NORTHWEST TURTLE BAY MARSH CREATION PROJECT (BA-125)

Coastal Wetland Planning, Protection, and Restoration Act PPL 21

95% DESIGN REPORT
October 2016

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1.0 INTRODUCTION

The Northwest Turtle Bay Marsh Creation Project (herein referred to as BA-125) is located in the Barataria Basin on the southern end of the Barataria Landbridge. The Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA) Task Force designated BA-125 as part of the 21st Priority Project List in 2012. The United States Fish and Wildlife Service (USFWS) was designated as the lead federal sponsor with funding approved through the Coastal Wetlands Planning, Protection and Restoration Act of 1990 by the United States Congress and the Wetlands Conservation Trust Fund by the State of Louisiana. The Coastal Protection and Restoration Authority of Louisiana (CPRA) is serving as the local sponsor in addition to performing the engineering and design work. The Natural Resources Conservation Service (NRCS) performed engineering and design activities up to the 30% design milestone. In the summer of 2014 upon review of the 30% design, CPRA elected to assume engineering and design responsibilities and progress engineering and design to the 95% level. This project has been redesigned to avoid the numerous pipelines and canals in the southern area of the original project footprint (Figure 1). The northern portion of the original design area will be retained and designated as the West Marsh Creation Area (West MCA) containing 437 acres while the original southern portion will be removed (Figure 1). An additional marsh creation area east of the Harvey Cut Channel will be created and designated as the East Marsh Creation Area (East MCA) containing 369 acres (Figure 1).

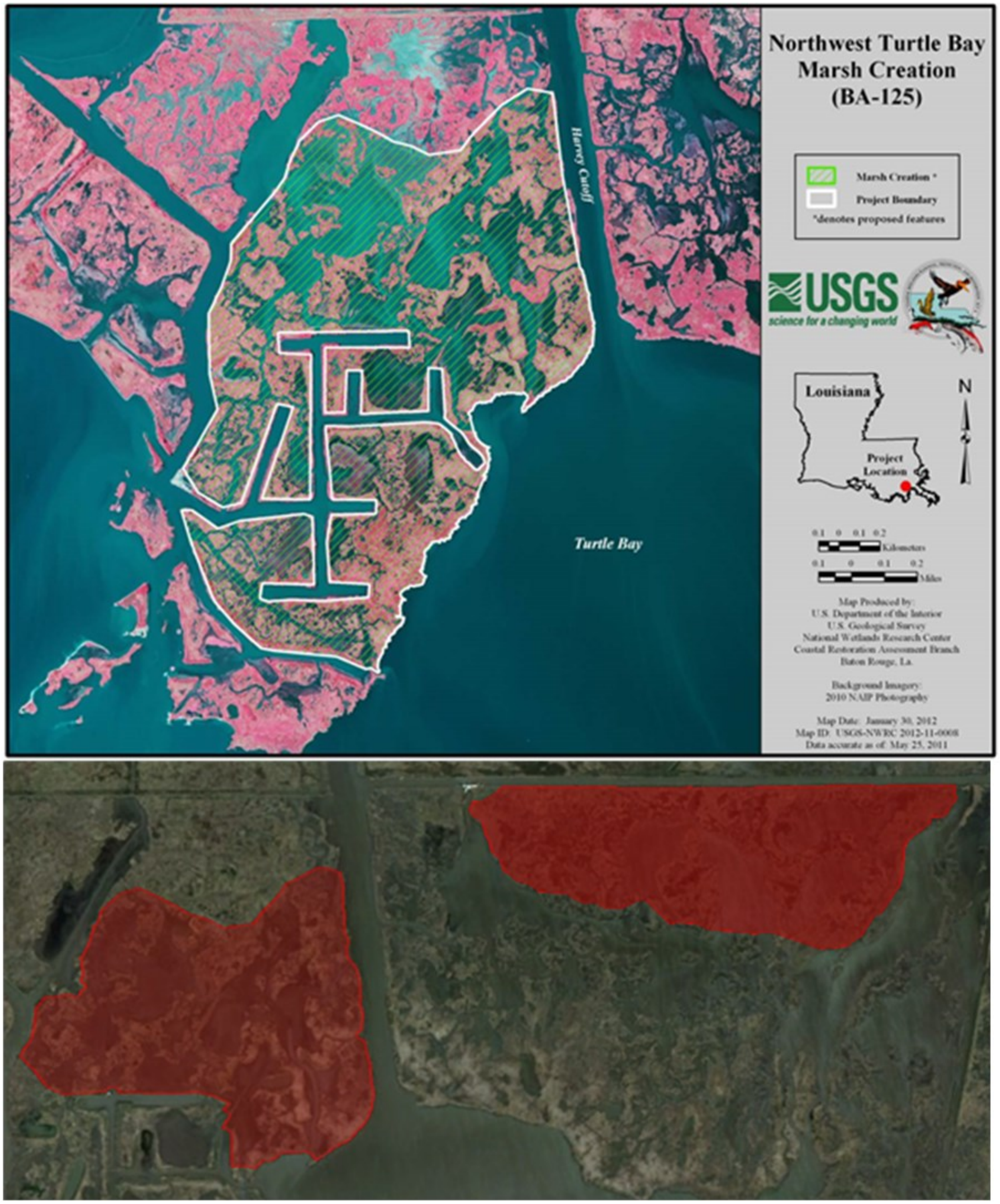


Figure 1: Top: Phase 0 Project Area, Bottom: 95% Project Area

During Phase 0, an aerial photography analysis was conducted on the project features and determined that approximately 423 acres of marsh would be created and 337 acres would be nourished on the peninsula between Turtle Bay and Little Lake. Creating and nourishing the marsh will aid in prevention of land loss by adding elevation to subsided land and by reinforcing the area to avoid excess tidal exchange through existing bayous, cuts, and the shoreline. The determination of whether an area will be marsh creation or marsh nourishment was made from a 2010 USGS land/water analysis of the area. Areas of existing water were assumed to be marsh creation while areas of land were assumed to be marsh nourishment.

The poor condition of this marsh is likely due to a combination of subsidence, hurricanes, and excess tidal exchange through adjacent oil and gas canals and the shoreline. Without action, these cumulative effects will lead to increased land loss rates of the interior marsh.

The restoration strategy for this project is to hydraulically dredge material for marsh creation and marsh nourishment. The proposed marsh creation/nourishment will be achieved by hydraulically dredging approximately 4,501,000 cubic yards of sediment from Turtle Bay to fill open water and mud flat areas into the two MCAs separated by the Harvey Cut Channel. One aspect of this project that will be different than most previous marsh creation projects is to minimize the use of earthen containment dikes by using existing marsh vegetation to contain dredged material in the Western MCA. This semi-confined approached was also intended for the Eastern MCA but had to be abandoned due to the severely degraded marsh along the southern boundary in favor of the more traditional, fully-contained, marsh creation approach.

Topographic and magnetometer surveys and geotechnical investigations have been completed for both Marsh Creation Areas. Bathymetric, magnetometer, oyster seed ground surveys, and a geotechnical investigation for the borrow area have also been conducted. Additionally, a tidal datum analysis has been performed to determine the mean water elevations in the fill areas. This information was used to evaluate the immediate and long-term properties of the hydraulic dredge fill material. All surveys and elevations cited in this report correspond to the NAVD88 Geiod12A datum.

The project team, consisting of members of USFWS, NRCS, and CPRA performed a kick-off meeting on May 31, 2012. Based on that meeting, a plan was developed to identify and address all of the project requirements. The engineering and design, ecological requirements, land ownership investigation, and preliminary cultural resources investigation have been completed to the 95% level as required by the CWPPRA Standard Operating Procedures.

2.0 TIDES AND WATER LEVELS

2.1 Relative Sea Level Rise

In order to properly design the BA-125 project and ensure it is built and performs according to the objectives for a 20-year project life, certain natural processes such as relative sea level rise (RSLR) must be assessed. Relative sea level rise consists of two components: Eustatic (or global) Sea Level Rise (ESLR) and subsidence.

Sea level rise refers to a global average of increasing water levels that takes into account a number of variables such as thermal expansion, loss of glaciers and ice caps, and deposition of sediment on the ocean floor. CPRA Planning and Research Division recommends a historic rate of SLR of 0.0079 feet/year consistent with the 2012 Master Plan. This is based on an examination of regionally-stable tide gauges and satellite altimetry data for the northern Gulf Coast (DeMarco et al., 2012).

Subsidence is defined as the local change in land elevation relative to a fixed vertical datum. CPRA Planning and Research Division recommends a regional rate of subsidence of 0.0067 meters/year consistent with the 2012 Master Plan. Eight and a half years of elevation data from nearby Coastwide Reference Monitoring System (CRMS) stations (CRMS4218: +0.52 cm/yr; CRMS0220: +0.72 cm/yr) as well as basin-wide trends (Terrebonne: +0.65 ± 0.09 cm/yr; Barataria: +0.70 ± 0.26 cm/year) indicate that existing marsh in the project area has the ability to keep up with regional subsidence. While the mechanisms necessary for this positive elevation change may not be all present in the created marsh-particularly early in the project life, it is worth noting that accretion could reduce local subsidence rates or potentially offset local subsidence over the 20 year project life.

Additionally, instead of applying subsidence to water levels in calculating RSRL, recent thought has been to remove subsidence from RSLR and apply regional subsidence rates to the settlement curve of the hydraulic dredge fill. This method better captures what is acutally happening in the MCA (i.e. the water level does not increase because of subsidence, rather the ground is moving downward relative to the water level). By separating subsidence from RSRL, we can more accurately predict the behavior of the constructed marsh. Therefore, ESLR will be the only component applied to future water level conditions.

The rate of ESLR was used to determine the annual incremental RSLR for the BA-125 project area over the 20-year project life presented in Table 1. RSLR is calculated using the following equation using 1992 as a start data:

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

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

Year	Annual Incremental Subsidence (*St*) (feet)	Annual Incremental ESLR ($at + bt^2$) (feet)	Annual Incremental RSLR ($at + bt^2 + St$) (feet)
2018	0.000	0.000	0.000
2019	0.000	0.019	0.019
2020	0.000	0.038	0.038
2021	0.000	0.058	0.058
2022	0.000	0.078	0.078
2023	0.000	0.099	0.099
2024	0.000	0.120	0.120
2025	0.000	0.141	0.141
2026	0.000	0.163	0.163
2027	0.000	0.185	0.185

2028	0.000	0.208	0.208
2029	0.000	0.231	0.231
2030	0.000	0.255	0.255
2031	0.000	0.278	0.278
2032	0.000	0.303	0.303
2033	0.000	0.328	0.328
2034	0.000	0.353	0.353
2035	0.000	0.378	0.378
2036	0.000	0.404	0.404
2037	0.000	0.431	0.431
2038	0.000	0.458	0.458

Table 1: BA-125Annual Incremental RSLR (feet NAVD88 Geoid12A)

2.2 Tidal Datum

Establishment of the tidal datum for BA-125 occurred in the early stages of preliminary engineering since it pertains to many aspects of the project design including surveys, geotechnical analysis, and constructability. The tidal datum is a standard elevation defined by a certain phase of the tide and issued to measure local water levels and establish design criteria. Typically, the primary objective for computing the tidal datum is to establish the target construction hydraulic dredge fill elevation that maximizes the duration that the restored marsh will be at intertidal elevation throughout the 20 year project life.

A tidal datum is referenced to a fixed point known as a benchmark and is typically expressed in terms of mean high water (MHW), mean low water (MLW), and mean tidal levels (MTL) over the observed period of time. MHW is the average of all the daily high water elevations observed over one tidal epoch. MLW is the average of all the daily low water elevations observed over one tidal epoch. MTL is the mean of the MHW and MLW for that time period. A normal tidal epoch lasts approximately 19 years; however, since this project is located near the Gulf of Mexico and has anomalous sea level changes, a modified tidal epoch of 5 years was used (NOAA 2013).

Water level data from CRMS monitoring stations CRMS4218 and CRMS0220 were analyzed to determine historical water levels due to the close proximity to the project area and data availability. CRMS gauge 4218-H01 is located approximately one mile west of the project area and CRMS0220 is located approximately 2 miles east of the project area. The period of record used for analysis for CRMS4218 was February 12, 2008 to June 16, 2016 and CRMS0220 was June 13, 2006 to June 28, 2016. The location of both gauges is shown in Figure 2.

Figure 2: Water Gauges Used for Water Level Analysis.

This analysis reflects a datum adjustment (Geoid99 to Geoid12a) of -0.69' for the data collected between February 12, 2008 and September 30, 2013, for CRMS4218. A datum adjustment (Geoid99 to Geoid12a) of -0.56' for data collected between June 13, 2006 and September 30, 2013, was applied to CRMS0220. The datasets yielded very similar water level elevations from the analysis and are presented in Table 2:

	CRMS 4218-H01	CRMS 0220-H01	Difference
MHW	**+0.68'**	+0.76'	0.08'
MTL	**+0.44'**	+0.48'	0.04'
MLW	**+0.20'**	+0.19'	0.01'

Table 2: Water Levels Calculated for BA-125.

When conducting a water level analysis, it is standard practice to correlate the data back to a gauge with a long period so that it covers a full tidal epoch. A full tidal epoch lasts approximately nineteen (19) years and encompasses all the solar and lunar combinations that may affect tides. However, in south Louisiana, an exception can be made to use a modified 5-year epoch because of the extremely high rate of relative sea level rise. NOAA station #8761724 located at Grand Isle, Louisiana near Barataria Pass at 29°15'48"N, 89°57'24"W was investigated for use as a control station. The epoch published for the gauge was from January 1, 2002 to December 31, 2006. Because the data downloaded from gauges CRMS 4218-H01 and CRMS0220-H01 was more recent, closer to the project site, and covered approximately eight years for each gauge, it is likely a more accurate representation of water levels for the project site and was therefore chosen to determine water elevations.

The CRMS monitoring station CRMS4218 located at 29°33'47.52"N, 90°10'0.12"W was selected as the control station because of its proximity to the project area and additional data sets such as salinity measurements and vegetation types were a better representation of the project area than CRMS0220. CRMS4218 water levels used in the design of BA-125 are presented bolded in Table 2.

2.3 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 mean high water (MHW) and mean low water (MLW) has been the accepted range for healthy marsh. This approach only takes into account the tidal influences on the water levels, whereas in many areas, non-tidal influences such as meteorological events, river discharges, and management regimes often have a large impact on the water levels found in that region. Therefore, using percent inundation rather than tidal range as a proxy for marsh health can give a more accurate representation of the water levels found in the area. Percent inundation refers to the percentage of the year a certain elevation of land would be flooded based on projected water levels for the project life. To illustrate the two approaches, Figure 4 shows both MHW, MLW, 20%, and 80% inundation levels. For BA-125 the tidal range and the optimal inundation range are similar, so either method would be yield similar results.

To determine percent inundation the percentiles were calculated based on data gathered from the CRMS4218 station. A summary of the percent inundation calculations is shown in the Design Calculations Packet located in Appendix H. The result of the percent inundation determination for BA-125 at TY0 and TY20 are shown in Table 3 and Table 4.

TY0	Elevation (ft NAVD88)
10%	+1.06’
20%	+0.84’
30%	+0.68’
40%	+0.54’
50%	+0.42’
60%	+0.28’
65%	+0.21’
70%	+0.13’
80%	+0.00’
90%	-0.22’

Table 3: Percent Inundation Elevations at TY0

TY20	Elevation (ft NAVD88)
10%	+1.52’
20%	+1.30’
30%	+1.14’
40%	+1.00’
50%	+0.88’
60%	+0.74’

65%	+0.67'
70%	+0.59'
80%	+0.46'
90%	+0.24'

Table 4: Percent Inundation Elevations at TY20

Intermediate marshes, like those in the BA-125 project area, are most productive when innundated between 20% and 80% of the time (Snedden 2012). The project team utilized best professional judgment to identify target constructed marsh elevations that would maximize short term and long-term marsh function while taking into account ESLR presented in Figure 3.

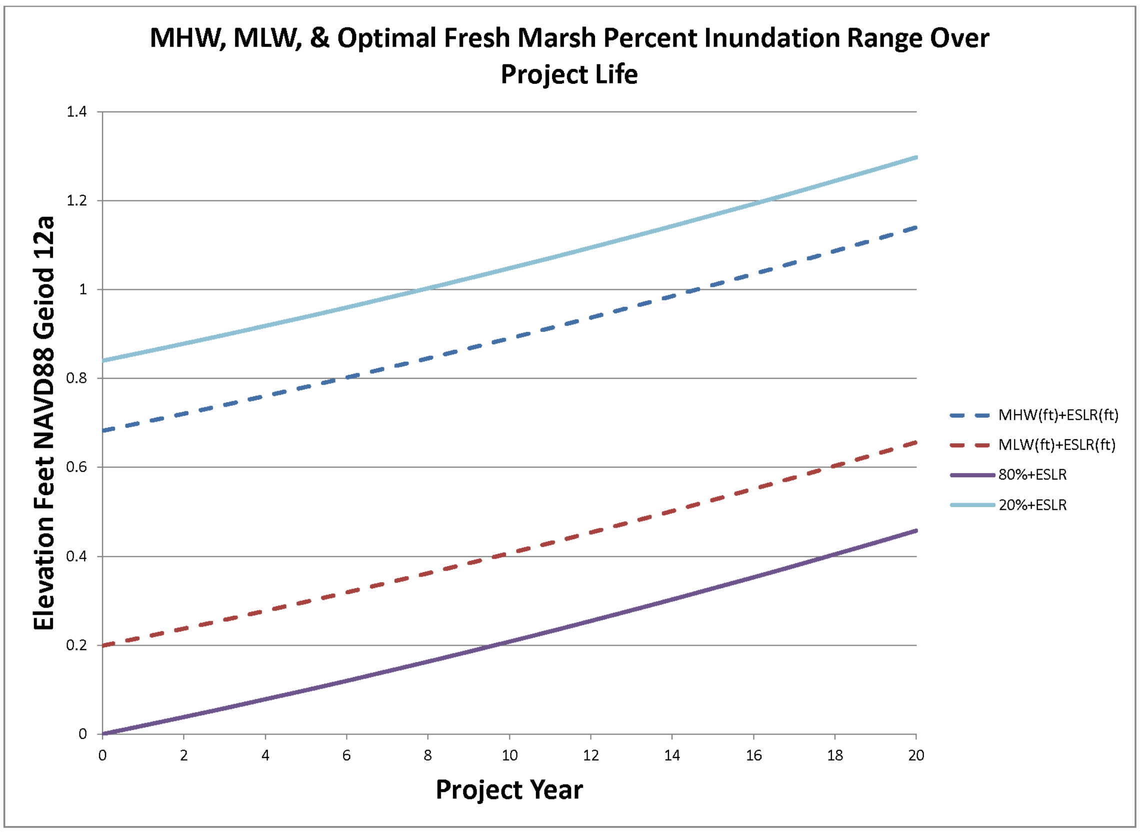


Figure 3: Percent Inundation, MHW, & MLW Comparison Over Project Life

3.0 SURVEYS

Topographic, bathymetric, and magnetometer surveys were performed within the West MCA to facilitate the design of the project. In addition, bathymetric and magnetometer surveys were performed in Turtle Bay to help delineate a suitable borrow area. The majority of surveys were performed by T. Baker Smith, LLC (TBS) between September 2012 and March 2013. Some supplementary surveys were conducted by NRCS. CPRA tasked HydroTerra Technologies, LLC to perform topographic, bathymetric, and magnetometer surveys in the East MCA and potential access routes. These surveys were performed between June 2015 and August 2015.

3.1 Secondary Monuments

Two existing secondary monuments were located and updated for use on the project. TBS completed static GPS readjustment surveys on monuments BA27-SM-01R and BA27-SM-02 during October 2012 and January 2013. The readjustments were used to update the orthometric heights on the monuments from Geoid03 to Geoid12A. The details for the monuments are shown in Table 5. Updated monument data sheets are found in Appendix B. Both TBS and HydroTerra used BA27-SM-02 for all surveys due to its close proximity to most areas of the project.

MONUMENT ID	X NAD83 LA S 1702, FT	Y NAD83 LA S 1702, FT	ELEVATION (NAVD88,FT) Geoid12A
BA27-SM-01R	3,651,413.49	392,242.41	+1.44
BA27-SM-02	3,662,195.77	390,435.18	+0.83

Table 5: Existing Secondary Monuments and Geoid12A Elevations

3.2 West MCA Surveys

Topographic, bathymetric, and magnetometer surveys were performed within the proposed West MCA by TBS. For topographic/bathymetric surveys, a Trimble model R7/R8 GPS RTK unit and Trimble TSC3 data logger were used to perform the survey. For subaqueous portions of the survey, data was collected by hand with a Standard 25' Stadia Rod with a 6" diameter bottom plate. All surveys were processed in Trimble Business Center.

Forty-three survey (43) transects were recorded through the proposed West MCA in an east-west orientation. Elevations were recorded at 25 foot intervals or less when topographic features that may have an influence on the project were discovered. The transect surveys were used for determination of volumes. The survey layout and details are shown on the TBS survey drawings located in Appendix C. it should be noted that due to the redesign of the West MCA, only transects MC-1 through MC-22 were used to calculated the fill volume.

Twenty-six (26) magnetometer lines were surveyed in or near the proposed West MCA. One hundred eighty-six (186) magnetic anomalies were reported in the survey area, many of which appear to be associated with known pipelines in the area. Anomalies that were determined to be pipelines were probed for the length of the pipeline that existed in the project area and identified when possible. Details of these anomalies and pipelines are shown on the TBS survey drawings located in Appendix C.

3.3 West MCA Pipeline Canal Surveys

Cross sections of the interior pipeline canals were surveyed approximately every 200' to record pre-project dimensions of the canals. Sixty-five cross sections were surveyed across the canals and beyond the spoil banks on each side of the canal back to natural ground. Additionally, profile surveys were taken along the centerline of the canal spoil banks to determine if containment was needed to prevent dredged material from flowing into the canals.

3.4 East MCA Surveys

Topographic, bathymetric, and magnetometer surveys for the East MCA were performed HydroTerra Technologies, LLC. For topographic/bathymetric surveys, a Trimble GNSS R8 RTK System (Including Receiver, Base and Data Collector) and Odom MKIII Depth Sounder with Dual Frequency Transducer with YSI Cast Away CTD Probe (Velocimeter) were used to perform the survey. For subaqueous portions of the survey, data was collected by hand with a Fixed Height Aluminum Rod (8' or 10' in length) with a 6" diameter metal plate as the base of the rod. All surveys were processed in Trimble Geomatics Office (TGO) software version 1.62.

Sixteen (16) survey transects were recorded through the proposed marsh creation area in an east-west orientation with an additional eleven transects recorded in a north-south orientation. Elevations were recorded at 25 foot intervals or any change of elevation greater than 0.5'. The transect surveys were used for determination of volumes of hydraulic dredge fill and dredge pipeline access through the marsh. The survey layout and survey details are shown on the HydroTerra survey drawings located in Appendix D.

A centerline profile of the East MCA perimeter was also surveyed. Transect 46 was located at the proposed centerline of the earthen containment dike. This transect provided specific information on the gaps that will be filled with earthen material and used for determination of earthen containment dike volume.

Nineteen (19) magnetometer lines were surveyed in or near the proposed East MCA. One hundred forty-one (141) magnetic anomalies were reported in the survey area, many of which are associated with two known pipelines in the area. Anomalies that were determined to be pipelines were probed for the length of the pipeline that existed in the project area and identified when possible. Details of these anomalies and pipelines are shown on the HydroTerra survey drawings located in Appendix D.

3.5 East MCA Canal & Access Surveys

Centerline profiles and cross sections of 3 potential access routes from the borrow area to both MCAs were surveyed in addition to the East-West canal that borders the northern section of the East MCA. Transect 1 was surveyed from the borrow area to the West MCA with three cross-sections surveyed every 1000'. Transect 5 surveyed from the borrow area north through the Harvey Cut Channel to the northern border of the East

MCA with 5 cross sections taken every 2000’. Transect 47 surveyed from the borrow area through an existing bayou into the south-east corner of the East MCA with 20 cross sections surveyed every 1000’ or at points of inflection. Lastly, Transect 11 surveyed the east-west canal that forms the northern border of the East MCA with 7 cross sections taken every 2000’.

3.6 Healthy Marsh Elevation Surveys

Marsh elevation surveys were conducted at fourteen (14) locations determined to be healthy by NRCS and USFWS biologists. It was determined that the new East MCA was similar in location and topography to the West MCA to not require additional healthy marsh elevation surveys. Three (3) shots were taken at each location. Marsh elevations for each location were derived by averaging the three elevation shots at that location. Table 6 shows the data acquired from the surveys. The average marsh elevation points are shown on the TBS survey drawings located in Appendix C. The cumulative average marsh elevation from all shots was determined to be +0.76’. This was used along with other factors such MHW, MLW, percent inundation, estimated settlement, and field investigations to choose the final target marsh elevation for each cell. Section 5.0 provides detailed methodology for determining the final target marsh elevation for each marsh creation cell.

Point	Northing	Easting	Average Elevation
1	388,527.97	3,657,817.85	+0.79’
2	388,166.43	3,658,540.12	+0.84’
3	388,222.59	3,659,409.89	+1.06’
4	388,050.38	3,660,823.26	+0.93’
5	386,608.18	3,657,438.39	+0.67’
6	387,264.84	3,659,890.74	+0.80’
7	385,930.55	3,660,375.68	+0.82’
8	384,357.35	3,656,820.14	+0.55’
9	384,329.20	3,661,346.01	+0.64’
10	382,885.20	3,656,184.51	+0.58’
11	382,839.26	3,659,534.46	+0.76’
12	381,410.01	3,656,156.08	+0.69’
13	381,132.56	3,658,369.93	+0.81’
14	380,115.52	3,658,485.86	+0.69’
Overall Average Elevation			**+0.76’**

Table 6: Average Marsh Elevation Survey Results (Locations shown in Appendix B)

3.7 Surveys of Previous Project Areas

Two completed projects in the nearby vicinity (BA-27 Barataria Basin Landbridge Shoreline Protection and BA-36 Dedicated Dredging on the Barataria Basin Landbridge) had marsh creation features that were constructed with minimal containment as proposed for BA-125. Topographic and bathymetric surveys were completed on each to provide insight into performance of such projects over time. NRCS surveyed four small ponds that were filled with beneficially used dredged material on the BA-27 project. \TBS surveyed a total of twenty (20) transects on the three expansion areas of the BA-36 project that were constructed in 2009. The survey layout and survey details are shown on the TBS survey drawings located in Appendix C.

3.8 Borrow Area Surveys

TBS conducted bathymetric and magnetometer surveys of a borrow search area in Turtle Bay. An area larger than required was surveyed to allow for adjustments due to oyster seed grounds, pipelines, magnetic anomalies, or other impediments that might reduce the usable area of the borrow search area. Twelve (12) transects were completed on a 500' spacing running east-west using a dual frequency echo sounder interfaced with RTK GPS. Twenty-three magnetometer transects were completed in a 500' grid pattern. One hundred thirty (130) magnetic anomalies were discovered with two areas of avoidance recommended. Details of these anomalies are shown on the TBS survey drawings located in Appendix C.

4.0 GEOTECHNICAL EVALUATION

In order to determine the suitability of the soils in the BA-125 project area for the various proposed marsh creation features, geotechnical subsurface investigations and analyses were performed by GeoEngineers for both Marsh Creation Areas. GeoEngineers collected soil borings in the West MCA and borrow area and performed laboratory tests to determine soil characteristics on those samples in 2013. When the East MCA was incorporated into the BA-125 project footprint, GeoEngineers was tasked by CPRA to perform sampling and analysis on soil borings and CPTs in the summer of 2015. In addition to standard laboratory testing, self-weight consolidation tests were completed to further analyze material behavior. Following all testing, analyses were completed to determine consolidation of the hydraulic dredge fill material and stability and settlement of proposed containment features. General construction recommendations were also provided. Both Geotechnical Investigation Reports prepared by GeoEngineers are included in Appendices E and F.

4.1 Subsurface Conditions

In the West MCA, a layer of organic clay and peat was observed in the top 2' – 3' of all borings. Beyond the organic clay / peat layer, clay and silty clay were the predominant material, but periodically contained silt and sand seam layers that ranged from a few inches to several feet thick. Stiffer clays were found at increasing depths. Several of the borings, especially BHMC-2, contained shells and shell fragments.

In the East MCA, a layer approximately 10' to 14' of organic soils, including peat, organic clay, and interlayered peat and clay was observed. According to GeoEngineers, these organic soils are generally very soft and underlain predominantly by very soft to soft gray clay and silty clay soil deposits with occasional loose silt and sand layers.

Beyond the organic clay / peat layer, clay and silty clay were the predominant material, but periodically contained silt and sand seam layers that ranged from a few inches to several feet thick. Stiffer clays were found at increasing depths. It was observed in the deepest boring, B-4, from 40' below mudline to about 72' below mudline, the soil is generally soft to medium inorganic clay with occasional silt layers and lenses. From 72' to the bottom of the exploration, the soil was dense clayey sand.

In the project borrow area, borings contained mostly clay and silty clay with shell fragments and layers present in many of the borings. Organic clay was observed in the top 2' to 4' of borings BHBA-2 through BHBA-5. Clayey sand was observed at the bottom of borings BHBA-1 and BHBA-6.

4.2 Soils Investigation

Borehole samples for the project were obtained using a 30'' long, 3'' outside diameter Shelby tube sampler pushed into the ground a distance not exceeding 24'' per sample. Samples were classified in the field immediately upon recovery and subsequently sealed for transport to the lab. All boreholes were backfilled with bentonite grout to their full depth.

A total of nine (9) subsurface borings were drilled by GeoEngineers in the East MCA between May 13th and May 20th, 2013. Eight (8) borings were drilled to depths of thirty (30) feet and one (1) boring was drilled to a depth of eighty (80) feet. Boring BHMC-2 was terminated at 26.5' below the mudline because shell falling into the borehole was causing drilling difficulties. After completing drilling of each borehole, a GEONOR H-10 vane shear apparatus was used to perform vane shear tests immediately adjacent to each borehole to determine in-situ undrained shear strength.

A total of six (6) subsurface borings and twelve (12) Cone Penetrometer Tests (CPT) were drilled by GeoEngineers in the West MCA between August 31 and September 3, 2015. Five (5) borings were drilled to depths of forty (40) feet below the mudline and one (1) boring was drilled to a depth of eighty (80) feet below the mudline. Ten CPT's were completed to a depth of 40' below the mudline while C-10 and C-12 were only able to achieve depths of 37' and 39' below the mudline respectively. All borings and CPTS's were completed in open water.

Six (6) boreholes were drilled in the borrow area on May 14th and 15th, 2013. Boreholes were drilled to twenty (20) feet below the mudline. All boring logs for BA-125 can be found in Appendices E and F.

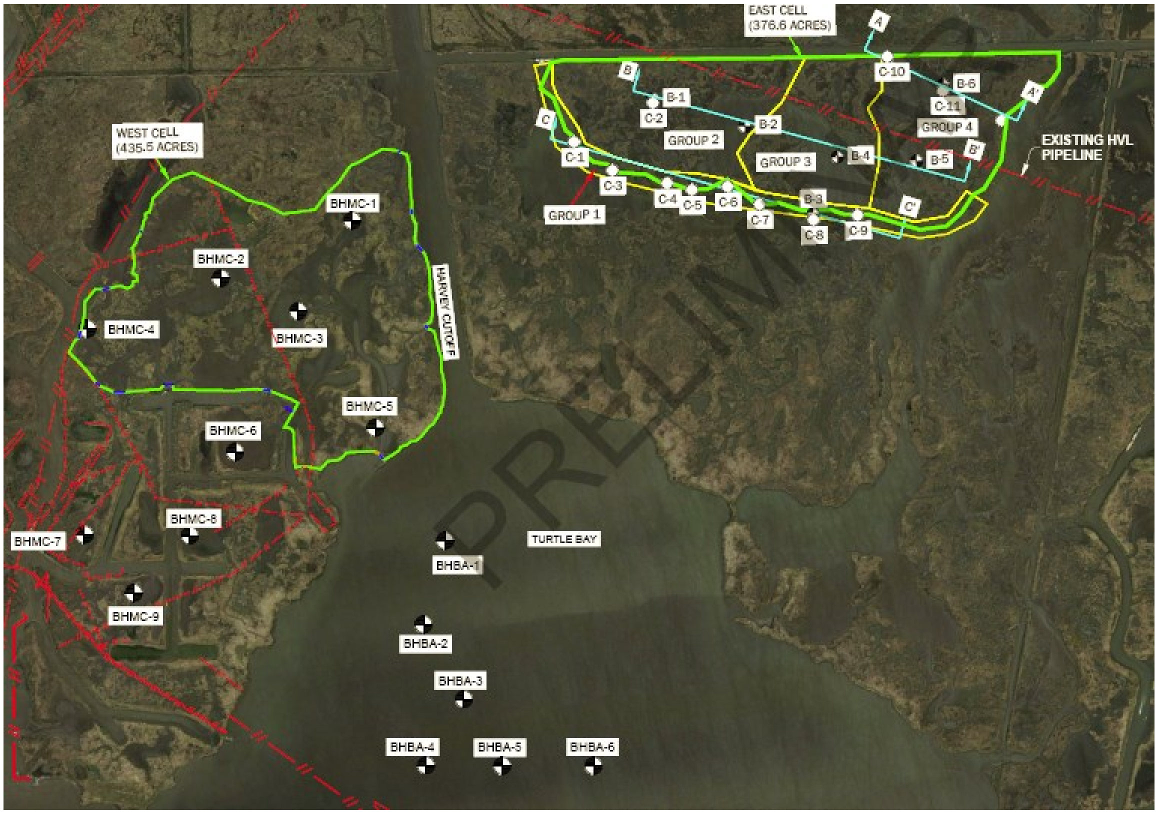


Figure 4: Soil Boring Locations

4.3 Laboratory Testing

For samples collected from the MCAs, a mini vane shear test was conducted on intact samples prior to extrusion. Following extrusion, the field classifications were verified or modified as necessary and underwent laboratory testing for moisture content, dry unit weight, unconfined compression, unconsolidated undrained compression, organic content, grain size, consolidation testing, specific gravity, and Atterberg limits.

Samples collected from the borrow area were extruded and field classifications were verified or modified as necessary and tested for moisture content, Atterberg limits, organic content, and grain size. Samples were then mixed to create composite samples, which were also tested for the same parameters as the individual samples. Six composite samples were sent to the Louisiana State University Department of Civil and Environmental Engineering (LSU) for self-weight consolidation testing. All test results can be found in Appendices E and F.

4.4 West MCA Hydraulic Dredge Fill Settlement Analysis

A marsh creation settlement analysis was performed in the West MCA to determine the construction hydraulic dredge fill elevation of the marsh creation fill areas and the total volume of fill material. The final year 20 elevation of the marsh creation area is governed by two forms of settlement: (1) the settlement of the underlying soils in the marsh creation areas caused by the loading exerted by the placement of the dredged fill material, and (2) the self-weight consolidation of the dredged material (See Figure 5). Settlement of the underlying soils or sub-layer material was calculated using Primary Consolidation Theory in conjunction with SETANL settlement analysis software. Properties of the sub-layer soils were obtained from the results of the laboratory tests conducted on the borings taken by GeoEngineers. The self-weight consolidation of the hydraulically dredged material was calculated using the Army Corps of Engineers (USACE) program, Primary Consolidation, Secondary Compression, and Desiccation of Dredged Fill (PSDDF). Properties of the fill material were obtained from self-weight consolidation testing conducted by LSU. In addition, climatic data was input into PSDDF. Both settlement components were used to develop settlement curves at the boring locations.

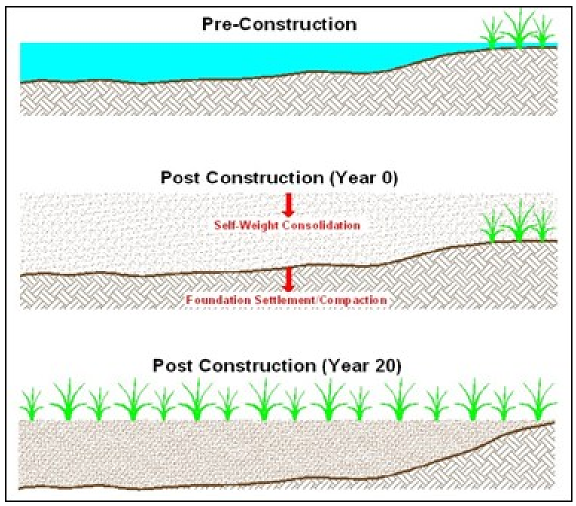


Figure 5: Marsh Creation Settlement

Time rate of settlement was analyzed in 0.5' increments for the nine borings using fill heights that ranged from +1.5', to +4.0'. As a result of the changes to the West MCA project features, borings BHMC-6, BHMC-7, BHMC-8, and BHMC-9 are no longer located in the West MCA. Boring BHMC-3 was determined to be the most representative of the West MCA due to both its location near the center of the West MCA where we expect to achieve a construction fill elevation of +1.5' and the mud line used for analysis of -0.79' is the closest to the average existing bottom elevation of the West MCA. While BHMC-2 is also in an interior location that is expected to achieve a target fill elevation of +1.5', the deeper mud line of-0.94' used for analysis was considered to be not as representative of the entire MCA. Borings BHMC-1, BHMC-4, and BHMC-5 were all located in areas where it is not expected to achieve the full target elevation of +1.5' as a result of the semi-confined construction method. A settlement curve for boring BHMC-3 is shown in Figure 6.

Boring BHMC-3 is located near the center of the West MCA was selected as the basis for calculating volumes and settlement. The area surrounding BHMC-3 is expected to achieve the full construction fill elevation of +1.5' and should provide a good representation of the West MCA settlement behavior. From Figure 6, the target hydraulically dredged fill elevation of +1.5' appears to be the best option for achieving the most productive marsh over the 20 year project life when applying the parameters outlined in Section 2.3. More detailed discussion regarding the selected target marsh elevation can be found in Section 5.1. At these locations, an average of 1.3’ of total settlement is estimated over the 20 year life of the project with an initial elevation of +1.5’. Of this total settlement, approximately 0.7’ is foundation settlement, with the remaining 0.6’ of settlement due to self-weight consolidation. The settlement curves are available in Appendix F. The majority of this settlement occurs within the first two years post construction, resulting in a marsh platform that maximizes time within the optimal intermediate marsh range (20%-80% inundated) for the duration of the 20 year project life.

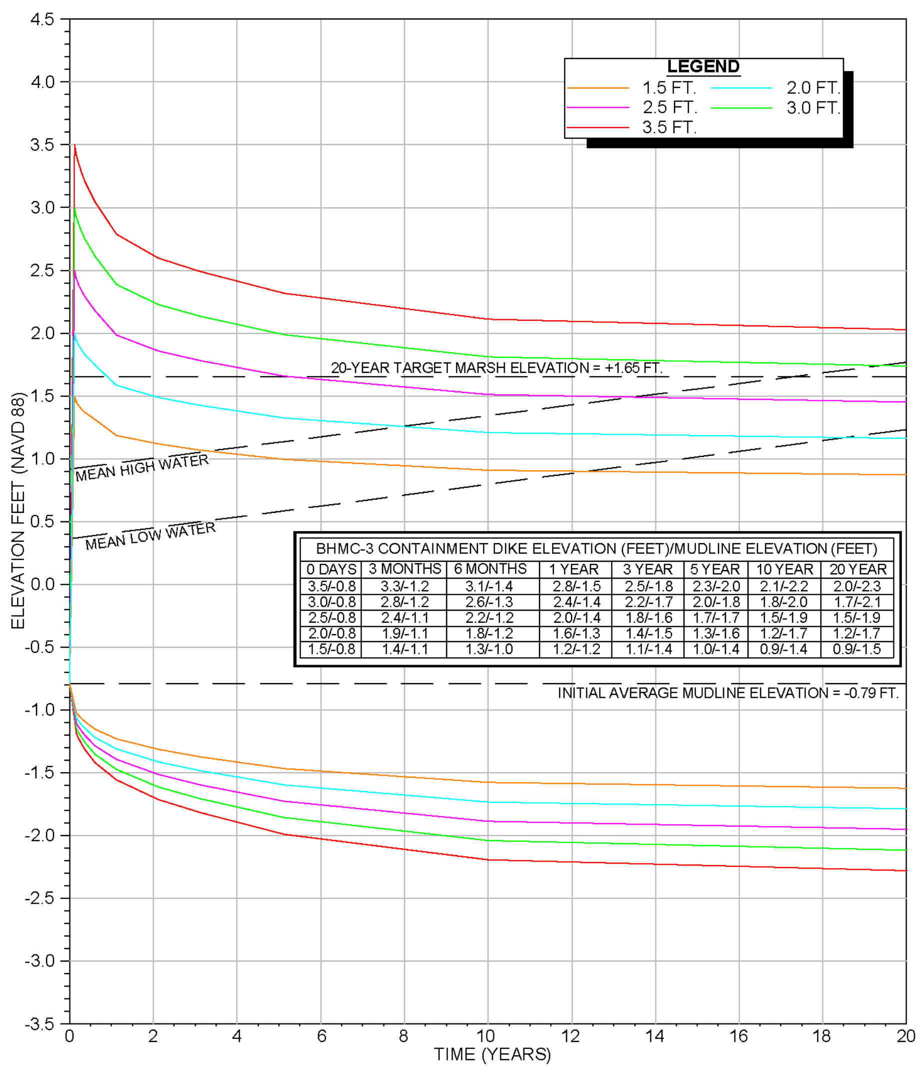


Figure 6: BHMC-3 West MCA Hydraulic Dredge Fill Settlement Curve

It is important to note that the hydraulic dredge fill settlement analysis assumes a uniform fill elevation. Because the project is semi-contained, there could be locations near the dredge pipe outfall locations that will be higher than +1.5 and inversely, locations near the marsh fringe that will not achieve the target hydraulic dredge fill elevation of +1.5’.

The +1.5' settlement curve was chosen to represent the average condition over the majority of the West MCA and was used to calculate fill volumes. See Section 5.3 for additional details.

4.5 East MCA Hydraulic Dredge Fill Settlement Analysis

A marsh creation settlement analysis was performed also in the East MCA to determine the construction hydraulic dredge fill elevation of the marsh creation fill areas and the total volume of fill material. As mentioned in Section 4.4, the final year 20 elevation of the marsh creation area is governed by two forms of settlement: (1) the settlement of the underlying soils in the marsh creation areas caused by the loading exerted by the placement of the dredged fill material, and (2) the self-weight consolidation of the dredged material (See Figure 5). Settlement of the underlying soils or sub-layer material was calculated using Primary Consolidation Theory in conjunction with SETANL settlement analysis software. Properties of the sub-layer soils were obtained from the results of the laboratory tests conducted on the borings taken by GeoEngineers. The self-weight consolidation of the hydraulically dredged material was calculated using the USACE program PSDDF. Properties of the fill material were obtained from self-weight consolidation testing conducted by LSU. In addition, climatic data was input into PSDDF. Both settlement components were used to develop settlement curves at the boring locations.

Time rate of settlement was analyzed in 0.5' increments for the six borings using fill heights that ranged from +1.5', to +4.0'. Borings and CPTs were grouped into analysis groups to represent different regions of the East MCA. Figure 7 and Table 7 detail the analysis groups and constituent data.

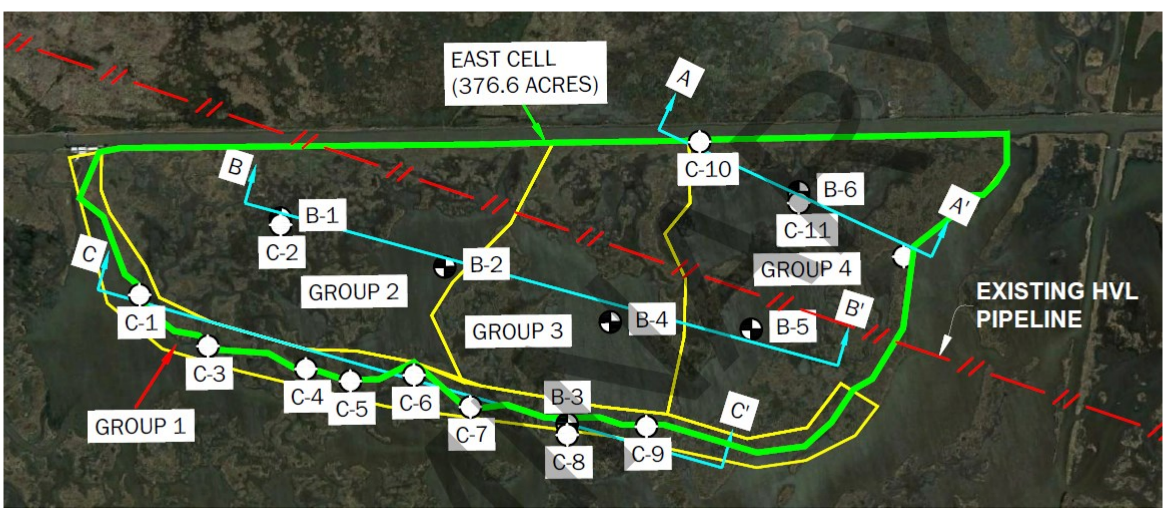


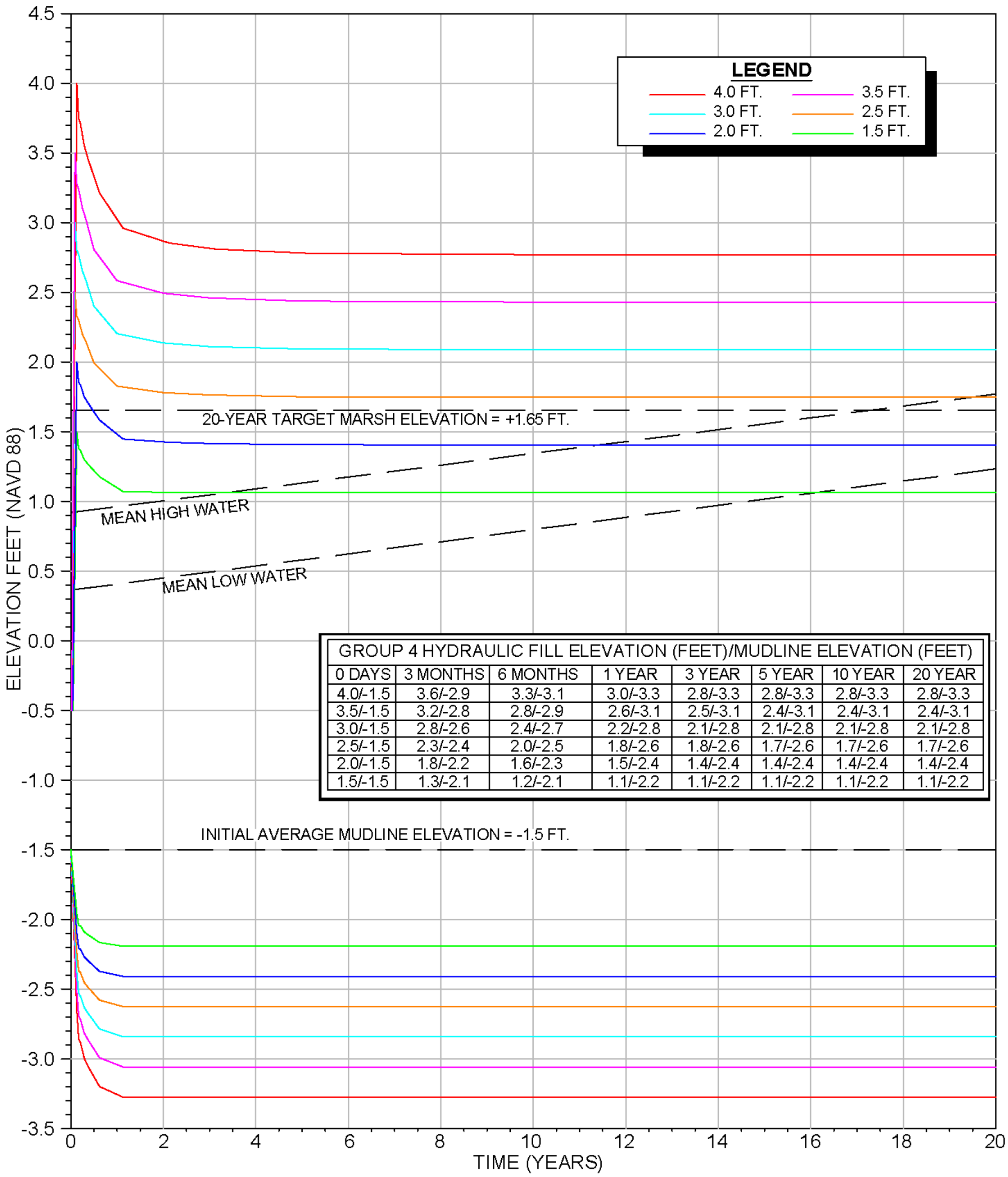
Figure 7: East MCA Analysis Groups

Analysis Group	Borings Incorporated	CPT's Incorporated
Group 1	**B-3**	**C-1, C-3, C-4, C-5, C-6, C-7, C-8, C-9**
Group 2	**B-1, B-2**	**C-2**
Group 3	**B-4**	**N/A**
Group 4	**B-5, B-6**	**C-10, C11**

Table 7: East MCA Analysis Groups

Group 4 was determined to be the best representation of the East MCA due to the combination of median settlement behavior, good mix of marsh and open water representative of the East MCA, and mudline used for analysis of -1.5' is the closest to the average existing bottom elevation of the East MCA. Group 2 analysis yielded minimal settlement results most likely as a result of having the least amount of open water. Group 3 analysis resulted in large settlement values due to the large amount of degraded marsh and open water.

From Figure 8, the target fill elevation of +1.5' appears to be the best option for achieving the most productive marsh over the 20 year project life when applying the parameters outlined in Section 2.3 More detailed discussion regarding the selected target marsh elevation can be found in Section 5.4. At these locations, an average of 1.1' of total settlement is estimated over the 20 year life of the project with an initial elevation of +1.5'. Of this total settlement, approximately 0.7' is foundation settlement, with the remaining 0.4' of settlement due to self-weight consolidation in the hydraulically dredged fill. All available settlement curves are located in Appendix F. The majority of this settlement occurs within the first two years post construction, resulting in a marsh platform that maximizes time within the optimal intermediate marsh range (20%-80% inundated) for the duration of the 20 year project life.



GROUP 4 HYDRAULIC FILL ELEVATION (FEET)/MUDLINE ELEVATION (FEET)							
0 DAYS	3 MONTHS	6 MONTHS	1 YEAR	3 YEAR	5 YEAR	10 YEAR	20 YEAR
4.0/-1.5	3.6/-2.9	3.3/-3.1	3.0/-3.3	2.8/-3.3	2.8/-3.3	2.8/-3.3	2.8/-3.3
3.5/-1.5	3.2/-2.8	2.8/-2.9	2.6/-3.1	2.5/-3.1	2.4/-3.1	2.4/-3.1	2.4/-3.1
3.0/-1.5	2.8/-2.6	2.4/-2.7	2.2/-2.8	2.1/-2.8	2.1/-2.8	2.1/-2.8	2.1/-2.8
2.5/-1.5	2.3/-2.4	2.0/-2.5	1.8/-2.6	1.8/-2.6	1.7/-2.6	1.7/-2.6	1.7/-2.6
2.0/-1.5	1.8/-2.2	1.6/-2.3	1.5/-2.4	1.4/-2.4	1.4/-2.4	1.4/-2.4	1.4/-2.4
1.5/-1.5	1.3/-2.1	1.2/-2.1	1.1/-2.2	1.1/-2.2	1.1/-2.2	1.1/-2.2	1.1/-2.2

Figure 8: Group 4 East MCA Hydraulic dredge fill Settlement Curve

4.6 West Containment Feature Analyses

A key aspect of the BA-125 project is the semi-contained method of construction. Existing marsh vegetation will be used to contain dredged material except in locations where there is a direct hydrologic connection to surrounding water bodies or where the marsh vegetation is low and/or sparse. The exception to this strategy is along the southern border of the West MCA where in addition to closing perimeter gaps, an existing spoil bank will be relifted to protect the pipeline canals directly south of the West MCA and an existing camp directly south of the West MCA. In most of these locations, traditional ECDs will likely be the best option though some deeper openings will require alternative closure methods.

GeoEngineers was tasked with calculating the stable parameters for ECDs and determining the type and parameters of alternative measures for locations that are not conducive to traditional ECDs. The original 30% containment designs assumptions were determined to be more conservative than needed for expected conditions at the gap closures. Since no fill is expected to stack above existing grade at the West MCA perimeter, the gap closure crown elevations lowered from +2.5’ to +1.5’ to reduce volume requirements. GeoEngineers reanalyzed these parameters for the reduced top elevations.

4.6.1 Earthen Containment Dikes

Different configurations were analyzed for earthen containment dikes using parameters from borings near areas where earthen containment will be necessary (BHMC-1, 4, 5, and 6). Each configuration was analyzed at the borings for slope stability, bearing capacity, and settlement.

4.6.2 Containment Dike Stability Analyses

Global slope stability analyses were performed for the earthen containment dikes. Slope stability was evaluated for local failures within the dike itself and for global failure into the borrow channel. Bearing capacity analyses were also performed to ensure that the foundation soils can support the load of the dikes. The results of this analysis are shown in Table 8. The following general recommendations were made:

- The minimum distance between the toe of the dike and the start of the borrow channel should be 25’.
- The minimum crown width should be 5’.
- Dikes constructed to an elevation of +1.5’ should have a 4:1 side slope
- Dikes constructed to an elevation of +3.0’ should have a 4:1 side slope.
- The side slope of the borrow channel should be a 3:1 or flatter
- The maximum elevation of the borrow channel should not exceed -10.0’

Crown Elevation NAVD88	Crown Width	Side Slope (H:V)	Bench Width	Max Borrow Depth NAVD88	Minimum Slope Stability FOS	Minimum Bearing FOS
+1.5’	5’	4:1	25’	-10.0’	2.00	1.70
+3.0’	5’	4:1	25’	-10.0’	1.66	2.40

Table 8: Stability and Bearing Results

4.6.3 Containment Dike Settlement Analyses

Settlement analyses were completed using laboratory results from the same borings that were used for the slope stability analyses. Settlement was calculated using the computer program SETANL, the drainage distance of each soil layer, and the C_v values from borings near the perimeter of the project area. Depending on boring location and dike parameters, settlement ranges from 4'' to 10'' during construction and from 1'' to 4'' over the first year following construction. ECD settlement is not a major concern, as the relatively small quantity of containment dikes will allow quick deployment for maintenance when necessary. More information about computation methods, dike parameters, and results can be found in the full geotechnical report in Appendix F.

4.6.4 Alternative Containment Features

Several tidal gaps that exist between the interior marsh and exterior water bodies are not conducive to traditional earthen containment because of their depth and large tidal prism,. GeoEngineers recommended a sheet pile closure for these situations: A PZ-22 sheet pile was recommended with an installed bottom elevation of -21.0' and a top elevation of +1.5'. Due to the low required top height consistent with the earthen gap closures, GeoEngineers removed their earthen support recommendation for the sheet pile closure. More information about computation methods, dike parameters, and results can be found in the full geotechnical report in Appendix F.

4.7 East Containment Feature Analyses

The East MCA will employ the traditional fully-confined method of construction. Earthen containment dikes will be constructed along the perimeter to a height greater than the constructed fill elevation to contain and facilitate the dredge fill's process of falling out of suspension. Traditional ECD will be the best option for a majority of the East MCA, although 2 areas are deeper, carry more tidal flow, and require alternative containment. GeoEngineers was tasked by CPRA to conduct analysis on containment configurations for these areas.

4.7.1 Earthen Containment Dikes

Earthen containment configurations were analyzed for earthen containment dikes using parameters from boring groups 1 and 4 near areas where earthen containment will be necessary. The planned configurations were analyzed at each boring group with two design mudlines for slope stability, bearing capacity, and settlement.

4.7.2 Containment Dike Stability Analyses

Global slope stability analyses were performed for the earthen containment dikes. Slope stability was evaluated for local failures within the dike itself and for global failure into the borrow channel. Bearing capacity analyses were also performed to ensure that the foundation soils can support the load of the dikes. The results of this analysis are shown in Table 9. The following general recommendations were made:

- The minimum distance between the toe of the dike and the start of the borrow channel should be 25'.
- The minimum crown width should be 5'.
- Dikes constructed to an elevation of +3.0' should have a 6:1 side slope.
- The side slope of the borrow channel should be a 3:1 or flatter.
- The maximum elevation of the borrow channel should not exceed -10.0'

Crown Elevation NAVD88	Crown Width	Side Slope (H:V)	Bench Width	Max Borrow Depth NAVD88	Minimum Slope Stability FOS	Minimum Bearing FOS
+3.0'	5'	6:1	25'	-10.0'	**1.20**	**1.42**

Table 9: Stability and Bearing Results

4.7.3 Containment Dike Settlement Analyses

Settlement analyses were completed using laboratory results from the same borings that were used for the slope stability analyses. Settlement was calculated using the computer program SETANL, the drainage distance of each soil layer, and the C_v values from borings near the perimeter of the project area. Depending on boring location and existing mudline elevation, settlement ranges from 7'' to 14'' during construction. In the first year post construction, very little settlement is expected on the order of 2'' to 4 ''. More information about computation methods, dike parameters, and results can be found in the full geotechnical report in Appendix F.

4.7.4 Alternative Containment Features

Similar to the West MCA, several tidal gaps exist between the interior marsh and exterior water bodies which were initially not thought to be conducive to traditional earthen containment because of their depth, large tidal prism, GeoEngineers recommended a sheet pile containment closure design which was later determined to not be required. Design specifications and analysis results of the sheet pile closures can be found in Appendix F. Sand Core Closures were decided as the better closure option due to access concerns, cost, and deepest East MCA closure mud lines in lieu of sheet pile closures.

5.0 MARSH CREATION DESIGN

This project proposes to create and nourish marsh by pumping sediment from Turtle Bay into two designated MCAs employing two different construction methods; the semi-confined West MCA and fully-confined East MCA. The design was broken into six (6) components: Semi-Confined West MCA design, Fully-Confined East MCA design, Semi-Confined West MCA containment feature design, Fully-Confined East MCA containment feature design, hydraulic dredge borrow site, and floatation access. The design and analysis of each component is discussed in the sections below.

5.1 Semi-Confined West Marsh Creation Cell Design

Several factors were considered in the design of the fill site including construction methodology, knowledge gained from previous projects, target marsh elevation, and required volume of fill material. To determine the final constructed hydraulic dredge fill elevation that would yield the most productive marsh at the end of the 20-year project life, the percent inundation method described in section 2.3 was employed. Based on the results of the hydraulic dredge fill settlement analysis described in Section 4.4 and incorporating those results into a percent inundation graph, an optimum hydraulic dredge fill elevation of +1.5' was chosen. As shown in Figure 8, the selected hydraulic dredge fill elevation of +1.5' will settle below 20% inundated upper bound around mid-year 4 and provide approximately 16 years within the preferred inundation range through TY 20. Compared with the +2.0' fill elevation, the +1.5' elevation settles into the preferred range 5 years sooner which provides an additional 5 years within the preferred intermediate marsh range over the 20 year project life.

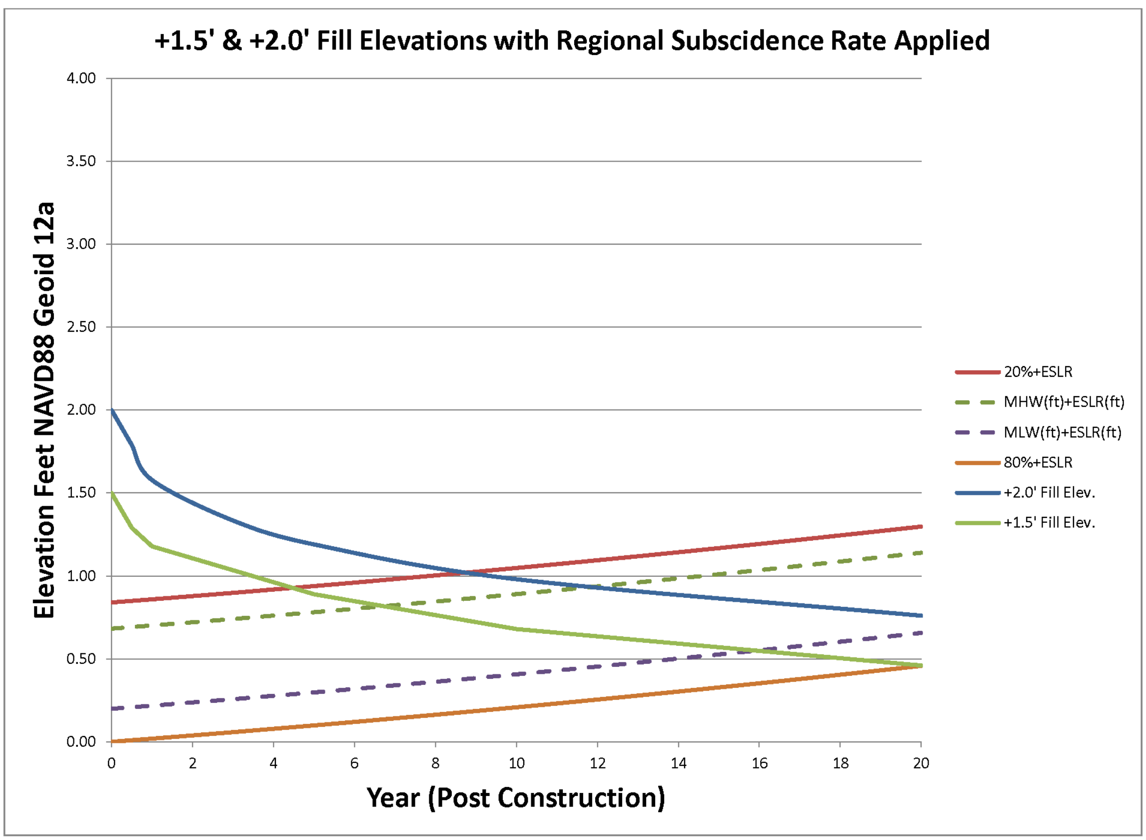


Figure 9: West MCA Settlement & Percent Inundation over Project Life

The West MCA is proposed to be constructed in a semi-confined manner using both the vegetation around the project boundary for containment and closure of existing bayous and cuts around the perimeter to prevent losses of the dredged material due to channelization out of the project boundary. The lack of traditional containment will prevent dredge material from forming a uniform platform all of the way to the perimeter of the MCA. Instead, we expect to see a “transitional” zone which begins at the existing marsh surface and gains in elevation at a 250H: 1V slope until reaching the target marsh elevation of +1.5’. Using the average existing marsh elevation for the West MCA, this equates to a roughly 375’ transition band inland from the cell perimeter encircling the entire West MCA. Beyond the transition band, it is expected the marsh will fill to a uniform marsh platform elevation of +1.5’ before transitioning back down to existing marsh elevations along the perimeter of the cell as can be seen in Figure 10.

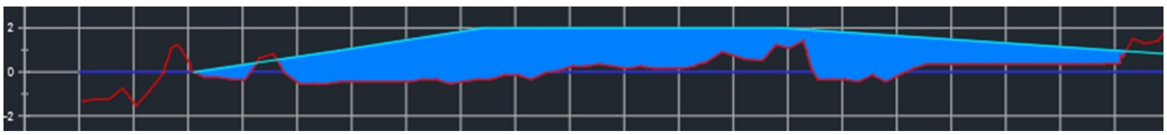


Figure 10: Cross Section of Constructed West MCA

It is assumed that even though the West MCA will not achieve a uniform +1.5’ marsh elevation, the majority of the open water areas located along the marsh fringe will be filled in to the of average existing of 0.0’. This “filling in” process will occur in the immediate vicinity each dredge discharge location before any material stacking can occur. Closing the perimeter gaps will reduce the flow velocities in existing channels allowing hydraulically dredged material to fill in the existing channels to approximately existing West MCA elevations. Since the gap closures are designed to be slightly higher than the existing marsh perimeter, the remaining material in suspension will have to flow around and through the adjacent perimeter marsh. The existing marsh vegetation will have a filtering effect which should minimize losses. A cut to fill ratio of 2 will be applied for hydraulic dredge fill in the West MCA due to greater expected losses of material when compared to a fully-confined method.

5.2 Previous Semi-Confined Projects

As the first full-scale CWPPRA project to be designed to utilize a semi-confined construction methodology for over 50% of the project area, an important first step is to quantify available data from previous projects that utilized this construction methodology. Semi-confined construction has been conducted as a secondary benefit on several previous projects that required disposal of dredged material. Six projects which utilized various forms of semi-confined construction methods are profiled in Appendix A. While each project is unique and end result highly dependent on factors such as existing topography, borrow material characteristics, dredge size, flow rate, etc., the following observations can be made about these projects and semi-contained construction methodology:

1. Marsh vegetation can be successfully used as containment for hydraulically dredged material.
2. Losses of suspended sediments will be greater than losses from fully contained cells.

3. No dewatering structures are necessary.
4. Marsh created by this method has maintained healthy elevations and vegetation up to fourteen years, and will likely continue to do so for much longer.
5. As the data from the BA-36 and TV-21 project indicate, it appears that there is a law of diminishing returns associated with fill elevation. Increasing fill heights do not appear to have a linear relationship with the final settled elevations of the marsh.
6. Visual observations of the BA-36, TV-21, and PO-75 projects indicate that minimal use of containment dikes provide a more functional marsh platform, in terms of tidal exchange and colonization of marsh vegetation sooner than a fully contained area. This construction technique appears to encourage development of a more natural marsh community.

5.3 Semi-Confined West Marsh Creation Cell Fill Volumes

The West MCA is proposed to be constructed in a semi-confined manner using both the vegetation around the project boundary for containment and closure of existing channels and cuts around the perimeter to prevent losses of the dredged material due to channelization out of the project boundary. The lack of traditional containment will prevent dredge material from forming a uniform platform all of the way to the perimeter of the MCA. Instead, we expect to see a “transitional” zone which begins at the existing marsh surface and gains in elevation at a 250H: 1V slope until reaching the target marsh elevation of +1.5’. Using the average existing marsh elevation for the West MCA, this equates to a roughly 375’ transition band inland from the cell perimeter encircling the entire West MCA. Beyond the transition band, it is expected the marsh will fill to a uniform marsh platform elevation of +1.5’ before transitioning back down to existing marsh elevations along the perimeter of the cell.
Using the design outlined in Section 5.1 West MCA Design, the traditional method of calculating hydraulic dredge fill volume with Microsoft Excel will not account for the transitional zones along the perimeter of the West MCA. Instead, a composite approach was performed in which the volume calculation was broken into three main components:

- Existing ground to 0.0’ Volume
- 0.0’ To +1.5’ Incorporating Transition Zones Volume
- 0.0’ To +1.5’ Incorporating Transition Zones Cut Volume

Figure 11 illustrates each component. The cross sections in Figure 11 are purely to assist in explaining the volume calculation concept and were not used in the analysis.

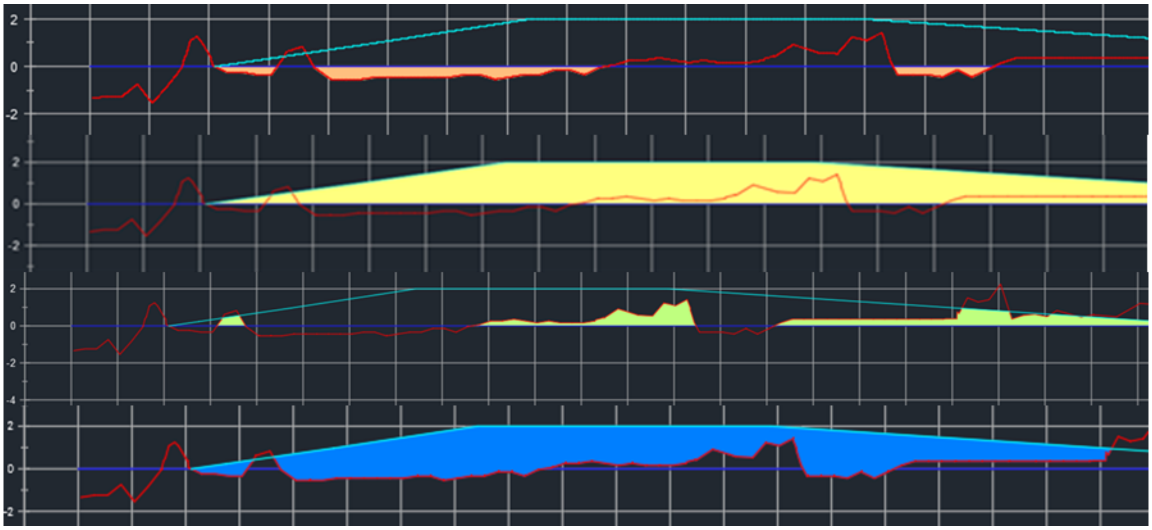


Figure 11: Transect Area Calculation Components (Starting From Top: Existing ground to 0.0’ Volume, 0.0’ to +1.5’ Fill Volume, 0.0’ to +1.5’ Cut Volume, Resultant Transect Area used in Volume Calculation)

5.3.1 Existing Ground to 0.0’ Volume

As mentioned in Section 5.1, it is assumed the entire West MCA will be filled to the average existing marsh elevation of 0.0’. This was calculated by setting the target elevation to 0.0’ and setting every elevation point greater than 0.0’ to 0.0’ along each transect. The average end area method was then performed to determine the volume. These values are presented in Table 10.

5.3.2 0.0’ to +1.5’ Fill Volume

The transect area method traditionally employed cannot take into account the sloping transition zone that encircles the perimeter of the West MCA, therefore a TIN surface utilizing the semi-confined design assumptions and parameters describe was created in CAD. Cross sections along the locations of the actual survey transects were generated and used in the average end area to calculate a volume from 0.0’ to +1.5’ disregarding the existing marsh above elevation 0.0’ in the West MCA shown in Table 10. This volume must then be used in conjunction with the volume of existing marsh above 0.0’ to avoid overestimating the amount of required material.

5.3.3 0.0’ to +1.5’ Cut Volume

The existing marsh above elevation 0.0’ in the West MCA was calculated similarly to the existing marsh to 0.0’. The target elevation was again set to 0.0’ and the elevations points along each transect were set to 0.0’ if they fell outside of the 0.0’ to +1.5’ range. This provided the transect areas to perform the average end area method and yield the volume that must be removed from the 0.0’ to +1.5’ Fill Volume. These values are presented in Table 10.

5.3.4 Total West MCA Volume

With these three volume components calculated and including the volume required for Gap Closures (GC) and Southern Perimeter ECD (SPECD) borrows, the total required volume of the semi-confined West MCA can be calculated as the sum of the four components (Table 10).

Volume Component	Volume (CY)	Hydraulic Dredging Cut to Fill Ratio	Cut Volume
Existing to 0'	478,459	2:1	956,918
0' to 1.5' Cut	-123,496		-246,993
0' to 1.5' Fill	624,122		1,248,244
Gap Closure Borrow	12,518		25,036
Excel Total Volume	991,603		**1,983,206**

Table 10: Summary of West MCA Composite Calculated Volumes

As shown in Table 11, the total West MCA volume (less the GC and SPECD volumes) was then compared to the volume calculated in CAD which utilized both a Triangulated Irregular Network (TIN) surface containing the existing marsh survey data and TIN surface representing the expected constructed marsh surface. AutoCAD then used the XYZ differences of each surface to calculate the volume of the West MCA. The required gap closure fill volumes were added to these volumes and the 2:1 cut to fill ratio was applied, resulting in a final estimate of volumes for the marsh creation fill area. Table 11 summarizes the fill volume comparison for the semi-confined West MCA. The CAD calculated volume of 1,988,116 CY was selected as the more conservative approach.

West MCA Calculation Method	Constructed Fill Elevation (ft NAVD88)	Hydraulic Dredging Cut to Fill Ratio	Volume of Fill (CY) (w/ GC Volume)	Volume of Cut (CY)	Percent Difference
Excel	+1.5'	2.0	991,603	1,983,206	0.25%
CAD			994,058	**1,988,116**	

Table 11: Summary West MCA Acreage and Volume

Though the final constructed fill elevation of the West MCA will be +1.5', NAVD88, volume calculations were determined at a hydraulically dredged fill elevation lower than the final constructed hydraulic dredge fill elevation to allow for primary consolidation settlement of the fill to occur. In addition, the existing marsh was adjusted in both calculation methods to account for the expected sub layer settlement. Only areas that achieve the full target elevation will experience the full 0.7' of sub layer settlement. As a result of the semi-confined construction method, only 60% of the West MCA is expected to achieve the target elevation of +1.5'. To prevent overestimating volumes due to sub layer settlement in areas not expected to achieve the full target fill elevation, the value used for accounting for sub layer settlement in the volume calculations is 60% of the total 0.7' of sub layer settlement or roughly 0.4'. These adjustments to the volume calculations better account for the required fill volume by separating and applying each settlement to the component that is most affected over the life of the project.

5.4 Fully-Confined East Marsh Creation Cell Design

In order to replace the lost acreage from the removal of the southern portion of the 30% project design, the federal sponsor worked with the landowner to find a suitable replacement area for the 370 lost acres. Three alternatives similar location and marsh condition shown in Figure 12 were provided to CPRA in the fall of 2014 for consideration. A combination of distance from the original project area, difference in acres from Phase 0 footprint, access concerns, and dredge pipeline pumping distances led CPRA to recommend alternative 3 over alternatives 1 and 2. After approval from the federal sponsor and the landowner, data collection and design was initiated.

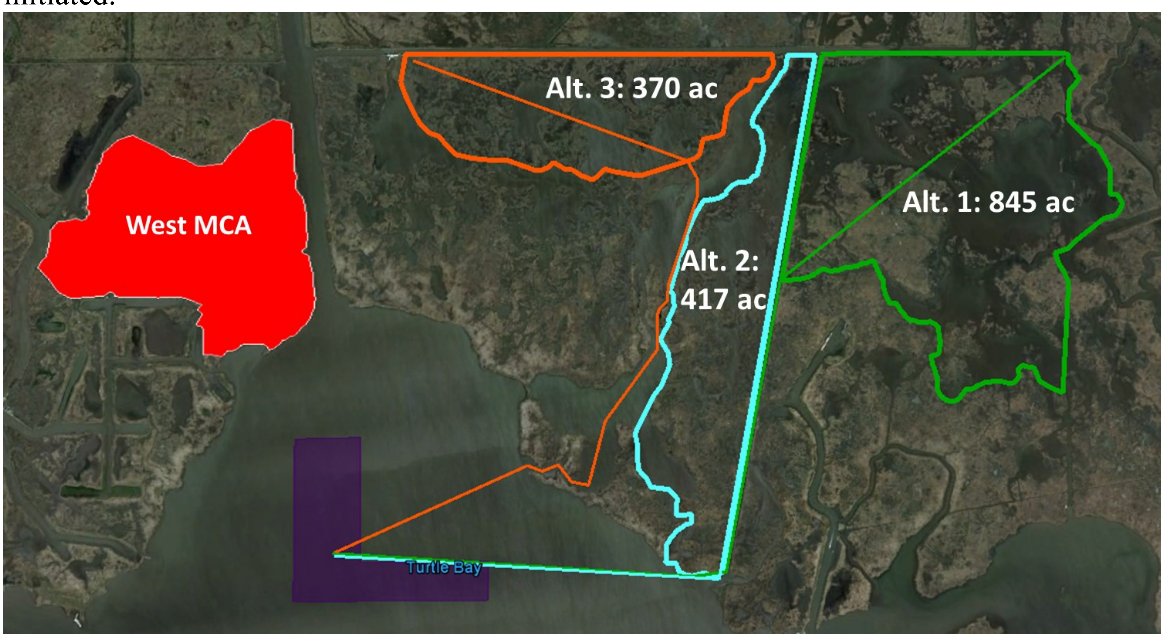


Figure 12: Alternative Marsh Creation Areas Considered

The East Marsh Creation Area (MCA) is proposed to be constructed in the traditional full-confined manner using earthen containment dikes to contain the hydraulic dredge fill material. As previously mentioned, the East MCA was initially planned to be constructed similar to the semi-confined East MCA but due to the severely deteriorated marsh along the southern boundary, the East MCA was not considered a good candidate for the semi-confined method. The East MCA is 370 acres consisting of approximately 40% open water and 60% existing marsh. The average elevation of the East MCA is approximately +0.06'. The Little Lake Hunting Camp is located near the North West corner of the East

MCA. The close proximity of the hunting camp to the East MCA required a buffer area between them to reduce the risk of damage to the camp should a containment failure occur. Therefore a 250' buffer was incorporated into the East MCA footprint between the camp and containment dike alignment shown in Figure 13.

Figure 13: East MCA Offset from Camp

The land surrounding the East MCA is used by the Little Lake Hunting Club for recreational hunting and it fishing and is their preference for the land and bayous adjacent to the East MCA to remain unaffected by the construction of the East MCA as much as reasonable. To accommodate this, the contractor will be instructed to dewater only along the southern boundary of the East MCA to prevent infilling of the existing bayous adjacent to the East MCA which the club actively use.

Determining an appropriate constructed East MCA elevation is governed by several factors including the tidal range, percent inundation, the healthy marsh elevation, the physical properties of the borrow material, and the bearing capacity of the foundation soils in the marsh creation fill area. Determination of the constructed hydraulic dredge fill elevation was based on consideration of the average marsh elevation over the life of the project with respect to intended functioning of the marsh from both a habitat perspective and meeting the project goals and objectives. An important aspect of the constructed hydraulic dredge fill elevation is to maximize the time period that the marsh platform has at an elevation within the functional intermediate marsh inundation range (20%-80% inundated) and maximize the time period spent in the range that most closely correlates to the tidal range (20%-80% inundated). Over the 20-year project life, accounting for eustatic sea level rise as discussed in Section 2.3, the preferred inundation range is expected to rise from 0.00' and 0.84' (80%-20% inundated) to +0.46' and +1.3', respectively. A cut to fill ratio of 1.5 will be applied hydraulic dredge fill in the East MCA to account for losses associated fully-confined construction methods. This cut to fill ratio is fairly consistent with other CPRA designed fully-confined marsh creation projects.

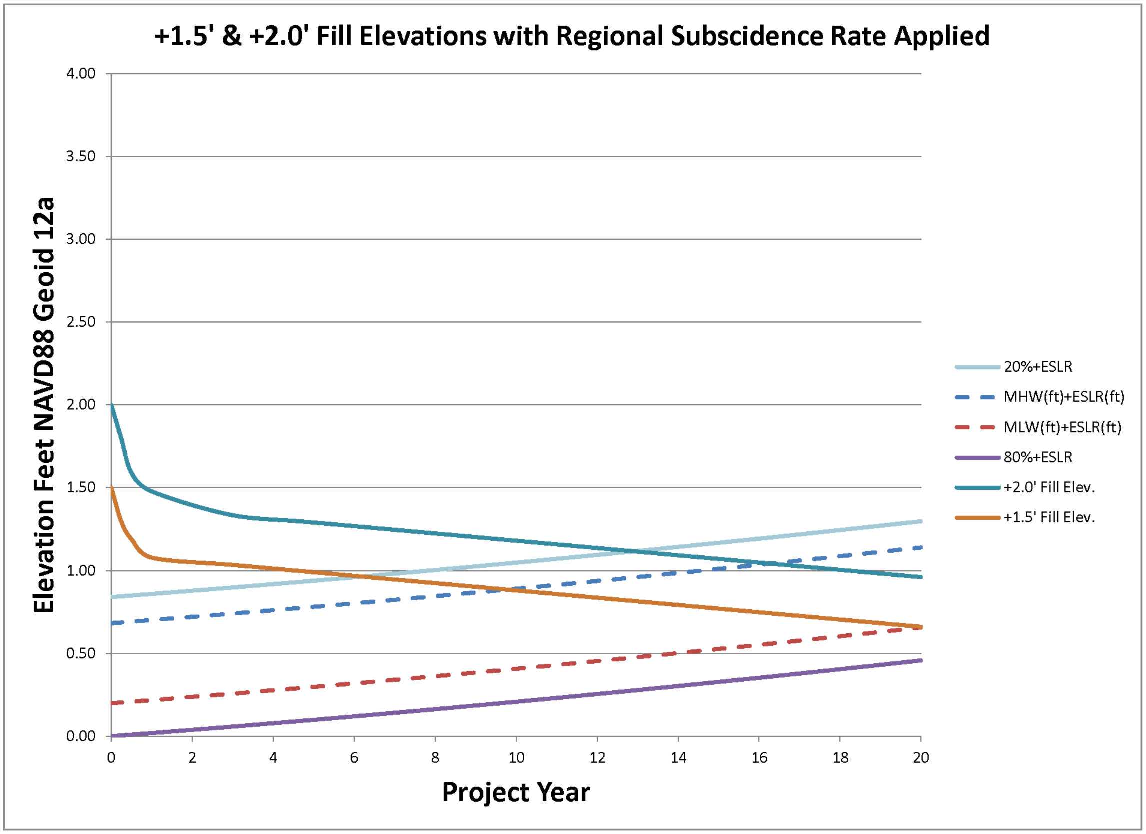


Figure 14: East MCA Settlement & Percent Inundation over Project Life

To achieve a healthy marsh over the 20 year project life, the marsh platform will initially have to be pumped to a constructed hydraulic dredge fill elevation above of the optimal intermediate marsh range and settle into the range over the design life. To satisfy these conditions, the East MCA will be pumped to a final constructed hydraulic dredge fill elevation +1.5'. As shown in Figure 14, this elevation will settle below 20% inundated upper bound around year 6 and provide approximately 14 years well within the preferred inundation range through TY 20. Compared with the +2.0', the +1.5' elevation settles into the preferred range 7 years sooner and provides an additional 7 years within the optimal intermediate marsh range over the 20 year project life.

5.5 Fully-Confined East Marsh Creation Cell Fill Volumes

After determining the constructed hydraulic dredge fill elevations, the total volume of the marsh creation fill area was calculated using both Microsoft Excel computed average end area and AutoCAD Civil software. As discussed in Section 5.3, both a TIN surface containing the survey data of the exiting marsh and a flat TIN surface at the creation construction elevation was created by AutoCAD. AutoCAD then uses the XYZ differences of each surface to calculate the volume of the marsh creation fill area. A mechanical dredging cut-to-fill ratio of 2.0 is applied to account for interior containment borrow volume. The hydraulic dredge cut-to-fill ratio of 1.5 is then applied, resulting in a final estimate of borrow volume for the marsh creation fill area. Table 12 summarizes the volumes for the East MCA.

East MCA Calculation Method	Constructed Fill Elevation (ft NAVD88)	Volume of Fill (CY)	CD Borrow Volume (CY)	Hydraulic Dredging Cut to Fill Ratio	Volume of Cut (CY)	Percent Difference
Excel	+1.5’	1,583,507	88,761	1.5	**2,512,831**	3.45%
CAD	+1.5’	1,526,773	91,713		2,427,729	

Table 12: Summary of East MCA Acreage and Volume

Though the final constructed fill elevation of the East MCA will be +1.5’, NAVD88, volume calculations were determined at a hydraulically dredged fill elevation lower than the final constructed hydraulic dredge fill elevation to allow for primary consolidation settlement of the fill to occur. In addition, the existing marsh was adjusted in both calculation methods to account for the expected sub layer settlement. These adjustments to the volume calculations better account for the required fill volume needed by separating and applying each settlement to the component that is most affected over the life of the project.

5.6 West Containment Design

With the semi-confined construction method, the goal of the containment structures is not to contain hydraulic dredge fill above existing grade as would traditional containment, but to act more as an earthen plug to prevent channelization of hydraulic dredge fill out of the project area and reduce flow velocities which will allow more material to fall out of suspension. As a result, the slurry will flow around the closure structures and allow the exiting marsh vegetation to act as a final filter before the water leaves the project area. The design of the containment features to close off tidal gaps and cuts is a critical component. As detailed in Section 4.6, three types of containment were recommended:

1. Earthen gap closures with a +1.5’ crown elevation for perimeter locations
2. Traditional earthen dike with a +3’ crown elevation for the southern boundary to protect the pipeline canals and existing infrastructure
3. Sheet pile closure for deep gaps up to a maximum bottom elevation of -5.5’

Locations proposed for the three types of containment features are shown in Figure 15:

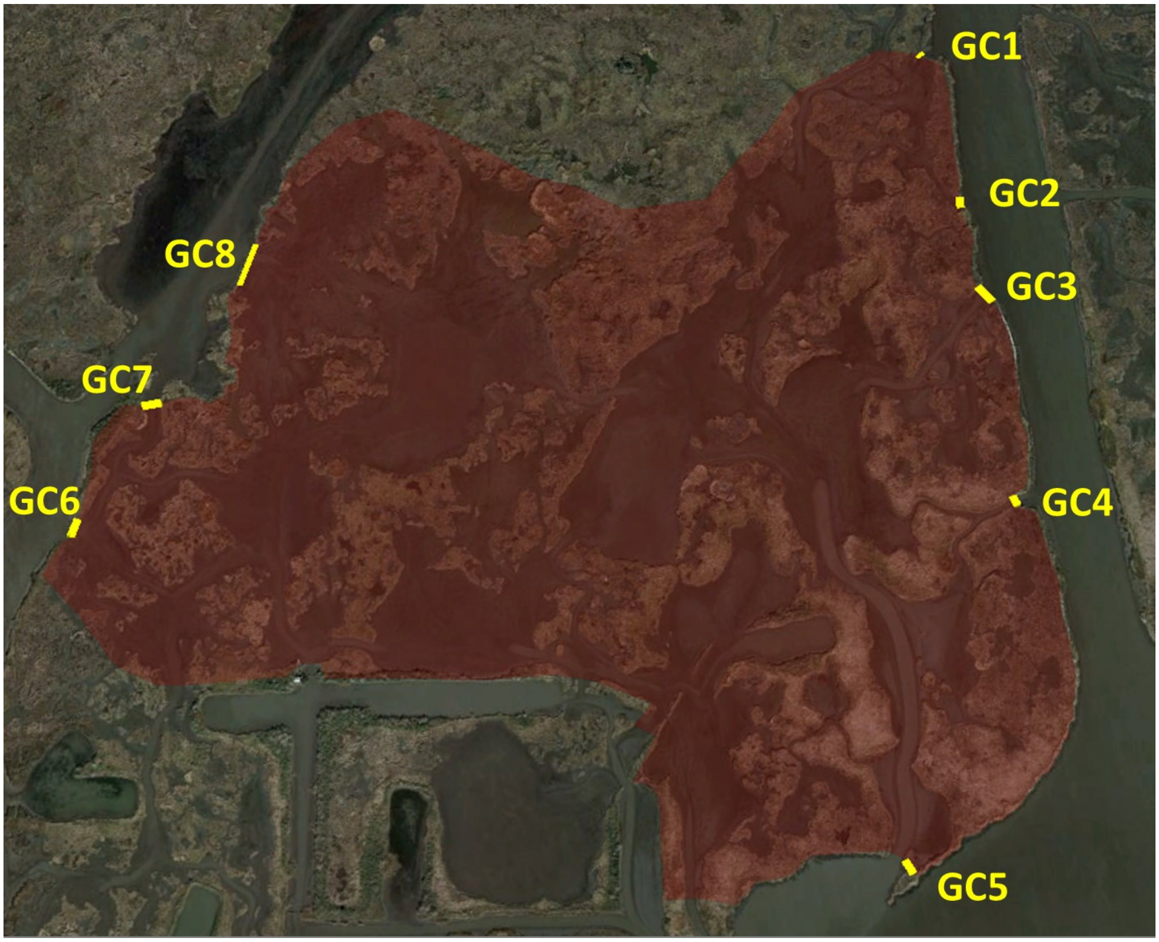


Figure 15: West MCA Gap Closure Locations

5.7 Earthen Gap Closures

The primary design parameters associated with the ECD design include crown elevation, crown width, and side slopes. Based on recommendations from the geotechnical analysis discussed in Section 4.6, the earthen gap closures will be constructed to a crown elevation of +1.5', a 5' crown width with 4(H):1(V) side slopes. Earthen gap closures will be constructed using in situ material via interior borrow. A 25' bench from the edge of the borrow to the toe of the gap closure will be required with 2(H):1(V) side slopes and a maximum excavation depth of -10.0'. Figure 16 shows a typical detail of an earthen containment closure. All earthen gap closures on the perimeter of the West MCA will be built to these parameters.

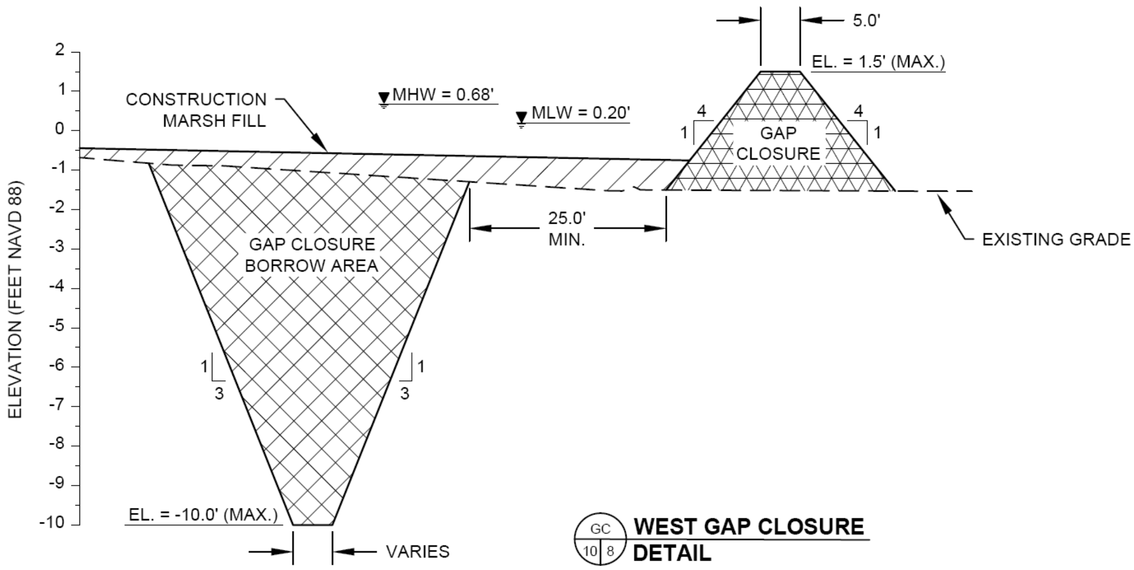


Figure 16: Typical East MCA Perimeter Earthen Containment Gap Closure

Once the gap closure parameters were determined, cross-sectional areas and containment volumes were calculated in Microsoft Excel. A mechanical dredging cut to fill ratio of 2:1 was applied to the gap closure volumes. Table 13 summarizes the containment dike volume calculations.

Gap	Length	Low Pt.	Volume	Cut to Fill	Cut Volume
GC1	75	-1.45	138	2.0	276
GC2	75	-0.75	61		122
GC3	110	-2.10	195		389
GC4	160	-1.68	176		351
GC5	45	-1.25	28		56
GC6	228	-1.63	219		438
GC7	139	-1.30	133		265
GC8	280	-1.58	174		347
Total Gap Closure Cut Volume (CY)					**2244**

Table 13 – East MCA Earthen Containment Gap Closure Volume Summary

5.8 Southern Perimeter Earthen Containment Dike

The primary design parameters associated with the containment dike design include crown elevation, crown width, and side slopes. As discussed in Section 4.6, the containment dike built along the southern West MCA border will be constructed to a crown elevation of +3.0’, a 5’ crown width with 4(H):1(V) side slopes. The containment dike will be constructed using in situ material via interior borrow. A 25’ bench from the edge of the borrow canal to the toe of the gap closure will be required with 3(H):1(V) side slopes and a maximum excavation depth of -10.0’. Near the exiting camp, the alignment will be offset inward from the existing spoil bank to avoid an existing water control structure and boat access to the camp. Figure 17 shows a typical detail of an earthen containment along the southern West MCA border.

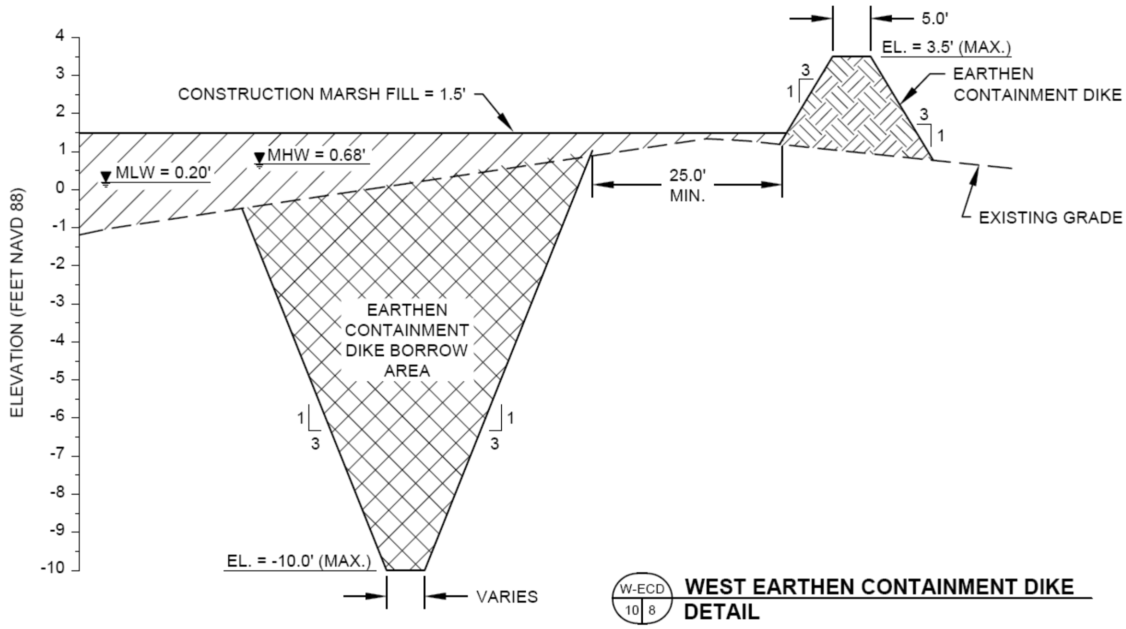


Figure 17: Typical East MCA Southern Perimeter Earthen Containment Dike

West MCA CD	Length	Low Pt	Crown Elev.	Side Slope H:V	Volume	Cut to Fill	Cut Volume
	3485	-3.21	+3	4:1	5137	2.0	10274
Total Containment Dike Cut Volume (CY)							**10274**

Table 14– East MCA Southern Perimeter Earthen Containment Dike Volume Summary

Once the containment dike parameters were determined, cross-sectional areas and containment volumes were calculated in Microsoft Excel using average end area. Table 14 summarizes the containment dike volume calculations.

The alignment and camp offset of the earthen containment for the West MCA southern border can be seen highlighted in Figure 18.

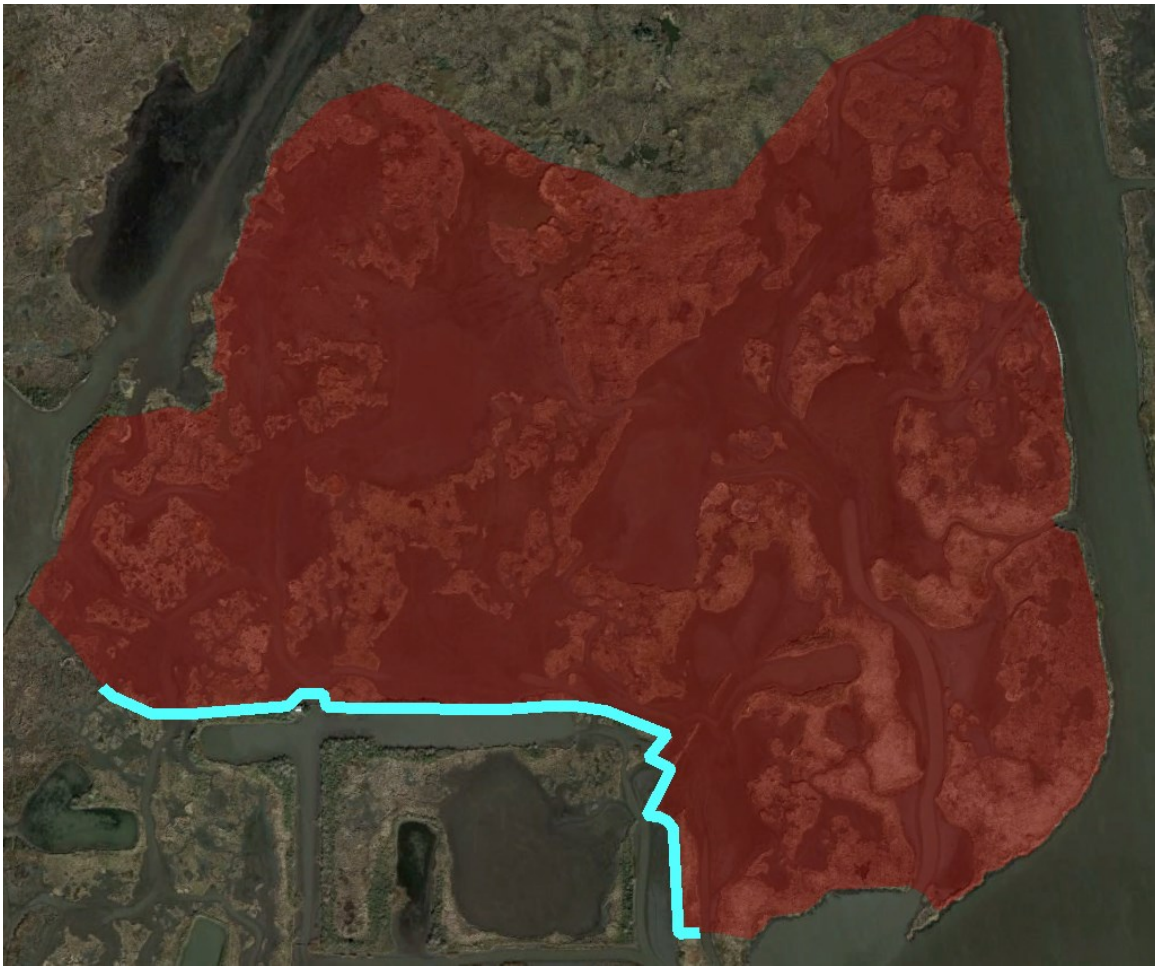


Figure 18: East MCA Southern Perimeter Earthen Containment Dike Alignment

5.9 Sheet Pile Closures

For closure areas that were deeper than -3.0’, GeoEngineers recommended sheet pile closures. Two locations, shown above in Figure 19, met these requirements with bottom elevations of -4.0’ and -4.7’. A PZ-22 sheet pile was recommended with an installed bottom elevation of -21’ and a top elevation of +1.5’. Due to the low required top height consistent with the earthen gap closures, GeoEngineers removed their earthen support recommendation for the sheet pile closure.

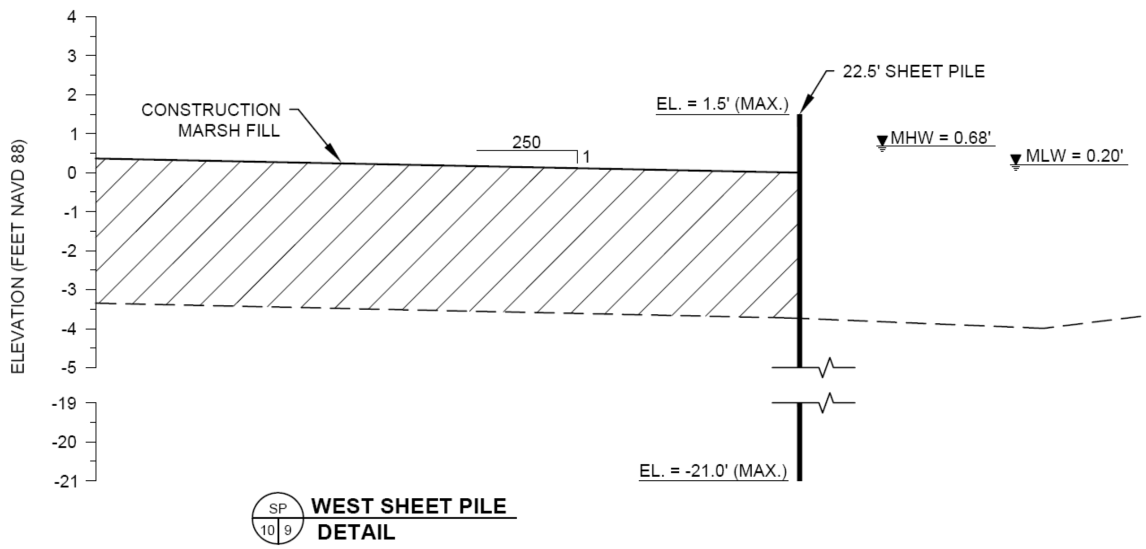


Figure 19: West MCA Sheet Pile Closure Typical Detail

5.10 Fully-Confined East Marsh Creation Containment Design
Earthen Containment Dike

The primary design parameters associated with the earthen containment dike (ECD) design include crown elevation, crown width, and side slopes. A minimum of one foot of freeboard is required to ensure the dredge slurry stays contained within the marsh creation fill area during construction. Additionally, because the contractor will be allowed up to +0.5’ tolerance on the initial constructed fill marsh elevation of +1.5, the crown elevation needs to be adjusted accordingly. Therefore, the earthen containment dikes will be constructed to an elevation of +3.0’ based on the initial constructed fill marsh elevation of +1.5’, allowable construction tolerance of 0.5’, and 1’ of freeboard. As shown in Figure 20, the dikes will be constructed with a crown width of 5’ and a side slope of 6H:1V. The in situ borrow material to build the ECD will be mechanically dredged from the interior of the MCA with a maximum bottom elevation of -10’. Side slopes within the borrow area will be 3H:1V, and the borrow will be located a minimum of 25’ from the toe of the containment. Figure 20 shows a typical section of the earthen containment dikes for the East MCA. Containment Dike volumes were computed in excel using average end area and compared to CAD calculated volumes in Table 15. The CAD volume was selected to be conservative.

There are two locations along the containment dike alignment that the Chevron pipeline crosses as shown in red on Figure 21. The magnetometer and probing results indicate the Chevron pipeline has between 2’ and 12’ of cover throughout the East MCA. As a result, a 50’ excavation buffer will extend on either side of the pipeline/containment dike intersection and will require minimal double handling of material to build containment at these two locations.

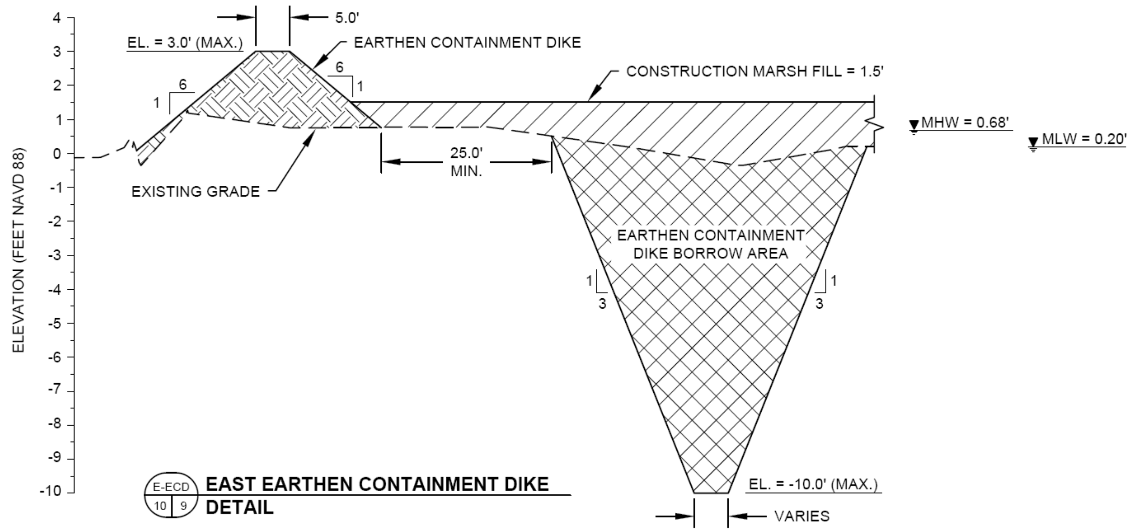


Figure 20: Typical Section of East MCA Earthen Containment Dikes

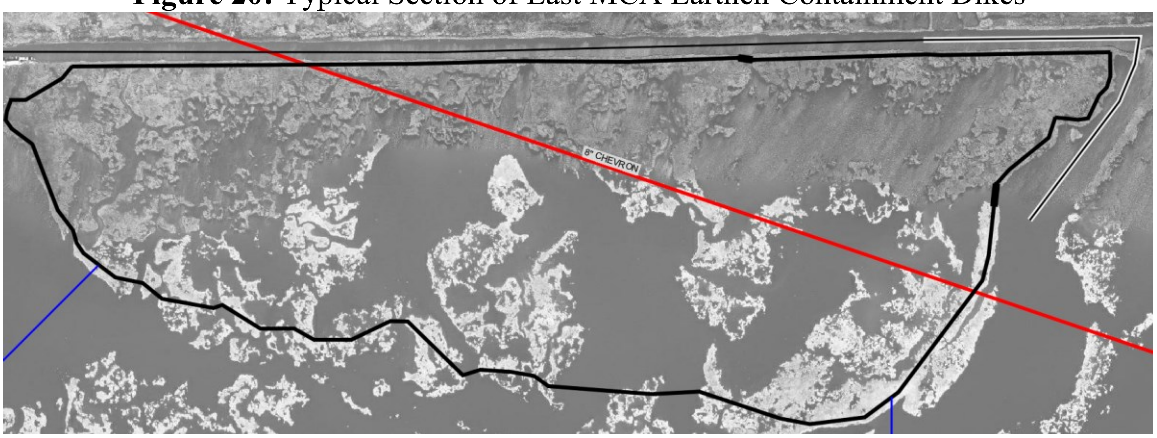


Figure 21: 8” Chevron Pipeline (Red) Intersecting East MCA

Calculation Method	Constructed Crown Elevation (ft NAVD88)	Volume of Fill (CY)	Mechanical Dredging Cut to Fill Ratio	Volume of Cut (CY)	Percent Difference
Excel Volume	+3.0’	44,380	2.0	88,761	3.27%
CAD Volume		45,857		**91,713**	

Table 15: East MCA Earthen Containment Dike Volume Summary

5.11 Sand Core Closures

Two locations along the East MCA perimeter required closures more substantial than the typical earthen containment due to depths and risk of failure from tidal effects. These gaps shown in Figure 22 were within 0.5’ of the maximum bottom elevation analysis and are both situated along existing channels with heavy tidal exchange. Two closure options were considered; a sand core closure or sheet pile closure. Sheet pile closures were not preferred due to expense, pipeline issues, and construction access concerns.

Figure 22: East MCA Sand Core Closure Locations

The Sand Core Closure is designed to go from existing grade to a crown elevation of +1.0’ with a 5’ crown width. This crown elevation is higher than MHW and should help reduce losses during construction due to tidal exchange. The side slopes will be 6H: 1V. This sand template will then be covered with an earthen cap of in situ material to the typical earthen containment parameters of +3.0’ crown elevation, 5’ crown width, and 6H: 1V side slopes as can be seen in Figure 23. Quantities are presented in Table 16.

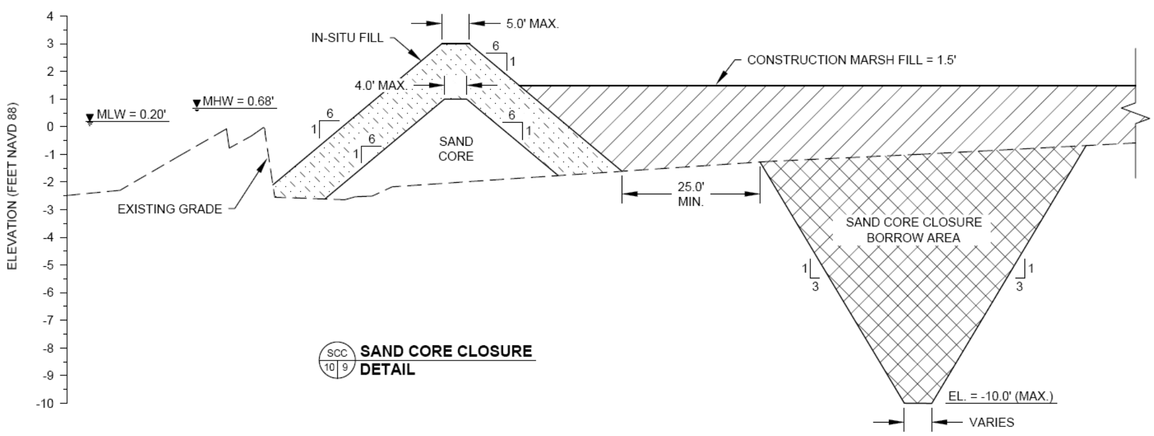


Figure 23: East MCA Typical Sand Core Closure

Sand Core Closure	Constructed Crown Elevation (ft NAVD88)	SCC Sand Volume (CY)	In Situ Cap Volume (CY)	Mechanical Dredging Cut to Fill Ratio (H:V)	In Situ Cap Borrow Volume (CY)
SCC 1	+3.0’	**190**	395	2:1	**790**
SCC 2	+3.0’	**560**	685		**1,370**
Total Sand Volume (CY)		**750**	**Total In Situ Cap Volume (CY)**		**2160**

Table 16: East MCA Sand Core Closure Volume Summary

As a result of the larger depths and shallow side slopes, the centerline alignment of these gap closures will require a 50' approximate inward shift to keep the outer toe out of the camp canal. The earthen containment alignments will gently transition at each gap closure to accommodate the inward shifts.

5.12 Borrow Site Design

After calculating the required borrow volume of 4,501,000 cubic yards for both MCAs, a borrow area had to be selected to provide the required volume. Turtle Bay was chosen as the borrow location due to its proximity to the project site. The location of a specific borrow area within Turtle Bay began with a 536 acre search area shown in Figure 24 that was based on proximity to the project site and shoreline, and known oil and gas infrastructure from the Louisiana Department of Natural Resources (LDNR) database. With a bottom elevation of approximately -5.0' determined from field investigations and an expected dredging depth to -20.0', this search area contained approximately 13,000,000 cubic yards of material. This quantity was far in excess of what was necessary, but was intentionally larger than the area required because of the expectation that certain locations may have impediments to dredging.

Next, bathymetric and magnetometer surveys were conducted to determine the bottom elevations and to detect the presence of any magnetic anomalies. Bottom elevations in the search area ranged from -3.0' to -6.5'. Many magnetometer hits were identified in the search area, a few of which were considered significant. A plugged and abandoned wellhead was discovered during the borrow area magnetometer investigation. A 250' radius dredging exclusion zone emanating from the location of the well head will ensure that there are no issues during construction. This buffer is based on previous projects with similar situations involving a well head within the borrow area. A contour map of the magnetometer hits is shown in Figure 25. The magnetometer survey results, proximity to the project site, and safety of marine traffic through Harvey Cut were used to delineate a more specific borrow location of 234 acres.

Because Turtle Bay is an oyster seed ground, and approval to dredge in a seed ground is required by the Louisiana Department of Wildlife and Fisheries (LDWF), the selected borrow area was forwarded to CPRA, who issued a task order to TBS to determine if any oyster resources were present. TBS determined that oyster resources were present, especially at the northern end of the borrow area. Figure 19 shows the original borrow area and oyster resources in the vicinity. This information was forwarded to LDWF, and they requested that 53 acres of the borrow area not be dredged. This portion was removed, and the borrow area was finalized for 30% at 181 acres. It is shown in Figure 20. The 95% borrow area is shown in Figure 26 in relation to the oyster resources in the surrounding area.

Post 30% it was determined that the borrow area would need to be expanded from the 30% design to accommodate the increased sediment volumes as a result of the project redesign. Using a combination of LDWF input from the 30% borrow area design, oyster survey, magnetometer, and bathymetry data for the original borrow area investigation zone, the expanded borrow area is shown in Figure 27 compared to the 30% borrow area. After factoring in the 250’ wellhead exclusion radius previously discussed, the expanded borrow area footprint is now 265.5 acres.

The maximum bottom elevation of dredging in the borrow area was selected to be -20.0’ and was based on previous inshore dredging projects that have been permitted to the same depth. Volumes available in the borrow area were calculated in Excel and AutoCAD and are shown in Table 17. The AutoCAD volume of 6,625,465 cubic yards provides a factor of safety of 1.47 for borrow material availability from the required 4,501,000 CY.

Method	Volume	% Difference (from CAD)
AutoCAD (-20')	6,625,465	-
Excel (-20')	6,847,986	+3.30%

Table 17: Available Borrow Area Volume

Figure 24: Borrow Search Area

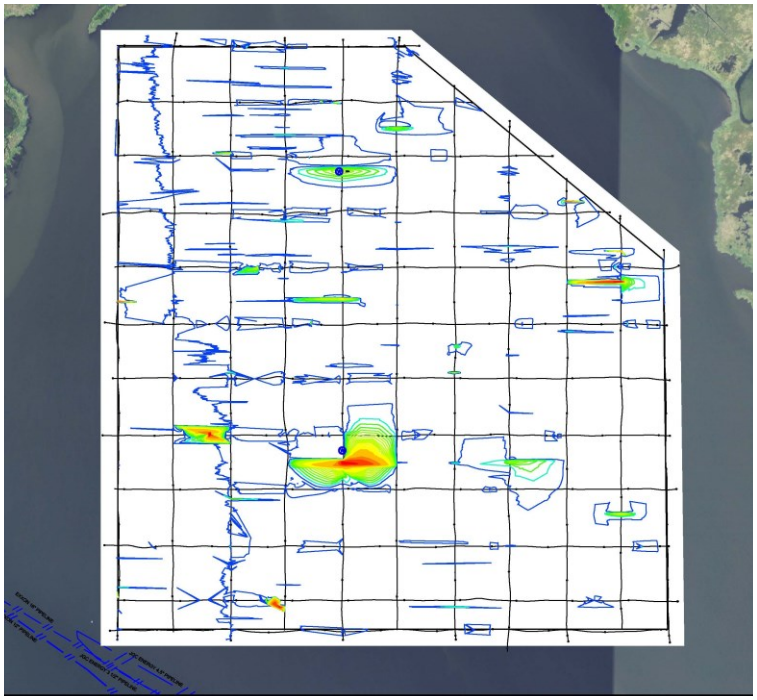


Figure 25: Magnetic Anomaly Contour Map of Borrow Search Area

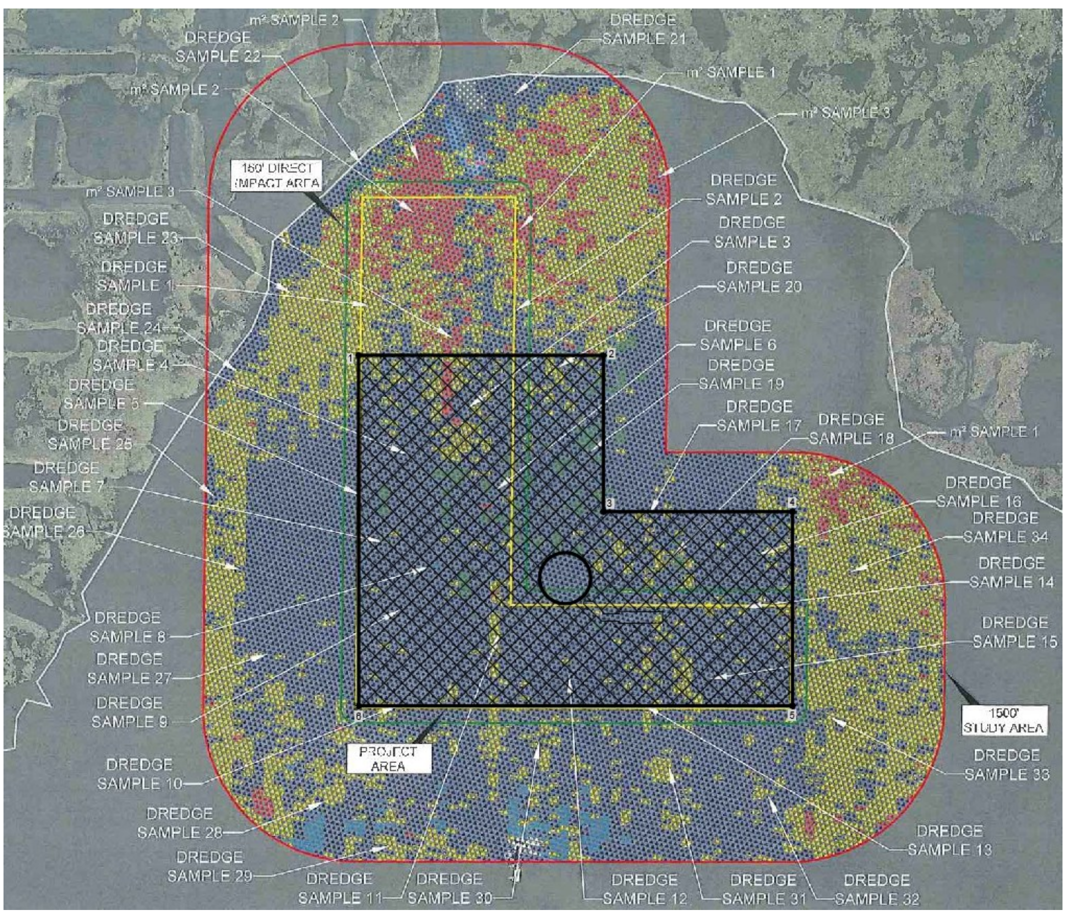


Figure 26: Oyster Resources within Potential Borrow Area

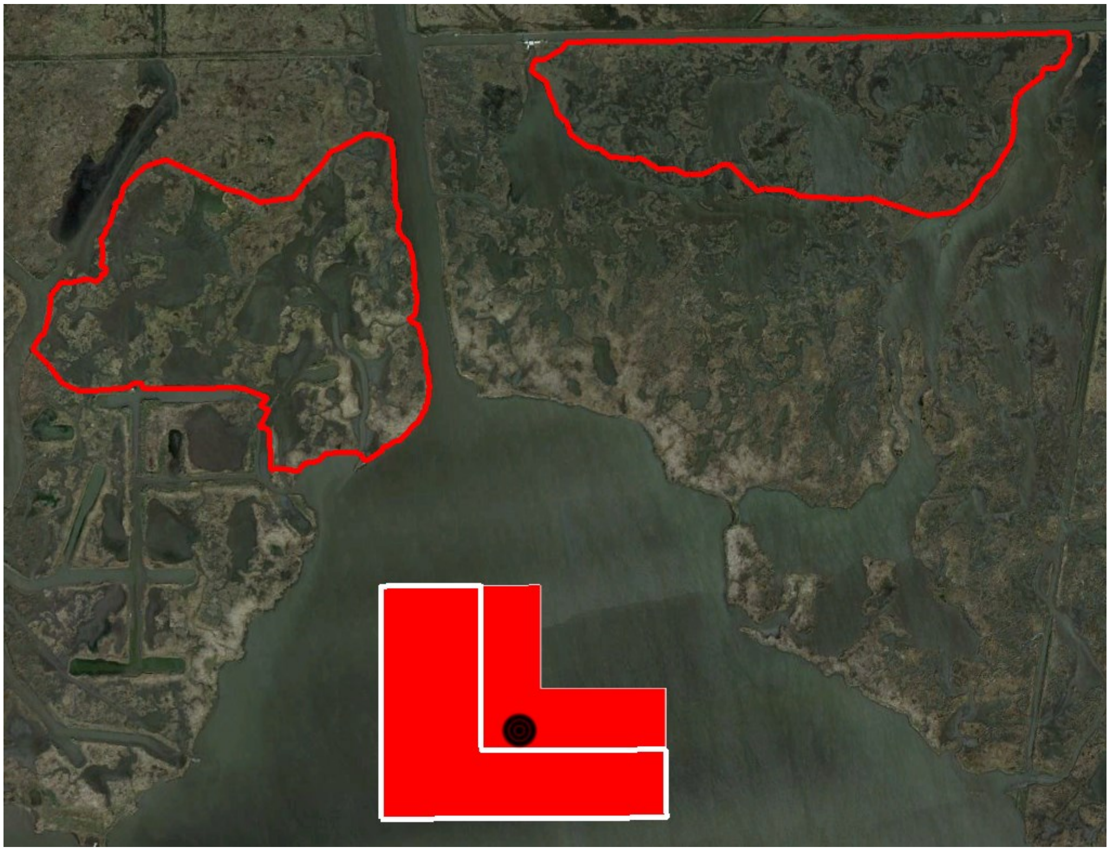


Figure 27: Final Borrow Area (30% Borrow Area shown in White)

5.13 Floatation Access Dredging

Due to the shallow nature of Turtle Bay, it may become necessary to mechanically dredge along designated corridors for floatation access depending on the equipment the contractor chooses to utilize. All access dredging will be required to be backfilled prior to contractor demobilization. Three designated potential access dredging corridors are listed below and shown in Figures 28 and 29 to help facilitate construction of the project features.

- Mouth of the Harvey Cut Channel to the Borrow Area
- Borrow Area to the West MCA
- Eastern Edge of the Camp Canal to the Sand Core Closure 2

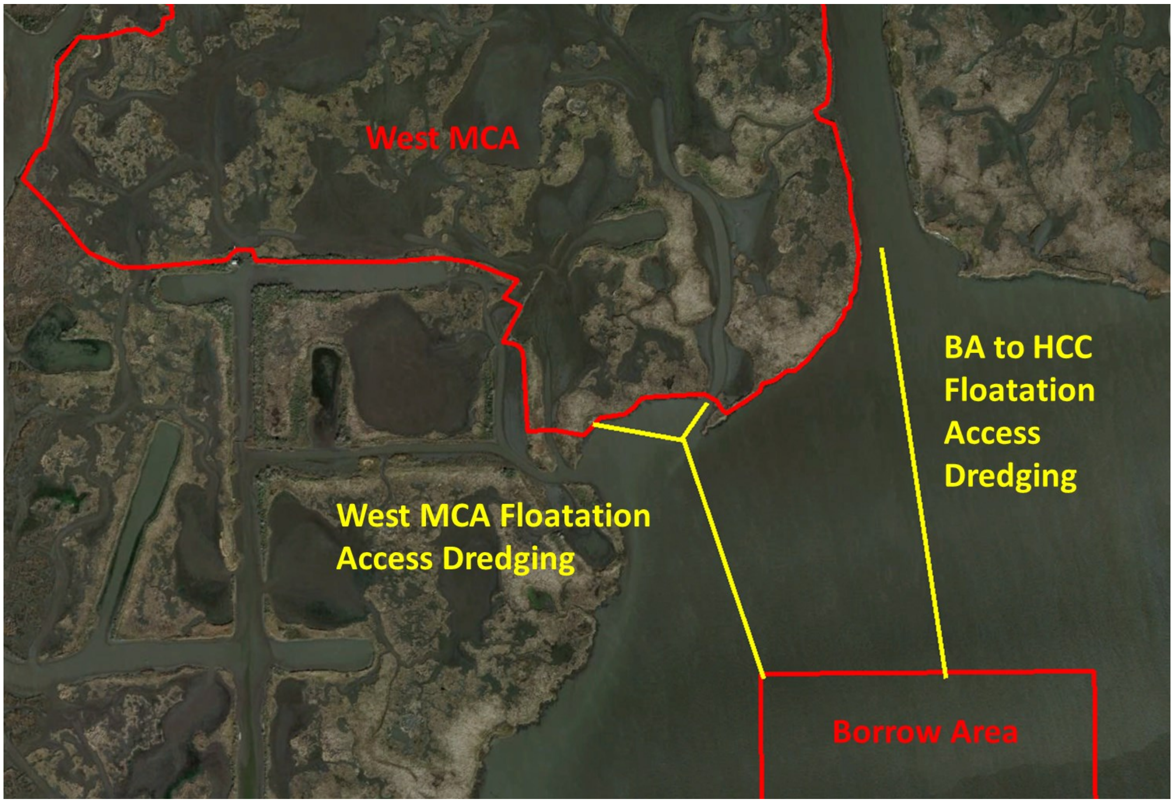


Figure 28: Floatation Access Dredging within Turtle Bay

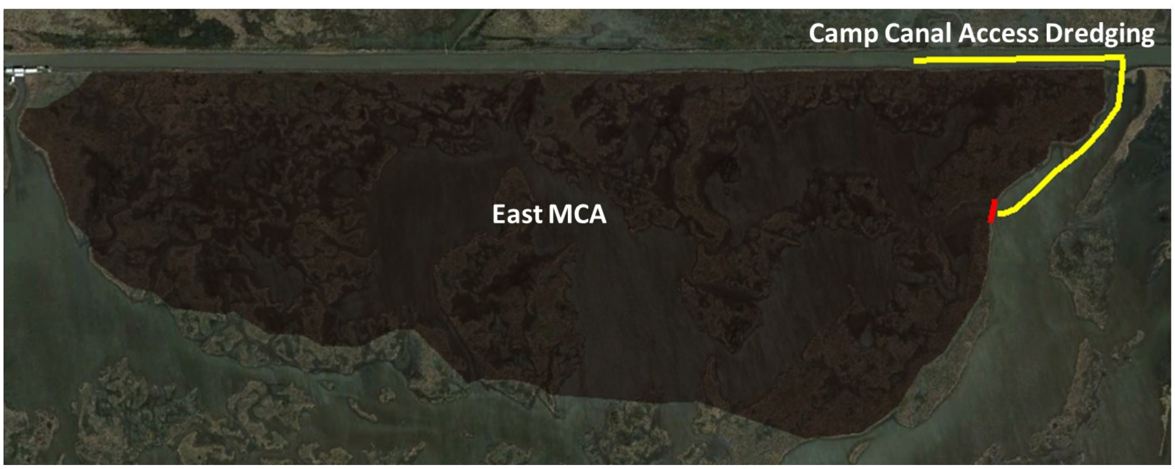


Figure 29: Floatation Access Dredging within Camp Canal & East MCA Project Area

Access Channel	Length of Access Dredging	Bottom Width	Side Slope (H:V)	Volume (CY)
West MCA to BA	2,800’	60’	2:1	20,500
BA to HCC	850’	60’	2:1	2,000
Camp Canal to SCC 2	3,500’	50’	2:1	18,400
Total Volume (CY)				**40,900**

Table 18: Floatation Access Dredging Volume Summary

Although the Harvey Cut Channel (HCC) is well over 20’ deep in some areas, Turtle Bay shallows fairly quickly to depths as shallow as 4’ as you move south of the HCC toward the borrow area. To allow the use of reasonably sized dredge for a project this size, it was decided to allow for floatation access dredging. Any access dredging performed in Turtle Bay would be to a maximum bottom elevation of -6’ and bottom channel width of 60’. The Harvey Cut Channel to the Borrow Area access dredging would be approximately 850’ in length and 2,000 CY. The Borrow Area to the West MCA access dredging would be approximately 2,800’ in length and 20,500 CY.

Access dredging of Camp Canal would be permitted starting roughly 8,500’ east of the HCC for 1,500’ east to the blocked intersection of an existing bayou to allow for a small draft barge to bring sand to the SCC 2 location. This would also require breaking through an existing spoil bank and dredging the existing bayou along the East MCA perimeter as for 2,000’ shown in Figure 27. Any dredging in this area would be limited a maximum bottom elevation of -4’ and bottom channel width of 50’. This depth was selected to maintain the existing water bottom elevation of -4’ along the camp canal. The total expected volume of access dredging this reach would be 18,400 CY. Due to a pipeline crossing with shallow cover in the camp canal 4,000’ from the HCC, the camp canal cannot be dredged any deeper. In addition to requiring access channel backfilling, the contractor would be responsible for returning the affected spoil bank to its preconstruction condition.

6.0 MODIFICATIONS TO 30% DESIGN

As a result of comments and concerns to the 30% design, the 95% design has undergone modifications to produce a more constructible project. When the responsibility of engineering and design was transferred from NRCS to CPRA in the summer 2014, the project was redesigned to avoid the numerous pipelines in the southern portion of the 30% design. The northern portion of the original design area was retained and designated as the West MCA containing 437 acres. The West MCA was designed to utilize a semi confined construction method. The southern portion of the 30% design was removed to avoid the multitude of pipelines in the area which could have led to numerous issues in land rights, construction, and increased risk to both the contractor and engineer of record.

To replace the lost acreage due to the modification of the 30% project footprint, an additional marsh creation area east of the Harvey Cut Channel was created and designated as the East MCA containing 369 acres. Due to the significantly deteriorated marsh along the southern boundary of the East MCA, it was decided that this area would be constructed using traditional fully contained construction methods. Containment features and their locations have been more specifically identified. Due to the redesign of the West MCA and creation of the East MCA, the total acreage has decreased from 807 to 806 acres. Overall, the project location, acreage, and features remain similar to Phase 0. The Phase 0, 30%, and 95% project boundaries are shown in Figure 30.

Figure 30: Phase 0, 30%, & 95% Project Boundaries

6.1 Preliminary Cultural Resources Investigation

The State Historic Preservation Office (SHPO) issued clearance for the project on June 26, 2013for the West MCA and Borrow Area. A SHPO clearance letter for the East MCA was issued Marsh 16, 2016. No known historic properties will be affected. Copies of both clearance letters can be found in Appendix I.

7.0 CONSTRUCTION

7.1 Construction Methodology

7.1.1West MCA

The West MCA is proposed to be constructed in a semi-confined manner using both the vegetation around the project boundary for containment and closure of existing bayous and cuts around the perimeter to prevent losses of the dredged material due to channelization out of the project boundary. Most of the marsh fringe is at an elevation of -0.5’ to +1.0’, it must be noted that these are elevations recorded at the mudline / root ball interface. The dense stems and leaves of the marsh vegetation extend considerably higher than this and may act to trap sediments to build elevations higher than the surveyed marsh elevation.

It is assumed that the contractor will start by pumping an “outer ring” of dredge material as close to the cell perimeter as feasible. For design purposes, it was assumed that these initial discharge locations would have the following characteristics:

- A maximum stacking height of +1.5’ and 250’ radius from the discharge location
- A 250H:1V side slope from the edge of the maximum stacking height down to natural grade.

Using these assumptions, these discharge “cones” would form the basis of a pseudo containment from which the interior of the cell could then be filled to an assumed +1.5’. Using the average bottom elevation for the West MCA of 0.0’, the discharge locations would be roughly 625’ offset from the cell perimeter shown in Figure 31 and would have a 375’ wide transition zone to +1.5’. Depending on the behavior of the material during construction, these offsets can be adjusted to minimize losses of the dredge material. Because the cones will not form a uniform containment wall, the interior area will be able to dewater through the low spots between cones. Ideally, these low spots will silt up as the interior area begins to stack in elevation and yields a consistent marsh platform of elevation+1.5’.

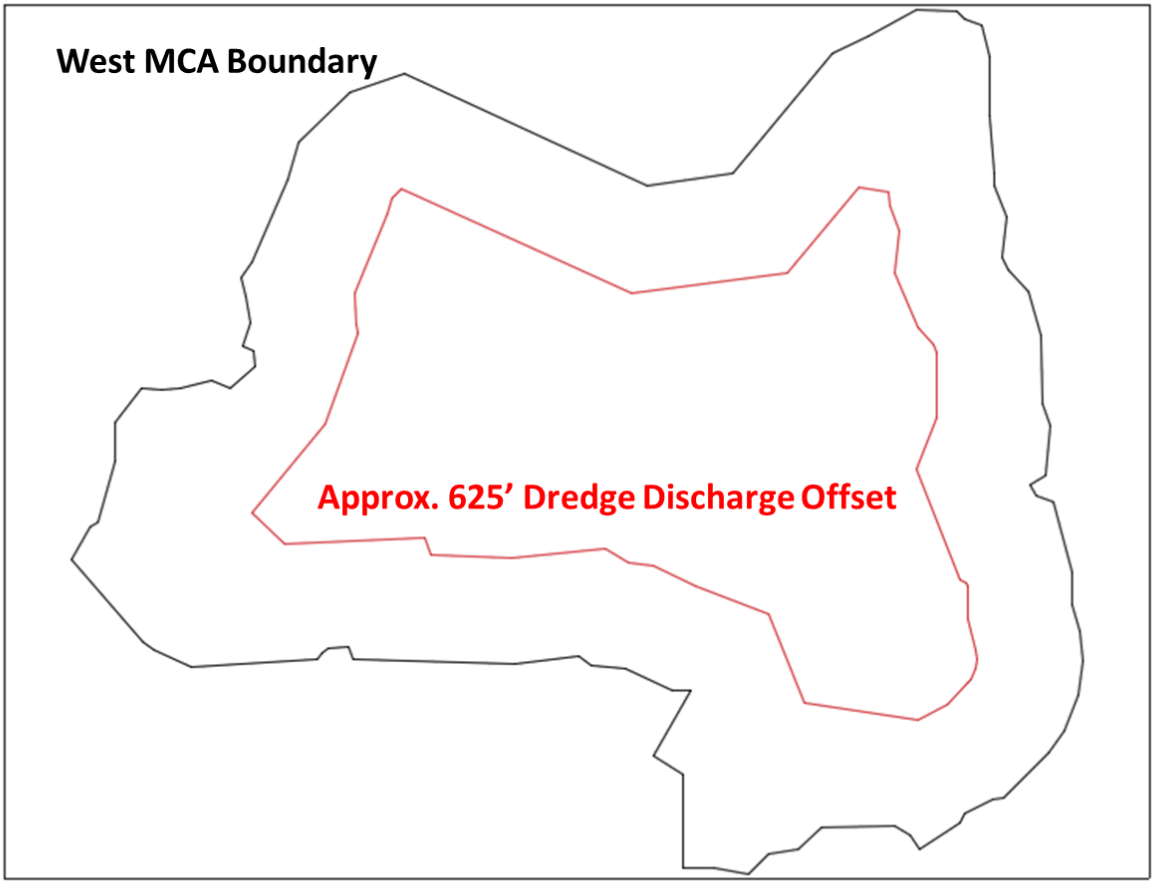


Figure 31: West MCA 625' Initial Discharge Location Offset

<u>7.1.2 East MCA</u>

The East MCA is proposed to be constructed in a more traditional fully-confined manner to an elevation of +1.5'. This will be accomplished by constructing earthen containment dikes and sand core closures around the perimeter of the cell to an elevation of +3.0' to allow for construction tolerance and freeboard. The Chevron pipeline that crosses through the cell will have a 50' excavation buffer for safety. Because the Chevron has varying cover depths throughout the project area compounded with very soft near surface soils, the engineer will coordinate with the pipeline owner prior to construction to specify adequate crossing locations within the East MCA. The contractor will be instructed to dewater along the southern boundary of the cell to prevent silting in the bordering canals to the north and west and the open water directly east of the cell which is used by the hunting camp.

7.2 Construction Duration

Approximate construction duration was developed using the CDS Dredge Production and Cost Estimation Software and Microsoft Project. The assumptions used for the construction duration are as follows:

- The contractor would first complete the West MCA gap closures and southern perimeter containment dike then mobilize the dredge.
- The contractor would begin pumping in the West MCA while completing the East ECD and SCCs. Upon completion of the East ECD and SCCs, pumping could be switched to the East MCA to allow for dewatering and consolidation of the West MCA. Additional material can be pumped into the West MCA upon acceptance of the East MCA to ensure the semi-confined West MCA achieves design parameters. This strategy would greatly reduce or eliminate down time for the dredge during construction.

The time to fill both marsh creation areas would be approximately 6 months using a 24'' hydraulic cutter head dredge and incorporating weather days. The estimated total construction time from mobilization to demobilization is approximately 1 year.

7.3 Cost Estimate

An Engineers Estimate of Probably Construction Cost was prepared for this project using the CWPPRA PPL 26 spreadsheet. The estimated construction cost including a 20% contingency is $27,642,814.

7.4 Risk

The engineering analyses effort completed for this final design report provides guidance and insight pertaining to the construction of the proposed project features based on the data acquired to date. The 95% level of design provides moderate risk to the Engineer of Record, the Owner, and the Contractor, and should not be utilized for the Construction of the proposed project features

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