E C O L O G I C A L   R E V I E W

West Lake Boudreaux Shoreline Protection and Marsh Creation
CWPPRA Priority Project List 11
State No. TE-46

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This document reflects the project design as of the 95% Design Review meeting, incorporates all comments and recommendations received following the meeting, and is current as of November 22, 2005.

ECOLOGICAL REVIEW
West Lake Boudreaux Shoreline Protection and Marsh Creation

In August 2000, the Louisiana Department of Natural Resources initiated the Ecological Review to improve the likelihood of restoration project success. This is a process whereby each restoration project's biotic benefits, goals, and strategies are evaluated prior to granting construction authorization. This evaluation utilizes monitoring and engineering information, as well as applicable scientific literature, to assess whether or not, and to what degree, the proposed project features will cause the desired ecological response.

I. Introduction

The West Lake Boudreaux Shoreline Protection and Marsh Creation (TE-46) project is located in Terrebonne Parish along the western side of Lake Boudreaux, south of Bayou Butler and east of Bayou Grand Caillou (Figure 1). The project area encompasses 1,207 acres comprised of 434 acres of marsh and 773 acres of open water (United States Fish and Wildlife Service [USFWS] 2005a). The western shoreline of Lake Boudreaux protects adjacent intermediate marsh and aquatic grass beds against wind-generated high wave energy that occurs in the lake. Shoreline erosion rates in the area are very high, yet variable, due to the highly organic composition of the soils in the Lake Boudreaux area (USFWS 2005a). Soils of this type have high shearing capacities, are easily compacted, are more susceptible to subsidence, and have low bearing capacities.

Shoreline erosion and high marsh loss rates in the area can be attributed to direct exposure to wind-generated wave energy, subsidence, turbidity detrimental to submerged aquatic vegetation (SAV) populations, and saltwater intrusion (USFWS 2005a). An analysis of shoreline erosion rates was undertaken by the United States Geological Survey (USGS) reviewing 1988 to 2004 aerial photography. In that analysis, shoreline erosion rates ranged from approximately 91 feet/year (northwestern shore) to 10 feet/year (southwestern shore) with a total weighted average erosion rate of 42 feet/year. (USFWS 2005a). Furthermore, a Professional Engineering and Surveying Company, Inc. (PENSCO) survey, taken in the spring of 2004, indicated that there had been as much as 600 feet of shoreline erosion in the six year period since the baseline aerial photo utilized for the project plan was taken on February 4, 1998 (PENSCO 2004).

The objectives of this project are to protect critically eroding portions of the western bank of Lake Boudreaux and to provide marsh creation within the existing marsh interior (USFWS 2005b). *Coast 2050* has identified the protection of lake shorelines and the dedicated delivery of sediment for marsh building as Region 3 ecosystem strategies that will maintain shoreline integrity and preserve marsh areas (Louisiana Coastal Wetlands Conservation and Restoration Task Force and the Wetlands Conservation and Restoration Authority 1999).

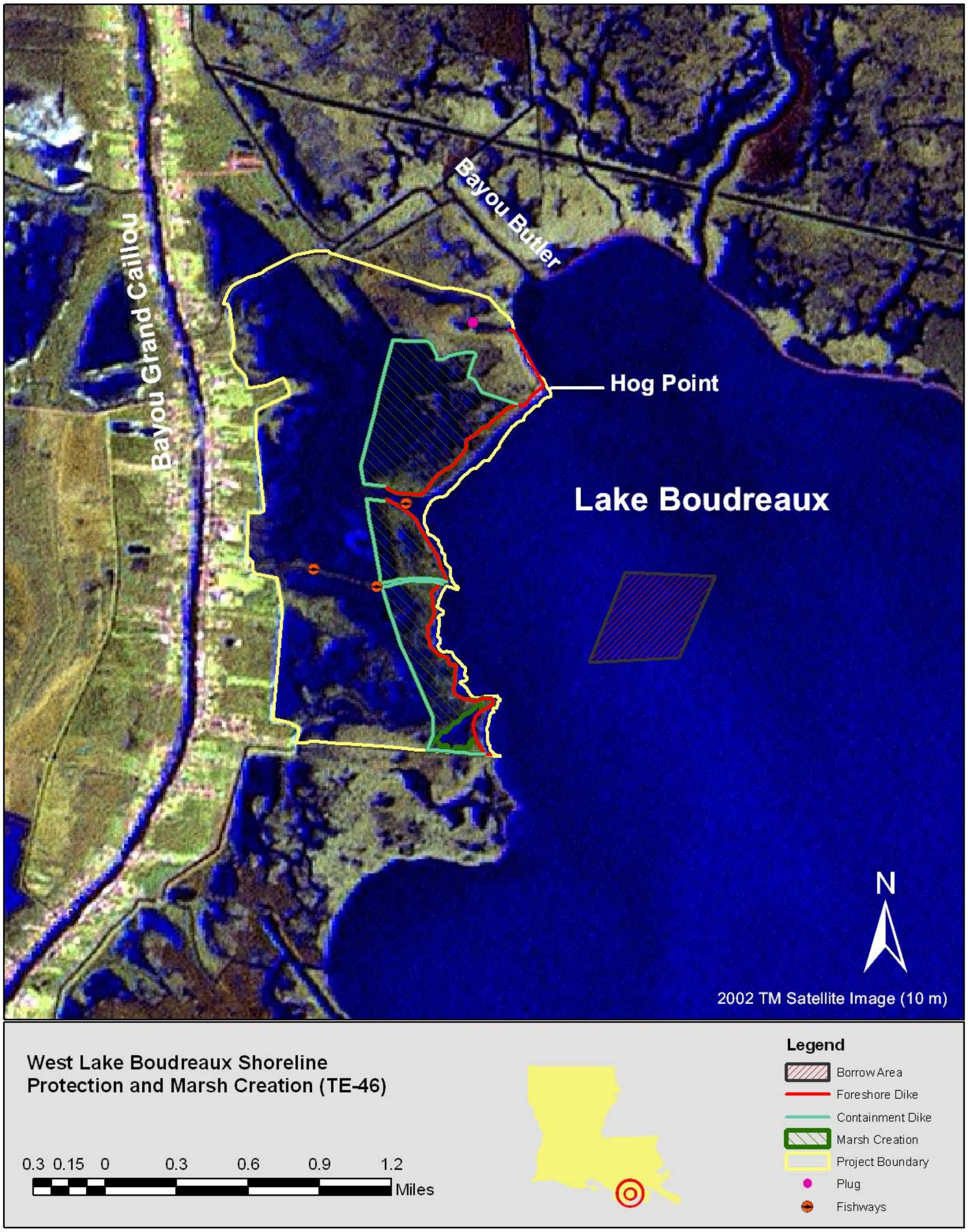


Figure 1. West Lake Boudreaux Shoreline Protection and Marsh Creation project plan map.

II. Goal Statement

- Stop shoreline erosion along approximately 14,207 linear feet of the western shoreline of Lake Boudreaux over the 20-year project life.
- Initially create 284 acres of marsh by the completion of project construction with intertidal marsh developing after year 3 of the project's life.
- Reduce erosion rates by 50%, from 3.68% per year to 1.84% per year, in the created and nourished marsh over the 20-year project life.
- Reduce erosion rates by 25%, from 3.68% per year to 2.76% per year, in the non-directly affected marsh over the 20-year project life.

III. Strategy Statement

A foreshore rock dike will be built on the -1.0-foot NAVD 88 contour along the western shoreline of Lake Boudreaux in three sections (northern, central, and southern) with a combined linear distance of 14,207 feet. The distance between the foreshore rock dike and the shoreline ranges from approximately 20 feet to approximately 75 feet. A flotation channel will be bucket dredged for access to the area with the material beneficially used for construction of a portion of the containment dike surrounding the marsh creation areas. The marsh creation fill material will be obtained via hydraulic dredging from the Lake Boudreaux borrow site shown on the project area map (Figure 1).

IV. Strategy-Goal Relationship

Shoreline protection and stabilization in the form of a foreshore rock dike should attenuate shoreline retreat by baffling high-energy, wind-driven waves thus providing protection to the existing interior marsh with the expectation that erosion rates will be reduced. Dredge material will be placed in the open-water areas behind the rock dike structure to create 284 acres of marsh within the existing marsh interior.

V. Project Feature Evaluation

The project design is primarily based on the geotechnical report, predicted settlement rates, the United States Army Corps of Engineers (USACE) *Shore Protection Manual* incorporating usage of the Automated Coastal Engineering System (ACES) program, and historical knowledge of existing similar projects (USFWS 2005b). The geotechnical report (Burns Cooley Dennis, Inc. 2003) consists of analyses of (1) the settlement and stability for a rock dike, (2) the feasibility of a composite light weight aggregate dike, (3) a containment dike for marsh creation, and (4) the settlement/consolidation of the created marsh.

<u>Rock Dike Section Design</u>

Initially, a concrete pile with concrete panel wall utilizing 16-inch square piles and 20-foot long wall panels was considered for this project. Depending on the selected loading, pile lengths of 45 to 80 feet would have been required and the lateral deflections of these piles would have varied greatly. Consequently, this option was eliminated in favor of a rock dike, which had the advantages of lower cost and less variability in design requirements (Burns Cooley Dennis, Inc. 2003).

The process of cost comparisons of a rock dike versus composite lightweight aggregate dike demonstrated that a rock dike was the most economical shoreline treatment (USFWS 2005b). An additional consideration that lead to the selection of rock for the shoreline protection structure (as opposed to concrete panels or light aggregate core materials) was the presence of a sand lens, located beneath the organic and mineral soils throughout the entire project area, which can structurally support the load of rock (Burns Cooley Dennis, Inc. 2003).

Separate settlement curves were provided in the geotechnical report for individual boring locations based on a rock dike height of +4.0 feet NAVD 88 (Burns Cooley Dennis, Inc. 2003). An aggregated overlay of each of these individual curves is shown in Figure 2 below. A review of the settlement predictions by the project team engineers determined that a dike elevation of +3.5 feet NAVD 88 would provide adequate protection for the design wave height. It should be noted that the settlement predictions do not account for subsidence.

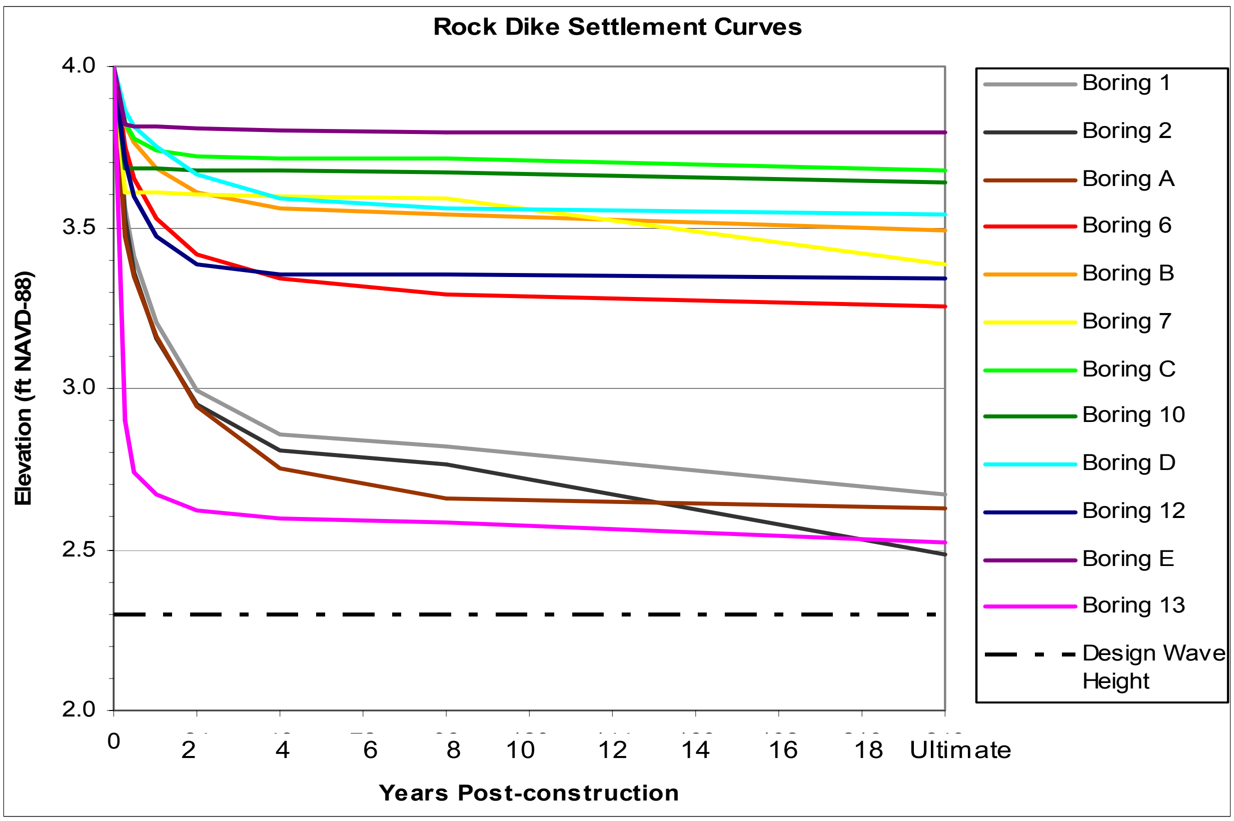


Figure 2. Rock dike settlement curves overlay (data from Burns Cooley Dennis, Inc. 2003).

The geotechnical design for the rock dike was evaluated for structural stability relative to wave impacts. A design 70 mile per hour wind was evaluated as per guidance provided by the Louisiana Department of Natural Resources (LDNR)/Natural Resources Conservation Service (NRCS) Design Guidelines for Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA) Shoreline Protection Structures (LDNR/NRCS 2000). These guidelines govern rock section geometry and gradation requirements. The side slope, generated by the geotechnical analysis, with a 3.0-foot top width set at an elevation of +3.5 feet NAVD 88 was determined to be adequate (USFWS 2005b). Due to the varying soil properties, the northern segment of the dike will have a 2.5H:1V side slope and the central and southern segments of the dike will have a 2H:1V side slope (USFWS 2005b). The details of the (1) rock dike with adjoining earthen containment dike, (2) earthen containment dike only, and (3) rock dike only are presented below (Figure 3).

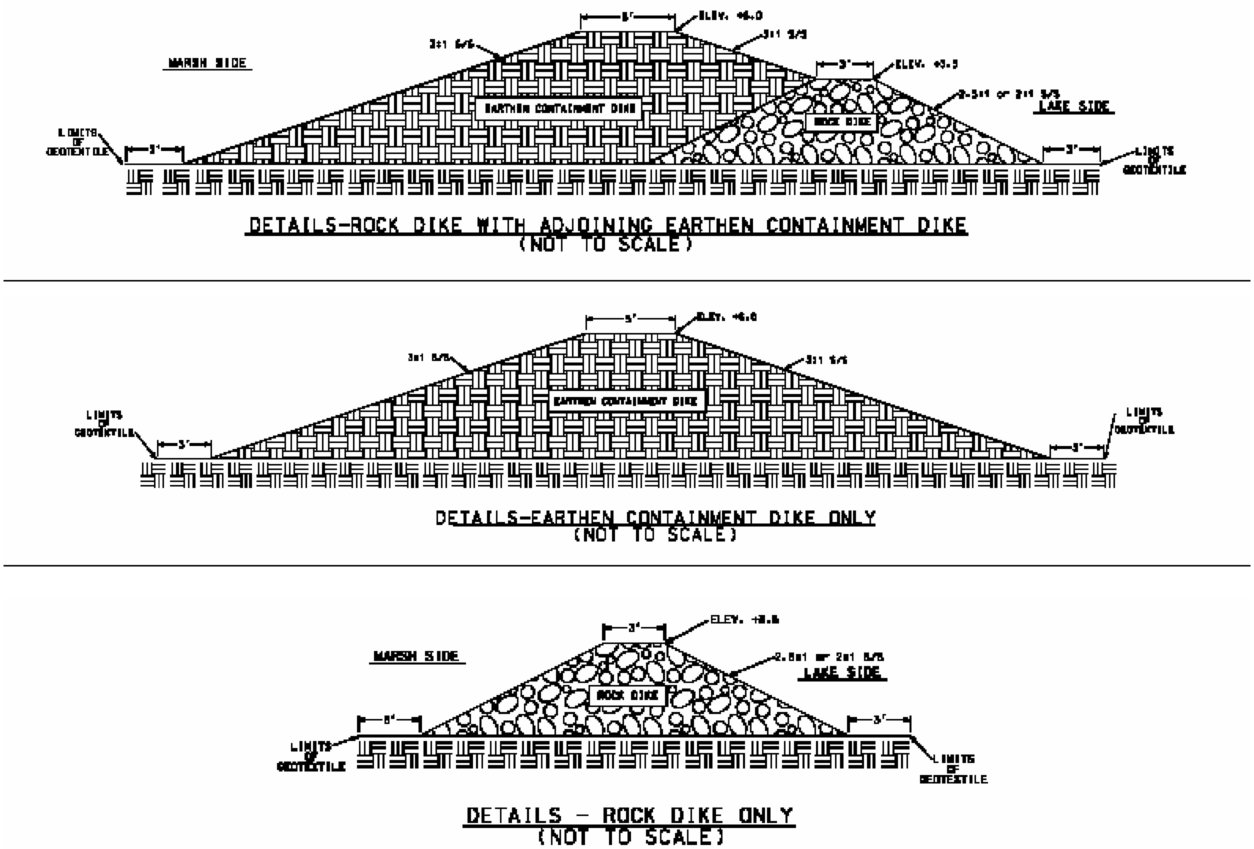


Figure 3. The details of the (1) rock dike with adjoining earthen containment dike, (2) earthen containment dike only, and (3) rock dike only (USFWS 2005b).

There are three areas currently open to water interchanges that will remain open to allow for fish access (fishways); therefore, no fish dips will be constructed *per se* as a part of this project (Figure 1). The northernmost fish access area is the opening between the northern and central rock dike segments. The other two openings are located at the interface between the central and southern marsh creation sections of the project.

Marsh Creation Design

The desired average healthy marsh elevation was determined to be +1.3 feet NAVD 88 based on the PENSCO survey (2004) and the best professional judgment of scientists on the project's engineering and design team. The PENSCO survey of three sites within the project area found that the existing marsh elevations range from approximately +0.9 to +1.3 feet NAVD 88. A USFWS field reconnaissance trip (April 16, 2003) corroborated PENSCO's findings and documented the existing mean marsh elevation at +1.0 feet NAVD 88. Project team members felt that this elevation is lower than the ideal healthy marsh elevation. The project team members, comprised of LDNR, USFWS, and NRCS, reached a consensus that +1.3 feet NAVD 88 was the desirable marsh height (Jurgensen 2004 and USFWS 2005b). Originally, the agreed upon marsh creation fill height was

+2.5 feet NAVD 88. However, in an effort to account for subsidence, the fill height was increased by 0.7 feet, which equates to a subsidence rate of 1.09 centimeters per year (0.43 inches per year) based on estimates calculated by Penland and Ramsey (1990), yielding a subsidence-adjusted fill height of +3.2 feet NAVD 88. The settlement curves, as reproduced from the geotechnical report by Burns Cooley Dennis, Inc. (2003), were based on fill heights of +3.5 feet NAVD 88 and +3.0 feet NAVD 88 (Figure 4). The resultant marsh elevations projected over the 20 year project life based on a fill height of +3.2 feet NAVD 88 may be visually approximated by viewing both components of Figure 4. By accounting for settlement, shrinkage, and subsidence, it appears that this design will yield marsh in a desirable elevation range throughout most of the project life.

Borrow Area for Marsh Creation Fill Material

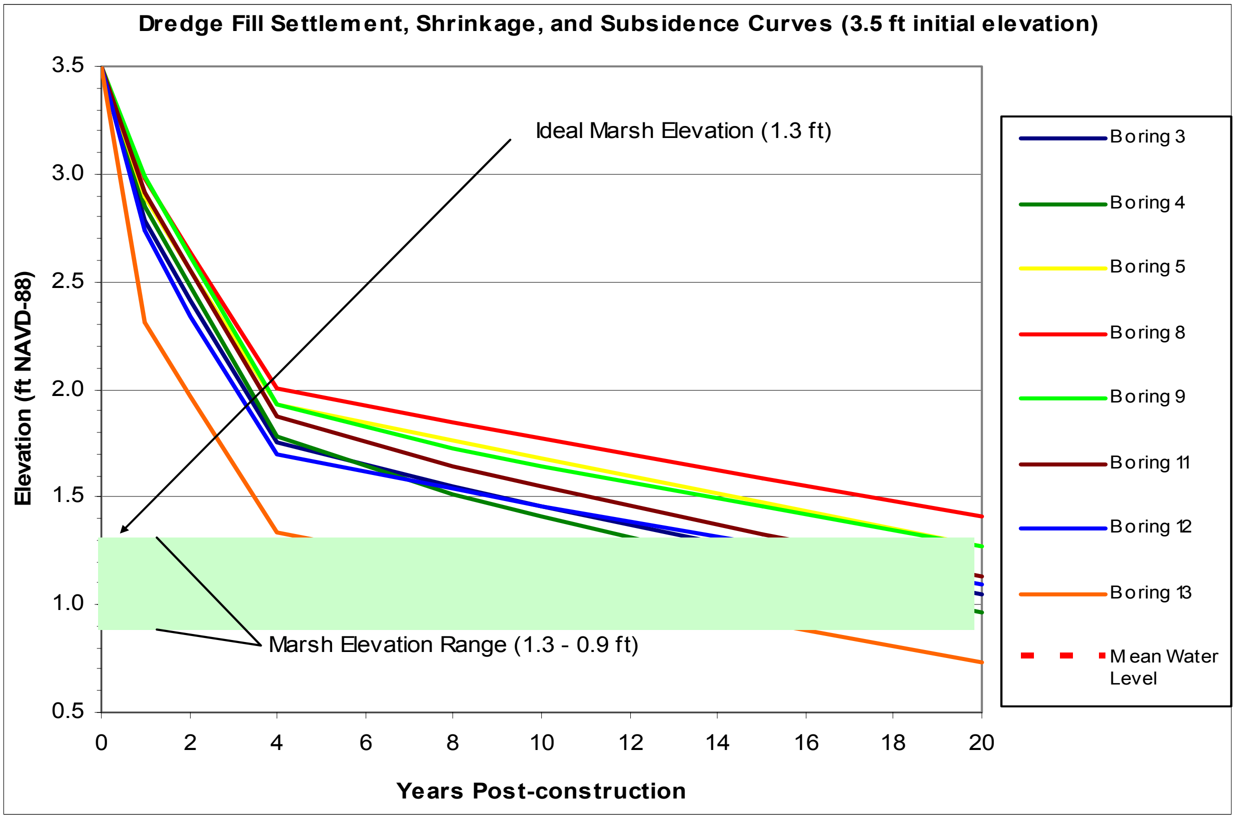
The fill material required for the marsh creation feature will be obtained from the borrow site shown in Figure 1. The average depth of cut below the existing lake bottom in this area is approximately 15.0 feet, which equates to an elevation of -20 feet NAVD 88 (USFWS 2005b).

Earthen Containment Dike

The containment dike will be constructed to an elevation of +6.0 feet NAVD 88 (USFWS 2005b). The material used to construct the containment dikes that are not adjacent to the rock dikes will be borrowed from the marsh creation area interior. The material used to construct the containment dikes that are adjacent to the rock dikes will be material that is bucket-dredged during the creation of the access flotation channel. The containment dikes will be wrapped with geotextile material on the back side of the dike in order to contain the dredge fill material (USFWS 2005b). The expectation is that the earthen containment dike will degrade over time, thereby eroding to marsh elevation, and hence eliminating the need for it to be manually breached.

Earthen Plug

An earthen plug will be placed in the project area on the western end of the canal located midway between Bayou Butler and Hog Point. This plug construction feature will replace a previously existing, yet breached, plug that serves to hydrologically control flow within the project area so as to prevent lake water from entering the interior marshes in an attempt to minimize erosion in the northern area of the project.



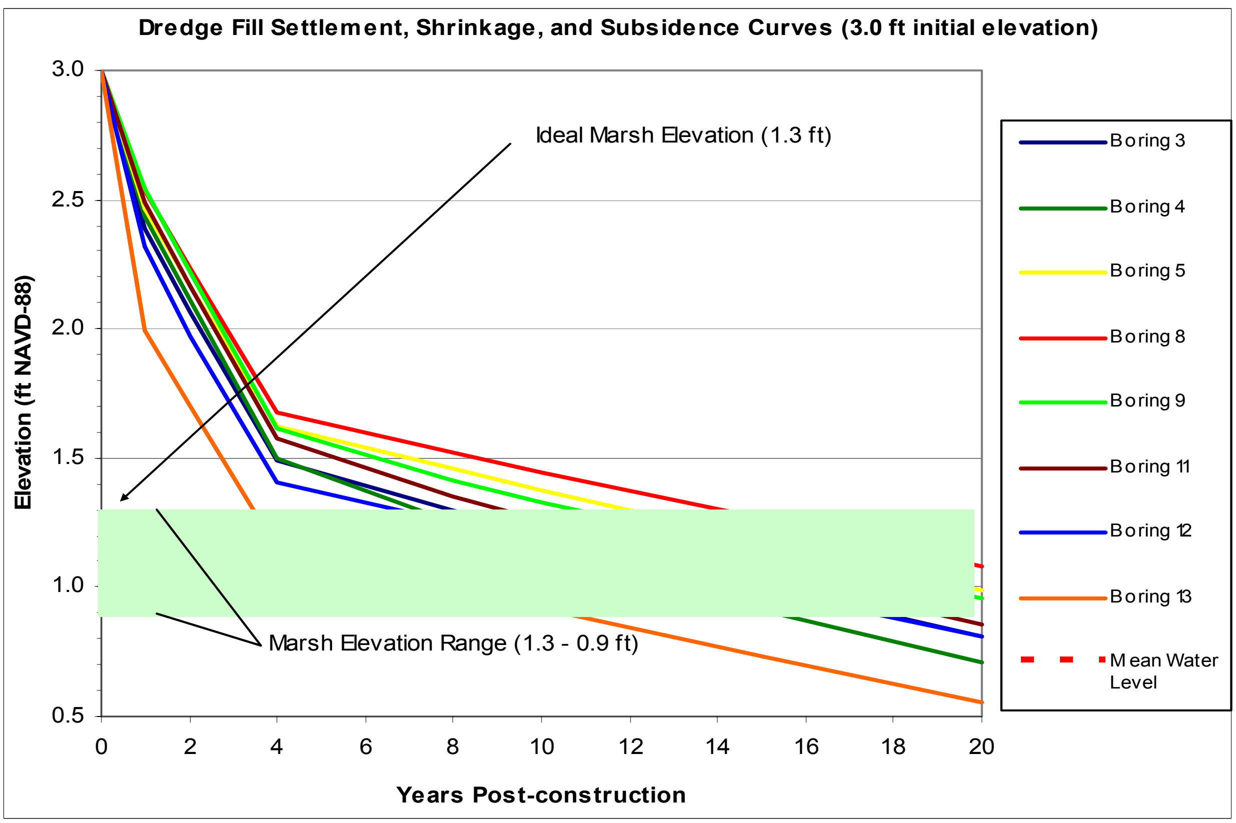


Figure 4. Dredge fill settlement curves overlays (data from Burns Cooley Dennis, Inc. 2003).

VI. Assessment of Goal Attainability

Environmental data and scientific literature documenting the effects of the proposed project features in field application are included below to assess whether or not, and to what degree, the project features will cause the desired ecological response. Design parameters of previously constructed shoreline protection projects are summarized in Table 1 and discussed below.

Shoreline Protection on Bays and Lakes

CWPPRA and State-authorized shoreline protection projects similar to the West Lake Boudreaux Shoreline Protection and Marsh Creation project have been implemented on other lake, bay, and cove shorelines as a means of protecting those banks from erosive elements.

- Bayou Chevee Shoreline Protection (PO-22) is located on the southern shoreline of Lake Pontchartrain just west of Chef Menteur Pass within the northern section of the Bayou Sauvage National Wildlife Refuge. The project is delineated into two coves (northern and southern). Construction was completed in 2001. The total length of the project was 8,875 feet with both rock dikes constructed using 200-400 pound rock placed at an elevation of +3.5 feet NGVD 29 (Carter 2003). The shoreline position was documented in an as-built survey conducted in 2002 (Carter 2003). The first post-construction survey work was conducted at the end of January 2005 (Brady Carter, LDNR, Personal Communication, March 2, 2005).

  The areas behind the rocks showed little change from the shoreline survey of 2002, with the exception of the north facing bank on the southeast side of the North Cove project area. This area had degraded significantly before the rocks were placed, and was probably too degraded to recover. Also, the small island in the middle of the North Cove project area had lost the vegetation on the northern tip; however, the resulting mud flat may be of sufficient elevation to re-vegetate by the next shoreline survey. The spoil placed behind the rocks in the South Cove project area has vegetated in two spots resulting in 0.67 acres of land gain.

  The North Cove reference area showed no discernable change from the 2002 survey. Of particular interest was the lack of retreat for the shoreline of Lake Pontchartrain adjacent to the reference area. Over the three years between surveys, this area has only moved approximately one to two feet.

  The South Cove reference area has had markedly different results. A total of 5.67 acres was lost in three years. This bank faces northwest and is exposed to the full force of waves created during cold fronts, which probably resulted in its demise. Since the boundaries for the South Cove project and reference areas were decided long before the project was constructed, they now appear in open water. This made determining the cut-off point between the two difficult. A straight line was drawn from the terminal end of the rocks to the shoreline to split the two. Splitting them in that manner shows the "erosional shadow" realized by not having the rocks terminate on land, and accounted for the majority of land loss within the project area.

Table 1. Design parameters of constructed shoreline protection projects (sorted by construction date).

Project Name	Project Number	Coast 2050 Region	Construction Date	Depth Contour (ft)	Structure Length (ft)	Structure Elevation (ft NAVD 88)	Distance from Shoreline (ft)	Preliminary Monitoring Results
Blind Lake (State)	N/A	4	1989		2,339	4.0	70	Positive
Cameron Prairie National Wildlife Refuge Shoreline Protection	ME-09	4	1994	-1.0	13,200	3.7	0 to 50	Positive
Freshwater Bayou Bank Protection (State)	TV-11	3	1994		25,800	4.0		
Holly Beach (State)	CS-01	4	1991-1994		7.2 miles	4.0 ft NGVD 29	185 to 595	
Turtle Cove (State)	PO-10	1	1994		1,640^{+}	3	0 to 300	Positive
Boston Canal / Vermilion Bay Bank Protection	TV-09	3	1995		1,405	3.8 ft NGVD 29		Positive
Freshwater Bayou Wetlands Protection	ME-04	4	1995	-1.0	28,000	4.0	0 to 150	Positive
Grand Isle Bay Side (State)	N/A	2	1995		4,500			
North Grand Isle Breakwaters (State)	N/A	2	1995					
Sabine National Wildlife Refuge Erosion Protection	CS-18	4	1995		5.5 miles			
LeBranche Shoreline (State)	PO-03b	1	1996		8,850	5.3 ft NGVD 29	constructed onshore	
Vermilion River Cutoff Bank Restoration	TV-03	3	1996		6,520	3.5 ft NGVD 29	landward toe @ waters edge	
Clear Marais Bank Protection	CS-22	4	1997	-1.2	35,000	3.0 ft NGVD 29	0 to 50	Positive
Bayou Segnette (State)	BA-16	2	1994, 1998		6,800	3.0 to 5.0		
Freshwater Bayou Bank Stabilization	ME-13	4	1998		23,193	3.7 to 4.0		Positive
Lake Salvador Shore Protection Demonstration	BA-15 Phase II	2	1998	-1.0 to -1.4	8,000	2.51	100	Positive
Quintana Canal/Cypermort Point (State)	TV-4355NP1	3	1998	-1.5 -1.0	3,700 2,900 1,500	3.5 ft NGVD 29 (seg. BW) 3.0 ft NGVD 29 (dike) 4.0 ft NGVD 29 (revetment)		
Cote Blanche Hydrologic Restoration	TV-04	3	1999		4,400	3.0	60 to 450	
Perry Ridge Shore Protection	CS-24	4	1999		12,000	3. to 4.0	60	
Barataria Bay Waterway West Side Shoreline Protection	BA-23	2	2000		9,900	4.0		

Table 1. Design parameters of constructed shoreline protection projects ([sorted by construction date] continued).

Project Name	Project Number	Coast 2050 Region	Construction Date	Depth Contour (ft)	Structure Length (ft)	Structure Elevation (ft NAVD 88)	Distance from Shoreline (ft)	Preliminary Monitoring Results
Point Au Fer Canal Plugs	TE-22	3	1997, 2000		3,600 (1997) 3,662 (2000)			
Barataria Bay Waterway East Side Shoreline Protection	BA-26	2	2001		17,054	4.0 ft NGVD 29		
Bayou Chevee Shoreline Protection	PO-22	1	2001		8,875	3.5 ft NGVD 29	300	
Chenier Au Tigre Sediment Trapping Demonstration	TV-16	3	2001					
GIWW Perry Ridge West Bank Stabilization	CS-30	4	2001		10,705			
Marsh Island Hydrologic Restoration	TV-14	3	2001		3,600 1,800	5.0 4.0	50 to 70	
Oaks/Avery Canals Hydrologic Restoration, Increment 1	TV-13a	3	2002		5,300 1,200 300	3.0 3.0 -24 to +5	0 to 30 0 to 30	
Oaks/Avery Structures (State)	TV-13b	3	2002		1,200	3.0	12 to 16 (onshore)	
Black Bayou Hydrologic Restoration	CS-27	4	2003		23,400	3.0	10 to 60	
Jonathan Davis Wetland Protection	BA-20	2	2001, 2003		1,385 (2001) 3,967 (2001) 13,088 (2003)	3.0 3.5 3.5		
Mandalay Bank Protection Demonstration	TE-41	3	2003	-1 to -3	1,494	1.5 to 3.0	10 to 200	
Grand-White Lakes Landbridge Protection	ME-19	4	2004	-1 to -2	12,000	2.5	50 to 200	
Barataria Basin Landbridge Shoreline Protection, CU 1, CU 2, CU 3	BA-27 and BA-27c	2	2004 (CU 3) 2004 (CU 2) 2001 (CU 1)	0 (CU 3) -2 (CU 2) -2.5 (CU 1)	10,865 (CU 3) 6,403 (CU 2) 3,200 (CU 1)	3.5 (CU 3) 3.5 (CU 2) 3.0 (CU 1)	0 to 50 (CU 3) 50 to 600 (CU 2) 50 to 100 (CU 1)	CU 1 tested five different designs

$^{+}$ denotes that structure was rock-gabion instead of rip-rap.

- Barataria Basin Landbridge Shoreline Protection (BA-27), Phases 1, 2, 3, and 4 are located in Jefferson and Lafourche Parishes and encompass a variety of shoreline protection techniques along approximately 107,500 feet of shoreline. Geotechnical investigations have revealed poor soil conditions throughout the area prompting the testing of non-traditional protection techniques that included rock dikes consisting of either earthen cores, lightweight aggregate cores, or lightweight aggregate cores with a furrow (to reduce the load) beneath the rip rap structure, as well as, testing of concrete sheetpile as an alternative to the rock dikes. In 2001, all of the test sections for Phase 1 of the project (test section of sheetpile, rock, and composite aggregate) were completed. One year after all the test sections were constructed, surveys were conducted to determine their settlement rates and to estimate settlement after 10 years. The concrete sheetpile wall sections showed very little movement vertically or horizontally, but the rock and composite dike sections experienced significant amounts of settlement ranging from 2.7 to 3.5 feet over the first year (NRCS 2002). The soils in unit 1 were of a much poorer quality than units 2 or 3 (Karim Belhadjali, LDNR, Personal Communication, May 23, 2005). The sheetpile in unit 1 performed the best; however, because geotechnical analysis indicated that the soils were of a better quality in units 2 and 3, cost considerations led to the least expensive alternative of rock being chosen (Karim Belhadjali, LDNR, Personal Communication, May 23, 2005). In 2004, construction units 2 (rock), and 3 (rock) were completed. The monitoring plan for this project indicates that the first set of post-construction surveys will be taken in 2006, after which time an analysis of the effectiveness will be produced.

- The Lake Salvador Shore Protection Demonstration (BA-15) project evaluated a series of shoreline protection measures in Lake Salvador in St. Charles Parish, Louisiana. Phase II of this project was conducted in 1998 and evaluated the effectiveness of a rock berm to protect the lake shoreline from high energy wave erosion. The rock structure itself appears to be holding up well, showing little sign of deterioration and subsidence. Recent surveys of the area revealed that the rock dike was successful in stabilizing the shoreline and some accretion is occurring behind the structure (Curole et al. 2001). However, the effectiveness of the structure over the long term may be in question since it was not built according to design specifications. The rock dike was designed to be constructed with a crest elevation of +4.0 feet NAVD 88. A 2002 survey of the rock dike determined that the average height of the structure was +2.49 feet NAVD 88. The average settlement of the structure, measured from 1998 to 2002, was approximately 0.26 feet. After applying this settlement rate retrospectively, it was concluded that the rock dike was built to an inadequate crest elevation of +2.75 feet NAVD 88 (Darin Lee, LDNR, Personal Communication, July 19, 2002).

- The Turtle Cove Shoreline Protection (PO-10) was initiated in 1993 to protect a narrow strip of land in the Manchac Wildlife Management Area that separates Lake Pontchartrain from an area known as "The Prairie" (O'Neil and Snedden 1999). Wind-induced waves contributed to a shoreline erosion rate of 12.5 feet/year. A 1,642-foot rock-filled gabion was constructed 300 feet from shore at an elevation of 3 feet above mean water level with the goal of reducing erosion and increasing sediment accretion behind the structure. Post-construction surveys conducted during the period of October 1994 to December 1997 revealed that the shoreline had prograded at a rate of 3.47 feet/year in the project area (O'Neil and Snedden 1999). The rate of sediment accretion, as determined from elevation surveys conducted in January 1996 and January 1997, was 0.26 feet/year (O'Neil and Snedden 1999). The soils in "The Prairie" and Turtle Cove area consist of Allemands-Carlin peat which is described as highly erodible organic peat and muck soils (USDA 1973). Due to the weak and compressible nature of the subsurface soils, the gabions settled 0.59 feet in just over two years (October 1994 to January 1997) (O'Neil and Snedden 1999). Also, five years after construction the rock-filled gabion structure exhibited numerous breaches and required extensive maintenance in August 2000 (John Hodnett, LDNR, Personal Communication, August 2004).

- The Boston Canal/Vermilion Bay Bank Protection (TV-09) project was designed to abate wind-driven wave erosion along Vermilion Bay (estimated at 7 feet/year) and at the mouth of Boston Canal (Thibodeaux 1998). To accomplish that goal, a 1,405-foot foreshore rock dike was constructed in 1995 at an elevation of +3.8 feet NGVD 29 along the bank of Boston Canal extending into Vermilion Bay. In 1997, two years after construction, the project was estimated to have protected 57.4 acres of marsh and 1.4 to 4.5 feet of sediment was deposited behind the breakwater while the reference area continued to erode. The rock breakwater at the mouth of Boston Canal has been successful in stabilizing the shoreline with an overall shoreline gain for the area of 15.04 acres from 1998-2001 (Thibodeaux 1998). Data collection in the reference area was discontinued in 2000 as a result of the Oaks/Avery Shoreline Protection (TV-13a) project boundary incorporating the Boston Canal reference area within it (Thibodeaux and Guidry 2004). The project also appears to be maintaining the integrity of approximately 466 acres of wetlands and stabilizing 14.3 miles of the Vermilion Bay shoreline (Thibodeaux and Guidry 2004). Plantings of *Spartina alterniflora* have become well established and are indistinguishable from each other along most of the shoreline (Thibodeaux and Guidry 2004). Sediment build-up behind the dike on the east and west sides is continuing and vegetation has taken over the exposed mud flats (Thibodeaux and Guidry 2004). Elevation data show an increase in sedimentation behind the rock breakwater (Thibodeaux and Guidry 2004).

<u>Shoreline Protection on Navigation Channels</u>

There are also several examples of projects involving the use of shoreline protection to stop erosion along navigation canal banks.

- The Cameron Prairie National Wildlife Refuge Shoreline Protection (ME-09) project, constructed in 1994, is located in north-central Cameron Parish and includes 350 acres of freshwater wetlands (Barrilleaux and Clark 2002). A 13,200-foot rock breakwater was constructed at an elevation of +3.7 feet NAVD 88, 50 feet from (and parallel to) the northern shore of the Gulf Intracoastal Waterway (GIWW) to prevent wave action from eroding the bank and breaching into the interior marsh. Aerial photography and survey points were used to monitor any changes in land-to-water ratio and shoreline position. Three years after construction, results indicate that the project area shoreline advanced 9.8 ± 7.1 feet/year while the reference area retreated 4.1 ± 3.1 feet/year (Barrilleaux and Clark 2002). A two-sample t-test found a significant difference in shoreline change rates between the two areas ($P < 0.001$) (Barrilleaux and Clark 2002). Shoreline change data were collected in 1995, 1997, 2000, and 2003. Between the 2000 and 2003 surveys mean shoreline change rates were calculated to be +13 ± 15.4 feet/year and -2.1 ± 2.1 feet/year for the project and reference areas, respectively (Mouledous and Guidry 2004). The data indicate that the project has continued to be effective in preventing erosion at all project area stations. Shoreline position at the reference sites continued to retreat.

- The Clear Marais Bank Protection (CS-22) project was constructed in 1997 to prevent breaches in the GIWW shoreline and subsequent erosion of the interior marsh while preventing saltwater intrusion (Miller 2001). Approximately 35,000 linear feet of rip-rap was placed 50 feet from the northern shoreline of the GIWW at an elevation of +3.0 feet NGVD 29. Results indicate that the foreshore rock dike has been effective in preventing erosion of the GIWW shoreline. Data collected in May 1997 (as-built), May 2000, and May 2003 have been analyzed to indicate whether the project has been effective in preventing erosion within the severe, moderate, and mild erosion classification areas after construction (Miller and Guidry 2004). Areas experiencing severe erosion prior to construction gained 1.89 feet/year, areas experiencing moderate erosion gained 3.02 feet/year, and areas experiencing mild erosion gained 17.00 feet/year (Miller and Guidry 2004). Overall the project area gained an average of 7.66 feet/year as compared to the reference area which is losing 9.10 feet/year (Miller and Guidry 2004).

- The Intracoastal Waterway Bank Stabilization and Cutgrass Planting project at Blind Lake was a state wetland restoration project constructed to prevent the GIWW and Sweet Lake from coalescing with Blind Lake (LDNR 1992). A limestone foreshore rock dike built at an elevation of +4.0 feet NGVD 29 was placed 70 feet from the edge of the main channel along 2,339 feet of bank on a six inch layer of shell and filter cloth. Large stones were used to prevent movement of rocks and to allow sediments and organisms passage. In 1991, two years after project completion, an average increase in elevation of 0.32 feet in the area behind the dike was observed along transects from the deposition of suspended sediments (LDNR 1992). Data indicate that the project was successful in protecting the shoreline at Blind Lake and maintaining the hydrology of the Cameron-Creole Watershed (LDNR 1992).

- The Freshwater Bayou Wetlands Protection (ME-04) project is positioned on the western bank of Freshwater Bayou (Vincent et al. 2000). Construction of this project was initiated in January 1995 and includes water control structures and a 28,000-linear foot foreshore rock dike designed with a crown elevation of +4.0 feet NAVD 88. Analysis of initial monitoring data suggests that the rock dike reduced wave-induced shoreline erosion after construction. The average rate of shore progradation between June 1995 and July 1996 was measured at 2.2 feet/year while the reference area continued to erode at an average rate of 6.7 feet/year (Raynie and Visser 2002). In contrast, between March 1998 and May 2001, the protected shoreline eroded an average of 2.6 feet/year while the reference area eroded at an average of 10.0 feet/year (Raynie and Visser 2002). Substandard recycled construction material and inadequate funds for maintenance of the structure, which were not disbursed in a timely manner, are believed to be the reason for the increase in erosion rates in the project area (Raynie and Visser 2002).

- The Freshwater Bayou Bank Stabilization (ME-13) project is located in Vermilion Parish on the west bank of Freshwater Bayou Canal. The main cause of wetland loss in the ME-13 project area is boat wake-induced shoreline erosion of the canal spoil banks and organic soils of the interior marsh (USACE and LDNR 1994). A 23,193-foot continuous rock dike, built to an elevation of +3.7 to +4.0 feet NAVD 88, was installed parallel to the western shoreline in 1998 to address this loss. Pre-construction data from the ME-13 reference areas on the east bank of Freshwater Bayou Canal indicated that the canal eroded at an average rate of 6.54 feet/year between April 1995 and July 1996 (Vincent and Sun 1997). Post-construction data collected from July 1998 through July 2003 revealed that the shoreline behind the constructed rock dike prograded an average 0.84 feet/year (Vincent 2003). During the same period, the unprotected reference areas eroded an average 11.94 feet/year (Vincent 2003).

Marsh Creation

The following project discussion is an example of a marsh creation project from which the lessons learned may be applied to the West Lake Boudreaux Shoreline Protection and Marsh Creation project.

- The Bayou LaBranche Wetland Creation (PO-17) project encompasses 436 acres and is located in St. Charles Parish, near the southwestern shore of Lake Pontchartrain, east of the Bonnet Carre' Spillway (Boshart 2004). A combination of events, dating back to the 1800's, contributed to an almost complete loss of marsh in the area and subsequent conversion into open water (Pierce et al. 1985). This project was the first constructed under CWPPRA with construction completed on April 1, 1994. Due to significant land loss, the project area was mostly shallow, open-water habitat, and only a narrow band of marsh along the shoreline separated the project area from the lake (Boshart 2004).

  Sediment elevation that was measured from temporary staff gauges in October 1994 ranged from +1.33 to +2.80 feet NAVD 88. In June 1995, the sediment elevation ranged from +0.82 to +1.62 feet NAVD 88. The target range of sediment elevation for this project, after five years of consolidation, was estimated at +0.65 to +1.62 feet NAVD 88; as of August 2002, elevation at 11 of the 19 staff gauges was within this target range (Boshart 2004).

  The project has benefited the LaBranche wetlands by creating marsh in place of open water in an area of critical need along the Lake Ponchartrain shoreline, thus providing the important functions of wetland ecosystems. As of 1997, the project area was approximately 82% land and 18% water, which was higher than the minimum goal of 70% marsh to 30% water (Boshart 2004). The consolidation of dredge material over time has reached an elevation that appears to sustain the 70% (land and marsh) component of the project area (Boshart 2004). In addition, the soil properties and the vegetation community of the project have continued to develop towards characteristic wetland habitat for the region (Boshart 2004).

Summary/Conclusions

A review of both published and unpublished literature of previously constructed restoration projects similar in nature and design to the proposed project were used to confirm the efficiency of rock dikes as shoreline protection features. Monitoring results for the Lake Salvador Shore Protection Demonstration (BA-15), Boston Canal/Vermilion Bay Bank Protection (TV-09), Cameron Prairie National Wildlife Refuge Shoreline Protection (ME-09), Intracoastal Waterway Bank Stabilization and Cutgrass Planting at Blind Lake, and the Freshwater Bayou Bank

Stabilization (ME-13) have shown that these projects have successfully reduced shoreline erosion in areas of poor soil conditions and some have even accreted land behind the structures.

However, monitoring results for the Turtle Cove Shoreline Protection (PO-10) and the Freshwater Bayou Wetlands Protection (ME-04) have shown a lack of success with respect to structure integrity in areas with poor soil conditions, potentially due to use of substandard materials and inadequate maintenance. These findings provided insight as to how effective the constructed projects were at achieving their specified goals and assisted team scientists and engineers in predicting how well similar designs may perform.

The true driving force for breakwater success is the soil bearing capacity. Sufficient bearing capacities allow easier construction and proper alignments for foreshore breakwaters or rock dike structures to better perform their objective. Geotechnical investigations for this project determined the capabilities of area soils and their potential bearing capacity. The consideration that led to the selection of rock as the shoreline protection feature (as opposed to concrete panels or light aggregate core materials) was the presence of a sand lens, located beneath the organic and mineral soils throughout the entire project area, which can structurally support the load capacity of rock (Burns Cooley Dennis, Inc. 2003).

Monitoring of the Bayou LaBranche Wetland Creation (PO-17) project can provide guidance for recommended improvements on similar marsh creation project types. It has been suggested that creating gaps or removing sections in the containment dikes would increase tidal exchange for increased productivity in the project area (Boshart 2004). In addition, a project of this nature could be constructed in staged construction with incremental filling or successive lifts with additional dredged material added at a time 2 to3 years post construction. This would contribute to achieving the goals of (1) optimizing the elevation needed to maximize plant productivity and (2) increasing long-term natural sustainability of marsh elevation via accretion processes that include plant aboveground/belowground productivity (Raynie and Visser 2002). The data gathered by monitoring this project may be considered for calculating and maintaining the correct elevations of dredged material and its placement in future marsh creation projects (Boshart 2004).

VII. Recommendations

Based on the evaluation of available ecological, geophysical, and engineering information, in addition to the investigation of similar restoration projects, the proposed strategies of the West Lake Boudreaux Shoreline Protection and Marsh Creation project will likely achieve the desired ecological goals. The Louisiana Department of Natural Resources, Coastal Restoration Division recommends that this project be considered for CWPPRA Phase 2 authorization with an awareness of the following issues:

- The geotechnical report evaluated the settlement of the foreshore rock dike constructed to an elevation of +4.0 feet NAVD 88 (Figure 2). Based on the estimates of settlement for 12 individual soil borings, it was determined by project team members that the rock dike could be constructed to an elevation of +3.5 feet NAVD 88 and still provide the desired level of protection for the 20-year project life. Although this seems logical, the analysis fails to take into consideration local subsidence that has been estimated to be 0.43 inches per year (1.09 centimeters per year) or 0.7 feet over 20 years (Penland and Ramsey 1990). Therefore, maintenance and monitoring efforts should be coordinated to ensure structural stability and functionality over the 20-year project life. It is important to note that subsidence was not accounted for in the design of the rock dike; however, subsidence was acknowledged and accounted for in the marsh creation component of this project.

- The expectation is that the earthen containment dike will erode to marsh elevation, thereby eliminating the need for it to be manually breached. However, if this phenomenon does not occur naturally within the first 2 to 4 years of the project life, breaks should be made so that the created marsh does not become impounded. This will promote a more natural hydrologic flow within the project area, thereby allowing movement of nekton to and from the marsh, and allowing for sediment and nutrient transport (Shafer and Streever 2000).

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