TECHNICAL MEMORANDUM

To: Coastal Protection & Restoration Authority (CPRA), National Oceanic and Atmospheric Administration (NOAA)

From: Greater Lafourche Port Commission (GLPC)

Date: November 15, 2022

March 5, 2023 (Rev. 1)

June 7, 2023 (Rev. 2)

July 13, 2023 (Rev. 3)

Project: TE-134 West Fourchon Marsh Creation and Nourishment Project

Subject: Alternate Borrow Evaluation

Prepared by: GIS Engineering, LLC (GISE)

EXECUTIVE SUMMARY

The purpose of this Technical Memorandum is to present findings and results for the Alternate Borrow Evaluation developed for the TE-134 West Fourchon Marsh Creation and Nourishment Project, which may create and nourish as much as 814 acres of marsh and nourish as much as 458 acres of existing marsh through dewatering. This Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA) project was approved for construction in January 2020 following the completion of Phase I Design in 2018. CPRA, that serves as the local sponsor of the project along with NOAA as the federal sponsor, was approached by GLPC to evaluate an alternate borrow area for the TE-134 project, consisting of the navigation channels located within Port Fourchon.

The TE-134 Alternate Borrow Evaluation included an extensive Geotechnical Subsurface Investigation performed by Ardaman and Associates, Inc. (Ardaman) with the purpose of evaluating the suitability of the material from the proposed alternate borrow area. This evaluation also included a 95% level design revision inclusive of the following items:

- Revised fill and borrow volume calculations for the marsh creation areas and earthen containment dike (ECD) project features based on Post-Ida Hurricane survey data, updated cut-to-fill ratios, and revised target settlement curves resulting from Ardaman's geotechnical investigation.
- Revised estimated cost for the construction of the TE-134 project utilizing the alternate borrow area.
- Revised Draft Engineering Plan set reflecting the proposed alternate borrow area.
- Evaluation of pipeline crossings and magnetometer hits in the proposed alternate borrow area.
- Other data considered relevant for the selection and suitability of the proposed alternate borrow area.

This Alternate Borrow Evaluation further identified around 5 million cubic yards of suitable borrow material that can be safely dredged without risk to existing infrastructure. The alternate borrow source is geotechnically suitable for marsh creation, with similar long-term settlement characteristics to the originally proposed offshore borrow area. Working within the existing navigation channel reduces average dredge pumping distance nearly 60% and increases the pool of suitable bidders. **Table ES1** below summarizes compliance with criteria required in the intergovernmental agreement (IGA) between CPRA and GLPC dated October 1, 2020:

Table ES1 – Compliance with Criteria

IGA Criterion	Result
a.i. Using methodology comparable to the one described in the TE-134, 95% Design Report, the fill material settlement curve must show a comparable amount of time between mean high water and mean low water as the original project, at least 16 to 17 years, using a constructible initial fill elevation given the ECD stipulations below.	Settlement curves produced by Ardaman indicate suitable performance over time, with slight variations to target fill.
a.ii. The dimensions of the ECDs may need to increase to accommodate a larger fill volume, but they must still be constructed with in-situ material to support the target fill elevation with 1 ft. (+0.5 ft. tolerance) freeboard. No alternative material or synthetic reinforcements will be accepted.	Increased dike elevation for MCA-2 satisfies geotechnical criteria. No alternative materials, geotextiles or similar treatments are required.
b. Sufficient suitable borrow material volume must be shown to exist in the Alternate Borrow Area to achieve the target fill elevation across marsh creation areas (MCA) 1 and 2, including contingency. CPRA will consider a proposed revised cut to fill ratio used to calculate the volume of material required, as informed by the results of the Alternate Borrow Area geotechnical investigation.	Construction of MCA-1, MCA-2 and MCA-3 would require approximately 3.0 million cubic yards. GLPC has identified 5.4 million cubic yards of suitable material available within the proposed alternate borrow area which can be safely utilized.

The revised construction cost estimate presented in this Technical Memorandum was prepared following a conservative approach, based on updated quantities and an analysis of recent similar projects. Accurate estimates are proving extremely challenging in current economic conditions. The alternate borrow source will result in a more constructible project by reducing the average dredge pumping distance nearly 60% and allowing smaller dredges, thus encouraging more bidders to participate.

GISE is estimating that the base bid (including 20% contingency) for constructing MCA-1 and MCA-2 is $33.8 million using material from the alternate borrow area.

CHAPTER ONE: OVERVIEW

PURPOSE

The Greater Lafourche Port Commission (GLPC) engaged GIS Engineering, LLC, (GISE) to perform an Alternate Borrow Evaluation for the proposed West Fourchon Marsh Creation and Nourishment Project (TE-134) proposed by the Louisiana Coastal Protection and Restoration Authority (CPRA) and the National Oceanic and Atmospheric Administration (NOAA). The purpose of this technical memorandum is to present the findings and results for the Alternate Borrow Evaluation performed by GISE for the above referenced project, to ultimately show that the alternate borrow area being proposed by GLPC meets the design criteria to be used for the construction of the project, as set forth by CPRA.

PROJECT DESCRIPTION

The TE-134 West Fourchon Marsh Creation and Nourishment CWPPRA project was originally approved for Phase I Engineering and Design in January 2015. The project was later approved for Phase II Construction funding in January 2020. The Phase II scope of work of the project included the creation and nourishment of 537 acres of marsh using offshore borrow material. The project also included an additional 277-acre marsh creation area (MCA-3) as a potential expansion area that will be fully or partially completed as allowed by the construction budget available.

GLPC later approached CPRA, the local sponsor of the project along with NOAA as the federal sponsor, about analyzing borrow material from the Port's navigation channels, henceforth referred to as "Alternate Borrow Area". This alternate borrow area would provide additional project benefits in terms of constructability, including a reduction of average dredge pumping distance by up to 60%, and allowing smaller dredges to participate in the bidding process – thus increasing the pool of participating bidders. This evaluation of the alternate borrow considers the marsh creation and nourishment of 537 acres and nourishment of 302 acres through dewatering from construction of MCA-1 and MCA-2 as well as the marsh creation and nourishment of 277 acres and nourishment of as much as 178 acres through dewatering from the construction of MCA-3. The total potential acreage with the expansion area would be 814 acres of marsh creation and nourishment and as much as 458 acres of marsh nourishment through dewatering.

IGA

For the purpose of this evaluation, an Intragovernmental Agreement (IGA) between CPRA and GLPC was developed. This IGA clearly stipulates criteria by which the alternate borrow area is to be evaluated to ensure the desired construction performance of the marsh creation and nourishment areas. The criteria are as follows:

1. Evaluate the feasibility of using the Alternate Borrow Area proposed by the GLPC to construct the project according to the following criteria:
    a. Approved project lifespan benefits and minimum habitat acreage must be shown to be achievable with the material available in the Alternate Borrow Area.

i. Using methodology comparable to the one described in the TE-134, 95% Design Report, the fill material settlement curve must show a comparable amount of time between mean high water and mean low water as the original project, at least 16 to 17 years, using a constructible initial fill elevation given the ECD stipulations below.

ii. The dimensions of the ECDs may need to increase to accommodate a larger fill volume, but they must still be constructed with in-situ material to support the target fill elevation with 1 ft. (+0.5 ft. tolerance) freeboard. No alternative material or synthetic reinforcements will be accepted.

b. Sufficient suitable borrow material volume must be shown to exist in the Alternate Borrow Area to achieve the target fill elevation across marsh creation areas (MCA) 1 and 2, including contingency. CPRA will consider a proposed revised cut to fill ratio used to calculate the volume of material required, as informed by the results of the Alternate Borrow Area geotechnical investigation.

c. CPRA and NOAA will offer the CWPPRA Engineering Workgroup the opportunity to review updated geotechnical information and revised project design. The project will not further pursue use of the Alternate Borrow Area if the CWPPRA Engineering Workgroup objects to it.

DELIVERABLE

As per the IGA described above, the items listed below are required to be provided by GLPC as part of this evaluation. This list contains references to the location of each deliverable.

1. Updated draft engineering plan set (PDF and CAD formats), including but not limited to: ***(See Appendix B)***
    a. Typical ECD section ***(See Sheets MCA02 and MCA03)***
    b. Marsh creation area layout ***(See Sheet MCA01)***
    c. Equipment access and dredge pipeline corridors ***(See Sheets BA01 through BA04)***
    d. Anticipated dredging template ***(See Sheets BA05 through BA07)***
    e. *Highlights to any design changes, with written explanatory material for any changes that may require permit modification.
2. Draft (for CPRA approval and NOAA concurrence) and Final Laboratory Test Assignments in regards to the fill material borings. ***(See Appendix C)***
3. Virtual meeting(s) with CPRA to discuss/determine target constructed marsh fill elevations to be used in settlement analyses (and additional parameters to be used in settlement analysis, as applicable). ***Virtual meeting was held on August 31, 2022. CPRA, NOAA, GLPC, Ardaman, and GISE participated in the discussion. Final target elevations for each Marsh Creation area were defined during this meeting.***

4. Draft and Final Geotechnical Data Report (for each completed phase as applicable to the marsh creation areas/fill material). ***(See Appendix D)***
5. Draft and Final Geotechnical Engineering Report (for each completed phase as applicable to the marsh creation areas/fill material); ***(See Appendix E)***
6. Updated engineer's estimate of probable construction costs. ***(See Chapter Four of this Technical Memorandum).***
7. Memo with figures demonstrating whether/how the Alternate Borrow Area technical evaluation criteria specified above have been met ***(This Technical Memorandum).***

CHAPTER TWO: PROPOSED ALTERNATE BORROW AREA DESCRIPTION

PROPOSED BORROW AREA LOCATION

The proposed alternate borrow area for the TE-134 project is shown below in **Figure 1**. It includes Flotation Canal, Bayou Lafourche, Belle Pass, and Slips A, B, C, and D. **Table 1** below shows specific locations and extents for each of the canals and channels inside the proposed borrow area.

Figure 1 – Proposed Alternate Borrow Area

Table 1 – Proposed Borrow Channels & Lengths

Borrow Channel	Length (ft.)
Flotation Canal - Sta. 600+00 to Sta. 697+00	9,700.00
Slip A - Sta. 0+00 to Sta. 22+10	2,210.00
Slip B - Sta. 0+00 to Sta. 72+61	7,261.00
Slip C - Sta. 0+00 to Sta. 69+99	6,999.00
Slip D - Sta. 0+00 to Sta. 39+00	3,900.00
Bayou Lafourche - Sta. 0+00 to Sta. 130+00	13,000.00
Belle Pass - Sta. 130+00 to Sta. 330+00	20,000.00
Total Borrow Length (ft.)	63,070.00

The proposed borrow area typical section will consist of a 300-foot wide bottom with side slopes at 2H:1V, with the exception of Slip D which will have a proposed borrow section with a 600-foot wide bottom with side slopes at 3H:1V. The proposed borrow depth for all channels inside the borrow area is -33.00 ft. MLLW (-33.61 ft. NAVD 88). Further details about borrow typical sections and available borrow material are included in Chapter Three of this Technical Memorandum.

BORROW AREA SURVEYS

Hydrographic surveys along Flotation Canal, Slips A, B and C, Bayou Lafourche, and Belle Pass (Sta. 130+00 to Sta. 270+00) were performed by GISE from September 14 through September 23, 2021. Surveying data for the remaining portion of Belle Pass within the proposed borrow area (Sta. 270+00 to 330+00) was obtained from the United States Army Corps of Engineers (USACE) routine soundings for this area. Survey data for this portion of Belle Pass was gathered on February 9, 2022. Hydrographic surveys along Slip D were performed by Delta Coast Consultants, LLC as part of the Slip D Dredging project. These surveys were performed on February 23, 2022, March 3, 2022, and June 27, 2022. All of the surveys, which were performed post Hurricane Ida (August 29, 2021), were used for the computation of available borrow volumes.

MAGNETOMETER SURVEY

A magnetometer survey along Flotation Canal, Bayou Lafourche, and Belle Pass was performed by GISE in April 2021. Survey equipment consisted of dual frequency fathometer, proton magnetometer, RTK GPS, and computer-based data collection/navigation system. GISE field crew ran multiple track lines parallel with the channel to investigate preselected boring locations provided by Ardaman. All final locations recommended and ultimately selected for the geotechnical borings were greater than 500 ft. away from any detected anomaly.

Survey results were further evaluated along with other existing survey data in the project area, including a Cultural Resources Assessment Report prepared by Earth Search, Inc. in November 2018, and a magnetometer survey performed by Delta Coast Consultants, LLC in May 2018. Both of these efforts were performed in support of the Port Fourchon Belle Pass Channel Deepening Project, Section 203 Feasibility Study. The Cultural Resources Investigation from 2018 identified two targets (Targets 1 & 2) as fitting the criteria for magnetic anomalies representing potentially significant resources. The locations of these targets (including anomalies M094, M095, M101, M102) were compared with the GISE magnetometer survey results (2021). Neither of the two target clusters identified were located in close proximity to any of the magnetometer hits from the GISE surveys.

A cleaner version of all magnetometer survey hits identified in the project area, including the cultural resources investigation target clusters, as well as known utilities located within the proposed alternate borrow area, has been included as part of this Technical Memorandum under Appendix F.

PIPELINE CROSSINGS EVALUATION

Pipeline crossings in the vicinity and within the proposed alternate borrow area were evaluated in order to assess possible conflicts at each pipeline crossing identified (Table 2).

Table 2 – Pipeline Crossings Evaluation

No.	Operator	Crossing Location	Size	Description	Depth	Pipeline Status	Crossing Conflict Status
1	**Unknown**	Sta. 610+00* (Flotation Canal)	12"	Gas (DNR) - no operator identified	Unknown	N/A	**NO CONFLICT *(UNCONFIRMED)***
2	**Unknown**	Sta. 614+00 (Flotation Canal)	Unknown	Unknown	Unknown	N/A	**NO CONFLICT *(UNCONFIRMED)***
3	**Unknown**	Sta. 108+00*	12"	Gas (DNR) - no operator identified	Unknown	N/A	**NO CONFLICT *(UNCONFIRMED)***
4	**Unknown**	Sta. 125+00**	12"	Gas (DNR) - no operator identified	N/A	N/A	**NO CONFLICT (CONFIRMED)**
5	**Kinder Morgan**	Sta. 137+50	6"	Gas Pipeline	-72.0 ft. MLG (-73.87 ft. NAVD 88)	Permanently Abandoned	**NO CONFLICT (CONFIRMED)**
6	**Rosefield Pipeline Company**	Sta. 138+11	10"	Crude Oil Pipeline	-50.0' MLG (-51.87 NAVD 88)	Active	**NO CONFLICT (CONFIRMED)**
7	**Unknown**	Sta. 147+00**	12"	Gas (DNR) - no operator identified	N/A	N/A	**NO CONFLICT (CONFIRMED)**
8	**Unknown**	Sta. 164+00*	12"	Gas (DNR) - no operator identified	Unknown	N/A	**NO CONFLICT *(UNCONFIRMED)***
9	**Chevron Pipeline**	Sta. 199+27	10"	Crude Oil Pipeline	-36.2 ft. MLG (-38.07 ft. NAVD 88)	Permanently Abandoned	**CONFLICT (CONFIRMED) "NO DREDGING" BUFFER WILL BE REQUIRED**
10	**Chevron Pipeline**	Sta. 215+00	6"	Crude Oil Pipeline (abandoned in place and later removed)	N/A	Permanently Abandoned	**NO CONFLICT (CONFIRMED)**
11	**Enlink Midstream**	Sta. 335+00	12"	Gas Pipeline	-40.0 ft. MLG (-41.87 ft. NAVD 88)	Permanently Abandoned	**NO CONFLICT (CONFIRMED)**

***Denotes Same Pipeline**
****Denotes Same Pipeline**

NO CONFLICT (UNCONFIRMED)
NO CONFLICT (CONFIRMED)
CONFLICT (CONFIRMED)

Previously gathered information for the Port Fourchon Belle Pass Channel Deepening Project, Section 203 Feasibility Study, as well as data obtained by available databases including the Department of Natural Resources (DNR) SONRIS, Bureau of Safety and Environmental Enforcement (BSEE), and the National Pipeline Mapping System (NPMS) was used for this effort; construction drawings developed by the USACE[1] to maintain the existing federal channel in Port Fourchon, were referenced as well. Additionally, an LA ONE CALL was placed for the proposed work area in an effort to obtain further information on the unconfirmed crossings identified during this evaluation.

Out of the 11 pipeline crossings identified within the proposed alternate borrow area, only *one* pipeline crossing was *confirmed* to be in conflict with the proposed work. Chevron, which is the current operator of the line, has issued an official letter stating the status of each of their assets currently crossing Bayou Lafourche and Belle Pass. The pipeline cover, from the proposed dredging depth to the existing pipeline in conflict, is around 4.5 ft, as per the latest construction documents prepared by the USACE for the upcoming maintenance dredging work in Bayou Lafourche and Belle Pass. A "NO DREDGING" buffer above this pipeline crossing will be included in the construction drawings.

For the remaining pipeline crossings evaluated, 6 were *confirmed* with the corresponding pipeline companies to pose no conflict to the proposed work. Confirmation of pipeline status (operator, location, depth, whether it's active/abandoned, etc.) for the remaining 4 pipeline crossings was unsuccessful, despite the efforts of reaching out to several pipeline companies in the project area (including several ONE CALL tickets placed for the proposed work area). *Unconfirmed* pipeline crossings were originally obtained from the USACE's navigation maps available in 2018. Current available databases, including the latest USACE's navigation maps (2022), do not show the presence of these pipelines within the proposed alternate borrow area.

Detailed current status notes for each pipeline crossing evaluated, as well as proof of ONE CALL tickets placed for the proposed work area, can be found under Appendix G of this Technical Memorandum.

[1] USACE's construction documents for Solicitation No. W912P822B0031, Port Fourchon Navigation Channel, Maintenance Dredging #22-2.

CHAPTER THREE: ALTERNATE BORROW AREA FEASIBILITY

This section is organized according to the criteria set forth in the IGA described above in Chapter One.

CRITERIA A.I. COMPARABLE SETTLEMENT CURVES

Previous percent marsh inundation calculations developed by CPRA were revised to reflect the most-up-to date construction schedule of the project and its corresponding sea level rise. Additionally, the previously gathered water data was revised to reflect a modified 5-year epoch as per NOAA's recommendations for projects located in the Gulf of Mexico's vicinity. The new period of evaluation includes water data from August 17, 2016 through August 16, 2021. Water data was obtained from CRMS Station 0292. Mean High Water (MHW) and Mean Low Water (MLW) values were also recalculated to reflect the updated water data. Table 3 below shows summary of percent inundated marsh at Target Year (TY) 0 (2023) and TY20 (2043).

Table 3 – Percent Inundation Elevations for TY0 and TY20

Percent of Inundated Marsh	Elevation (ft. NAVD 88) TY0 (2023)	Elevation (ft. NAVD 88) TY20 (2043)
10%	1.240	1.733
20%	**0.980**	**1.473**
30%	0.800	1.293
40%	0.640	1.133
50%	0.480	0.973
60%	0.310	0.803
70%	0.120	0.613
80%	**-0.090**	**0.403**
90%	-0.380	0.113
MHW (ft. NAVD 88, GEOID 12A)	1.098	1.592
MLW (ft. NAVD 88, GEOID 12A)	-0.207	0.287
MTL (ft. NAVD 88, GEOID 12A)	0.446	0.939
Gulf Regional Sea Level Rise (ft. NAVD 88)	0.000	0.493

GLPC contracted Ardaman to perform extensive geotechnical data collection and analyses at the alternate borrow area. As part of this effort, Ardaman created fill settlement curves for each MCA to include the use of the alternate borrow material as fill for the construction of the MCAs. Percent inundation calculations were developed to determine optimal marsh elevation range which is needed for proper selection of the target fill at the marsh creation areas. Settlement curves were overlaid with the 20% and 80% inundation curves in order to provide a convenient visual determination of how long fill, at various target elevations, would remain in the optimal elevation range. On August 31, 2022, a virtual meeting was held with GLPC, CPRA, NOAA, Ardaman and GISE to review the draft settlement curves and reach a consensus decision on target elevation for each fill area. The results of this discussion are summarized in Table 4 below and are compared to

CPRA's 95% design report values. Detailed description and calculations are provided in Ardaman's final geotechnical engineering report included under **Appendix E** of this Technical Memorandum.

Table 4 – 95% Design Report vs. Ardaman Alternate Borrow Target Elevations

Marsh creation area	95% target elevation (ft. NAVD 88)	95% tolerance (ft.)	Years in target range	Alternate borrow target elevation (ft. NAVD 88)*	Alternate borrow tolerance (ft.)	Years in target range
MCA-1	+2.0	-0.5	1-20+	+1.75	+/- 0.25	1-20+
MCA-2	+2.0	-0.5	1-20+	+2.25	+/- 0.25	1-20+
MCA-3	Not provided	Not provided	Not Provided	+1.60	+/- 0.25	1-20+

*Subsidence after 20 years is estimated to be 0.42 ft for all MCAs, and mudline consolidation/foundation settlement range between ≈3 to ≈10 inches depending on each case, target fill elevation, and MCA.

Fill settlement curves for MCA-1, MCA-2, and MCA-3 can be found below for both Case 1 (0.5 ft. fill/10 days) and Case 2 (1.0 ft. fill/10 days). During the August 31, 2022 virtual meeting, Case 1 (slower fill placement rate - 0.5 ft/ 10 days) was collectively selected as the more applicable case for this project. The settlement curves shown for MCA-1 (**Figure 2**, **Figure 3**) and MCA-2 (**Figure 4**, **Figure 5**) have Ardaman's 2022 curves overlaid with the 2018 95% design report curves and both the 2022 and 2018 inundation curves with ESLR. The settlement curves shown for MCA-3 (**Figure 6**, **Figure 7**) show Ardaman's 2022 curves and the new inundation curves with ESLR. For visualization purposes, settlement curves that coincide with the MCA-3 projected target elevations (+1.60 ± 0.25 ft. NAVD 88) were linearly interpolated from the +1.50 and +2.00 ft. NAVD 88 curves that Ardaman provided. Additionally, the curves that coincide with the projected target elevations from **Table 4** are called out in the figure.

Ardaman's 2022 mudline elevation settlement curves are also shown, which considers both subsidence and compaction. For their settlement analysis with PSDDF, initial mudline elevations for MCA-1, MCA-2, and MCA-3 were -0.6, -0.5, and -0.1 ft. NAVD 88, respectively. These initial elevations represent the average surveyed mudline elevation for each MCA.

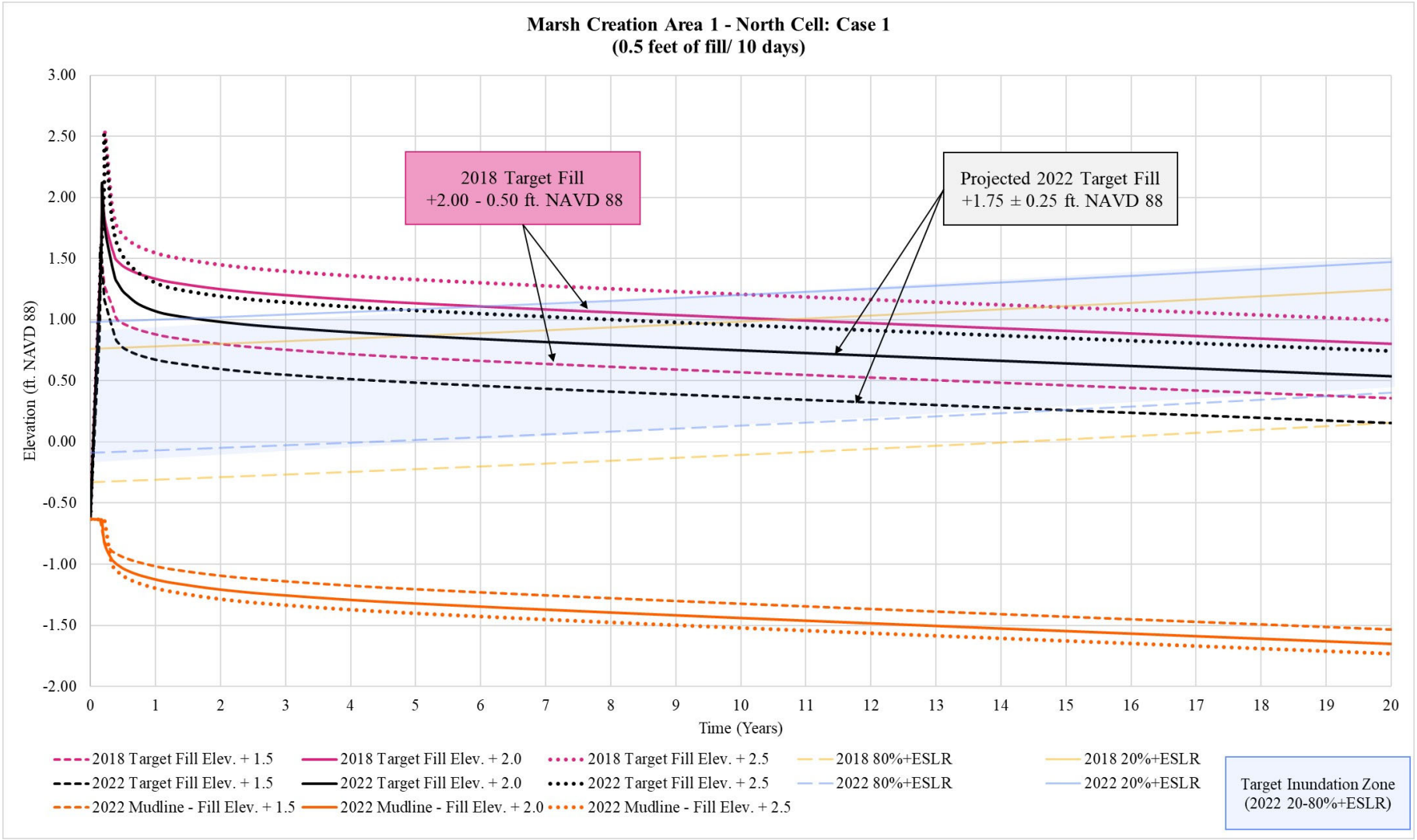

Figure 2 – MCA 1 Fill Settlement Curves: Case 1

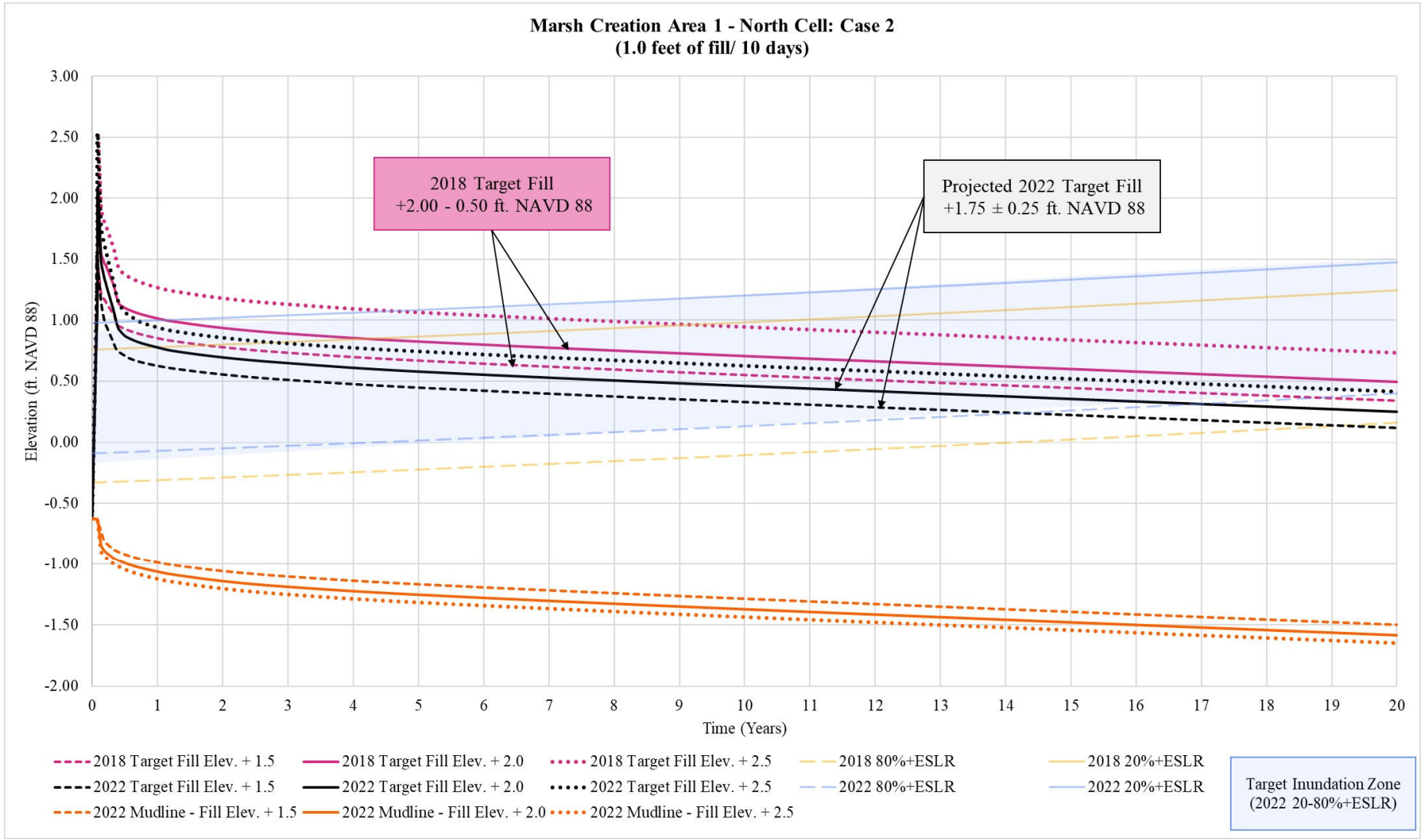

Figure 3 – MCA 1 Fill Settlement Curves: Case 2

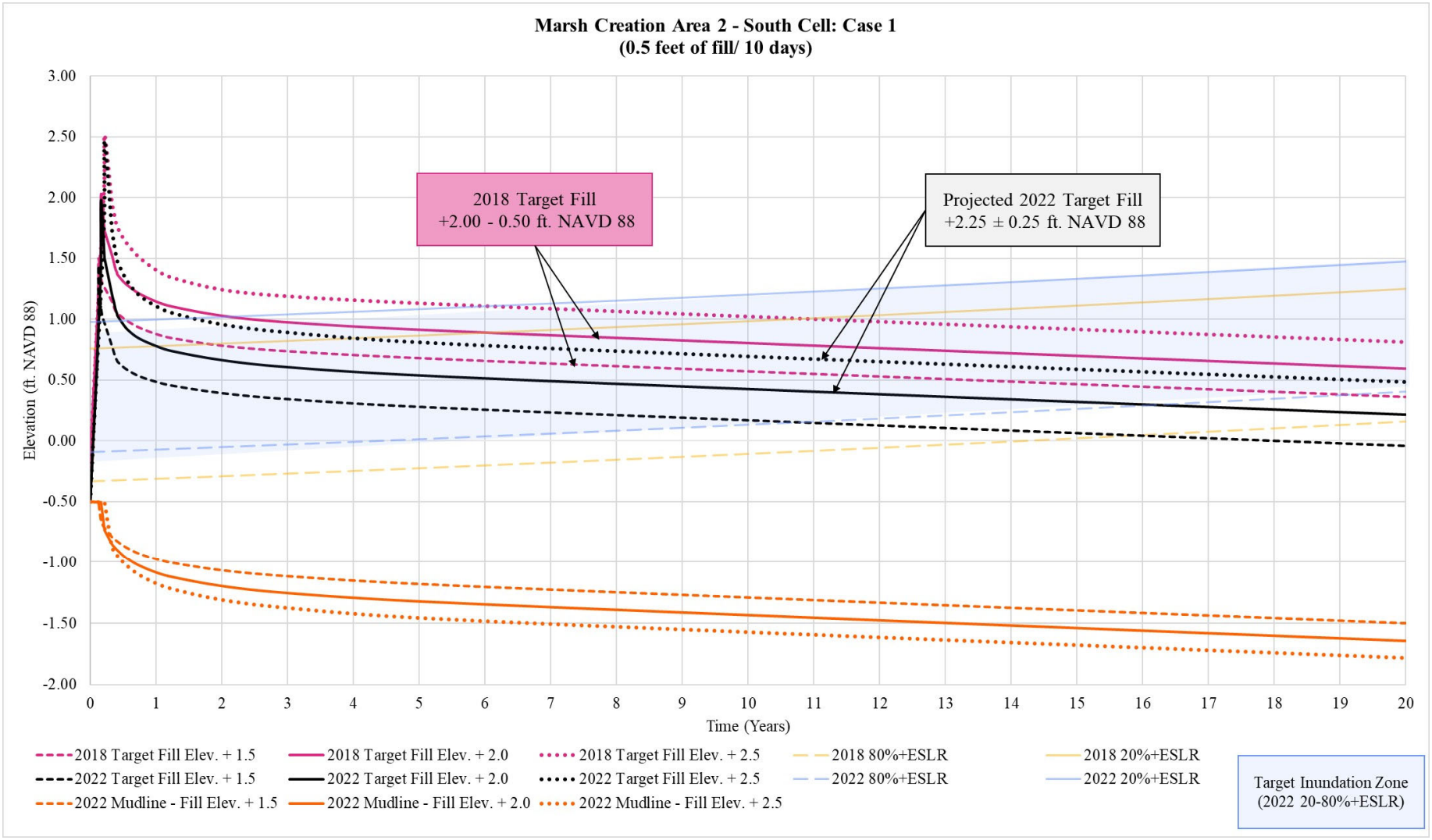

Figure 4 – MCA 2 Fill Settlement Curves: Case 1

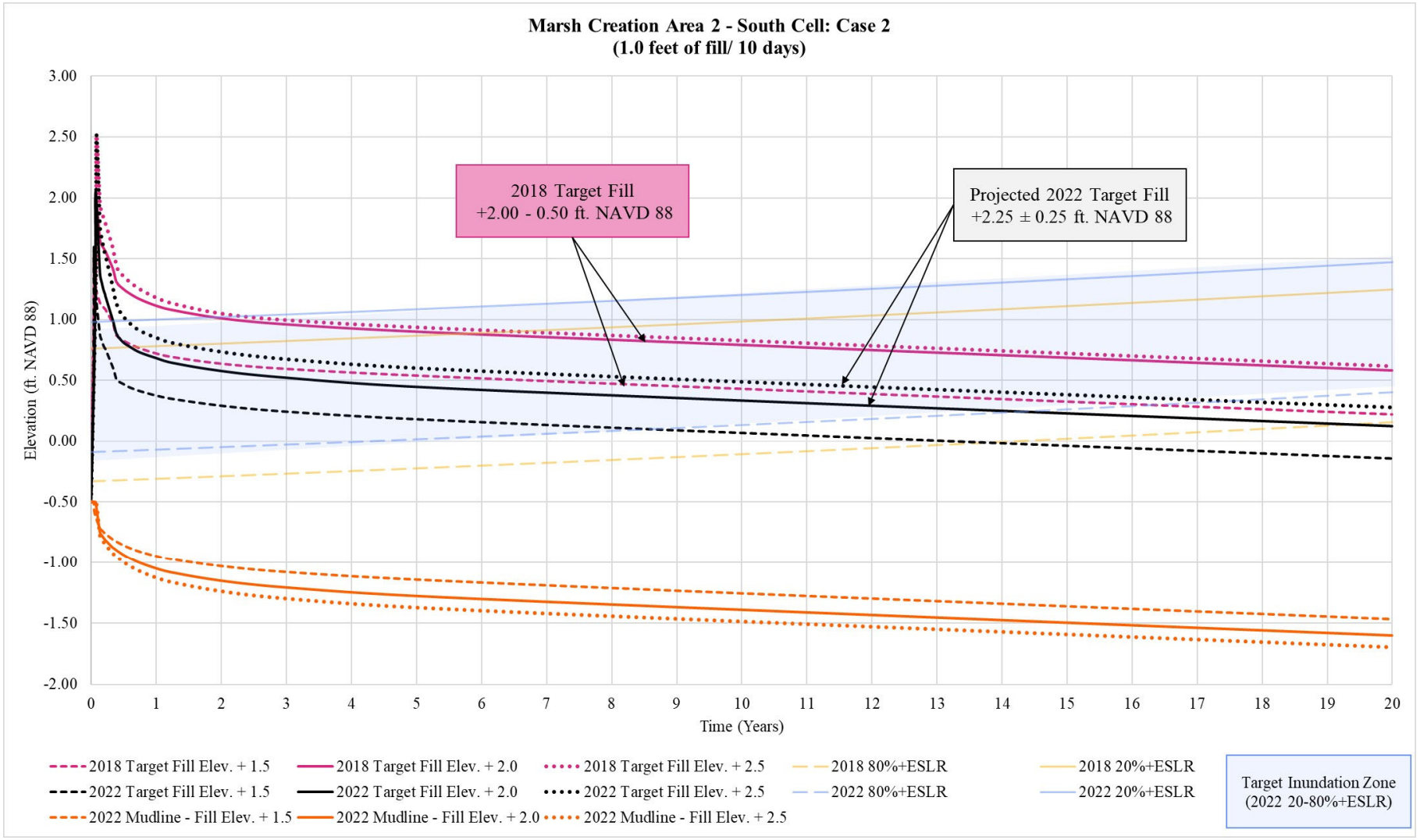

Figure 5 – MCA 2 Fill Settlement Curves: Case 2

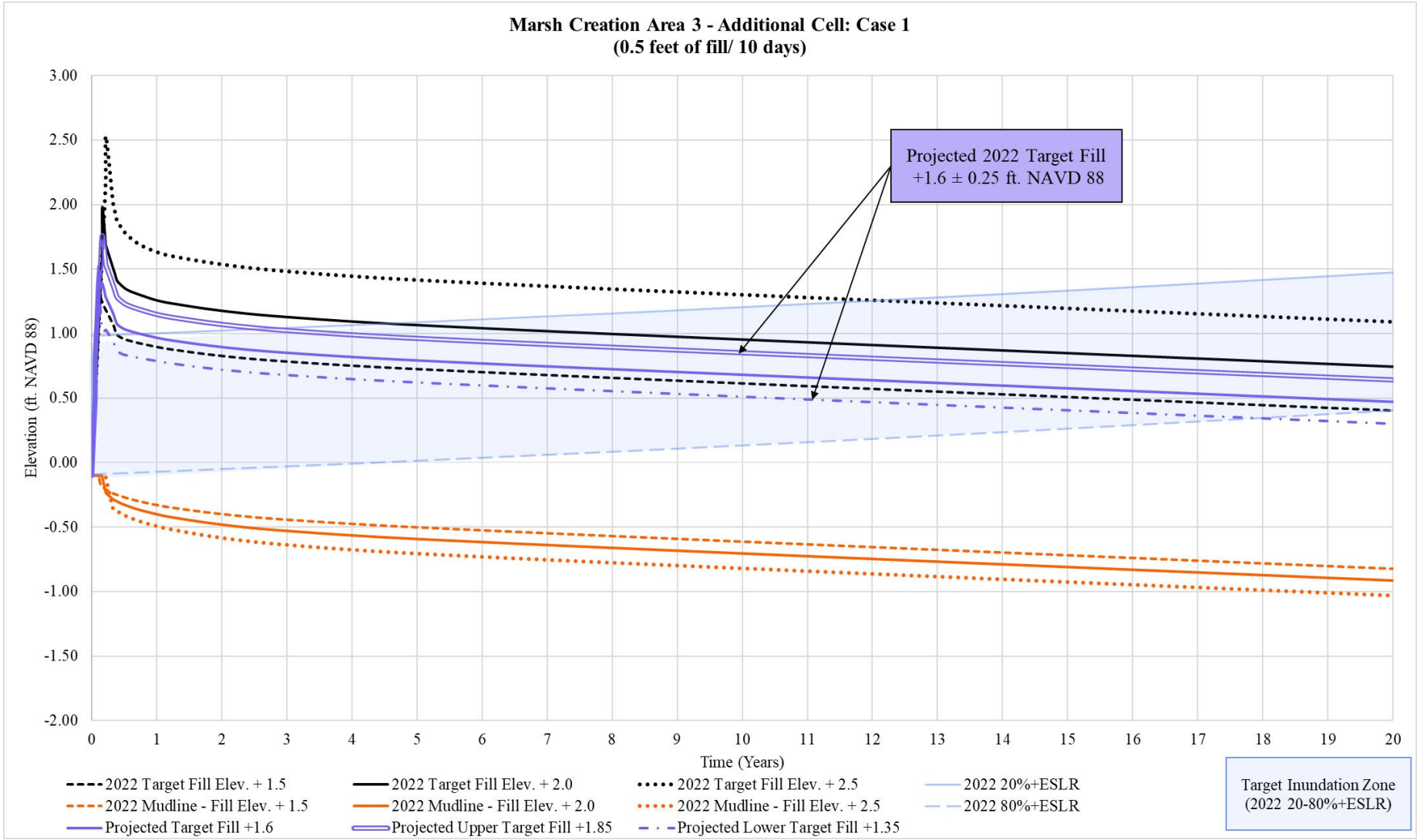

Figure 6 – MCA 3 Fill Settlement Curves: Case 1

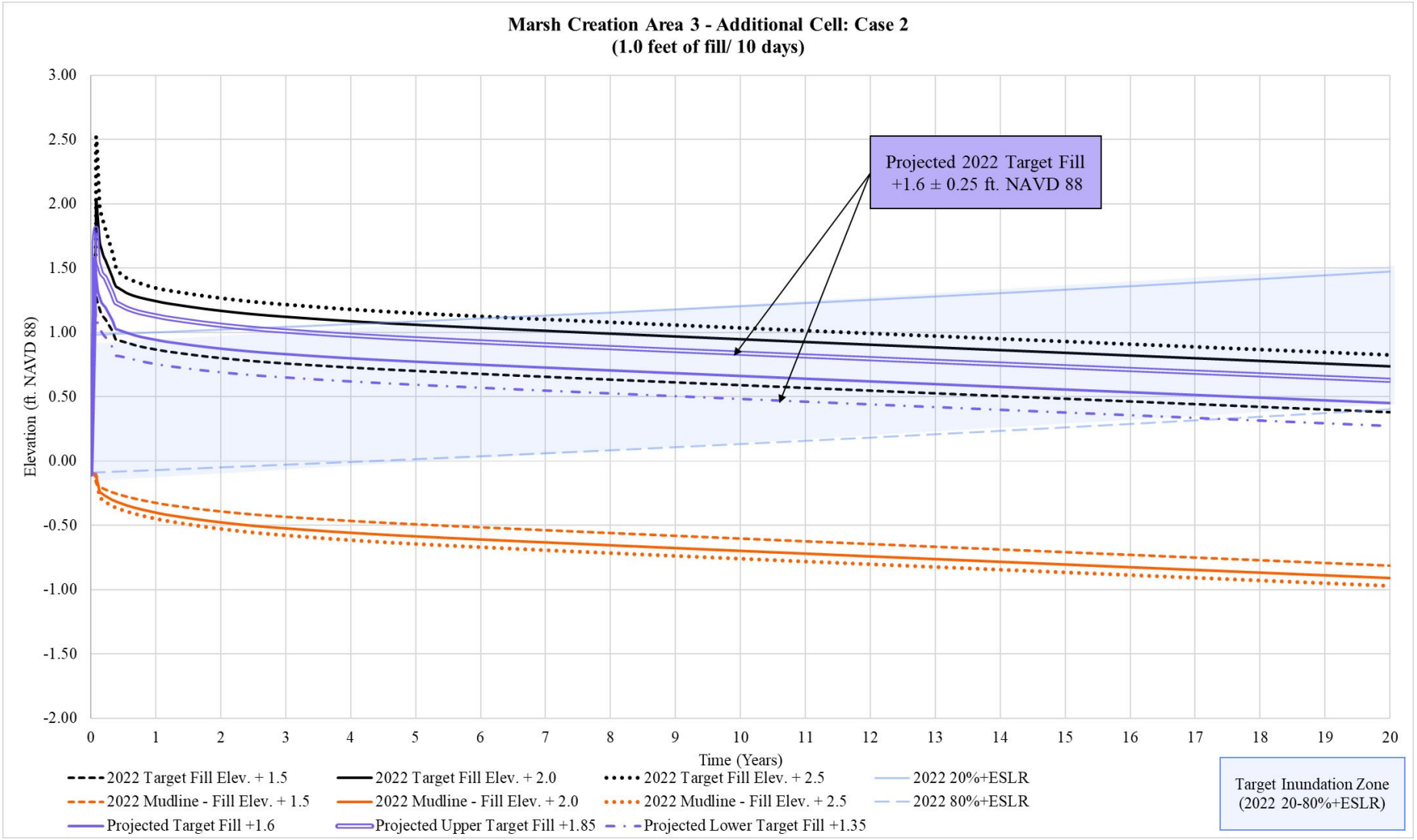

Figure 7 – MCA 3 Fill Settlement Curves: Case 2

CRITERIA A.II. EARTHEN CONTAINMENT DIKES (ECD)

As part of their Geotechnical Investigation, Ardaman performed a series of stability analyses to determine a satisfactory geometry for the ECDs that would comply with the minimum design factor of safety. All of the cases considered a 5 ft. wide crest width and a 20 ft. wide bench offset from the edge of the ECD toe to the edge of the borrow excavation, unless otherwise specified. Cases were evaluated against the target minimum factor of safety of 1.20 recommended in the geotechnical standards established by CPRA[2].

Slope stability analyses for the proposed ECDs focused on three cases: global stability check during borrow excavation (Case A-1), local stability check during borrow excavation with construction equipment surcharge (Case A-2), and global stability during marsh construction with fluid level at berm crest (Case A-3). **Table 5** below summarizes relevant ECD geometries for each marsh creation area and the corresponding factor of safety determined in the slope stability analyses performed by Ardaman[3]. In their report, Ardaman recommended a 25 ft. wide bench offset between the ECD toe and the borrow area in all marsh creation areas, a minimum side slope of 4H:1V for MCA-1 and MCA-2, and a minimum side slope of 5H:1V for MCA-3.

Table 5 – ECDs Slope Stability Analysis Summary

Marsh Creation Area	Average Mudline Elevation (ft. NAVD 88)	Crest Elevation (ft. NAVD 88)	ECD Side Slopes	Case Number	Minimum Factor of Safety
MCA-1	-0.6	+3.0	4H:1V	A-1	1.58
				A-2	1.29
				B	1.58
MCA-2	-0.5	+3.5	4H:1V	A-1	1.27
				A-2	1.23
				B	1.27
MCA-3 Average	-0.1	+3.0*	4H:1V	A-1	1.20
				A-2	1.13/1.39**
				B	1.20
MCA-3 Low	-4.0	+3.5*	5H:1V	A-1	1.40
				A-2	1.06/1.39**
				B	1.22

*Target elevation for MCA-3 has been defined at +2.85 ft. NAVD 88, so factor of safety will be slightly higher than those shown for a crest elevation at +3.5 ft. NAVD 88.

**For the A-2 cases, a 25 ft. wide bench offset was considered in order to meet the minimum factor of safety of 1.20.

[2] CPRA Marsh Creation Design Guidelines

[3] Appendix E of this Technical Memorandum

ECDs were tailored across the alignment to reflect the minimum required dimensions. **Table 6** below shows the selected design ECD geometries, side slopes, maximum crest elevations, and bench offset widths chosen for each MCA. ECD crown elevations were selected based on the target construction marsh fill elevation at each MCA plus the upper range of the ±0.25 ft. tolerance allowed for the marsh fill and the 1-foot freeboard as previously set forth by CPRA.

Table 6 – Selected TE-134 Alternate Borrow Design Geometry of ECDs

Marsh Creation Area	Average Mudline Elevation (ft. NAVD 88)	Max. Crest Elevation (ft. NAVD 88)	ECD Side Slopes	Bench Offset (ft.)
MCA-1	-0.6	+3.50	4H:1V	25
MCA-2 Average	≥ -0.5	+4.00	4.5H:1V	25
MCA-2 Below Average	< -0.5	+4.00	5H:1V	25
MCA-3 Average	≥ -0.1	+3.35	4H:1V	25
MCA-3 Below Average	< -0.1	+3.35	5H:1V	25

For MCA-1, a uniform cross-section will be used with side slopes of 4H:1V. For MCA-2, stations with mudline elevations at or above the calculated average elevation (EL -0.5 ft. NAVD 88) will have cross-sections with 4.5H:1V side slopes, and stations with below average mudline elevations will have cross-sections with 5H:1V side slopes. For MCA-3, stations with mudline elevations at or above the calculated average elevation (EL -0.1 ft. NAVD 88) will have cross-sections with 4H:1V side slopes, and stations with below average mudline elevations will have cross-sections with 5H:1V side slopes. For all MCAs, a 25 ft. bench offset will be observed.

To build the ECDs, material will need to be excavated from a borrow area within the marsh creation area. Cut-to-fill ratios are used to estimate the volume of the excavation area needed to fill the design volume of the ECD, while accounting for material "lost" during excavation or during or after placement of material (e.g. undrained settlement, material sloughed off during placement, organic soils drying once placed above water line). ECD design dimensions for the borrow area include a 2H:1V borrow excavation side slopes and a 10 ft. wide excavation bottom. For all MCAs, the maximum cut elevation for the ECD borrow will be at EL -10 ft. NAVD 88. These dimensions were conservatively designed to ensure enough material is available during construction for maintenance purposes.

After initial review of the November 15, 2022 technical memorandum, the size of the ECD borrow areas were revised to ensure enough material is available if the ECDs are constructed to the upper tolerance (+0.5 ft.) and as needed for maintenance purposes during construction. Updated slope stability analyses to evaluate the revised borrow areas were performed by Ardaman (February 16, 2023 and March 3, 2023) and can be found in **Appendix E.** Results of these analyses are summarized in **Table 7** below. The three of the updated analyses represent 'worst-case' scenarios for each MCA assuming conditions for Case A-2: Construction Equipment (260 psf) and the lowest

mudline elevations found in each cell (February 16, 2023). Three additional analyses were considered with the same borrow geometry and Case A-2 but with the average mudline elevations found in each cell. The changes in factor of safety were minor, and the minimum required factor of safety has been achieved for all conditions evaluated.

Table 7 – ECD Borrow Geometry and Factor of Safety

Marsh Creation Area	Max Dredge Elevation (ft. NAVD 88)	Borrow Side Slopes	Case Number	Mudline Elevation	Mudline Elevation (ft. NAVD 88)	Computed Factor of Safety
MCA-1	-10	2H:1V	A-2	Lowest	-5.1	1.291
				Average	-0.6	1.454
MCA-2	-10	2H:1V	A-2	Lowest	-4.6	1.495
				Average	-0.5	1.433
MCA-3	-10	2H:1V	A-2	Lowest	-4.0	1.390
				Average	-0.1	1.299

ECD borrow excavation volumes and cut-to-fill ratios are shown in **Table 8** for each MCA. Design fill volumes are shown in cubic yards per linear foot of dike (CY/LFT). Detailed fill and borrow calculations for the construction of the ECDs are included under **Appendix H** of this Technical Memorandum. Note that these design volumes include the allowable +0.5 ft. construction tolerance at the dike's crown. ECD volumes created were calculated using survey data and assumes 2H:1V borrow excavation side slopes and a 10 ft. wide excavation bottom.

Table 8 – ECD Borrow Excavation Volumes and Cut-to-Fill Ratios*

Marsh Creation Area	ECD Fill Volume (CY)**	ECD Cut-to-Fill Ratio***	Total Volume Created by ECD Borrow (CY)	ECD Length (LFT)	Design ECD Fill Volume (CY/LFT)
MCA-1	46,350	1.91	88,528	18,239	4.9
MCA-2	36,733	1.90	69,793	18,325	3.8
MCA-3	38,421	1.99	76,458	17,176	4.5

*Information found in Appendix H of this Technical Memorandum

**ECD fill volumes are based on post-Ida survey and ECD geometry detailed in Table 6

***CTFR of 1.90-1.99 was determined by the geotechnical engineer and was used for calculation of design fill volumes

Fill placement is recommended to be undertaken in successive horizontal lifts that encompass the entire dike and should be limited to heights that do not cause excessive local subsidence or mud-waving. Additionally, the borrow excavation volume for the dike will need to be accessible to an excavator situated within the 25 ft. wide bench offset between the dike and borrow excavation. It is anticipated that a sufficient volume of borrow materials could be accessed using a conventional marsh-compatible long -reach excavator (center-pin reach of 60 ft.).

CRITERIA B. SUITABLE AVAILABLE BORROW MATERIAL

The total volume of cut required from the alternate borrow area to construct MCA-1 & MCA-2 is estimated at 2,014,165 cubic yards (CY). This value represents the average of different volume calculation methods used by the GIS and CPRA design teams. The geotechnical engineer calculated a cut-to-fill ratio (CTFR) of 0.85 for the borrow material based on the in-situ and fill material void ratios; however, based on the experience of the design team with similar marsh creation projects, a more conservative CTFR of 1.00 to 1.10 was used to calculate the final required borrow volumes. Marsh creation area cut volumes are provided in **Table 9**. Detailed fill and borrow calculations are included under **Appendix H** of this technical memorandum.

Table 9 – Marsh Creation Area Cut Volumes

		MCA-1 & MCA-2	MCA-3	All MCAs
Average Mudline Elevation	(ft. NAVD 88)	-0.6 / -0.5	-0.1	-
Target Fill Elevation*	(ft. NAVD 88)	+2.00 / +2.50	+1.85	-
Area Created	(acres)	537	277	814
Fill Volume Method		**Borrow Area Cut Volume Required (CY)****		
CPRA 20yr Fill EL (Excel Method)		2,010,659	-	-
GIS 20yr Fill EL (Excel Method)		1,977,805	679,438	2,657,244
GIS 20yr Fill EL (CAD TIN Surface Method)***		1,894,581	711,870	2,606,452
GIS CMFE (CAD TIN Surface Method)****		2,173,610	825,936	2,999,546
Average Cut Volume Required		**2,014,165**	**713,847**	**2,728,012**
Average Volume/Area Created	(CY/acre)	3,751	2,577	3,351

* Includes 0.25 ft of upper marsh fill tolerance

**Volumes (CY) include Marsh Fill + ECD Volume Created with a CTFR of 1.1 (20yr Fill EL) or 1.0 (GIS CMFE)

*** Uses CPRA's Post-Ida Survey TIN Surface with minor corrections at MCA-2.

****Construction Marsh Fill Elevations (CMFE) conservatively include 0.25 ft. for allowable fill construction tolerance

Table 10 summarizes available volume material for each proposed borrow channel, based on the latest surveys and upcoming dredging projects in Port Fourchon. The total volume of cut required for all three MCAs is estimated to be 2,728,012 CY, which is less than the total volume available in the alternate borrow area (4,700,848 CY). Therefore, the alternate borrow area has enough available volume to successfully fill all three marsh creation areas and their respective ECD borrow areas.

Table 10 – Available Material at Alternate Borrow Area

Channel	West Fourchon Marsh Creation Project (TE-134) - Available Dredge Material at Alternate Borrow Area				
	Channel Width (ft.)	Channel Side Slopes	Dredge Depth (ft. NAVD 88)	Survey Date	Volume Available (Cubic Yards)
Flotation Canal (Sta. 600+00 to 697+00)[4]	300.0	2H:1V	-33.61	9/23/2021	608,749
Slip A	300.0	2H:1V	-33.61	9/14/2021	246,668
Slip B	300.0	2H:1V	-33.61	9/15/2021	693,102
Slip C	300.0	2H:1V	-33.61	9/20/2021	504,648
Slip D	600.0	3H:1V	-33.61	2/23/2022, 3/3/2022, 6/27/2022	1,176,116
Bayou Lafourche (Sta. 0+00 to 60+00)	300.0	2H:1V	-33.61	9/23/2021	358,573
Bayou Lafourche/Belle Pass (Sta. 60+00 to 240+00)[5]	300.0	2H:1V	-33.61	9/23/2021	898,250
Belle Pass (Sta. 240+00 to 330+00)[6]	300.0	2H:1V	-33.61	9/23/2021, 2/9/2022	214,741
				Total Material Available	4,700,848
				Borrow Material Required for MCA-1 & MCA-2	2,014,165
				Borrow Material Required for MCA-3	713,847
				Total Borrow Material Required for MCA-1, MCA-2, & MCA-3	2,728,012

CRITERIA C. CWPPRA ENGINEERING WORKGROUP APPROVAL

The final criteria required for approval of the alternate borrow area is approval from the CWPPRA Engineering Workgroup. While this document provides justification for use of the alternate borrow area, GLPC and GISE will continue to support CPRA and NOAA in securing timely review and approval from the CWPPRA Engineering Workgroup.

[4] Available volume includes deduction of 633,000 CY to be dredged under GLPC's Project Number M2003.
[5] Total available volume assumes federal channel is maintained to a depth of -27.0' MLG, as per USACE's construction documents for Solicitation No. W912P822B0031.
[6] Total available volume assumes federal channel is maintained to a depth of -30.0' MLG, as per USACE's construction documents for Solicitation No. W912P822B0031.

CHAPTER FOUR: CONSTRUCTION COSTS

CPRA provided the 95% design cost estimate, which was updated in September of 2019. Since the COVID19 pandemic and major hurricane events[7] impacting the southern Louisiana coast in 2020 and 2021, construction cost estimating has been extremely challenging. Prices for almost every category of construction materials increased drastically between supply shortages during the pandemic and demand afterwards. In order to provide a realistic comparison of construction costs between the nearshore borrow option and alternate borrow option, an analysis was made to compare the two options as well as to estimate price inflation since 2019 (**Table 11**).

Table 11 – Factors Affecting Unit Rate Changes for Alternate Borrow Area Compared to Nearshore Borrow Area

Major Line Item	Increase/ Decrease	Drivers	Likely source cost change
Mobilization	Decrease	▪ Smaller equipment ▪ Potentially less total length of dredge pipe ▪ Fewer booster pumps	▪ More potential bidders ▪ Less/smaller equipment
Dredging Unit Rate	Decrease	▪ Lower average pumping distance	▪ Decreased fuel consumption ▪ Smaller equipment ▪ Lower personnel count
Dredging Unit Rate	Increase	▪ More downtime because dredging is in heavy marine traffic area	▪ Increased time for personnel and equipment on site
Containment Dike Unit Rate	No Change	▪ Similar equipment, staffing, production rate	▪ No change

[7] Hurricane Laura which made landfall on Cameron, Louisiana, on August 27, 2020, and Hurricane Ida making landfall near Port Fourchon on August 29, 2021.

The key unit rates driving overall construction cost are dredging unit rate and mobilization, taking up 89% of the total construction cost or 62% and 27% respectively. The containment dike is also a significant item, comprising 7% of the September 2019 cost estimate. While the containment dike volume will change slightly with varying fill target elevations, there is no driver for unit price changes. Therefore, the containment dike unit rates were left constant between the two scenarios.

From CPRA's technical specifications, mobilization includes "all labor and equipment necessary to move personnel, equipment, construction materials (including dredge pipeline), and incidentals to and from the Project Site". Table 12 below shows the 95% design cost estimate developed by CPRA in 2019 for the nearshore borrow option. Switching from nearshore borrow to the Port Fourchon alternate borrow should affect the mobilization price in the following ways: The Port Fourchon alternate borrow will allow for smaller dredges and/or fewer booster pumps compared to the nearshore option, which subsequently increases the number of potential bidders. Depending on the successful bidder's strategy, the alternate borrow option could reduce the total length of dredge pipe mobilized to the project. All of these factors are expected to drive the mobilization cost down, compared to the nearshore option.

Drivers expected to decrease dredging unit rate are: reduced fuel consumption due to lower pump distance, potentially lower personnel count for a smaller dredge operation, and potentially lower capital cost for a smaller dredge operation. Drivers that tend to increase the dredging unit rate are: potential increased time on the job due to a smaller dredge's lower production rate, and increased time on the job due to downtime from operating in a heavy traffic area.

Table 12 – September 2019 Cost Estimate Provided by CPRA

Project:	TE-0134 West Fourchon Marsh Creation and Marsh Nourishment	Date:	25-Jun-18	Revised:	6-Sep-19
Computed by:	Thomas McLain, E.I.	*Project Priority List 29 (ver.061419)*			
Item No.	**Work or Material**	**Quantity**	**Unit**	**Unit Cost**	**Amount**
1	Mobilization/Demobilization	1	LS	$5,251,349	$5,251,349
2	Marsh Creation & Nourishment (w/dike backfill)	1,659,052	CY	$7.25	$12,028,127
3	Nesting Bird Abatement (DPL Beach Crossing)	10	Day	$1,000	$10,000
3	Containment Dikes	103,821	CY	$12.51	$1,298,801
4	Settlement Plates	6	Each	$3,000	$18,000
5	Instrumented Settlement Plates	4	Each	$12,100	$48,400
9	Construction Surveys	1	LS	$804,200	$804,200
ESTIMATED CONSTRUCTION COST					$19,458,877
ESTIMATED CONSTRUCTION + 15% CONTINGENCY					$22,377,708
EFFECTIVE UNIT RATE (INCLUDES CONTINGENCY)					$13.49/CY

RECENT BIDS

Recent bids from 2021 and 2022 were analyzed in order to better estimate the project cost (**Table 13**). Since unit rates and other variables were not always available, the total contract cost was divided by the total dredging volume to get an "effective unit rate". Recent projects came from Port of Iberia, CPRA bid tabulations downloaded from coastal.la.gov and from the USACE maintenance dredging program. Effective unit rates ranged from $7.07/CY to $21.02/CY. The Grand Cheniere Marsh Creation Project had the highest effective unit rate of $21.02/CY for the base bid, however, it was the most complex project with other significant bid items that were not directly related to marsh creation. Excluding these higher priced line items, the effective unit rate is estimated to be $15.70/CY. The project with the second highest effective unit rate was the smallest in size, with a total volume significantly lower than the others, and had an effective unit rate of $16.18/CY. Both of these factors (other significant bid items and small dredging quantity) should tend to increase the effective unit rate of these projects. The USACE Port Fourchon Navigation Channel Maintenance Dredging project, bid in August 2022, had the lowest effective unit rate at $7.07/CY. This project is very relevant since it consists of dredging a portion of the navigation channel located within the proposed alternate borrow area; however, it lacks other features such as containment dikes and fill area management.

Table 13 – Recent Project Bids

Project/Date	Dredge Volume (CY)	Unit Rate[8] ($/CY)	Mobilization [9]	Effective Unit Rate ($/CY)
Mid-Breton Land Bridge / March 2023	1,935,780 CY 351,800 CY	Base bid: $7.19/CY Additive: $9.65/CY	N/A	Base bid: $10.54/CY Additive: $13.45/CY
CPRA South Pass Bird Island Project / October 2022	82,000 CY	$7.65/CY $14.00/CY	$335,000 $870,000	$16.18/CY
USACE Port Fourchon Navigation Channel Maintenance Dredging / August 2022	650,000 CY	$5.20/CY	$1,000,000	$7.07/CY
CPRA Grande Cheniere Marsh Creation / June 2022	2,787,200 CY + substantial ancillary features	$15.25/CY $14.90/CY	$7,250,000 $18,300,000	Base bid: $21.02/CY Alternatives: $15.70 - $15.70/CY
Port of Iberia AGMAC Channel Dredging – Phase 1/ October 2021	1,302,925 CY + substantial ancillary features	$5.41/CY	$1,574,000	$8.37/CY

[8] First unit rate shown represents unit rate from lowest responsive bidder. Second unit rate shown represents average unit rate from all bids received.

[9] First mobilization cost shown represents cost from lowest responsive bidder. Second mobilization cost shown represents average mobilization cost from all bids received.

Additional cost information, publicly available, from the USACE dredging information system was analyzed[10]. The FY 2021 Dredging Contract Awarded Report provides a spreadsheet with dredging contracts awarded in FY 2021. The information provided includes District, job name, dredge type (hopper, pipeline, bucket etc.), dates (bid, award, advertisement), cubic yards bid, government cost estimate, winning bid total, winning bidder, number of bids received, contract type etc. In order to normalize the dredging cost rate, the winning bid total was divided by the cubic yards in order to create an effective unit rate. It is assumed that the effective unit rate includes all contract items such as mobilization, disposal, contractor surveys, navigation safety etc.

In FY 2021, the USACE awarded 94 dredging contracts nationwide. The New Orleans District Awarded six, of which two are hopper dredge projects and four are pipeline dredge projects. Select information from the New Orleans District pipeline dredging projects are provided below (Table 14).

Table 14 – New Orleans District Pipeline Dredging Projects

	NOH & VARIOUS BARS 3-21	ATC BASIN/GIWW/OLD IDIQ FY21	CALC MI 17-36/DEVL'S ELBO	HOUMA NAV CANAL BAY & BAR CY	SELECTED AVERAGES
DISTRICT	MVN-NEW ORLEANS	MVN-NEW ORLEANS	MVN-NEW ORLEANS	MVN-NEW ORLEANS	
DT	P	P	P	P	
BID DATE	6/24/2021	7/15/2021	9/2/2021	6/15/2021	
AWARD DATE	05/05/2021; 07/01/2021	7/13/2021	7/20/2021	7/23/2021	
ADV DATE	4/19/2021	6/15/2021	8/3/2021	3/9/2021	
CUBIC YARDS	1,032,036	2,200,000	4,500,000	2,727,569	2,614,901 CY
GOVT EST.	$7,981,665.00	$21,947,597.00	$40,403,344.00	$10,489,680.00	$20,205,572
WINNING BID	$7,684,200.00	$18,270,800.00	$37,035,608.00	$14,703,500.00	$19,423,527
WINNING BIDDER	WEEKS MARINE, INC.(GULF)	WEEKS MARINE, INC.(GULF)	CROSBY DREDGING LLC	WEEKS MARINE, INC.(GULF)	
# BIDS	3	2	2	2	
Eff. Unit Rate	$ 7.45	$ 8.30	$ 8.23	$ 5.39	$ 7.34
				STANDARD DEVIATION	$ 1.18
				UPPER BOUND 95%	$8.50

The effective unit rate for these four projects ranged from $5.39/cubic yard to $8.30/cubic yard. The average effective rate of the four selected projects in 2021 is $7.34/cubic yard with a standard deviation of $1.18. The upper bound of the 95% confidence interval is $8.50/cubic yard.

ACTUAL DREDGING COST DATA FOR 1963-2020

A second dataset, also downloadable as a spreadsheet is available on the Dredging Information System Website. The Actual Dredging Cost Data for time periods between 1963-2020 dataset provides multiple tabs of data as well as summary charts[11]. The data includes a long-term analysis of dredging totals in the United States from 1963 to 2020. The information provided is separated into USACE work, industry work, and combined totals (sum of corresponding USACE and industry value for that item) (Figure 8). The data is further divided into maintenance work, new work and combined totals. For each, total dollars and total cubic yards are provided. In order to normalize the totals, GISE divided the dollar totals by the cubic yards totals to generate an average effective unit rate for each item and year. Figure 8 shows a time series of the calculated effective unit rates.

[10] https://publibrary.planusace.us/#/document/51781df4-7ed3-4791-9988-5f30c1d0a3a1
[11] https://publibrary.planusace.us/document/6b825723-ba67-4233-e7d9-cfd576096d51

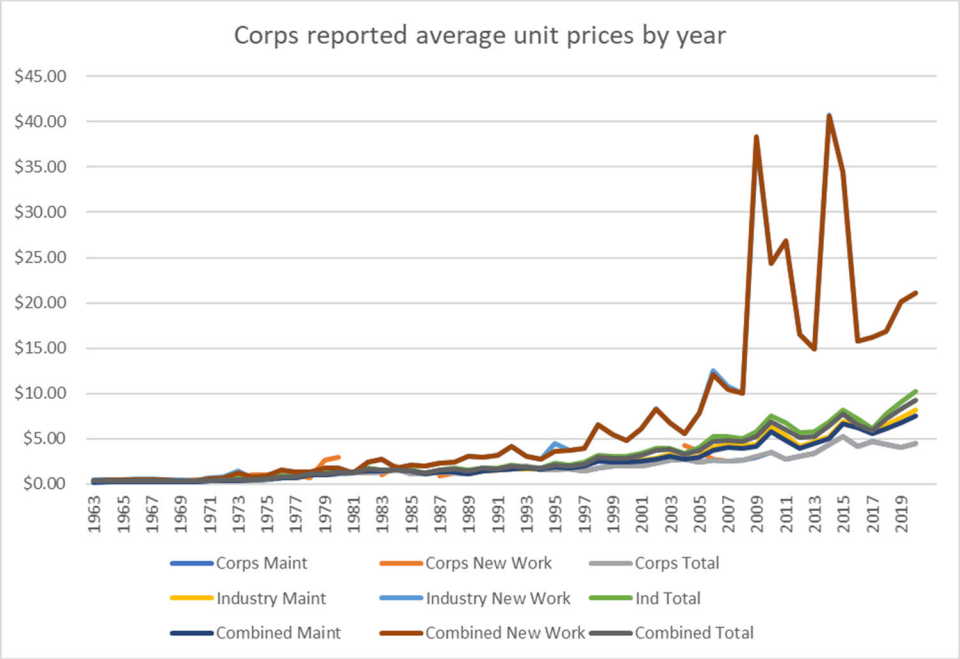

Figure 8 – Time Series of Calculated Effective Unit Rates

The Industrial New Work, and Combined New Work effective unit rates soared in 2009 through 2015. The total cubic yards for those categories represent only 3% to 9% of total volume dredged in those years, and 10% to 13% of material dredged in 2018 to 2020. Figure 9 below shows a time series of calculated effective unit rates with Industrial New Work and Combined New Work removed. The various dredging effective unit rates rose consistently over the years from under a dollar in 1963 to a range of $4 to $10 per cubic yard in 2020. Best fit regression equations reveal that the USACE effective unit rates rose approximately 7% year over year, while industrial effective unit rates rose approximately 14% year over year.

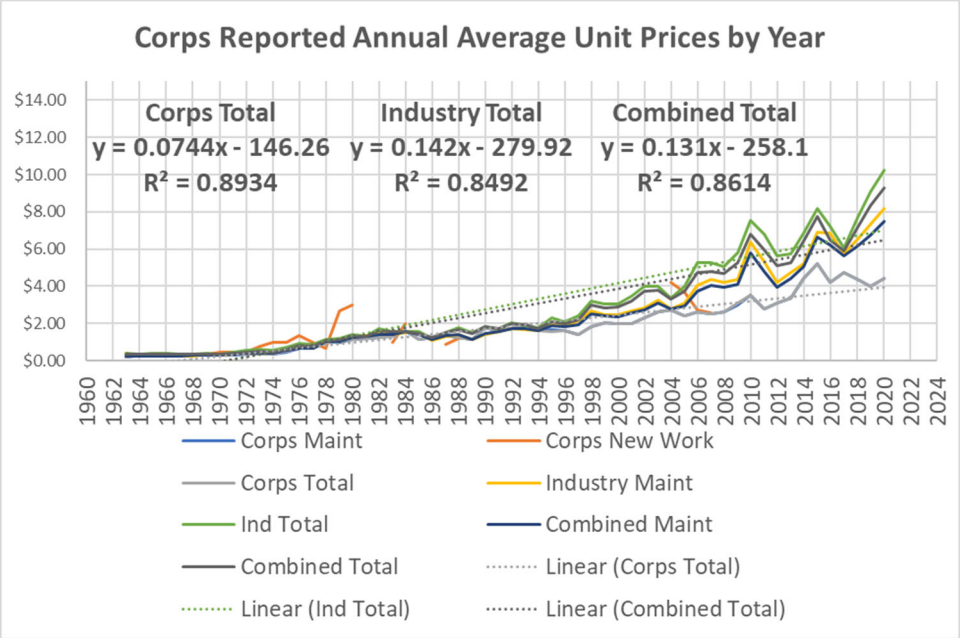

Figure 9 – USACE Annual Average Unit Prices by Year

GISE attempted to forecast the effective unit prices based on 2022 economic conditions. Readily available datasets that reflect relevant economic conditions were selected, specifically Consumer Price Index (CPI) and a price index for diesel (Source: U.S. Bureau of Labor Statistics). CPI was available for all of the years in the dredging dataset, however, the diesel price index was only available from 1973 onward. It should be noted that this does not reflect a robust effort to identify correlating economic metrics. GISE considered that CPI affects labor costs while diesel is the major consumed resource in hydraulic dredging. Therefore, these two metrics were considered to be most prominent for forecasting unit prices. The regression equation analysis tool kit in Microsoft Excel was used to perform a multivariate linear regression analysis, with effective dredging unit rate as the dependent variable, and CPI and diesel index as the independent variables.

The regression was performed for the USACE Total effective unit rate, the Industry Total effective unit rate and the Combined Total effective unit rate. The USACE Total regression had an R-squared value of 0.86, the Industry Total had an R-squared value of 0.86, and the Combined Total had an R-squared value of 0.87. The regression results in coefficients for the following generalized equation:

$$effective.unit.\cos t \;=\; intercept \;+ Coef_1 \cdot CPI \;+\; Coef_2 \cdot Diesel.Index$$

In order to apply this equation as a prediction, values for CPI and diesel in 2022 were input into the equation. At the time of writing of this Technical Memorandum, 2022-year end averages were not available. Therefore, for CPI, the 1st half CPI for 2022 was used, while an average of the published months was used for the diesel index. The equations produced the following forecasted values in Table 15 below.

Table 15 – Predicted Effective Unit Rates

Totals	Predicted Effective Unit Rate	Upper 95% Bound Effective Unit Rate
Corps Total	$4.62 per cubic yard	$7.34 per cubic yard
Industry Total	$11.45 per cubic yard	$18.97 per cubic yard
Combined Total	$8.65 per cubic yard	$13.62 per cubic yard

Based on the analysis above, three effective unit rates were considered: a lower bound of $8.00/CY, an upper bound of $19.00/CY and the average of the two or $13.50 (**Table 16**).

Table 16 – ROM Estimates Based on Effective Unit Rates

Scenario	Volume (CY)	Lower ($8.00/CY)	Middle ($13.50/CY)	Upper ($19.00/CY)
MCA-1 & MCA-2 only	2,014,165	$16,113,320	$27,191,228	$38,269,135
MCA-1, MCA-2 and MCA-3	2,728,012	$21,824,096	$36,828,162	$51,832,228

The method of forecasting based on regression represents a top down approach to generating a likely range of outcomes, rather than a definitive prediction of construction cost. The range of outcomes will be used along with the recently bid projects and a unit price based estimating to produce the final cost estimate for the alternate borrow area.

DREDGING PATH LENGTHS

Dredging path lengths from both the nearshore borrow and alternate borrow were estimated and compared. Estimated dredging path lengths from the alternate borrow area were nearly 60% shorter that dredging path lengths from the nearshore borrow for both scenarios: MCA-1 & MCA-2 only and MCA-1, MCA-2, and MCA-3. Estimates of the length of dredge pipeline needed to move dredge material to each MCA can be found in **Table 17**, rounded to the nearest 100 ft.

For this comparison, the length of dredge pipeline needed was estimated by drawing polylines in Google Earth Pro and recording their lengths in feet. For the nearshore borrow, lines were drawn following the pathways shown in the project's 95% Design Report. Although the 95% Design Report did not consider MCA-3, for this comparison, lines were also drawn from the nearshore borrow to MCA-3, overlapping significantly with the pathway used for MCA-1. For the alternate borrow, this estimation assumed that dredge material in Belle Pass would be used for MCA-2, dredge material in Bayou Lafourche would be used for MCA-1, and dredge material from Flotation Canal and the Slips would be used for MCA-3. Dredge pipelines from the alternate borrow areas followed similar pathways used for the nearshore borrow estimates.

Table 17 – Estimated Dredging Path Lengths Comparison

Nearshore Dredge Pipe Length (ft.)				
Marsh Creation Area	**Short in Marsh/ Long in Borrow**	**Middle in Marsh/ Middle in Borrow**	**Long in Marsh/ Short in Borrow**	**Borrow Area**
MCA-1	64,800	63,900	64,900	Nearshore
MCA-2	39,700	39,300	40,200	Nearshore
MCA-3	64,200	63,300	63,900	Nearshore
Total - MCA -1 and MCA-2	104,500	103,200	105,100	
Total - MCA -1, MCA-2, and MCA-3	168,700	166,500	169,000	

Alternate Dredge Pipe Length (ft.)				
Marsh Creation Area	**Short in Marsh/ Long in Borrow**	**Middle in Marsh/ Middle in Borrow**	**Long in Marsh/ Short in Borrow**	**Borrow Area**
MCA-1	30,300	25,500	23,200	Bayou Lafourche
MCA-2	25,600	16,900	11,800	Belle Pass
MCA-3	31,900	30,900	26,300	Flotation Canal/Slips
Total - MCA -1 and MCA-2	55,900	42,400	35,000	
Total - MCA -1, MCA-2, and MCA-3	87,800	73,300	61,300	

Reduction in Dredge Pipe Length (%)				
	Short in Marsh/ Long in Borrow	**Middle in Marsh/ Middle in Borrow**	**Long in Marsh/ Short in Borrow**	**Average % Reduction**
% Reduction (MCA-1 and MCA-2 only)	47	59	67	**57**
% Reduction (MCA-1, MCA-2, and MCA-3)	48	56	64	**56**

For both nearshore and alternate borrow areas, three scenarios were considered for each of the three MCAs:

1. Shortest distance inside the borrow area and longest distance inside the MCA
2. Middle distance inside the borrow area and middle distance inside the MCA
3. Longest distance inside the borrow area and shortest distance inside the MCA.

These scenarios were chosen to capture the variability of pipe lengths needed while also considering the sequence of dredging operations (e.g. material closest to the MCA might be used to fill the furthest reaches of the MCA – scenario 1). Maps of these dredging path length estimations can be found in Figure 10 and Figure 11 below. The percent reductions in dredge pipe length shown in Table 17 were calculated using the below equation for each of the three scenarios described:

$$\frac{Nearshore - Alternate}{Nearshore} * 100\%$$

The total lengths of dredge pipe needed for only MCA-1 and MCA-2 ranged from 103,200 – 105,100 ft. for the nearshore borrow and 35,000 – 55,900 ft. for the alternate borrow. The total lengths of dredge pipe needed for all three MCAs ranged from 166,500 – 169,000 ft. for the nearshore borrow and 61,300 – 87,800 ft. for the alternate borrow. By utilizing the alternate borrow, there was a 47 – 67% reduction of length for the MCA-1 and MCA-2 only estimates and a 48 – 64% reduction of length for the all three MCAs estimates. Overall, utilizing the alternate borrow over the nearshore borrow on average results in nearly a 60% reduction of dredge pipe length needed for this project.

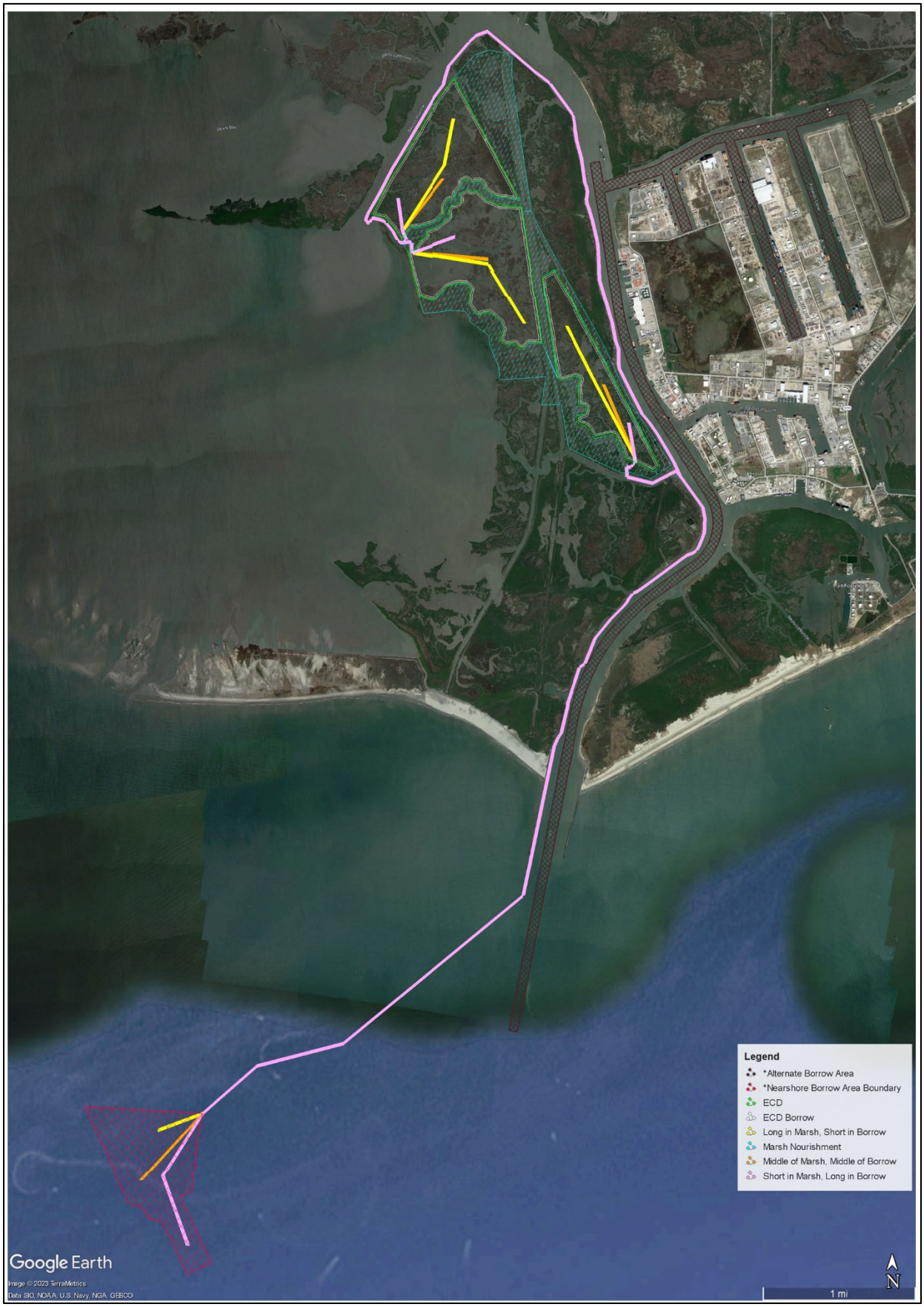

Figure 10 – Nearshore Borrow Dredging Path Length Estimation Map

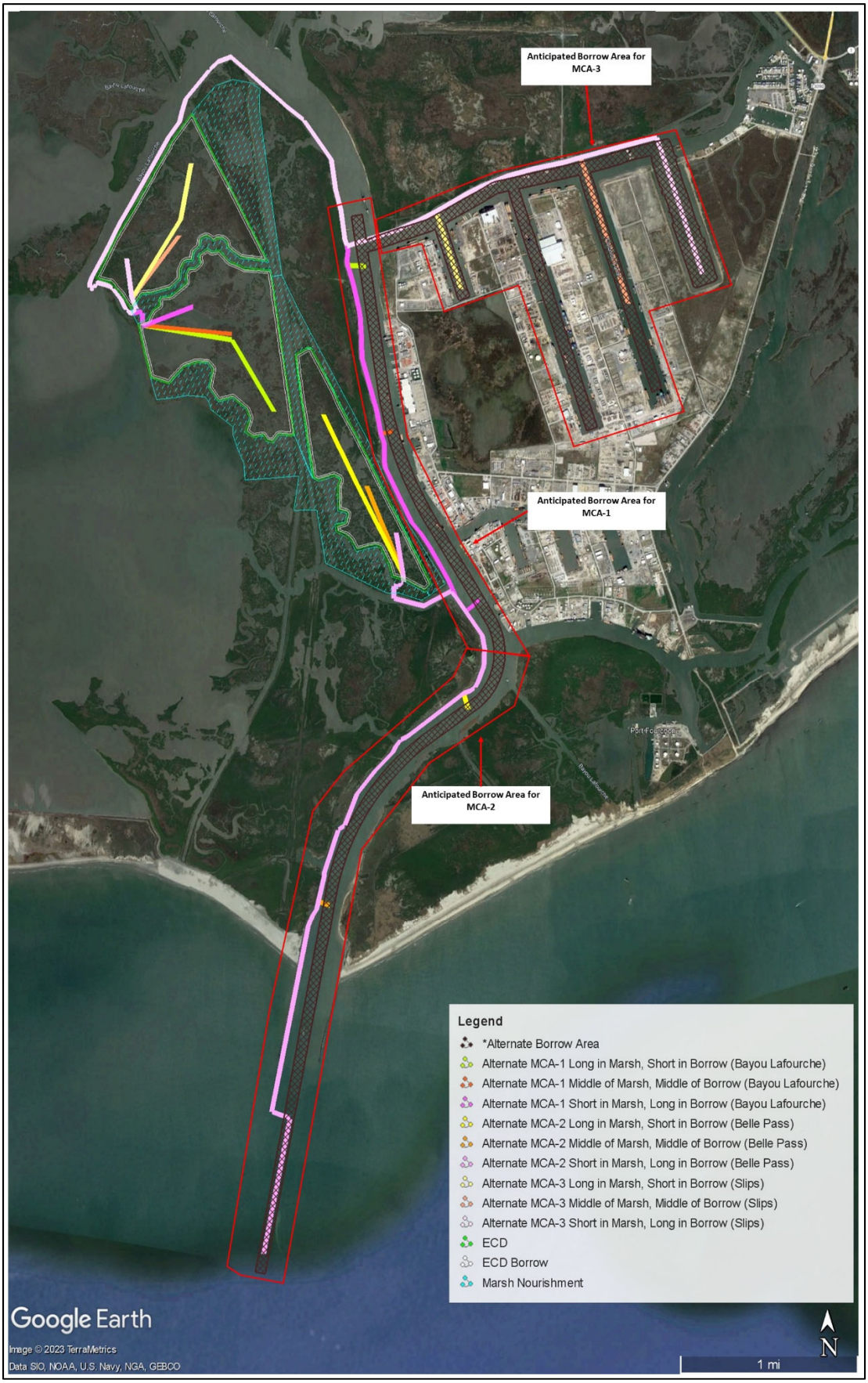

Figure 11 – Alternate Borrow Dredging Path Length Estimation Map

REVISED COST ESTIMATES

Due to the time lapse since the design surveys and the multiple hurricane impacts to the project area, CPRA conducted a new fill area survey in the first half of 2022 which GISE used to calculate revised quantities. Based on the 2022 survey, marsh creation fill quantities increased by 34,542 CY from the design survey (pre hurricane Ida) to the 2022 survey (post hurricane Ida) for MCA-1 and MCA-2 combined. No other considerations were incorporated into the offshore design fill volume (Ref. No. 2 in **Table 18** below). Updated offshore borrow cost estimate shown below also reflects dredging unit cost analysis previously described.

Table 18 – Offshore Borrow Cost Estimate Updated to 2022 Survey

TE-0314 West Fourchon Marsh Creation and Marsh Nourishment					
Estimated By:	Tyler Ortego, P.E. GIS Engineering, LLC	Date:	June 2023		
ENGINEERS ESTIMATE OF PROBABLE CONSTRUCTION COST					
OFFSHORE BORROW - UPDATED TO 2022 SURVEY					
Ref. No.	Description	Quantity	Unit	Unit Cost	Amount
1	Mobilization/Demobilization	1	LS	$ 5,251,349	$ 5,251,349
2	Marsh Creation & Nourishment (w/dike backfill)	1,693,594	CY	$ 12	$ 20,323,128
3	Nesting Bird Abatement (DPL Beach Crossing)	10	DAY	$ 1,000	$ 10,000
4	Containment Dikes[12]	36,564	LF	$ 80	$ 2,925,120
5	Settlement Plates	6	EACH	$ 4,000	$ 24,000
6	Instrumented Settlement Plates	4	EACH	$ 15,000	$ 60,000
7	Construction Surveys	1	LS	$ 804,200	$ 804,200
Notes:				SUBTOTAL:	$ 29,397,797
				CONTINGENCY:	20%
				TOTAL:	$ 35,277,356

Table 19 below, shows the Engineer's Estimate of Probable Cost for the alternate borrow area scenario prepared by GISE. While the range of unit rates should be conservative, an additional 20% contingency to account for ongoing economic uncertainty was included in this estimate. Including contingency, the effective unit rate calculates to $16.77/CY for the base bid and $17.36/CY for base + additive. These values fall well within the top of the range presented in **Table 16**, and exceed all but one of the effective unit rates presented in **Table 13**.

[12] For consistency on this technical memorandum report, ECDs for both the offshore and alternate borrow area cost estimates were measured by the linear feet, and the unit cost per linear feet was calculated based on the alternate borrow area ECD design fill volumes shown on Table 14. However, the marsh creation & nourishment fill volumes (Ref. No. 2) for the offshore borrow cost estimate do not reflect additional design considerations included in the volume fill calculations for the alternate borrow area ECDs.

Table 19 – Revised Cost Estimate for Alternate Borrow

MARSH CREATION PROJECT INFORMATION			
State P.M:	Katie Freer	Date:	June 2023
Project Name:	West Fourchon Marsh Creation TE-0134	MC Acreage:	537 ACRES (MCA-1 & MCA-2), 277 ACRES (MCA-3)
Project Status:	Final Design	Design Life (years:)	20
Estimated By:	Tyler Ortego, P.E. GIS Engineering, LLC	Project Sponsor:	NOAA

ENGINEERS ESTIMATE OF PROBABLE CONSTRUCTION COST					
ALTERNATE BORROW SCENARIO - BASE BID (MCA-1 & MCA-2)					
Ref. No.	Description	Quantity	Unit of Measure	Unit Price	Amount
1	Mobilization/Demobilization	1	LS	$ 4,250,000	$ 4,250,000
2	Marsh Creation & Nourishment (w/dike backfill)	2,014,165	CY	$ 10	$ 20,141,650
3	Nesting Bird Abatement (DPL Beach Crossing)	-	DAY	$ 1,000	$ -
4	Containment Dikes	36,564	LF	$ 80	$ 2,925,120
5	Settlement Plates	6	EACH	$ 4,000	$ 24,000
6	Instrumented Settlement Plates	-	EACH	$ 15,000	$ -
7	Construction Surveys	1	LS	$ 800,000	$ 800,000
Notes:				SUBTOTAL:	$ 28,140,770
				20% CONTINGENCY:	$ 5,628,154
				TOTAL BASE BID:	$ 33,768,924

BID ADDITIVE (MCA-3)					
Ref. No.	Description	Quantity	Unit of Measure	Unit Price	Amount
8	Marsh Creation & Nourishment (w/dike backfill)	713,847	CY	$ 10	$ 7,138,470
9	Containment Dikes	17,176	LF	$ 80	$ 1,374,080
10	Additional Construction Surveys	1	LS	$ 100,000	$ 100,000
Notes:				SUBTOTAL:	$ 8,612,550
				20% CONTINGENCY:	$ 1,722,510
				TOTAL BASE BID:	$ 10,335,060

Subtotal with MCA-3:	$	36,753,320
20% Contingency	$	7,350,664
Total with MCA-3	$	44,103,984

CHAPTER FIVE: SUITABILITY OF SLIP MATERIAL

The four slips constructed off of Flotation Canal can be dredged to provide additional material for the project. The following sections are intended to demonstrate that the available material in the slips is suitable for the construction of the proposed marsh creation project. The first section demonstrates that the material in the slips has been successfully utilized for marsh creation in the past. The following sections extract information from existing geotechnical reports, collected for various purposes, to demonstrate that the material in the slips is well categorized and similar to that analyzed by Ardaman in 2022 for the Alternate Borrow evaluation.

USE OF SLIP MATERIAL IN MITIGATION AREAS

The Greater Lafourche Port Commission has constructed four slips as part of their Northern Expansion project for their Master Plan. Phase I of this Expansion project saw the construction of Slip A and Slip B in 1999, Phase II started construction of Slip C in 2011, and Phase III commenced construction of Slip D in 2015.

For Port Fourchon's Northern Expansion, Slip dredge spoils were beneficially used in restoration projects north of Flotation Canal as well as east of Slip D (**Figure 12**). The results of this work include the Maritime Forest Ridge Restoration project, which is the first successful restoration of an elevated Chenier forest ridge habitat from open water, that spans over 6,000 ft. in length[13]. Additionally, over the last 25 years, the Port has or is in the process of creating over 1,000 acres of saltmarsh across the designated marsh creation and mitigation areas (**Figure 13**). The dredge volume beneficially used, acreage of marsh created, and vegetation coverages for each mitigation area are shown in **Table 20** below.

One challenge that had to be overcome was the initial target elevation set for the Phase I Mitigation Area A, where it was found – following completion in 2001 – that the initial target elevation of +3.25 ft. NGVD (+2.16 ft. NAVD 88) was too high to support marsh vegetation. To mitigate this issue, the Port constructed tidal creeks to increase tidal flow through the higher areas, and also later amended the permit for Mitigation Areas B and C, to change the *target* elevation of +3.25 ft. NGVD (+2.16 ft. NAVD 88) to a *maximum* elevation of +3.25 NGVD (+2.16 ft. NAVD 88) with no more than 15% of the site falling outside a range of +2.0 to +2.5 ft. NGVD (+0.91 to +1.41 ft. NAVD 88). The tidal creeks and passage of time seemingly resolved the issues originally encountered with Mitigation Area A as the Office of Coastal Management (OCM) identified over 80% vegetative coverage of the area in 2017.

On properly elevated sites, significant natural vegetation can be found within 2 years with no plantings necessary, such as was the case of Mitigation Area B. For the Phase III Mitigation Area, >95% vegetation cover was found within three years of filling with natural vegetation recruitment.

In all mitigation areas not initially planted, the Slip spoil material used was a sufficient substrate to foster natural vegetation recruitment and support marsh growth that meets its vegetation coverage benchmark (>80% cover within three growing seasons). Overall, there have been

[13] Review Assessment of Port Fourchon Belle Pass Channel Deepening Project Section 203 Feasibility Study

successful results in mitigation areas that were filled with material from the Slips during the Port's Northern Expansion project. Therefore, it is reasonable to assume that TE-134 marsh creation efforts utilizing similar material from the Slips would have similarly successful results as seen in the Port's mitigation areas.

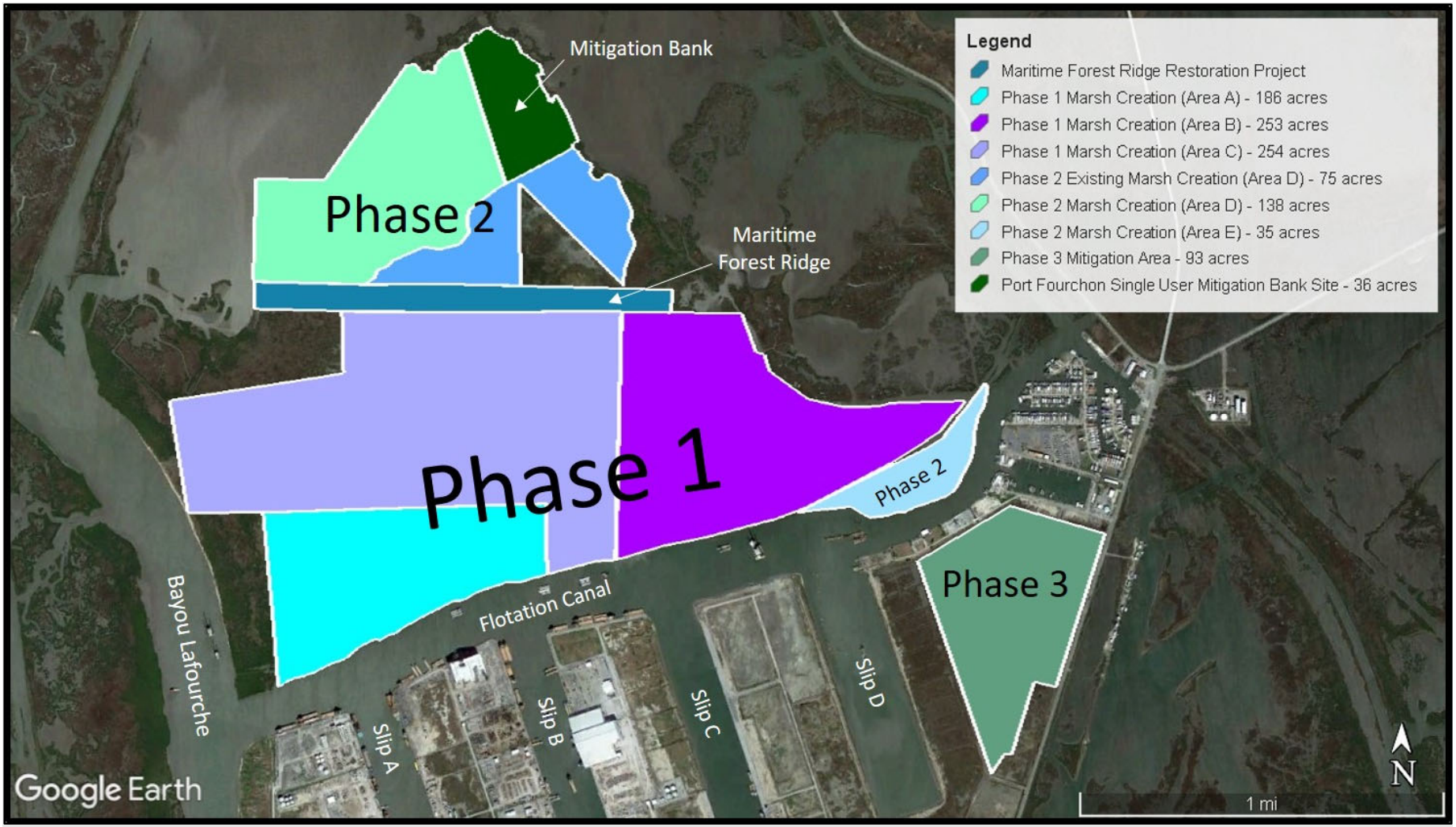

Figure 12 – Map of Port Fourchon's Northern Expansion Mitigation Areas, Mitigation Bank, and the Maritime Forest Ridge Restoration Project

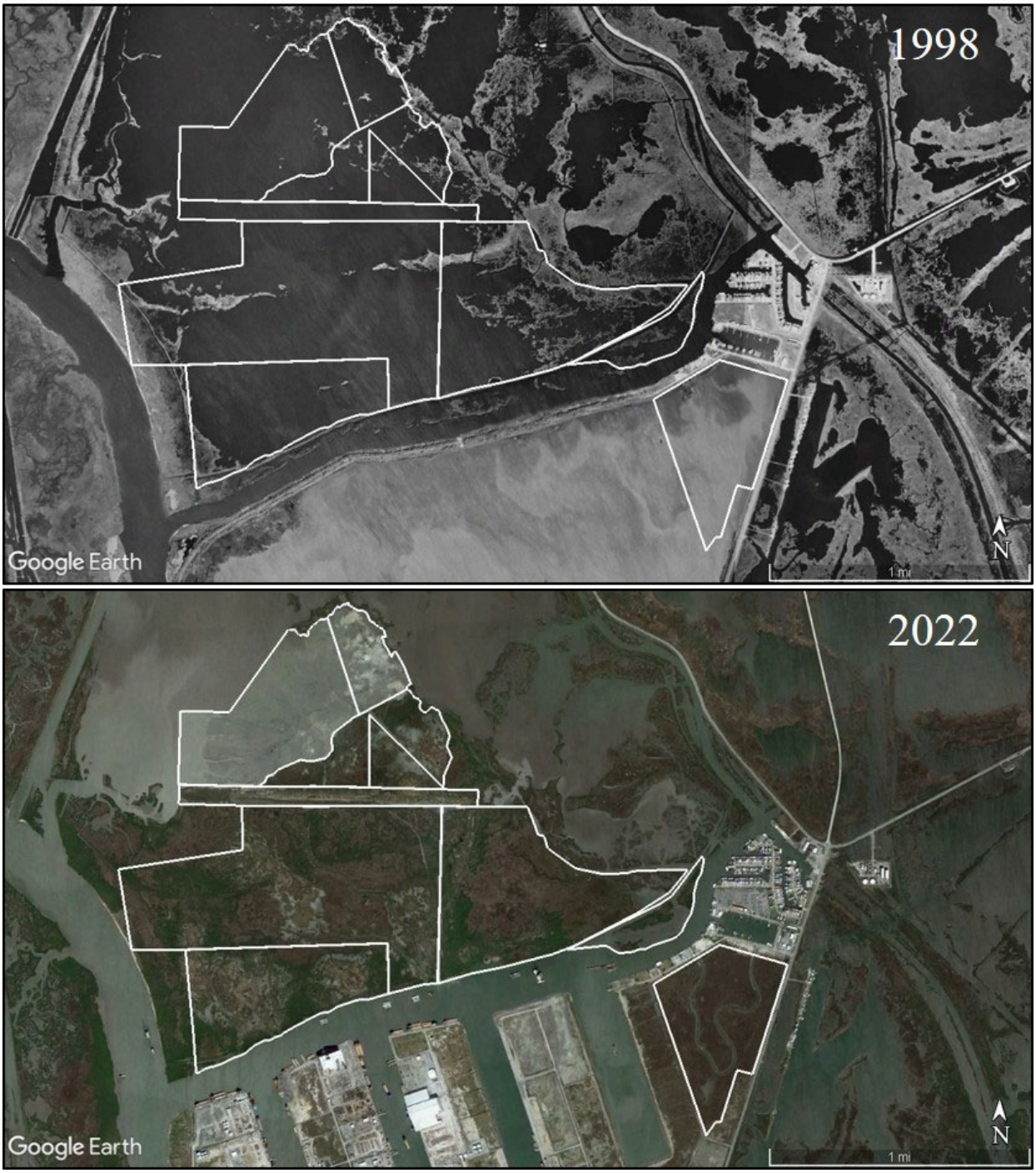

Figure 13 – Wetland Area 1998 vs. 2022 with Mitigation Areas & Maritime Forest Ridge Outlined

Table 20 – Mitigation Area Project Details

Construction Phase	Area Name	Fill Dates	Dredge Volume (MCY)	Area Created (acres)	Vegetation Success
Northern Expansion Phase 1 (Slips A&B)	**Area A**	Winter 2000 to Spring 2001	1.20	186	**Initially planted in 2001** with *Spartina alterniflora.* 85% vegetative cover from 2013 aerial survey. **OCM field survey confirmed >80% cover on May 11, 2017.**
	Area B	Fall 2003	0.96	253	**No plantings, natural vegetation recruitment**. 80% vegetative cover from 2006 aerial image survey. **OCM field survey confirmed >80% cover on May 11, 2017.**
	Area C	Fall 2004 to Spring 2011	2.05	254	**No initial planting, natural vegetation recruitment**. 80% vegetative cover from 2016 aerial image survey. OCM field survey found 65-70% coverage on May 11, 2017. **Additional planting in March 2018** (low survival rates), however, 87% cover from follow-up survey in 2021. **OCM Mitigation Monitoring Report acknowledges >80% cover on April 26, 2022.**
Northern Expansion Phase 2 (Slip C)	**Area D**	Winter 2012	0.78	75	**No initial planting, natural vegetation recruitment. Additional planting in April 2018** of *Paspalum vaginatum* and *Spartina patens* in areas displaying low survival rates. To date, no formal vegetative coverage analysis conducted.
	Area D	2021	1.59	138	Retainer levees erected in 2021. Merged area with Mitigation Bank. To date, no formal vegetation coverage analysis conducted.
	Area E	2017	0.22	35	Retainer levees erected in 2017. To date, no formal vegetation coverage analysis conducted.
Northern Expansion Phase 3 (Slip D)	**Phase 3 Mitigation Area**	Summer 2018	0.72	93	**No plantings, natural vegetation recruitment. OCM concurs with Port's determination of >95% vegetative cover from June 9, 2021 drone photography**
Single User Mitigation Bank (Bayou Lafourche)	**Mitigation Bank**	2021	0.26	36	Retainer levees erected in 2021. Merged area with Area D. To date, no formal vegetation coverage analysis conducted.

SOIL BORING COMPARISON WITH SLIP CONSTRUCTION BORINGS

In order to provide sufficient dredge volume to fill all MCAs proposed for this project, it was necessary to include the Slips located immediately south of Flotation Canal into the alternate borrow footprint. The slips, designated "Slip A", "Slip B", "Slip C", and "Slip D" (**Figure 14**) were created by both excavating and creating land in shallow open water. Since the addition of the Slips to the alternate borrow area was decided after the scoping of the geotechnical investigation (Ardaman 2022), available historical geotechnical data previously obtained from the Slips was thoroughly evaluated to demonstrate that dredged material originated from these is suitable for the construction of the proposed marsh creation project.

In order to demonstrate the utility of these past investigations to the current effort, a description of the construction sequence is helpful. The general area consisted of broken marsh and shallow open water. The slips were created by first side casting excavated material to define slip edges and containment berms, then hydraulically dredging material into the containment berms to create land and finally hydraulically dredging down to permit depth and depositing material into the various mitigation areas. In order to design structural bulkheads, geotechnical investigations were later conducted along the edges of each newly created slip. Existing geotechnical reports that were utilized for this evaluation can be found in **Table 21** below. The majority of the existing data reports were developed during Slip construction and evaluated sub-surface strata for bulkhead construction and slope stability analysis. Between these twelve reports, 81 soil borings were collected, ranging from 80 to 120 ft. in depth. Locations of these 81 borings can be found in **Figure 14** and are color coded by report (year, author). In most cases, the borings were collected by truck mounted drilling rigs on top of the created berms. Though in some instances, marsh buggies were used to collect borings prior to fill. Therefore, the upper strata of the borings likely reflect material excavated from the slips. The slips were excavated to approximately -26.0 ft NAVD 88.

Borings for Slips A-D were drilled on the landside adjacent to the slips. Based on the latest surveys (Post Hurricane Ida), existing ground inside the slips is around elevation -24.0 ft NAVD 88 for Slips A-C. Existing ground inside Slip D ranges from elevation -5.0 ft to -30.0 ft NAVD 88. The material proposed for TE-134 would come from the center of the slips, but at elevations not previously excavated. Borings previously drilled at Slips A, B and C are shown on **Figure 14**. The overall consistency of those borings, combined with the close spacing (700 ft to the other side of the slip) provides a level of confidence that the existing borings can be relied upon to describe the center of the slip. Note that the 'F boring' spacing from Ardaman 2022 is 2,000-3,000 ft.

The purpose of the next section is to demonstrate that proposed dredged material in the Slips can be reasonably expected to fit within parameters of the composite method used to generate the fill settlement curves.

Table 21 – Existing Geotechnical Reports for Slips A-D

Report Date	Geotechnical Firm	Location	Purpose of Analysis	Number of Borings
September 21, 2000	Eustis Engineering	Slip A	Bulkhead Evaluation	10
March 19, 2004	Eustis Engineering	Slip A	Western Bulkhead Failure Investigation	4
October 11, 2004	Eustis Engineering	Slip A	Bulkhead Reevaluation	3
July 1, 2004	Eustis Engineering	Slip B	Bulkhead Evaluation	5
May 15, 2003	Gore Engineering	Slip B	Foundation Analysis	7
September 23, 2003	Professional Service Industries (PSI)	Slip B	Bulkhead Evaluation	12
May 21, 2007	Eustis Engineering	Slip B	Expansion Bulkhead Evaluation (Phase 3&4)	10
March 7, 2008	Gore Engineering	Slip B	Foundation Analysis (Phase 4)	13
March 8, 2013	Eustis Engineering	Slip C	Bulkhead Evaluation (Part A, Western Side)	6
March 22, 2013	Eustis Engineering	Slip C	Bulkhead Evaluation (Part A, Eastern Side)	3
May 26, 2014	Stratum Engineering	Slip C	Bulkhead Evaluation (Part A, Eastern Side)	5
June 2, 2022	Eustis Engineering	Slip D	Bulkhead Evaluation	3

Figure 14 –Soil Boring Locations from Existing Slip Geotechnical Reports (Flotation Canal Borings were Excluded from Textual Analysis)

Comparison Based on Sample Description

A textual analysis was undertaken in order to compare the different groupings of borings based on textual descriptions found on the boring logs.

For each boring, descriptions were extracted from the log at elevations corresponding to the anticipated dredge depths. If borings were provided in depth from surface, the depth value was first converted to NAVD 88 using information found in the report. In many cases, more than one strata fell within the assumed dredge depths. A spreadsheet was created tabulating the description of each sampled strata, along with report designation and boring number. The borings were grouped according to location: Nearshore Borrow, Belle Pass, Bayou Lafourche, Flotation Canal and Slips. For the Flotation Canal, only Ardaman's 2022 borings were used in this textual analysis. This input spreadsheet was then loaded into a Jupyter Notebook[14] so that Python and various modules could be used for analysis. **Table 22** provides summary information for each area. **Table 23** shows a random sample of rows extracted from the strata spreadsheet.

Table 22 – Summary of Sampled Strata

Area		Report Source	Year	N Strata	Elevations
Bayou Lafourche		Ardaman	2022	37	Mudline to -33 ft
Belle Pass		Ardaman	2022	29	Mudline to -33 ft
Flotation Canal		Ardaman	2022	15	Mudline to -33 ft
Nearshore Borrow		Geoengineers	2017	13	Mudline to -50 ft
Slips	Slip A	Eustis	2000, 2004	27	-26 ft to -33 ft
	Slip B	Eustis, Gore, PSI	2003, 2007, 2008	79	-26 ft to -33 ft
	Slip C	Eustis, Stratum	2013, 2014	30	-26 ft to -33 ft
	Slip D	Eustis	2022	5	-26 ft to -33 ft

Table 23 – Random Sample of Rows from Borings Description Tabulation

Location	Boring ID	Description	USCS[15] Type	Source	Area
Slip B	B-4	soft gray sandy clay	-	Slip B-2008-Gore	Slips
Bayou Lafourche	S-05	Very Soft dark gray SANDY ORGANIC CLAY	OH	Ardaman final Design report	Bayou Lafourche
Belle Pass	F-10	Loose gray SAND w/ silt	SP-SM	Ardaman final Design report	Belle Pass
Slip B	B4	loose to medium compact gray sandy silt	ML	Slip B-2007-Eustis	Slips
Nearshore Borrow	WF17-10	Gray clay with silt pockets	CH	Geo Vibracore Core Data Report Appendix I	Nearshore Borrow

[14] Jupyter notebooks are an interactive computing platform which combines live code, equations, narrative text, visualizations, among other functions. Jupyter notebooks allow code to be executed on a cell by cell basis, and combined with formatted text cells to allow for efficient documentation of data analysis.

[15] Group soil classification from the Unified Soil Classification System (USCS).

For each area, the percent of descriptions containing search words “sand”, “silt” and “clay” were tabulated. The percent of strata containing each key word was calculated by combing the count by the total strata recorded in the respective group. Note that the percentages for each area add to more than 100% since many descriptions contained more than one key word, e.g. “silty sand” or “fat clay with sand lenses”. **Table 24** tabulates the percent of strata containing each key word for each area. **Figure 15** shows the same information in a bar chart.

Table 24 – Percent of Strata Containing “Sand”, “Silt”, or “Clay” by Area

Area	% with Sand	% with Silt	% with Clay
Bayou Lafourche	64.9%	21.6%	78.4%
Belle Pass	72.4%	17.2%	86.2%
Flotation Canal	86.7%	20.0%	66.7%
Nearshore Borrow	0.0%	92.3%	100%
Slips	76.6%	58.2%	67.4%

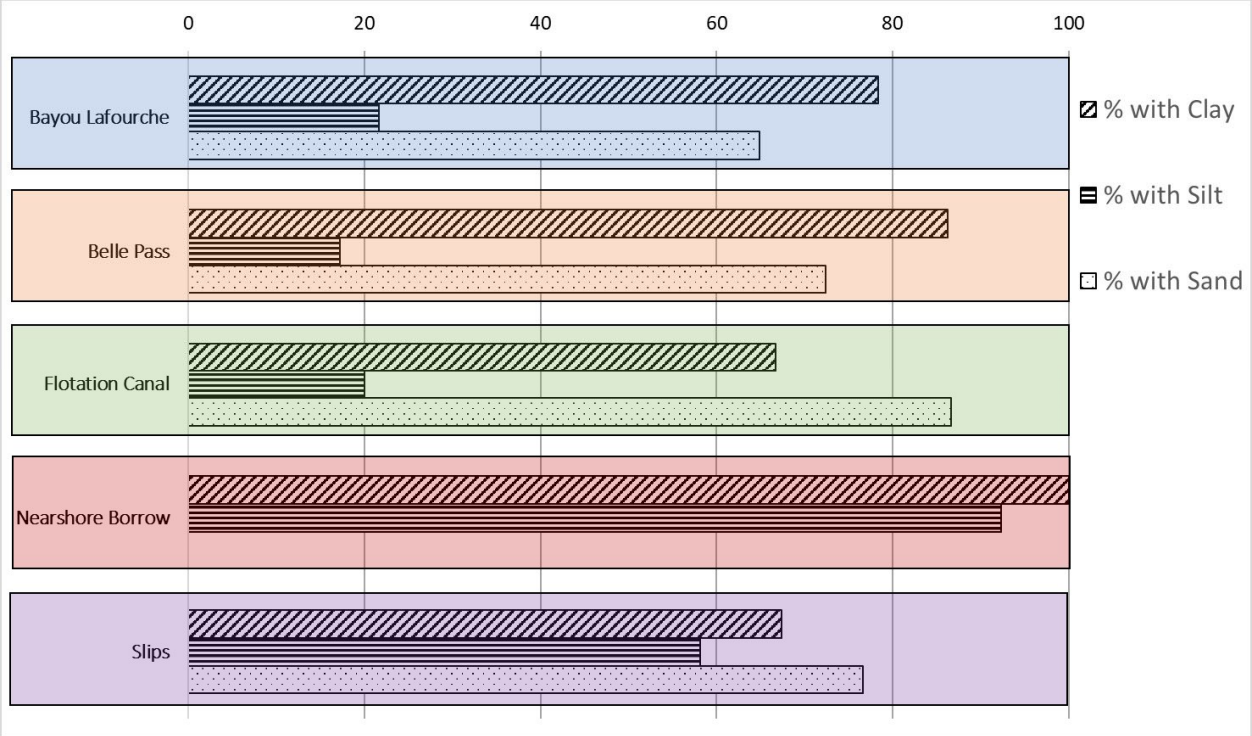

Figure 15 – Percent of Strata Containing “Sand”, “Silt”, or “Clay” by Area

Figure 16 shows a pair plot comparing the relationships of each ratio to the others, with the areas distinguished by color. For example, in the upper right corner, the ratio with sand is plotted against ratio with clay. In each case, the dots for Bayou Lafourche, Belle Pass, Flotation Canal and Slips are clustered together while the dot for Nearshore Borrow is offset.

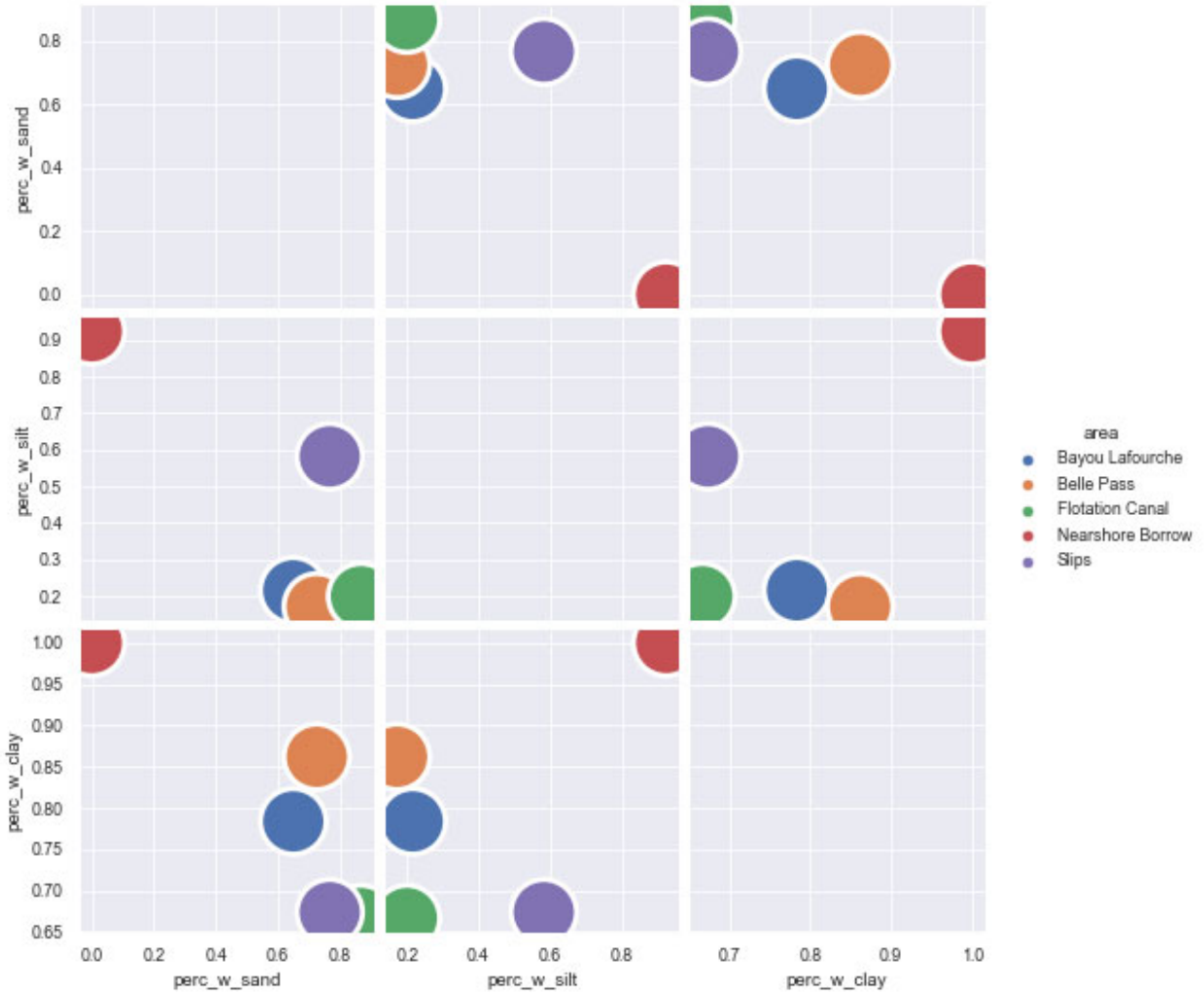

Figure 16 – Pair Plot of Strata Containing "Sand", "Silt", or "Clay" by Area

Pairwise Distance Matrix – Chosen Keywords

A final analysis treats the computed ratios as cartesian coordinates for the purpose of calculating a "distance" between each of the areas (**Figure 17**). Because there are exactly three variables, all scaled to 1.0 (100%), the distance can be thought of as points within a cube with sides of 1.0 units. In this pairwise plot, close distances (more similar material) are colored as faded green, and the farthest distances (more dissimilar material) are colored dark blue. The Nearshore Borrow is the furthest from all other areas with distances ranging from 0.89 to 1.2. Belle Pass and Bayou Lafourche are closest to each other with a distance of 0.12. The Slips are about equidistant from Belle Pass, Bayou Lafourche and Flotation Canal with distances of 0.33 to 0.36.

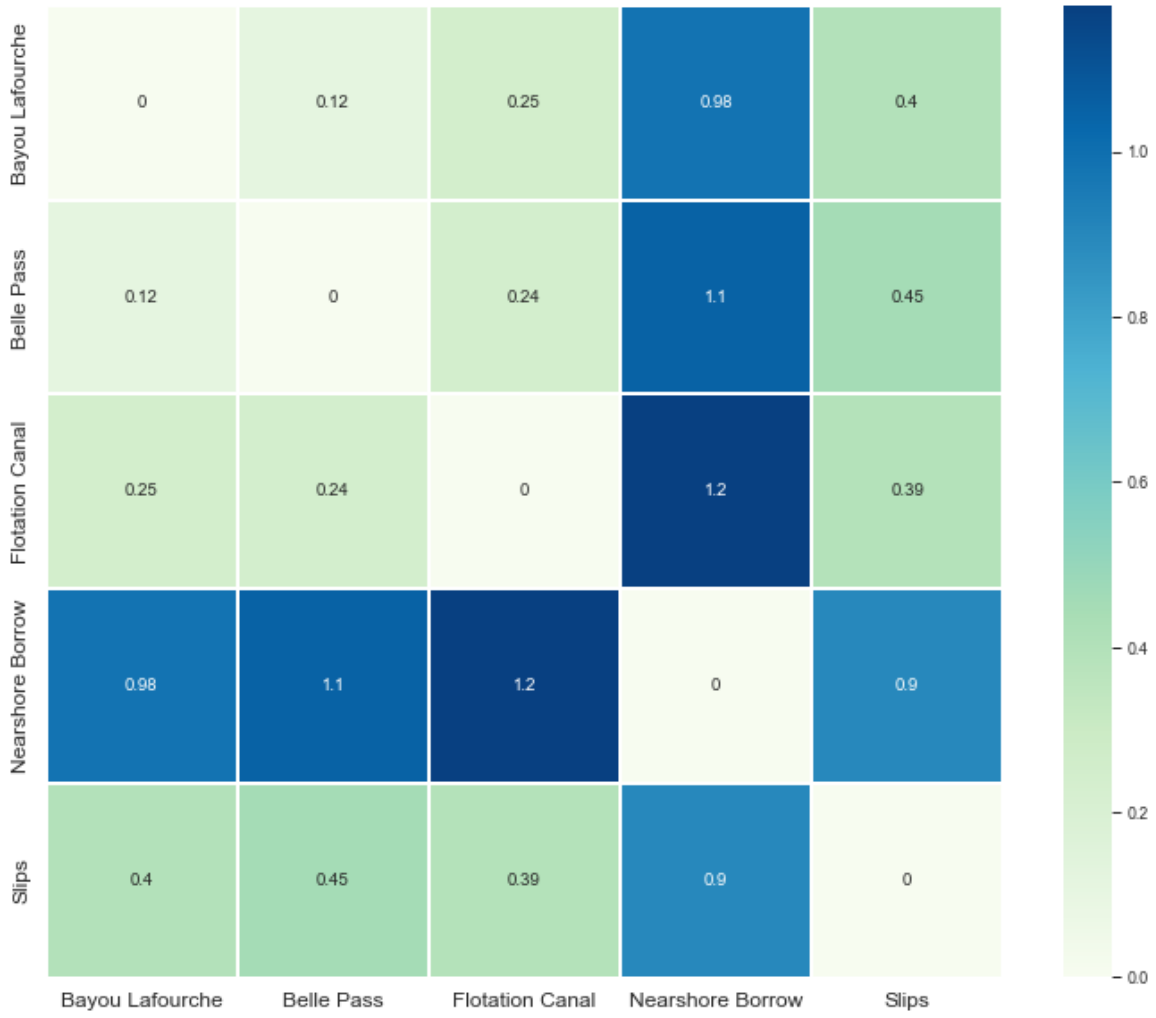

Figure 17 – Pairwise Distance Matrix Comparing Areas Based on "Sand", "Silt", and "Clay"

Pairwise Distance Matrix - Textual similarity using Tfidfvectorizer

To provide a more robust comparison and contrast of the textual descriptions of the strata, a language processing technique called "tf-idf" was used that considers all terms, not just keywords you select (i.e. "sand", "silt", and "clay" as used previously). Tf-idf transforms the text into mathematical representations by ranking the relative importance of a term by term frequency (tf) and by "inverse document frequency" (idf), and both scores are combined into a singular score between zero and one for each term in document corpus. Scikit Learn's TfidfVectorizer module was then used to transform these scores for analysis. After filtering out common words (a, an, the, etc.), a matrix of 235 rows (one row for each strata) and 35 columns (one column for each term) was created and assigned a td-idf score. These scores were then averaged into groups representing Bayou Lafourche, Belle Pass, Flotation Canal, Nearshore Borrow, and Slips. Scikit Learn's pdist module was then used to calculate the "distance" between groups and plot those differences in a colored pairwise distance matrix (**Figure 18**).

As before, close distances (more similar material) are colored as faded green, and the farthest distances (more dissimilar material) are colored dark blue. Similar trends can be found in **Figure**

18 as in Figure 17: The Alternate Borrow areas (Bayou Lafourche, Belle Pass, and Flotation Canal) are most similar to each other, the Slips are "closer" to the Alternate Borrow areas than to the Nearshore Borrow, and the Nearshore Borrow area is the most different from the other groups.

Figure 18 – Pairwise Distance Matrix Comparing Areas Based on Tf-idf Vectors

The top five ranked terms by td-idf score for each of the grouped areas were tabulated (Table 25). Note that "soft" and "fat" describe clay/clayey strata while "loose" and "dense" describe sand/sandy strata. The Alternate Borrow areas all have "gray" and "sand" in their top five ranked terms in common with each other. Likewise, the Slips also have "gray" and "sand" in its top five ranked terms. The Slips, Bayou Lafourche, and Belle Pass also have "clay" and/or "soft" in common with each other.

Table 25 – Top Ranked Terms by Td-idf Score by Area

Area	Top 5 Ranked Descriptive Terms
Bayou Lafourche	Fat – Gray – Loose – Sand – Soft
Belle Pass	Fat – Soft – Clay – Gray – Sand
Flotation Canal	Dark – Sand – Gray – Loose – Dense
Nearshore Borrow	Silt – Clay – Gray – Pockets – Lenses
Slips	Soft – Gray – Clay – Sand – Silty

All of these textual analyses show that material in the Slips contain relatively similar material classifications compared to the Alternate Borrow (Flotation Canal, Bayou Lafourche, Belle Pass). This is especially true when considering the difference between the Nearshore Borrow and the Alternate Borrow. Both the Slips and the Alternate Borrow have a mixture of sands, silts, and clays with the Slips having more strata textually described as silt. In comparison, the Nearshore Borrow contains only silts and clays with no textual description of sand in any strata.

Comparison of Composite Soil Profiles

In seven of the twelve existing geotechnical reports evaluated for the Slips, slope stability analyses were performed based on the soil boring data collected. For these analyses, a general composite profile of the sub-surface strata was developed as part of this evaluation, which included the USCS soil type, cohesion (psf), and total unit weight (pcf) for each layer. In Ardaman's 2022 design report, three composite profiles (developed from the borings collected in 2021) were provided at these locations: Flotation Canal Station 610+00, Bayou Lafourche Station 65+00, and Belle Pass Station 230+00. This section of this technical memorandum focuses on the comparison of these two sets of composite soil profiles.

USCS Soil Classification

Figure 19 shows the USCS major soil types of seven composite profiles from existing geotechnical reports and the three composite Alternate Borrow profiles from Ardaman. Additionally, this figure includes a general profile of the Nearshore Borrow Area 1 that was informed by borings (WF17-01 to WF17-13) from the 2017 GeoEngineers geotechnical report (Appendix I of CPRA's TE-134 95% Design Report).

Each date listed in the Figure 19 refers to the date of collection of the borings used to inform that composite profile, not the date of the geotechnical report. Composite profiles were all scaled to their starting ground elevations in ft. NAVD 88 (if necessary, elevations were converted from NGVD to MLG[16] , then MLG to NAVD 88[17]). The yellow area highlighted in the plot shows the Alternate Borrow Area's target dredging depth interval (existing water bottom up to -33.61 ft. NAVD 88) while the pink area highlighted in the plot shows the Nearshore Borrow Area's target dredging depth interval (existing water bottom up to -50 ft. NAVD 88). These highlighted areas are for visualization purposes only to help compare strata at different locations.

[16] MLG to MLLW Vertical Datum Conversion Calcasieu River and Pass, USACE
[17] Bayou Lafourche Bar Channel Survey, USACE

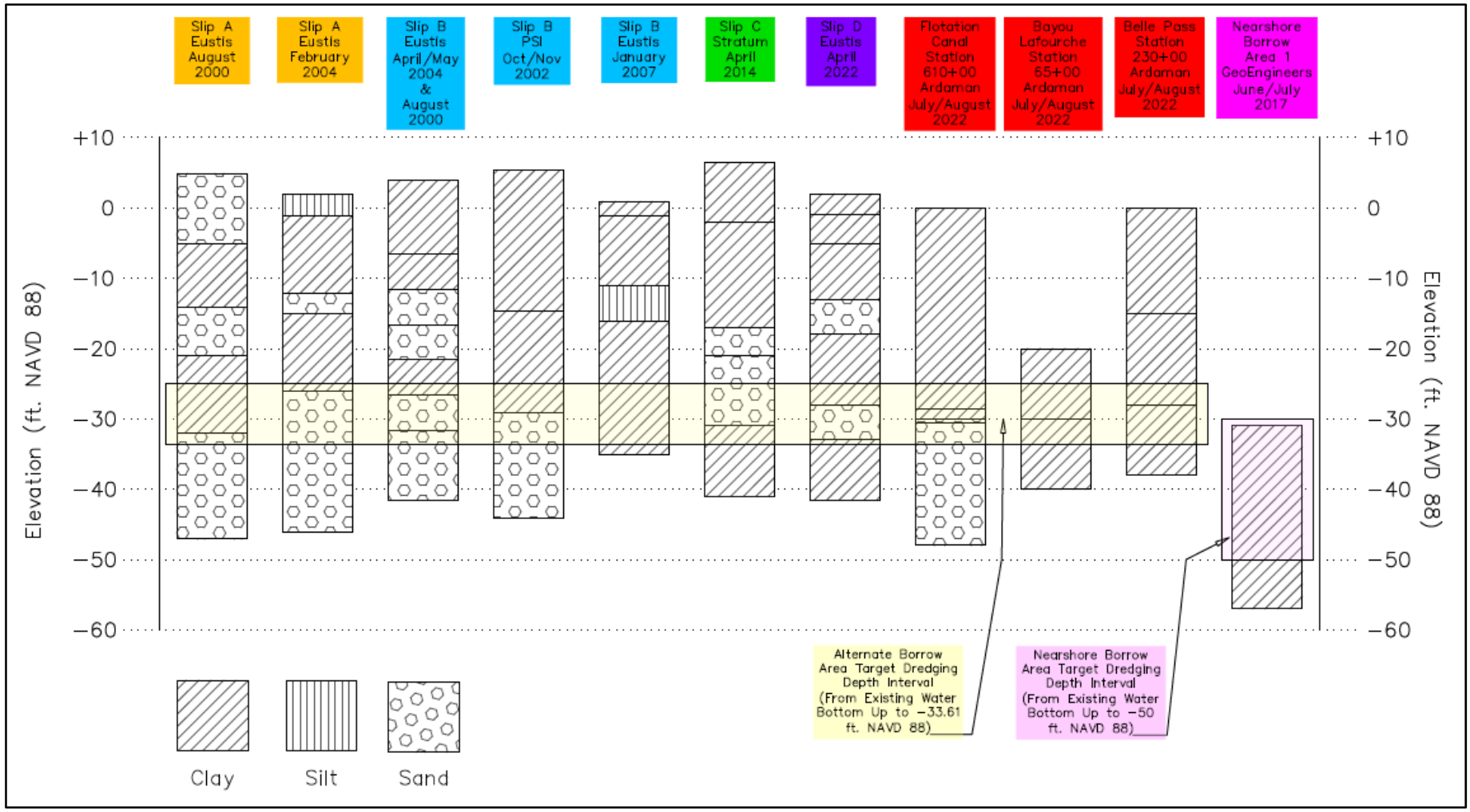

Figure 19 – Comparison of Composite Profiles from Slips A-D, Flotation Canal, Bayou Lafourche, Belle Pass, and Nearshore Borrow Area 1.

Within the target dredging depth interval (existing water bottom up to -33.61 ft. NAVD 88), composite profiles from Slips A-D show variable strata made of mostly clays and sands. When looking at individual borings within the Slips, layers of inorganic lean (low plasticity) clays (CL), inorganic fat (high plasticity) clays (CH), organic clays (OH), humus/peat (PT), poorly graded sands (SP), silty sands (SM), and sandy silt (ML) were found. Overall, the target interval in Slips A-D contains heterogenous layers of soft gray clays and loose to medium dense gray sands.

The composite profiles from Slips A-D corroborate with multiple of the geotechnical reports that described the stratigraphy but did not contain composite profiles for slope stability analysis. In Eustis's October 2004 report, Slip A was described with layers of "interbedded clay, silt and sand" and "lower sand" that overlap with our target dredging depth interval. In Gore's 2008 report, the target interval of Slip B was described as "heterogeneous in character and generally [consisting] of very soft to medium stiff clays and loose clayey silt, sandy silt and clayey sand." In both of Eustis's March 2013 reports, Slip C was described with layers of "very soft to soft gray clay and silty clay, interbedded with loose to medium compact gray sandy silt and clayey silt, soft to medium stiff brown and gray humus, and loose gray silty sand" in our target interval. Eustis's 2022 report of Slip D contained a composite profile used in **Figure 19** as well as a description of Slip D with layers of "very soft to soft gray fat clay and sandy lean clay interbedded with strata of loose to medium dense gray silty sand and sand" that overlap our target interval.

The major soil type in the composite profiles for the alternate borrow areas (Flotation Canal Station 610+00, Bayou Lafourche Station 65+00, and Belle Pass Station 230+00) are mostly clays with some sand. Ardaman's 2022 data report[18] describes soils encountered near the centerline of the Flotation Canal as generally consisting of "fat clays (CH) with varying amounts of sand and organic ranging in thickness" and underlying the clay is "silty sands (SM) and clayey sand (SC)". Likewise, Bayou Lafourche soils are described in the near surface as generally consisting of "fat clays (CH)" with "alternating layers of granular and cohesive soils" underlying the clay. Lastly, Belle Pass soils are described as generally consisting of "fat clays (CH) and organic clay (OH) with varying amounts of sand ranging in thickness" with "granular material…followed by cohesive soils" underlying the fat and organic clay.

In comparison, the major soil type found in all of the Nearshore Borrow borings was fat clay (CH). GeoEngineers' 2017 geotechnical report describes soils in the Nearshore Borrow Area as consisting primarily of "high plasticity clay with numerous silt streaks, lenses, seams, pockets and layers." Additionally, the composite soil samples GeoEngineers tested "generally contained less than 1% 'coarse' grained particles."

[18] Appendix D of this Technical Memorandum

Total Unit Weight and Cohesion

Figure 20 displays the composite soil profile's total unit weight (pcf) and cohesion (psf) of each soil layer with depth. Again, the areas on the plots highlighted in yellow show the Alternate Borrow Area's target dredging depth interval (existing water bottom up to -33.61 ft. NAVD 88) and are for visualization purposes only. Composite profile data of total unit weight and cohesion was not found for the Nearshore borrow, so the Nearshore borrow was excluded from this comparison.

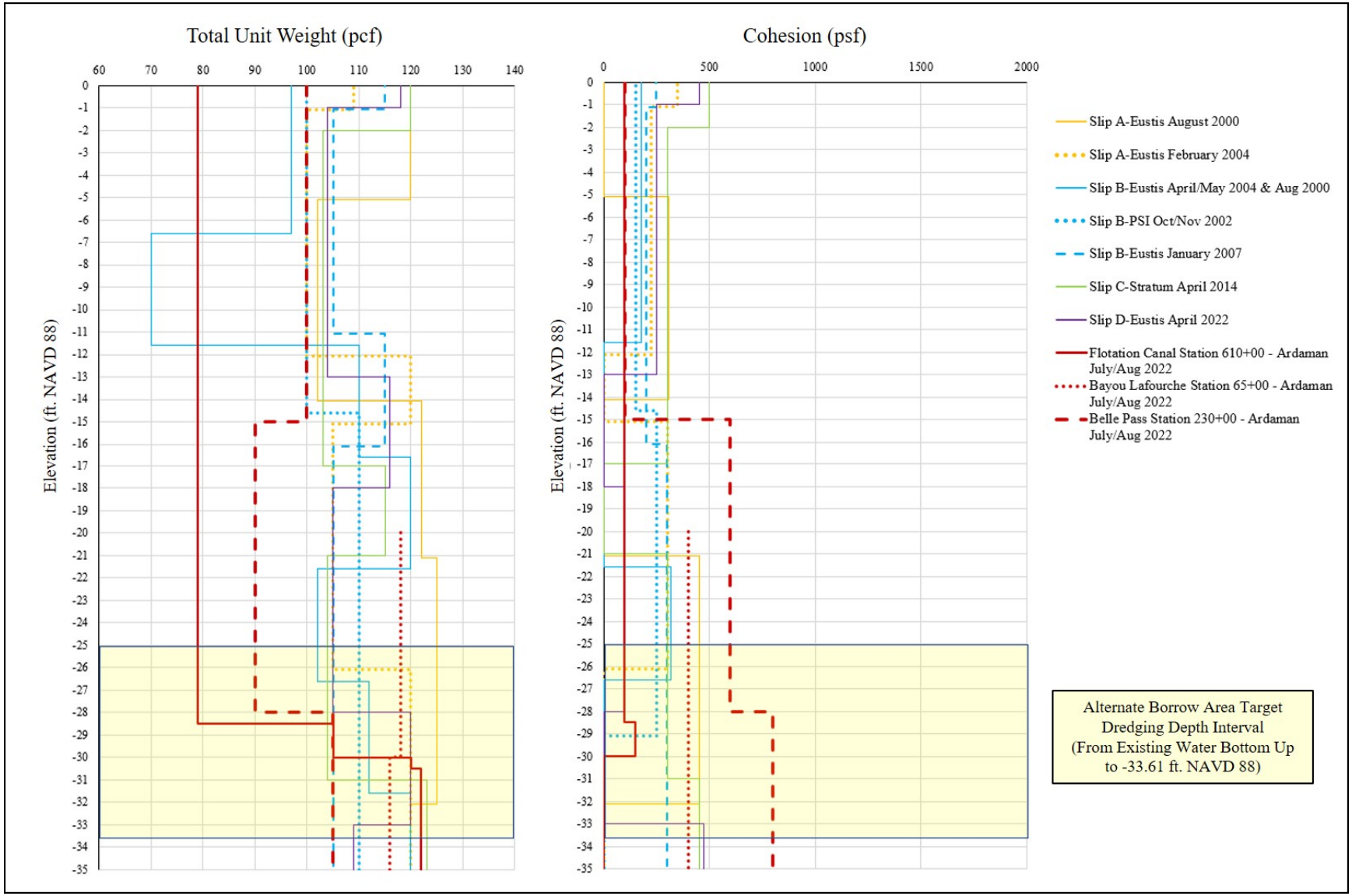

Figure 20 – Total Unit Weight and Cohesion of Alternate Borrow and Slip Composite Soil Profiles

Within the target dredging depth interval, the composite profiles of the Slips had total unit weights for strata that ranged from 97 pcf (Slip A – Eustis April/May 2004 & Aug. 2000) up to 125 pcf (Slip A – Eustis Aug. 2000). This range overlaps with the total unit weights of strata found for the composite profiles of the Alternate Borrow in this interval: 79 pcf (Flotation Canal 610+00) to 122 pcf (Flotation Canal 610+00).

Additionally, within the target dredging depth interval, the composite profiles of the Slips had cohesion values ranging from 0 psf (Slip A – Eustis Aug. 2000; Slip A – Eustis Feb. 2004; Slip B – PSI Oct./Nov. 2002; Slip B – Eustis April/May 2004 & Aug. 2000; and Slip D – Eustis April 2022) to 475 psf (Slip D – Eustis April 2022). This range falls within the range of cohesion for the Alternate Borrow composite profiles: 0 psf (Flotation Canal 610+00) to 800 psf (Belle Pass 230+00).

While the physical process of dredging mixes soil strata together and alters total unit weight and cohesion of soil, this information from the composite profile strata provides a way to quantifiably compare these soil strata. Also, when looking at the Slips composite profiles, the range of total weight and cohesion values within the target dredging depth interval is similar to the range of values in shallower strata (approx. -1 ft. to -25 ft. NAVD 88). Due to the boring's proximity to the interior of the Slips, it is reasonable to assume that the material in these shallower strata are similar to the material that was excavated from the slips and then used in the Mitigation Areas described previously.

Conclusion About Slips and PSDDF

The primary purpose of these soil boring analyses is to show that the soils in the Slips can reasonably be expected to behave similarly to samples used to generate the marsh elevation settlement curves. Ardaman used Primary consolidation, Secondary compression, and Desiccation of Dredged Fill (PSDDF) to model the elevation of the dredged material over time (Figure 2-Figure 7). The soil profile Ardaman used for PSDDF is a composite of composite profiles generated from samples taken throughout the Alternate Borrow footprint.

Figure 21 is an annotation of Ardaman's boring location map generated from the composite samples' description in their data report[19]. Clay-A came from cores in Bayou Lafourche (F-05, F-06, F-09), Clay-B came from cores in Belle Pass (F-10, F-11, F-12), Sand-A came from cores in Flotation Canal (F-01B, F-01C, F-03) and Bayou Lafourche (F-04), and Sand-Clay came from cores in Bayou Lafourche (F-06, F-07, F-08). Some of the properties of these composite samples that were used as PSDDF inputs were derived from settlement column tests[20] and slurry consolidation tests[21] Ardaman performed. These composite samples cover a large amount of area in order to include spatial and soil texture variability of the proposed dredged material in the PSDDF curves.

[19] Appendix D of this Technical Memorandum
[20] Appendix B.1 Setting Column Test Results of Ardaman's Data Report (Appendix D of this Technical Memorandum)
[21] Appendix B.2 Slurry Consolidation Test Results of Ardaman's Data Report (Appendix D of this Technical Memorandum)

Figure 21 – Locations of Borings Used to Create Composite Samples Clay-A, Clay-B, Sand-A, and Sand Clay for Composite Testing

Four main sets of parameters are input into PSDDF in order to generate the time series of elevations seen in the settlement curves:

1. Parameters describing the dredged material
2. Parameters describing the foundation soils
3. Parameters describing the placement of dredged material
4. Environmental parameters such as evaporation rates

For the purpose of this analysis, it is assumed that parameter sets 2-4 are constant and only the parameters describing the dredged material are of interest. These PSDDF dredged material input parameters include specific gravity (SG), ratio of secondary compression index to compression index (Ca/Cc), ratio between recompression index and compression index (Cr/Cc), desiccation limit (DL), saturation limit (SL), maximum depth of second-stage drying (H2), and degree of saturation at desiccation limit (SAT). This information is also used to generate a table describing the relationship of void ratio, effective stress and permeability.

Inputs of DL, SL, H2, SAT and the void ratio-effective stress-permeability relationships have all been shown to be well correlated with the Atterberg limits of dredged soils. Unfortunately, Atterberg limits in most of the existing geotechnical reports for the slips were not recorded at our target dredging depth interval of interest (~ -25 ft. to -33.61 ft. NAVD 88). However, Atterberg limits are used in both the USCS and AASHTO soil classification schemes, which were recorded in these reports. For example, sandy soils have very low liquid limits while silts and clays can have very high liquid limits. Additionally, sands and silts have almost no plasticity while clays can exhibit a range of plastic limits. Therefore, soil description based on USCS or AASHTO can provide some insight into how material would behave when compared to the materials that have been analyzed in detail. Based on the analyses described in the previous two sections, it can be said that Slip material contains a heterogenous mixture of sands, silts, and clays and is similar to the Alternate Borrow (Flotation Canal, Bayou Lafourche, Belle Pass) material. Therefore, GISE believes it is reasonable to assume that dredged Slip material would act and settle similarly to the Alternate Borrow material that was analyzed by Ardaman (2022).

Finally, it should be noted that the material dredged from the slips would makeup up only about 10% of the total material dredged and would be somewhat mixed with material dredged from Flotation Canal and upper Bayou Lafourche.

All of these points lead us to reasonably assume that including material from the Slips would not cause significant deviation from the Alternate Borrow settlement curves that Ardaman provided and that any deviation that might be seen would fall between the already overlapping settlement curves of the Alternate Borrow (Ardaman 2022) and Nearshore Borrow (Ardaman 2018).

APPENDICES

Appendix A – Intragovernmental Agreement (IGA)

Appendix B – Updated Draft Engineering Plan Set

Appendix C – Laboratory Test Assignments

Appendix D – Geotechnical Data Report

Appendix E – Geotechnical Design Report

Appendix F – GISE Magnetometer Survey Results

Appendix G – Pipeline Evaluation Notes

Appendix H – Fill and Borrow Calculations

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