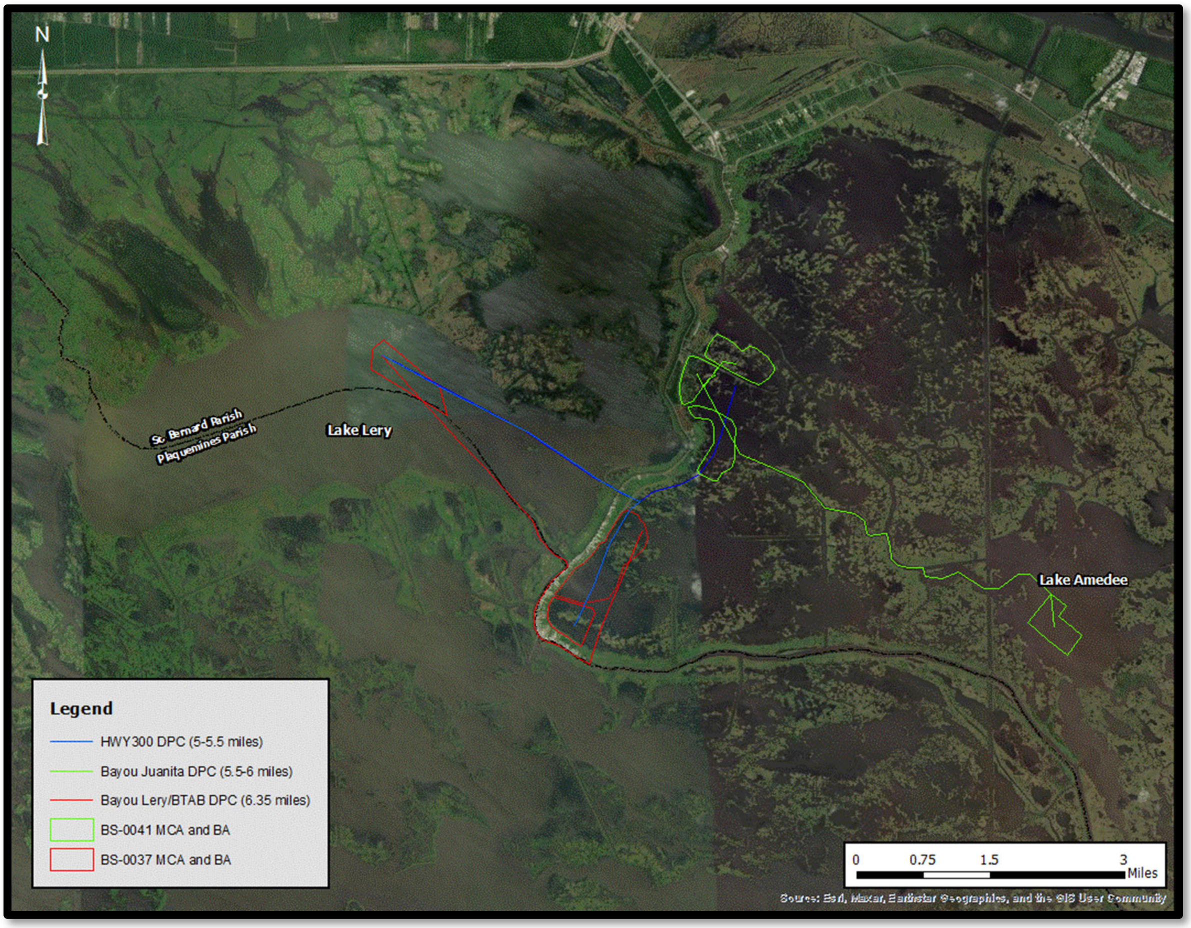

Figure 49: Dredge Pipeline Corridor Alternative Analysis Map

5.8 Bird Abatement

The BS-0032 project is near the BS-0041 project, southwest of BTAB. This project design included bird abatement, which it has utilized during construction. Bird abatement is intended to prevent birds from nesting on design features (such as ECDs and earthen terraces) during construction, which can prevent construction activities and delay the project. The BS-0041 project includes bird abatement during nesting season, between February 15 and September 15. To estimate the required duration, it was assumed that ECD and MCA construction were not concurrent, although earthen terrace construction was assumed to be concurrent with these items. This sequence of relevant construction items spanned three hundred fifty-four (354) total days including weather days. Based on this, one (1) full season, or two hundred ten (210) days, of bird abatement was included. The contractor will be required to inspect the project features and discourage birds from nesting while remaining in compliance with the Federal Migratory Bird Treaty Act.

6.0 CONSTRUCTION

6.1 Equipment Mobilization

It is anticipated that the project will be constructed using an eighteen inch (18”) CSD due to the shallow depths of Lake Amedee. For construction duration estimate purposes, an eighteen (18) inch CSD with an assumed production rate of 10,000 CY per day was utilized. It is anticipated that given the six (6) mile pumping distance to reach the MCA, the contractor will install a series of booster pumps throughout the DPC. Several permitted booster pump locations will be provided to the contractor; however it will ultimately be up to the contractor and the selected dredge equipment provided to decide the best location(s) along the DPC to install booster pumps.

Soft terrain vehicles or marsh buggies will be required to construct containment dikes and manage the marsh fill throughout the fill area. Long and short reach amphibious marsh excavators can be barged in and offloaded within the EAC to reach the project site. Spill boxes, sections of high density polyethylene (HDPE) pipe, and steel pipe can be floated or dragged through the EAC to reach the project site.

6.2 Marsh Fill Placement

After the completion of ECDs, marsh fill can be delivered to the project area via the dredge pipeline. The contractor will be required as part of the Work Plan to provide the layout and schedule for dredged material placement into the MCAs. Based on the estimated hydraulic dredge production rate, a dredging duration of at least two hundred forty-three (243) days is expected. The quantity required for each fill area, as shown on the plans, must be placed and spread out uniformly in each fill area.

6.3 Duration

A construction duration was developed assuming six (6) marsh buggies and an eighteen (18) inch CSD (10,000 CY/day) would be mobilized to the project area. The total construction duration, incorporating weather days, is approximately four hundred forty-seven (447) days. A breakdown of the construction duration is provided in **Table 19**. Tasks which can be completed concurrently are marked with an asterisk.

Table 19: Construction Duration

Task	Duration (days)
Pre-Construction Survey and Mobilization (includes laying dredge pipe)	83
Containment Feature Construction *	60
Hydraulic Dredging	233
Terrace Construction *	47
As-Built Survey	45
Demobilization (includes pick up dredge pipe)	14
Weather Days	60
Total (including task overlap)	**447**

6.4 Construction Cost Estimate

An Engineer's Estimate of Probable Construction Cost was prepared for this project using recent project bid data, and the guidance provided in MCDG1.0, Appendix E. The estimated construction cost is available as a government cost estimate retained by NOAA.

7.0 SUMMARY OF CHANGES TO 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. Changes from Phase 0 to 30% Design are shown in **Figure 50**, and specific modifications from Phase 0 to 95% Design are detailed in **Table 20** and **Figure 51**. The total project cost has increased by more than 25% of the Phase 0 cost estimate; as a result, the project team presented a scope change request to the CWPPRA Technical Committee, which was approved in March 2024 and by the CWPPRA Task Force in May 2024.

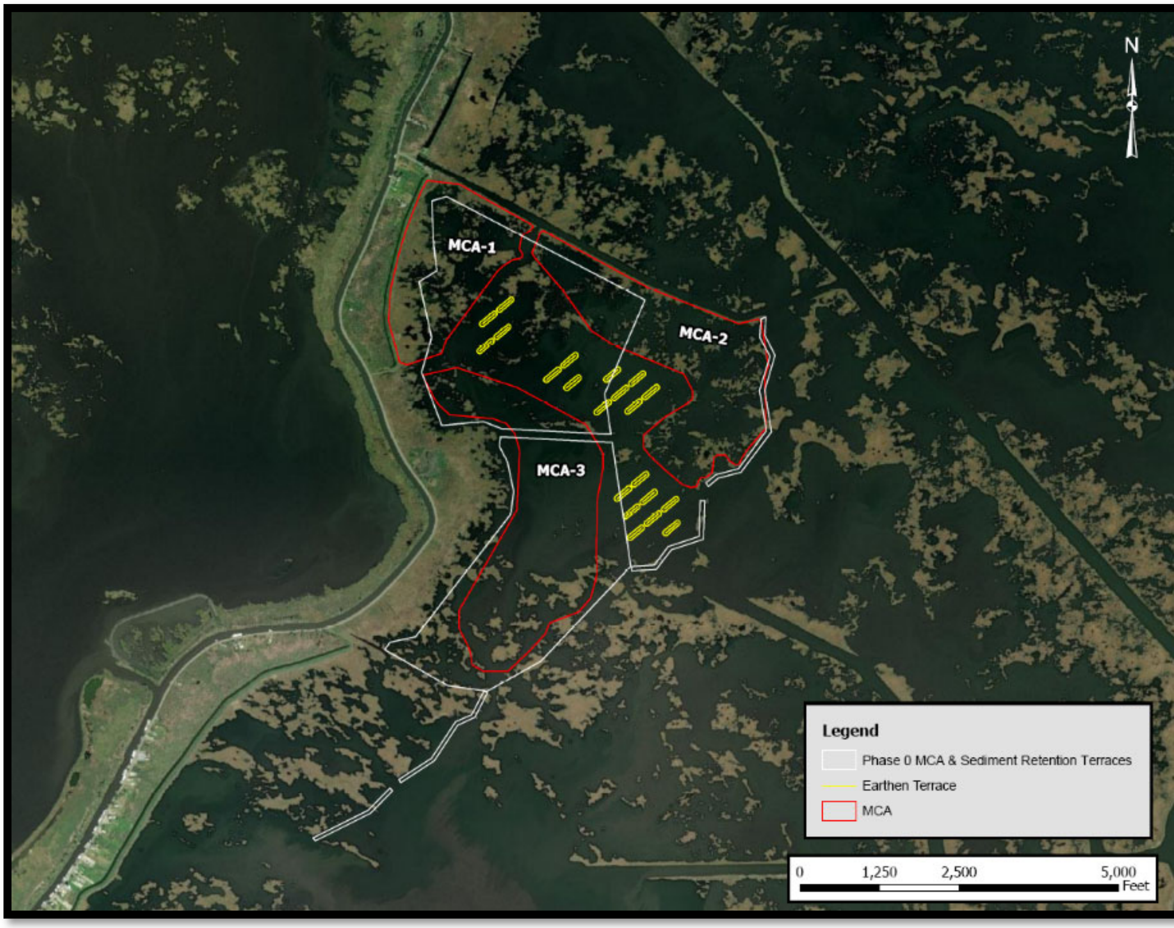

Figure 50: Changes from Phase 0 to 30% Design

Table 20: Summary of Changes from Phase 0 to 95% Design

Project Feature	Phase 0	95% Design	Percent Change
Marsh Creation Area	389 acres	378 acres	-2.8%
Terraces	8,548 LF	7,250 LF	-15.2%
Earthen Containment Dike	25,204 LF	29,100 LF	15.5%

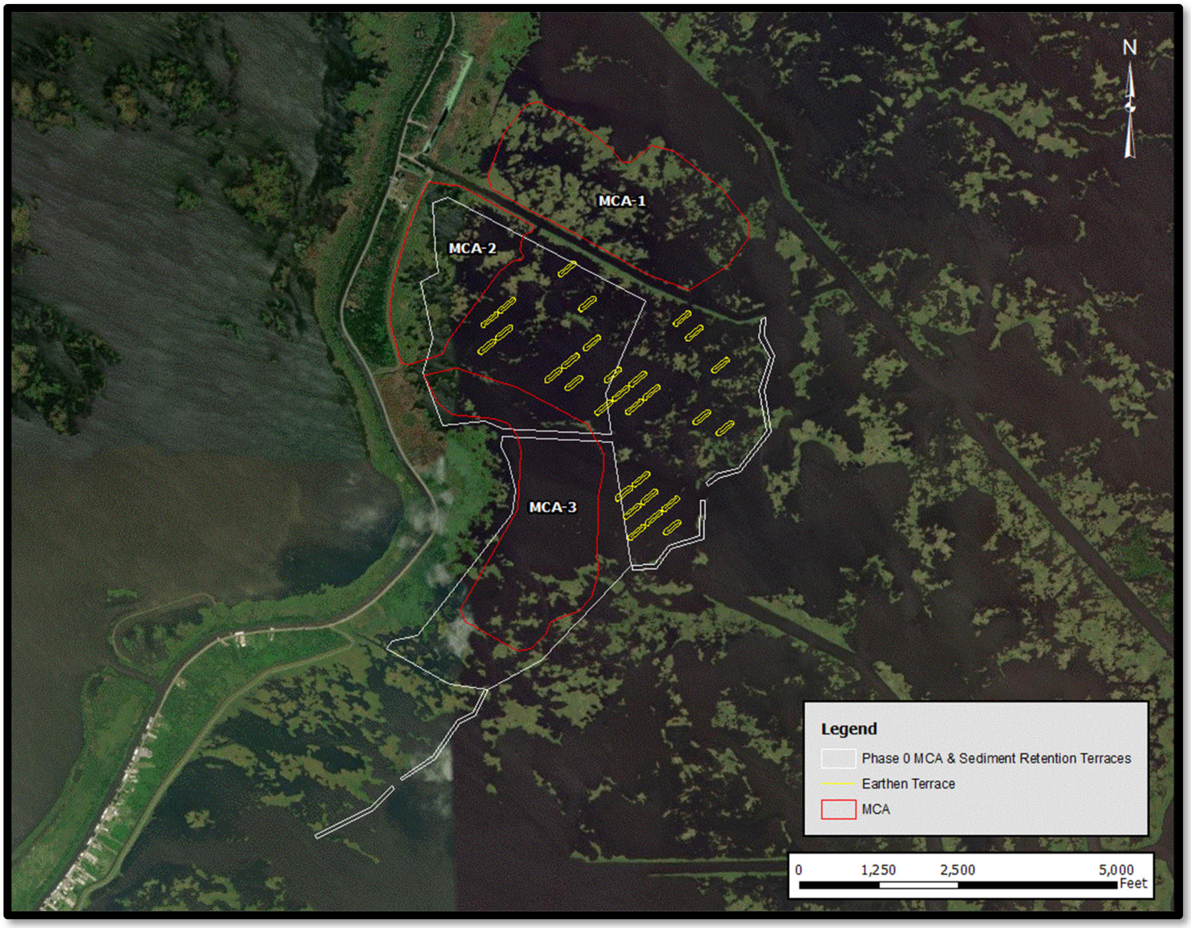

Figure 51: Changes from Phase 0 to 95% Design

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