Breton Landbridge Marsh Creation (West) River aux Chenes to Grand Lake
BS-0038
95% Design Report
Appendix J: Design Calculations

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ABBREVIATIONS

CPRA	Coastal Protection and Restoration Authority
CRMS	Coastwide Reference Monitoring System
CY	Cubic Yard
ECD	Earthen Containment Dike
ESLR	Eustatic Sea Level Rise
FT	Foot
LF	Linear Foot
LS	Lump Sum
MCA	Marsh Creation Area
MHW	5-year Mean High Water
MLW	5 year Mean Low Water
MN	5-year Mean Tide Range
MRHDM	Mississippi River Hydrodynamic and Delta Management
MTL	5-year Mean Tide Level
RSLR	Relative Sea Level Rise
SF	Square Foot
SY	Square Yard
TY	Target Year

1.0 TIDAL DATUM EVALUATION

a) Background Information and Data

Hourly hydrologic data was obtained from the following CRMS stations using the CIMS database:

Station	Latitude	Longitude
CRMS0121	N 29° 41' 37.65"	W 89° 49' 22.71"
CRMS0131	N 29° 41' 33.06"	W 89° 53' 07.87"

The hourly hydrologic data from each CRMS station was obtained for the most recent 5-year period from July 15, 2015 to July 14, 2020, and is referenced to Geoid12B.

b) Methodology

For each CRMS station, the MHW and MLW were determined for each day. The MHW and MLW values were averaged over the 5-year period to compute the average MHW, MLW, MTL, and MTR values as follows:

- **Mean High Water (MHW)** – the arithmetic mean of all the high water elevations observed over the 5-year period.
- **Mean Low Water (MLW)** – the arithmetic mean of all the low water elevations observed over the 5-year period.
- **Mean Tide Level (MTL)** – the tidal datum equivalent to the average of MHW and MLW observed over the 5-year period: $MTL = (MHW + MLW)/2$
- **Mean Tide Range (MTR)** – the tidal range between the MHW and MLW elevations observed over the 5-year period: $MTR = MHW - MLW$

c) Calculations

Known Variables	Equation	CRMS0121 Elev. (ft NAVD88 Geoid 12B)	CRMS0131 Elev. (ft NAVD88 Geoid 12B)	Average Elev. (ft NAVD88 Geoid 12B)
MHW= 5-Year Mean High Water	*Measured from Raw Data*	+1.06	+1.08	+1.07
MLW= 5-Year Mean Low Water	*Measured from Raw Data*	+0.35	+0.53	+0.44
MTL=5-Year Mean Tide Level	(MHW+MLW)/2	+0.71	+0.80	+0.75
MTR=5-Year Mean Tide Range	MHW-MLW	**Height (ft)**		**Average (ft)**
		0.72	0.55	0.63

2.0 PERCENT INUNDATION DETERMINATION

a) Background Information and Data

The 2017 Coastal Master Plan provides predicted sea level rise rates for use in the design of marsh creation projects. These rates range from 0.5 to 1.98 meters of sea level rise by 2100 and are bracketed in various scenarios to account for uncertainty. CPRA's Planning and Research Division recommends the use of the 1.0-m gulf sea-level rise scenario shown below (Demarco, 2012). This accounts for nearly 6 inches of sea-level rise over the 20-year project design life.

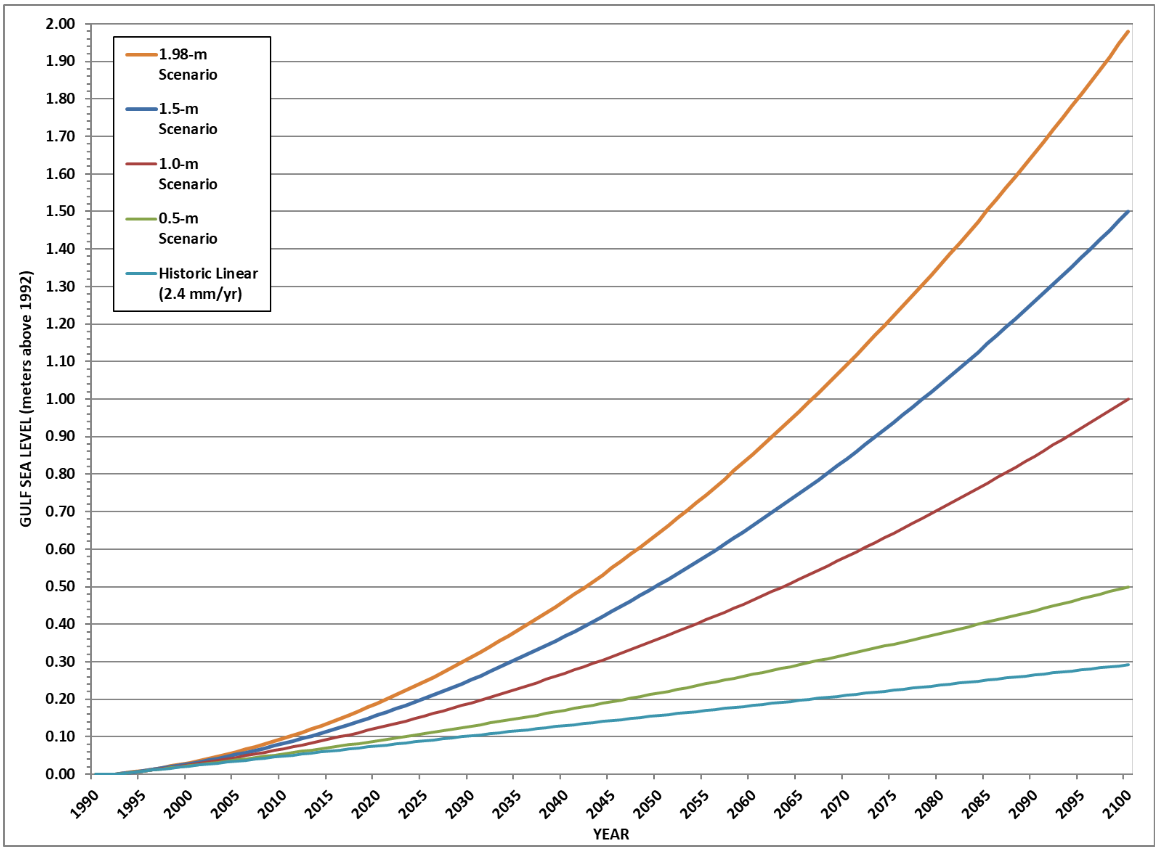


Figure 1: Gulf Sea-Surface Change Relative to 1990

Subsidence rates in this region are based on the 2017 Coastal Master Plan which uses the same rates from the 2012 Master Plan. The subsidence rates in the Breton Sound basin are approximately 4.4 mm per year (0.17 inches/year) (Applied Coastal Research and Engineering, 2019).

The rates of eustatic sea level rise (ESLR) and subsidence were used to determine the annual incremental relative sea level rise (RSLR) for the BS-0038 project area over the 20-year project life.

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

Where E is the change in relative sea level at time, t
a is the rate of ESLR (ft/yr),
b is an acceleration factor (ft/yr^2), and
S is the rate of subsidence (ft/yr).

The annual incremental ESLR and RSLR is shown in the following table:

Year	Annual Incremental Subsidence (St) (ft)	Annual Incremental Eustatic Sea Level Rise ($at + bt^2$) (ft)	Annual Incremental Relative Sea Level Rise ($at + bt^2 + St$) (ft)
2023 (TY0)	0.0000	0.0000	0.0000
2024	0.0144	0.0214	0.0358
2025	0.0288	0.0432	0.0720
2026	0.0432	0.0654	0.1086
2027	0.0576	0.0880	0.1456
2028	0.0720	0.1110	0.1830
2029	0.0864	0.1344	0.2208
2030	0.1008	0.1582	0.2590
2031	0.1152	0.1824	0.2976
2032	0.1296	0.2070	0.3366
2033	0.1440	0.2320	0.3760
2034	0.1584	0.2574	0.4158
2035	0.1728	0.2832	0.4560
2036	0.1872	0.3094	0.4966
2037	0.2016	0.3359	0.5375
2038	0.2160	0.3629	0.5789
2039	0.2304	0.3903	0.6207
2040	0.2448	0.4181	0.6629
2041	0.2592	0.4463	0.7055
2042	0.2736	0.4748	0.7484
2043	0.2880	0.5038	0.7918

b) Methodology

1. Collect the hourly hydrographic data from the CRMS stations.
2. Evaluate the marsh type present at CRMS 0121 and 0131 to determine the ideal percent inundation range. For BS-0038, this was determined to be intermediate marsh, relating to a 10-90% optimal inundation range.

Optimal marsh inundation ranges in Louisiana	
Marsh Type	**Optimal Inundation Range**
Fresh	10%-90%
Intermediate	10%-90%
Brackish	10%-65%
Saline	20%-80%

(CPRA Marsh Creation Design Guidelines v1)

3. For each inundation value, calculate the target percentile for the entire data set.
   - 1% Inundated = 99th Percentile of water level elevations
   - 10% Inundated = 90th Percentile of water level elevations

- 20% Inundated = 80th Percentile of water level elevations
- 30% Inundated = 70th Percentile of water level elevations
- 40% Inundated = 60th Percentile of water level elevations
- 50% Inundated = 50th Percentile of water level elevations
- 60% Inundated = 40th Percentile of water level elevations
- 70% Inundated = 30th Percentile of water level elevations
- 80% Inundated = 20th Percentile of water level elevations
- 90% Inundated = 10th Percentile of water level elevations
- 99% Inundated = 1st Percentile of water level elevations

4. Apply RSLR to the computed inundation elevations to determine the target year 20 (TY20) tidal elevations.

c) Calculations

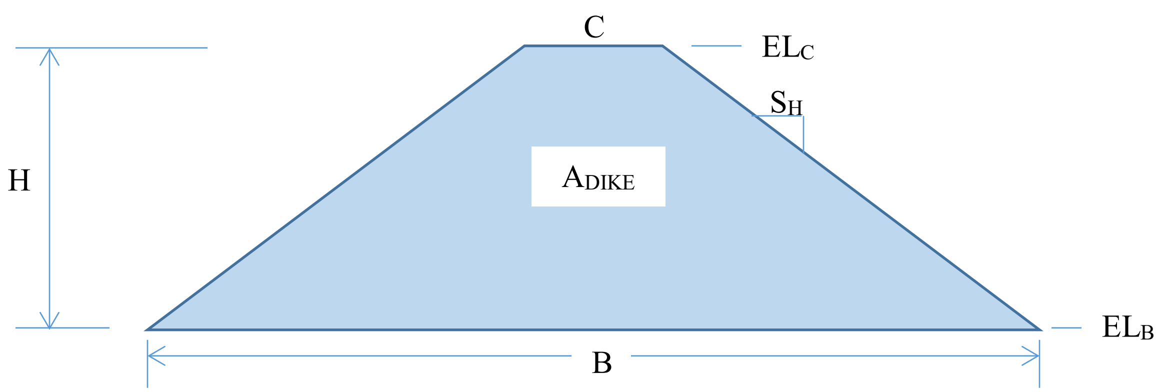
Percent Inundated	Equation	2023 Marsh Elevations (ft NAVD88 GEOID 12B)	2043 Marsh Elevations (ft NAVD88 GEOID 12B)
1	0.99*Raw Data Elevations	+2.75	+3.25
10	0.9*Raw Data Elevations	+1.61	+2.12
20	0.8*Raw Data Elevations	+1.30	+1.80
30	0.7*Raw Data Elevations	+1.10	+1.60
40	0.6*Raw Data Elevations	+0.93	+1.44
50	0.5*Raw Data Elevations	+0.79	+1.29
60	0.4*Raw Data Elevations	+0.59	+1.10
65	0.35*Raw Data Elevations	+0.57	+1.07
70	0.3*Raw Data Elevations	+0.49	+0.99
80	0.2*Raw Data Elevations	+0.29	+0.79
90	0.1*Raw Data Elevations	+0.03	+0.54
99	0.01*Raw Data Elevations	-0.61	-0.11

3.0 EARTHEN CONTAINMENT DIKE DESIGN

a) ECD Feature Parameters

Parameter	Measure
Crown Width (ft)	5.0 ft (ECD)
Side Slope (H:V)	4H:1V
Freeboard (ft)	1.0 ft above constructed marsh fill elevation
Crown Elevation (ft)	+3.25 ft +0.5 ft NAVD88, Geoid12B (MCA-1)
	+3.75 ft +0.5 ft NAVD88, Geoid12B (MCA-2 through 4 and MCA-7)
Survey Data (ft)	x-, y-, and z-coordinates from transects

b) Methodology



H = Dike Height
B = Base Width
C = Crown Width
EL_B = Base Elevation
EL_C = Crown Elevation
A_{A-B} = Cross-Sectional Area of dike between points A & B
L_{A-B} = Length between points A & B
S_H = Side Slope

1. Base Elevation: The base elevation between two points was determined by taking the average of the Z values between the two points of interest along the survey profiles.
2. Dike Height: The height of the dike is computed by subtracting the base elevation from the crown elevation (including construction tolerance, +3.75 (MCA-1) or +4.25 (MCA-2 through 4,and MCA-7) ft NAVD88) as shown in the following formula:

$$H = EL_C - EL_B$$

3. Base Width: The base width is governed by the dike height, the crown width, and the horizontal component of the side slope (4.0) and is computed using the following formula:

$$B = 2(S_H H) + C$$

4. Cross-Sectional Area: The cross-sectional area of each containment dike differs from site to site and is governed by the base elevation (given in the survey data), dike height, and base width at the proposed location. Once these variables are determined, the area can be calculated by treating the dike section as a trapezoid as shown in the formula below:

$$A_{DIKE} = ½ [H(C + B)]$$

5. Containment Dike Length: Calculated between each XYZ point along each profile:

$$L_{A-B} = [(x_b - x_a)^2 + (y_b - y_a)^2]^{1/2}$$

6. Containment Dike Volume: The volume of material required to construct each portion is computed by multiplying each area by its corresponding length.

$$V_{A-B} = A_{A-B} * L_{A-B}$$

c) Example Calculation (MCA-1)

Known Parameters

Survey Point Data (MCA-1)

Survey Point	Value	Measure
Point A	X_A (Easting)	3,759,790.73
	Y_A (Northing)	445,465.08
	Z_A (EB)	+0.49 ft NAVD88, Geoid12B
Point B	X_B (Easting)	3,759,792.02
	Y_B (Northing)	445,450.11
	Z_B (EB)	+0.89 ft NAVD88, Geoid12B

Earthen Containment Dike Parameters (MCA-1)

Parameter	Measure
Crown Width, C (ft)	5.0 ft
Side Slope, S_H (H:V)	4H:1V
Freeboard (ft)	1.0 ft above constructed marsh fill elevation plus 0.5 ft tolerance
Crown Elevation, EL_C (ft)	+3.25 ft +0.5 ft NAVD88, Geoid12B

Cross-Sectional Design

Base Elevation: $E_{A\text{-}B} = (Z_B + Z_A)/2 = +0.69$ ft NAVD88

Dike Height: $H = EL_C - E_{A\text{-}B} = 3.06$ ft

Base Width: $B = 2\,(S_H H) + C = 29.48$ ft

Cross-Sectional Area: $A_{A\text{-}B} = ½\,[H(C + B)] = 52.91\ ft^2$

Volume Calculations

Segment Length: $L_{A\text{-}B} = [(x_B\text{-}x_A)^2 + (y_B\text{-}y_A)^2]^{1/2} = 15.03$ ft

Dike Volume: $V_{A\text{-}B} = (A_{A\text{-}B} * L_{A\text{-}B}) / 27 = 29.45\ yd^3$

These calculations were performed using the Average End Area Method in a Microsoft Excel spreadsheet, as well as in AutoCAD from the TIN surface. The table below details the results of both of these calculations for required amount of fill material required with percent differences.

Earthen Containment Dike Volume Calculations

Area	Length of Containment (ft)			Volume of Fill (CY)		
	Calculated	CAD	% Difference	Calculated	CAD	% Difference
MCA-1	6,471	6,341	2.2%	16,537	19,436	16.1%
MCA-2	5,713	5,643	1.2%	17,213	17,020	1.1%
MCA-3	7,201	7,078	1.7%	23,157	27,415	16.8%
MCA-4	9,015	8,239	9.0%	34,879	32,223	7.9%
MCA-7	8,429	8,374	0.7%	30,134	34,146	12.5%
Totals	**36,829**	**35,675**	**3.2%**	**121,920**	**130,240**	**6.6%**

*Note: Quantities selected for design (highlighted): CAD lengths; larger volumes (to provide conservative estimate).

4.0 LAKE DIKE DESIGN

a) Given

Lake Dike 1 (MCA-1)

Parameter	Measure
Containment Feature Crown Elevation, EL_{CF} (ft)	+3.25 ft +0.5 ft NAVD88, GEOID12B
Lake Dike Crown Elevation, EL_{LD} (ft)	+3.0 ft +0.5 ft NAVD88, GEOID12B
Containment Feature Base Width, B_{CF} (ft)	12.25 ft
Containment Feature Crown Width, C_{CF} (ft)	10 ft
Lake Dike Crown Width, C_{LD} (ft)	40 ft
Side Slope (Lake Side), S_{LS} (H:V)	5H:1V
Side Slope (Marsh Side), S_{MS} (H:V)	4H:1V
Survey Data (ft)	x-, y-, and z-coordinates from transects

Lake Dike 2 (MCAs 2 & 4)

Parameter	Measure
Containment Feature Crown Elevation, EL_{CF} (ft)	+3.75 ft +0.5 ft NAVD88, GEOID12B
Lake Dike Crown Elevation, EL_{LD} (ft)	+3.0 ft +0.5 ft NAVD88, GEOID12B
Containment Feature Base Width, B_{CF} (ft)	16.75 ft
Containment Feature Crown Width, C_{CF} (ft)	10 ft
Lake Dike Crown Width, C_{LD} (ft)	40 ft
Side Slope (Lake Side), S_{LS} (H:V)	5H:1V
Side Slope (Marsh Side), S_{MS} (H:V)	4H:1V
Survey Data (ft)	x-, y-, and z-coordinates from transects

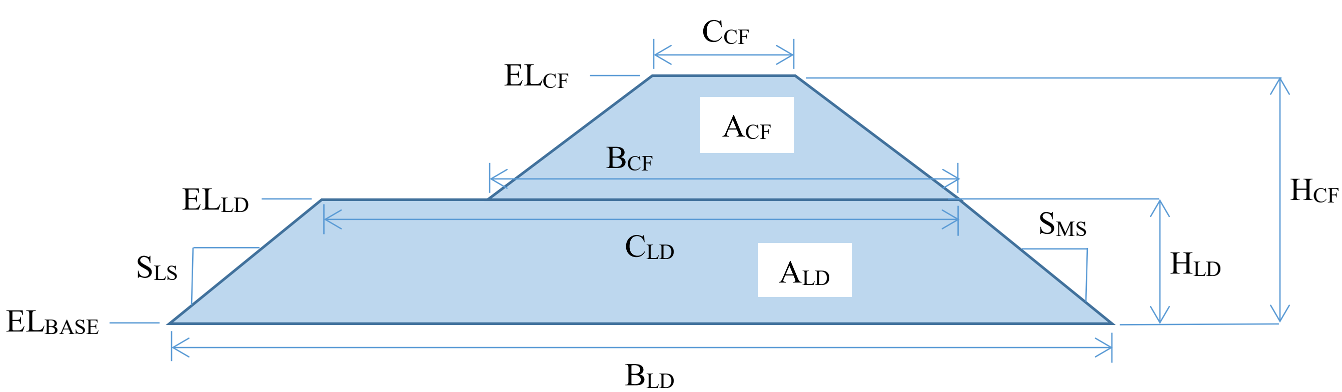
Lake Dike 3 (MCA-7)

Parameter	Measure
Lake Dike Crown Elevation, EL_{LD} (ft)	+3.75 ft +0.5 ft NAVD88, GEOID12B
Lake Dike Crown Width, C_{LD} (ft)	15 ft
Side Slope (Lake Side), S_{LS} (H:V)	5H:1V
Side Slope (Marsh Side), S_{MS} (H:V)	4H:1V
Survey Data (ft)	x-, y-, and z-coordinates from transects

b) Methodology

The methodology for the volume calculations of the lake dike and containment feature are the same as those used for the ECD.

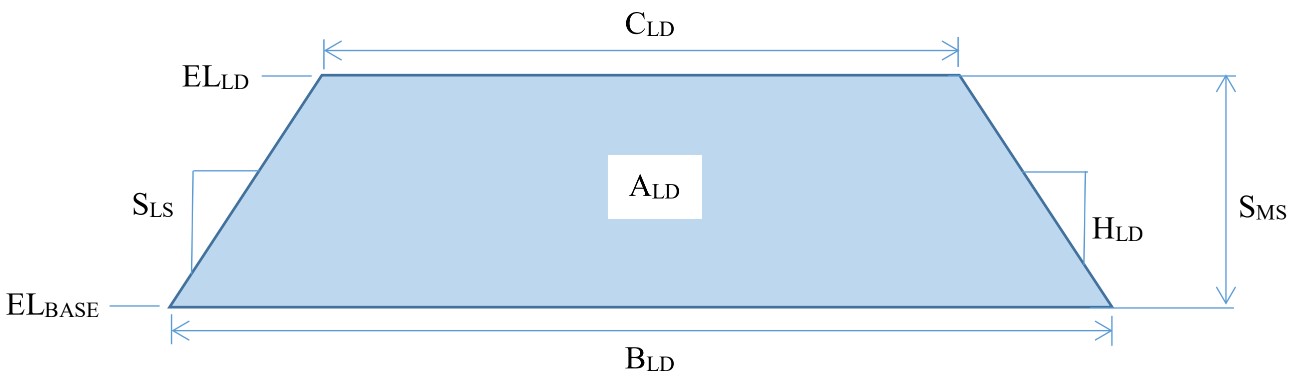
Lake Dike Design 1 (MCA-1) & Lake Dike Design 2 (MCAs 2 & 4)



Where:

EL_{CF} = Containment Feature Crown Elevation
EL_{LD} = Lake Dike Crown Elevation
EL_{BASE} = Lake Dike Base (Mudline) Elevation
B_{CF} = Containment Feature Base Width
H_{LD} = Lake Dike Height
H_{CF} = Containment Feature Height
B_{LD} = Lake Dike Base Width
C_{CF} = Containment Feature Crown Width
C_{LD} = Lake Dike Crown Width
$A_{CF\ A\text{-}B}$ =Containment Feature Cross-Sectional Area between points A & B
$A_{LD\ A\text{-}B}$ = Lake Dike Cross-Sectional Area between points A & B
$L_{A\text{-}B}$ = Length between points A & B
S_{LS} = Side Slope (Lake Side)
S_{MS} = Side Slope (Marsh Side)

Lake Dike Design 3 (MCA-7)



Where: EL_{LD} = Lake Dike Crown Elevation
EL_{BASE} = Lake Dike Base (Mudline) Elevation
H_{LD} = Lake Dike Height
B_{LD} = Lake Dike Base Width
C_{LD} = Lake Dike Crown Width
$A_{LD\ A\text{-}B}$ = Lake Dike Cross-Sectional Area between points A & B
$L_{A\text{-}B}$ = Length between points A & B
S_{LS} = Side Slope (Lake Side)
S_{MS} = Side Slope (Marsh Side)

c) Calculations

The lake dike calculations were performed using the Average End Area Method in a Microsoft Excel spreadsheet, as well as in AutoCAD from the TIN surface. The table below details the results of both of these calculations for required amount of fill material required with percent differences.

Lake Dike Volume Calculations

Area	Length of Containment (ft)			Volume of Fill (CY)		
	Calculated	CAD	% Difference	Calculated	CAD	% Difference
MCA-1	3,224	3,211	0.4%	31,222	34,431	9.8%
MCA-2	3,494	3,357	4.0%	38,339	45,597	17.3%
MCA-4	5,976	5,525	7.8%	44,969	51,196	13.0%
MCA-7	1,290	1,282	0.6%	8,809	6,467	30.7%
Totals	**13,984**	**13,375**	**4.5%**	**123,339**	**137,691**	**11.0%**

*Note: Quantities selected for design (highlighted): CAD lengths; larger volumes (to provide conservative estimate).

5.0 FILL AREA DESIGN

a) Given

The cross-sectional survey data of the marsh fill sites provided XYZ data for each fill area cross-section survey transect

Note that marsh fill volumes are computed using the TY20 elevation of the settlement curve + subsidence + mudline settlement.

Cell	Interpolated TY20 elevation (ft NAVD88 GEOID12B)	Subsidence (ft)	Mudline Settlement (ft)	Plane Height for Volume Calculation (ft NAVD88 GEOID12B)
MCA-1	+0.97		0.56	+1.82
MCAs 2, 3	+1.04	0.29	0.30	+1.63
MCAs 4, 7	+0.97		0.35	+1.61

b) Methodology

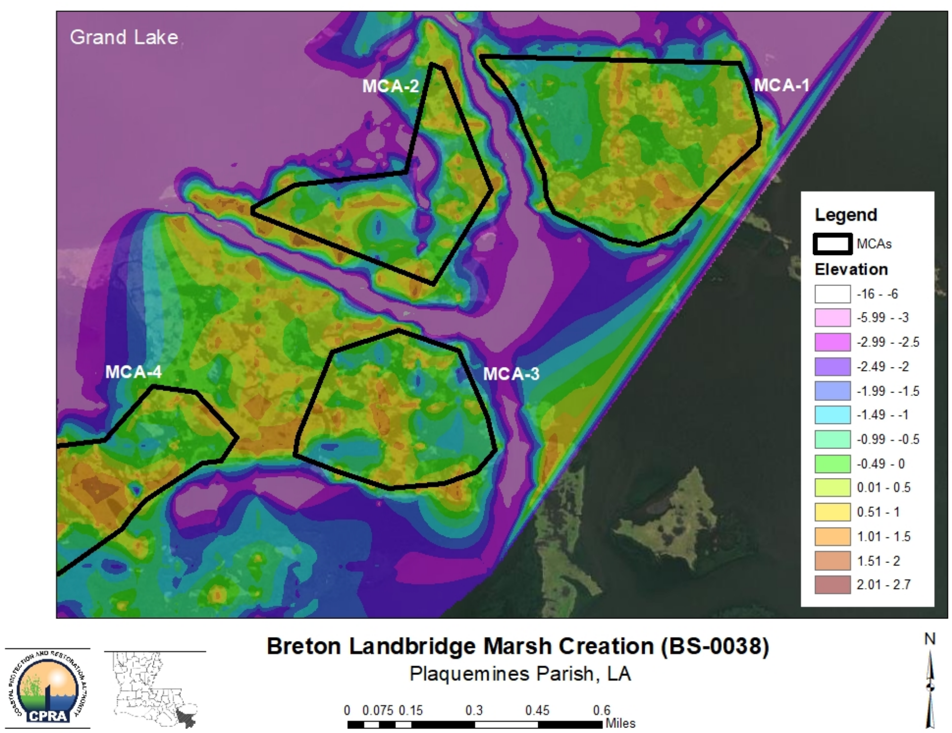


Figure 2: MCA-1, MCA-2, and MCA-3 Surface Elevations from 2020 Survey Transects

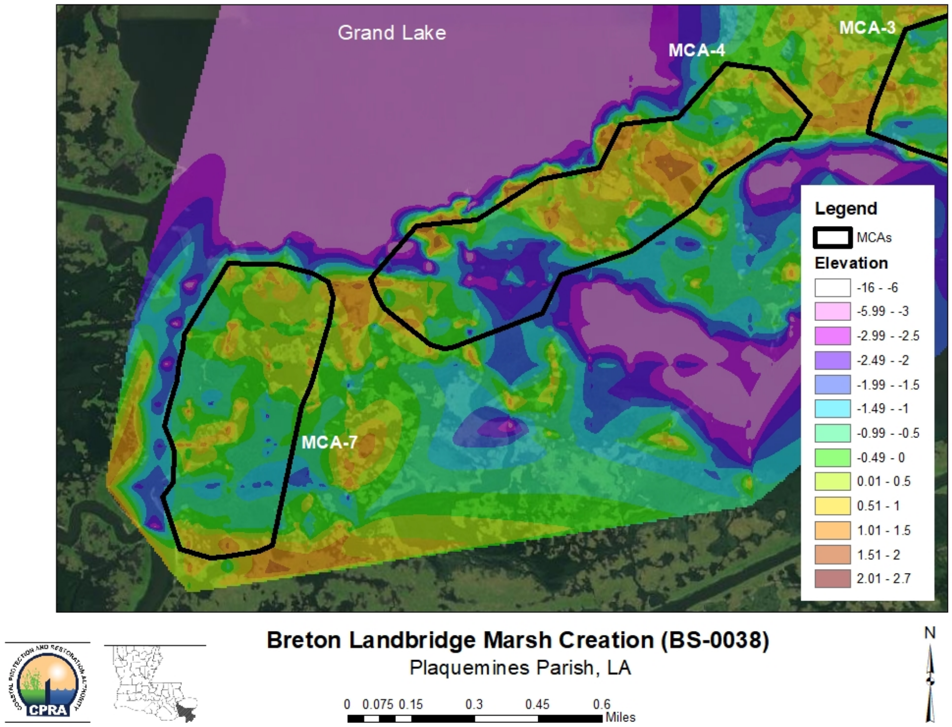


Figure 3: MCA-4 and MCA-7 Surface Elevations from 2020 Survey Transects

1. <u>Area Calculations</u>: The cross-sectional area of each marsh fill transect was calculated using the XYZ data mentioned above. Due to the large number of points involved with each cross-section, the following simplified example is used to show the method of calculating cross-sectional areas:

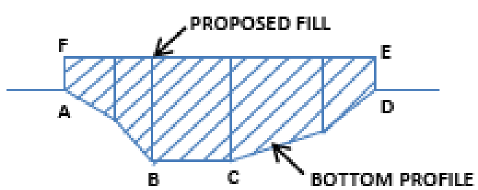


Figure 1

The area of this section can be obtained by incrementally computing the areas of each of the trapezoids ABCDEF shown in Figure 1. By treating the section as a traverse, fundamental survey methods can be utilized to calculate this area. These areas are calculated using the given data from the survey datasets with each point having a corresponding XYZ value. The incremental area calculations are carried out using the following formula:

$$A_i = \frac{1}{2} [D_i(Z_{i+1} - Z_{i-1})]$$

Where: A_i=incremental area

D_i=cumulative distance from beginning of transect to point i

Z_{i+1}=elevation of previous point

Z_{i-1}=elevation of next point

The cumulative distance is computed by continuously summing the distance between each point, which is calculated with the distance formula:

$$L_i = [(X_2 - X_1)^2 + (Y_2 - Y_1)^2 + (Z_2 - Z_1)^2]^{1/2}$$

Where: X = easting

Y = northing

Z = elevation

The total area of the cross sections can be then obtained by summing each incremental area. Because these computations are so labor intensive, a spreadsheet was used for these area calculations.

2. Distance between Cross Sections: Before the volume of the fill sites can be calculated, the distance between cross sections must be obtained. These distances represent the plan view area that each cross section will represent and were computed from the surveyor's CAD drawing.

3. Volume Calculations: The volume calculations for each cross section are computed by taking the product of the cross-sectional area and its corresponding distance. The incremental volumes are then added together to get the total volume of the fill site. This is accomplished using the simple formulas shown below:

$$V_{xs} = (A_{xs})(d)$$

Where: V_{xs} = Cross-sectional volume

A_{xs} = Cross-sectional area

D = Distance between cross-sections

Adding the cut volume of the internal borrow for the ECDs (V_{ECD}) to the sum of V_{xs} gives the total fill volume V_{tot}:

$$V_{tot} = V_{ECD} + \sum V_{xs}$$

c) Calculations

These calculations were performed using the Average End Area Method in Microsoft Excel, as well as in AutoCAD from the TIN surface. The table below details the results of both of these calculations for required amount of fill material, not including dike backfill, with percent differences.

Marsh Fill Area Volume Calculations at CMFE			
Area	**Volume (CY)**		**% Difference**
	Calculated	**CAD**	
MCA-1	329,029	362,504	9.7%
MCA-2	270,876	243,615	10.6%
MCA-3	214,471	225,263	4.9%
MCA-4	469,346	472,265	0.6%
MCA-7	298,983	365,214	19.9%
Sum	1,582,705	1,668,861	5.3%

*Note: Quantities selected for design (highlighted): larger volumes (to provide conservative estimate).

A summary of the 95% design fill volumes is shown below.

Fill Area	**CMFE (ft NAVD88)**	**Area (Acres)**	**Cut-to-Fill**	**Volume of Fill (CY)**	**ECD Fill Volume (CY)**	**ECD Internal Borrow Cut Volume (CY)**	**Volume of Fill + ECD Internal Borrow Cut (CY)**	**Volume of Cut (CY)**
MCA-1	+2.25	126	1.1:1	362,504	19,436	38,872	401,376	441,514
MCA-2	+2.75	73	1.1:1	270,876	17,213	34,426	305,302	335,832
MCA-3	+2.75	81	1.1:1	225,263	27,415	54,830	280,093	308,102
MCA-4	+2.75	157	1.1:1	472,265	34,879	69,758	542,023	596,225
MCA-7	+2.75	124	1.1:1	365,214	34,146	68,292	433,506	476,857
Total	**-**	**561**	**-**	**1,696,122**	**133,089**	**266,178**	**1,962,300**	**2,158,530**

6.0 Cut to Fill Ratio

To provide conservative volume estimates, the cut-to-fill ratios of the marsh fill and ECD/Lake dike were designed to be 1.1 and 2.0, respectively.

The total volume for marsh fill (including backfilling internal borrow containment dike volume), ECDs, and lake dikes needed based on this evaluation is presented in the table below:

ECD Volume (CY)	Fill Volume (CY)	Cut-To-Fill	Cut Volume (CY)	Total Cut Volume (CY)
Marsh Fill (including internal borrow backfill)	1,962,300	1.1	2,158,530	**2,704,774**
ECD	133,089	2.0	266,178	
Lake Dike	140,033	2.0	280,066	

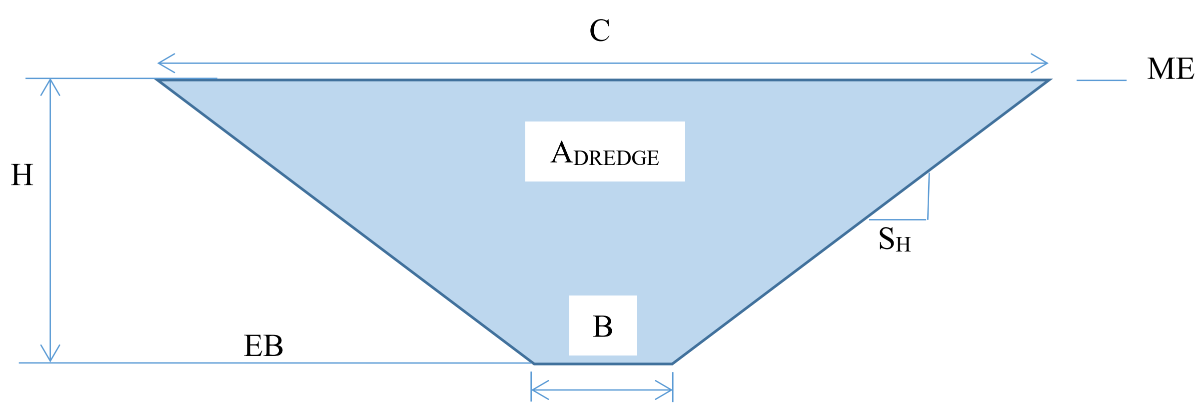
7.0 ACCESS DREDGING DESIGN

a) Access Dredging Parameters

Parameter	Measure
Bottom elevation (ft NAVD88 GEOID12B)	-6
Side Slope (H:V)	2H:1V
Bottom Width (ft)	60
Survey Data (ft)	x-, y-, and x-coordinates from transects (1,000 ft spacing along EAC centerline)

b) Methodology

Access Dredging Section



Where:

H = Depth of Cut
B = Base Width of Cut
C = Top Width of Cut
ME = Mudline Elevation
EB = Base Elevation
A_{DREDGE} = Cross-Sectional Area of dredged channel between points A & B
L_{A-B} =Length between points A & B that require access dredging
S_H = Side Slope

1. Mudline Elevation (ME): The mudline elevation between two points was determined by taking the average of the Z values between the two points of interest along the survey profiles.
2. Depth of Cut: The depth of the cut is computed by subtracting the base elevation from the average existing mudline elevation (varies) as shown in the following formula:

$$H = ME - EB$$

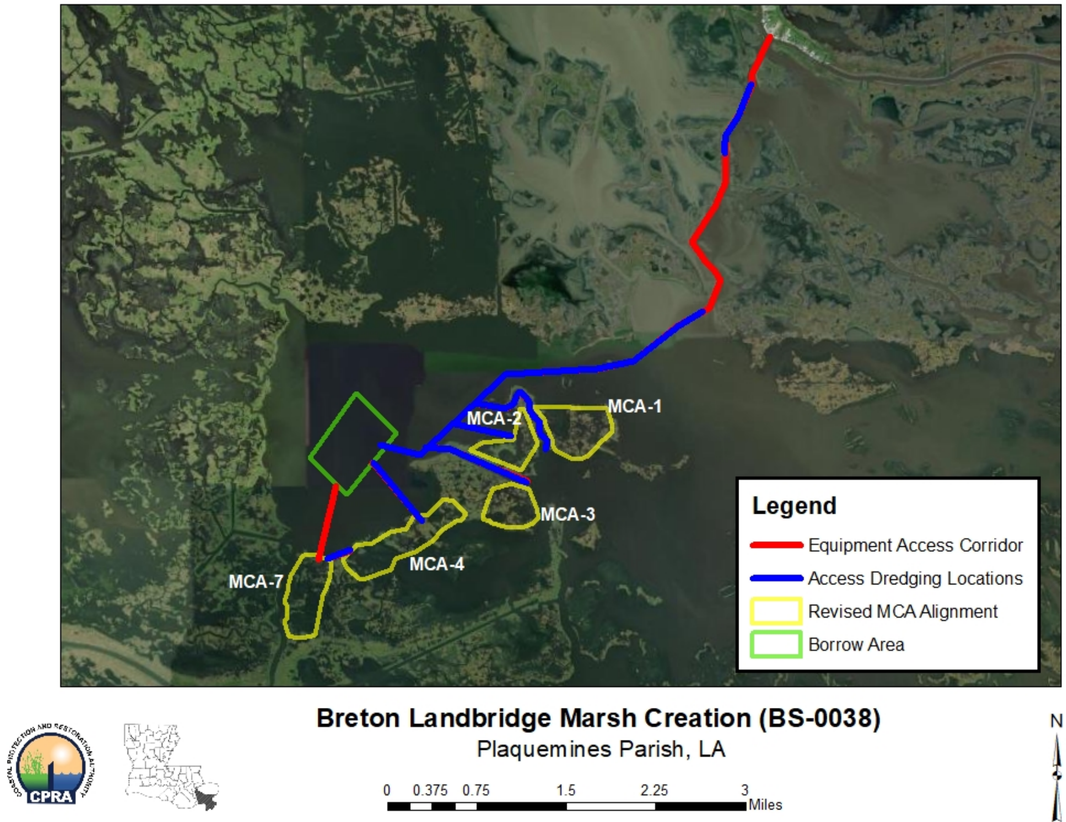


Figure 4: Location of Access Dredging

3. Top Width of Cut: The top width of the cut is governed by the depth of the cut, the base width of the cut, and the horizontal component of the side slope (2.0) and is computed using the following formula:

$$C = 2(S_H H) + B$$

4. Cross-Sectional Area: The cross-sectional area of each access dredge section differs from site to site and is governed by the top width of the cut, base width of the cut, the depth of cut, and the mudline elevation at the proposed location (from the survey data). Once these variables are determined, the area can be calculated by treating the dike section as a trapezoid as shown in the formula below:

$$A_{DREDGE} = ½ [H(C + B)]$$

5. Access Dredge Length: Measured distance of EAC requiring access dredging.

6. Access Dredge Volume: The volume of material requiring dredging in each portion is computed by multiplying each area by its corresponding length.

$$V_{A\text{-}B} = A_{DREDGE} * L_{A\text{-}B}$$

c) Calculations

Section	Length (LF)	Average Mudline Elevation (ft NAVD88 GEOID 12B)	Target Depth (ft NAVD 88 GEOID 12B)	Bottom Width (ft)	Side Slope	Dredge Volume (CY)
Bayou Gentilly Near Delacroix	1,700	-3.9	-6.0	60	2H:1V	5,536
Bayou Gentilly to BA	16,300	-4.4				60,383
Access to BA	1,100	-5.1				2,266
To MCA-1 Lake Dike	1,400	-3.1				9,894
To MCA-2 Lake Dike	2,800	-3.4				17,177
To MCA-4 Lake Dike	2,900	-4.3				18,022
From MCA-4 to MCA-7	1,200	-2.75				10,422
Total	**27,400**	**-**	**-**	**-**	**-**	**123,700**

8.0 REFERENCES

All references used for design computations can be found in the references section of the BS-0038 95% design report.