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

East Marsh Island Marsh Creation
CWPPRA Priority Project List 14
State No. TV-21

November 3, 2008

Summer R. Martin and Mandy M. Green
Environmental Section
Planning Branch
Planning and Project Management Division
Coastal Protection and Restoration Authority

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 17, 2008.

ECOLOGICAL REVIEW

In August 2000, the Louisiana Department of Natural Resources (LDNR) 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

Marsh Island is a large (approximately 70,000 acres), uninhabited, *Spartina patens* dominated island bordered on the south by the Gulf of Mexico and on the north by Vermilion Bay, West Cote Blanche Bay, and East Cote Blanche Bay (Figure 1; Merino et al. 2005, Nyman et al. 1994). The entire island also constitutes the Marsh Island Wildlife Refuge, which was established by the Louisiana Department of Wildlife and Fisheries (LDWF) as a sanctuary for migratory birds (Merino et al. 2005, Nyman et al. 1994). Recent aerial surveys have documented approximately 30,000 geese and 50,000 ducks utilizing the island (Jeb Linscombe, LDWF, personal communication, August 2008). The East Marsh Island Marsh Creation (TV-21) project is located in Iberia Parish at the eastern end of the Marsh Island Wildlife Refuge, southeast of Lake Sand (Figure 2). The TV-21 project will work synergistically with the Marsh Island Hydrologic Restoration (TV-14) project that was constructed in 2001 (Figure 1). Marsh creation was initially planned as part of the TV-14 project, but this portion of the project could not be completed due to cost (National Resources Conservation Service [NRCS] 2004). Additional Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA) projects that have been constructed in the vicinity of the East Marsh Island Marsh Creation (TV-21) project are listed in Table 1.

Average marsh loss rates within the TV-21 project area were historically relatively low, or -0.29% per year from 1974-2000 (NRCS 2004). However, after Hurricane Lili in 2002, aerial photography revealed that substantial areas of interior emergent marsh had been converted to open water (Environmental Protection Agency [EPA] 2008). A new land loss rate was calculated to include the most recent time period that included damage from Hurricane Lili. The new land loss rate was found to be considerably higher, or -1.31% per year from 1988-2007 (EPA 2008). Without action, the land loss rate will likely continue to increase. The project area, which consists of a total of 362 acres, targets the region that experienced the greatest land loss from hurricane damage (EPA 2008).

Due to the undercut appearance of the marsh-water interface, the mechanism of marsh loss on the island appears to be lateral erosion of unconsolidated sediments beneath the living root zone as opposed to the more rapid marsh loss observed in nearby marshes that is associated with vegetation stress from salt water intrusion or from waterlogging attributable to inadequate elevation (Nyman et al. 1994). Specifically, Nyman et al. (1994) revealed that the following chain of events is causing interior marsh loss on Marsh Island: 1) a disturbance occurs, such as scouring or plant stress from a hurricane, 2) the disturbance results in the formation of shallow ponds, 3) the ponds become deeper over time because they do not accrete as rapidly as adjacent marsh, and 4) as the ponds become deeper than the bottom of the living root zone in adjacent marsh, the marsh edges begin to erode. Filling of the open water areas in the TV-21 project area will prevent this process of lateral erosion.

The objectives of the East Marsh Island Marsh Creation (TV-21) project are to re-create brackish marsh in the open water and mud flat areas of the interior marsh primarily formed by hurricane damage and to nourish additional adjacent marsh (Gillen 2008). *Coast 2050* has identified the following as Region 3 ecosystem strategies that are projected to reduce future wetland loss and enhance marshes: vegetative planting; dedicated dredging to create, restore, or protect wetlands; and restoration and maintenance of Marsh Island (Louisiana Coastal Wetlands Conservation and Restoration Task Force and the Wetlands Conservation Restoration Authority 1999). Furthermore, the state's Master Plan (Coastal Protection and Restoration Authority of Louisiana [CPRA] 2007) has identified marsh restoration using dredged material at Marsh Island as a method for restoring and maintaining critical landscape features and providing hurricane protection to coastal Louisiana west of the Atchafalaya River.

II. Goal Statement

- To create approximately 165 acres of emergent marsh in shallow water and mud flats.
- To nourish an additional 197 acres of existing brackish marsh with dredged sediment.

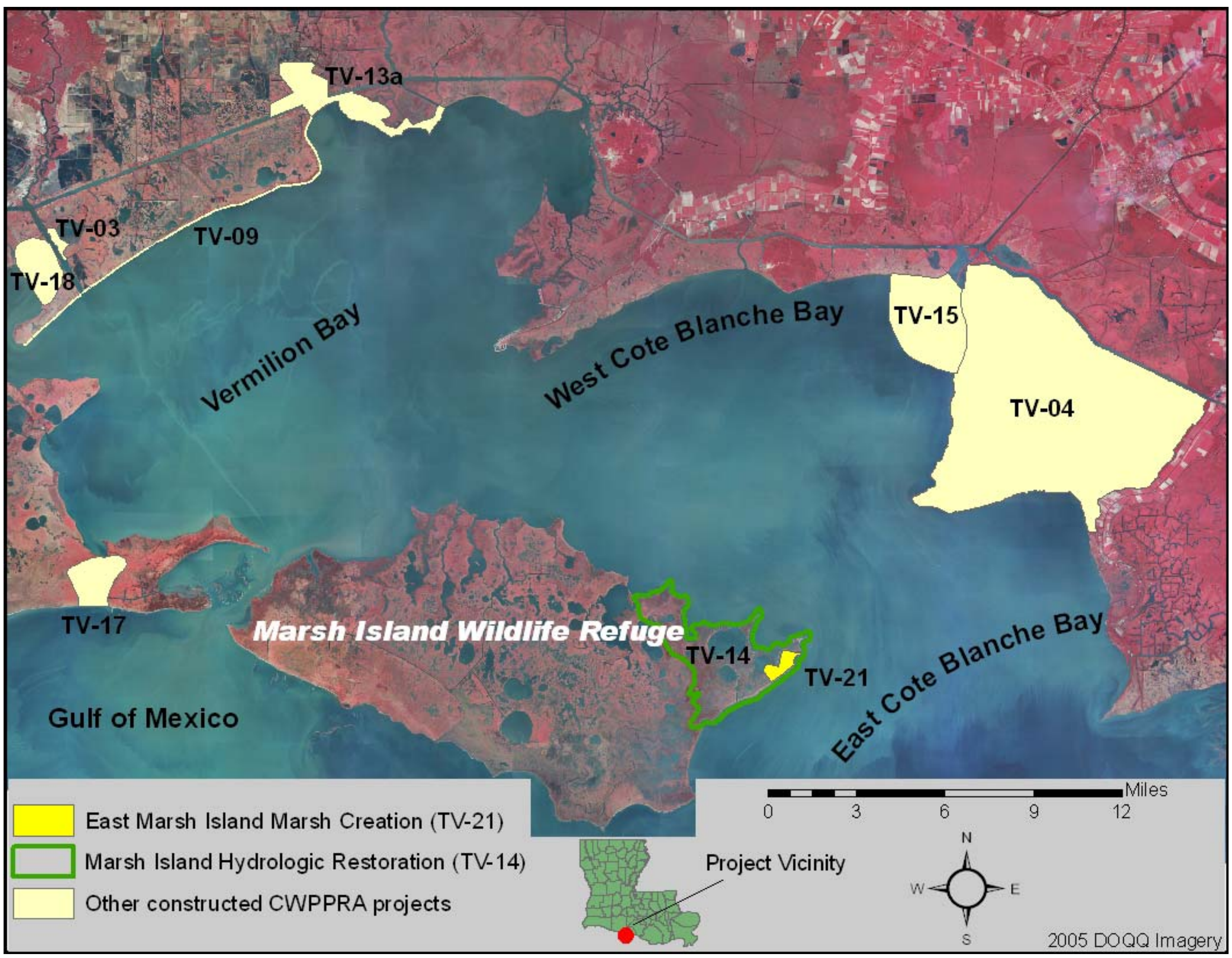

Figure 1. Locations of East Marsh Island Marsh Creation (TV-21), Marsh Island Hydrologic Restoration (TV-14), and other constructed CWPPRA projects in the vicinity of Marsh Island.

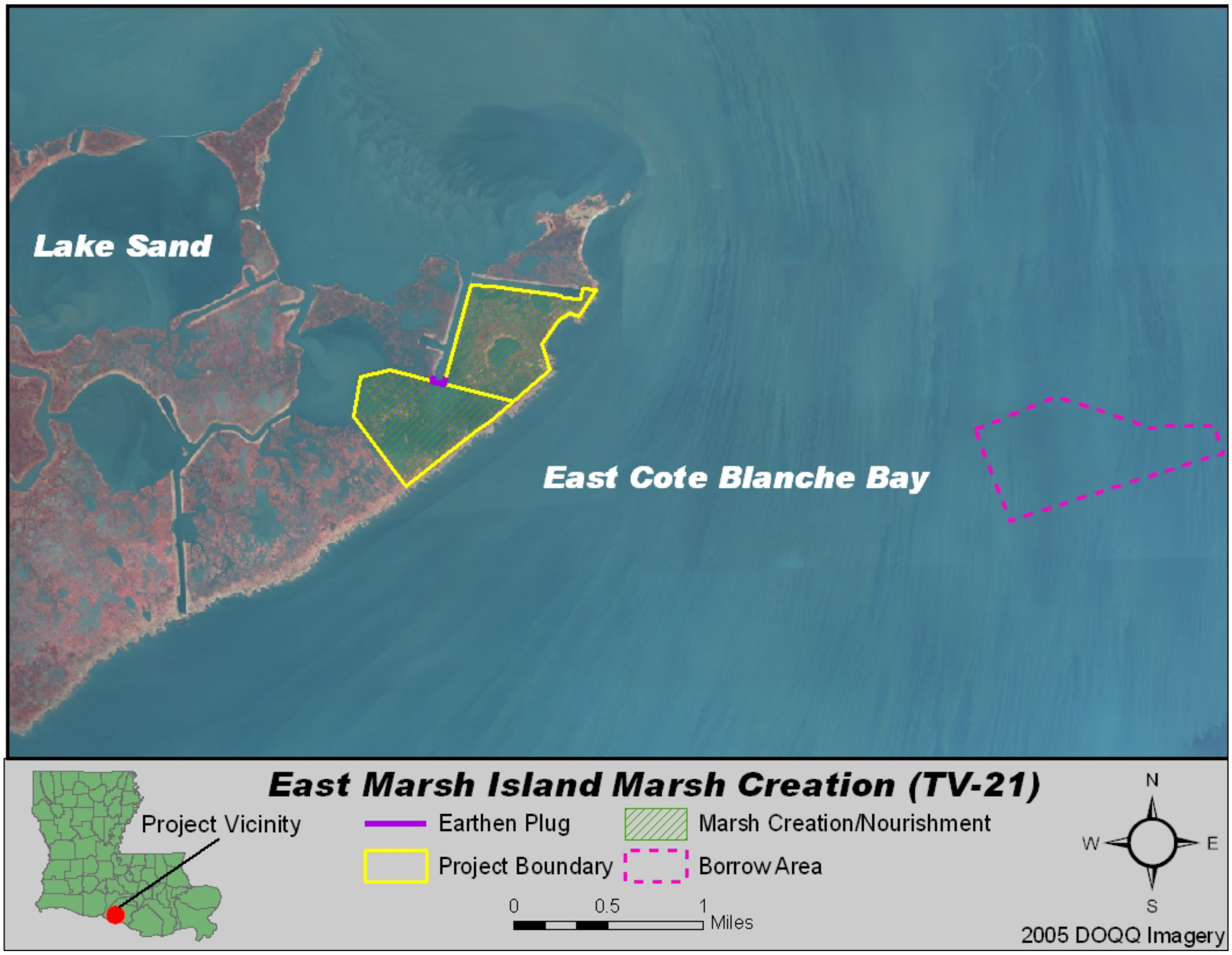

Figure 2. East Marsh Island Marsh Creation (TV-21) project boundary and features.

Table 1. Constructed CWPPRA projects neighboring the East Marsh Island Marsh Creation (TV-21) project area.

Project Number	Project Name	Construction Date
TV-09	Boston Canal/Vermilion Bay Bank Protection	1995
TV-03	Vermilion River Cutoff Bank Protection	1996
TV-04	Cote Blanche Hydrologic Restoration	1999
TV-14	Marsh Island Hydrologic Restoration	2001
TV-13a	Oaks/Avery Canals Hydrologic Restoration, Increment 1	2002
TV-15	Sediment Trapping at "The Jaws"	2004
TV-17	Lake Portage Land Bridge	2004
TV-18	Four Mile Canal Terracing and Sediment Trapping	2004

III. Strategy Statement

Marsh creation and nourishment will be achieved by hydraulically-dredging sediment from East Cote Blanche Bay and transporting it via pipeline to fill open water and to cover mudflats and existing marsh in the project area. The marsh platform will be planted in two phases with *Spartina alterniflora* (smooth cordgrass), *Spartina patens* (marshhay cordgrass), and *Distichlis spicata* (saltgrass) upon construction completion (Gillen 2008).

IV. Strategy-Goal Relationship

The placement of dredged material will result in an overall increase in elevation within the project area, the nourishment of existing marsh, and the creation of marsh in shallow open water and mud flat areas that resulted from Hurricane Lili. The filling of open water areas will prevent further erosion at the marsh-water interface, and the marsh nourishment and marsh creation components will work together to increase the longevity of the island by protecting existing habitats, reinforcing the tip of the island, and preventing breaches in the existing shoreline that may result in increased erosion of the interior marsh (Gillen 2008).

V. Project Feature Evaluation

Marsh Creation and Nourishment Design

Hydraulically dredged material from East Cote Blanche Bay will be pumped as mud slurry into open water ponds and over mud flats and deteriorated adjacent marsh within the East Marsh Island project area. Approximately 2,821,000 cubic yards of material will be dredged to create 165 acres of emergent marsh and to nourish 197 acres of existing marsh (Gillen 2008). The marsh creation and nourishment areas will be completely enclosed with containment dikes or existing canal spoil banks (Gillen 2008). Areas in which marsh currently exists will be considered marsh nourishment, while areas of open water and mud flats will be considered marsh creation (Gillen 2008).

Marsh elevation surveys were conducted by C.H. Fenstermaker and Associates, Inc. (2007) at three pre-determined sites within the project area. At each of the three sites, elevation was measured at 20 locations at the top of the plant's root mass, and the average marsh elevation was calculated for each site (Gillen 2008; Table 2). The overall average marsh elevation for the project area was determined to be +1.72 feet NAVD 88 (Gillen 2008). The condition of existing marsh was examined following completion of the marsh elevation surveys, and it was determined that the project area is currently supporting healthy marsh vegetation at the existing elevation (Cassidy Lejeune, LDWF, personal communication, February 2008). The results of this field investigation, as well the marsh elevation surveys, were used to choose a target marsh elevation of +1.8 feet NAVD 88, which is slightly higher than the average elevations measured at the top of the root mass of existing plants (Gillen 2008).

To determine the appropriate construction fill elevation necessary to achieve the target elevation of +1.8 feet NAVD 88, foundation settlement and self-weight consolidation tests were performed using soil samples collected from the project and borrow areas, respectively (Aquaterra 2008). The settlement analysis was conducted using the computer program Primary Consolidation, Secondary Compression, and Desiccation of Dredged Fill (PSDDF) that was developed by the U.S. Army Corps of Engineers (Aquaterra 2008). After evaluating a range of potential elevations, a fill elevation of +3.5 feet NAVD 88 was chosen because the marsh elevation would be at or near the target elevation of +1.8 feet NAVD 88 after the first two years of settlement and would remain in a desirable elevation range throughout the 20-year project life (Gillen 2008). Filling to this initial elevation, most of the foundation settlement and self-weight consolidation would occur within one year after construction, and 1.8 feet of total settlement is expected over the 20-year life of the project (Gillen 2008; Table 3 and Figure 3). Because the subsidence rates of the project area are relatively low, subsidence was not included in the settlement calculations.

The project area is proposed to be constructed in a minimum of two lifts by splitting the area into two cells so that the fill material from one cell can dewater while the other cell is being pumped to the required height (Figure 2; Gillen 2008). This construction technique would allow the final target elevation to be more easily reached (Gillen 2008). Because the settlement curves are based on one lift construction, it can be anticipated that the curves would be slightly higher for up to a year before approaching the single lift curve (Gillen 2008). The PSDDF model may be run again prior to construction based on the two lift construction scenario (Gillen 2008).

Table 2. Marsh elevation survey results (Gillen 2008).

Location Number	Marsh Elevation (feet NAVD 88)		
	Site 1	**Site 2**	**Site 3**
1	1.65	1.80	1.56
2	1.50	1.95	1.72
3	1.65	1.65	1.81
4	1.53	2.00	1.92
5	1.43	1.86	1.60
6	1.79	1.98	1.54
7	1.81	1.98	1.57
8	1.57	1.78	1.63
9	1.92	2.11	1.59
10	1.92	1.87	1.43
11	1.87	1.94	1.67
12	1.84	1.65	1.90
13	1.85	1.42	1.76
14	1.51	1.65	1.85
15	1.54	1.78	1.55
16	1.88	1.87	1.09
17	1.76	1.91	1.58
18	1.78	1.76	1.54
19	1.75	1.69	1.65
20	1.15	1.82	1.86
AVERAGE	**1.69**	**1.82**	**1.64**
OVERALL AVERAGE = +1.72 feet NAVD 88			

Table 3. Marsh fill settlement for a range of potential initial elevations (Gillen 2008).

Starting Elevation (feet NAVD 88)	Total Settlement at Year 20 (feet)	Final Elevation at Year 20 (feet NAVD 88)
+ 2.0	1.3	+ 0.7
+ 2.5	1.4	+1.1
+ 3.0	1.7	+ 1.3
+ 3.5	1.8	+ 1.7
+ 4.0	2.1	+ 1.9

Vegetation will be planted on the marsh platform in two phases after sufficient dewatering has occurred (Gillen 2008). The first phase of planting will take place immediately after construction in order to conserve the newly placed material. Phase one will consist of planting up to 60,000 units of *Spartina alterniflora* (smooth cordgrass) and approximately 9,600 units each of *Spartina patens* (marshhay cordgrass) and *Distichlis spicata* (saltgrass) around the perimeter of the newly created marsh and in areas immediately susceptible to wave energies and erosion (Gillen 2008). It is anticipated that approximately 63 acres of marsh will be planted during the first phase (Gillen 2008). Approximately six months after phase one is complete, the natural recruitment of native vegetation will be evaluated (Gillen 2008). Depending on the success of colonization, phase two will include the planting of up to 20,000 units of *Spartina alterniflora* and up to 9,600 units each of *Spartina patens* and *Distichlis spicata* in areas of the marsh platform that have not yet vegetated (Gillen 2008). It is anticipated that all of the 165 acres of the newly created marsh will either be planted or naturally vegetated in the two phases (Gillen 2008); however, vegetation will be monitored in order to assess whether more plantings will be required (Keith Lovell, CPRA, personal communication, July 2008).

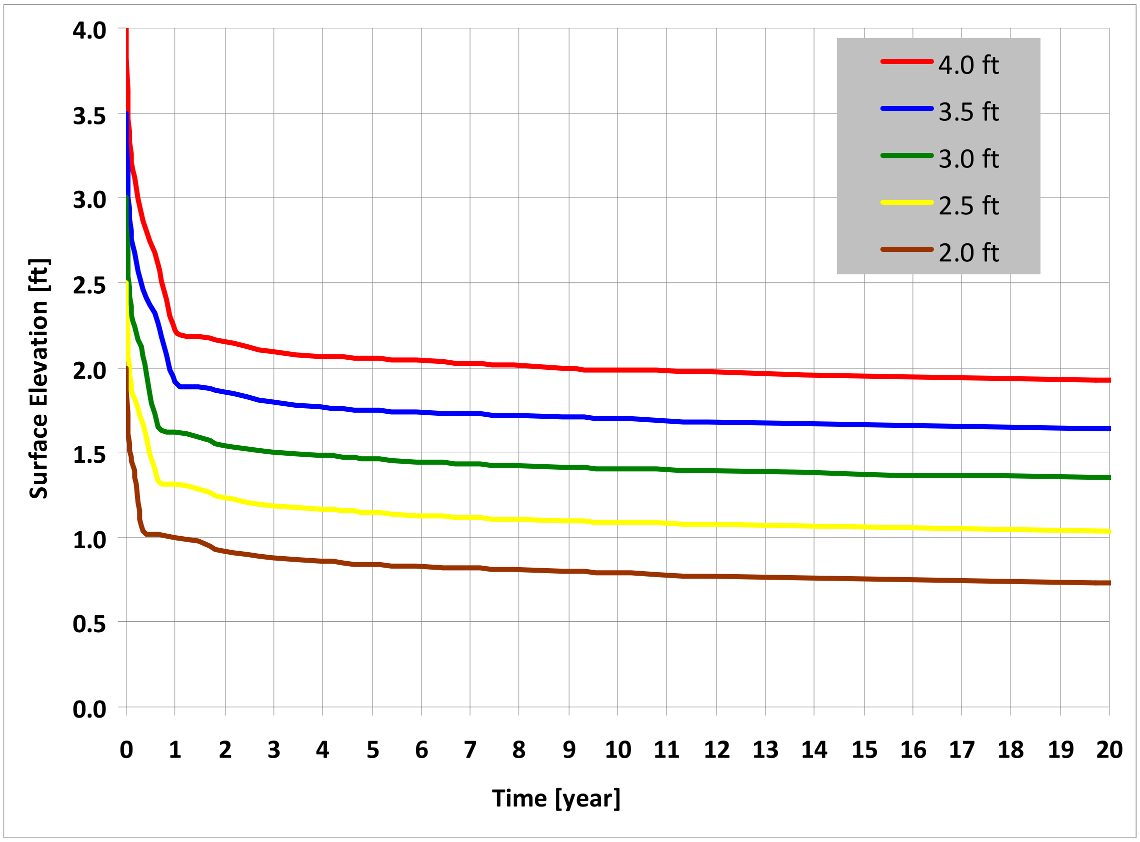

Figure 3. Marsh fill settlement curves for a range of potential initial elevations (Aquaterra 2008).

<u>Containment Dike Design</u>

Containment dikes will be constructed from in situ material borrowed from within the project area (Gillen 2008). Aquaterra Engineering, LLC (2008) recommended that the borrow pits be located at least 25 feet from the toe of the containment dikes for stability purposes and that the containment dikes be built with a crown elevation of +4.0 feet NAVD 88, a crown width of 5 feet, and side slopes of 1(V):5(H) to maintain a factor of safety of 1.3 (Figure 4). However, allowing 1 foot of freeboard above the marsh fill elevation to help eliminate the loss of dredged material during construction will require a crown elevation of +4.5 feet NAVD 88 (Gillen 2008). A stability analysis conducted by Aquaterra determined that a crown elevation of +4.5 feet NAVD 88 with side slopes of 1(V):4(H) or 1(V):5(H) would result in factors of safety ranging from 1.14 to 1.21 (Gillen 2008). A factor of safety over 1.1 is considered adequate for marsh creation containment dikes because the dikes can be maintained during construction; therefore, side slopes of 1(V):4(H) were selected (Gillen 2008).

Settlement of the containment dikes is estimated to be approximately 1 foot within the first year after construction and a total of 1.9 feet over the 20-year project life, which would result in the dikes being about 0.9 feet above the marsh platforms at year 20 (Gillen 2008). Therefore, the containment dikes will be degraded down to the elevation of the marsh platform approximately one year following construction, or when the marsh platform is determined to be stable (Gillen 2008). If the marsh platform has not yet settled to the target elevation of +1.8 feet NAVD 88 at that time, the containment dikes may be degraded down to an elevation of +1.8 feet NAVD 88 so that the marsh platform does not become impounded as the marsh continues to settle (Gillen 2008).

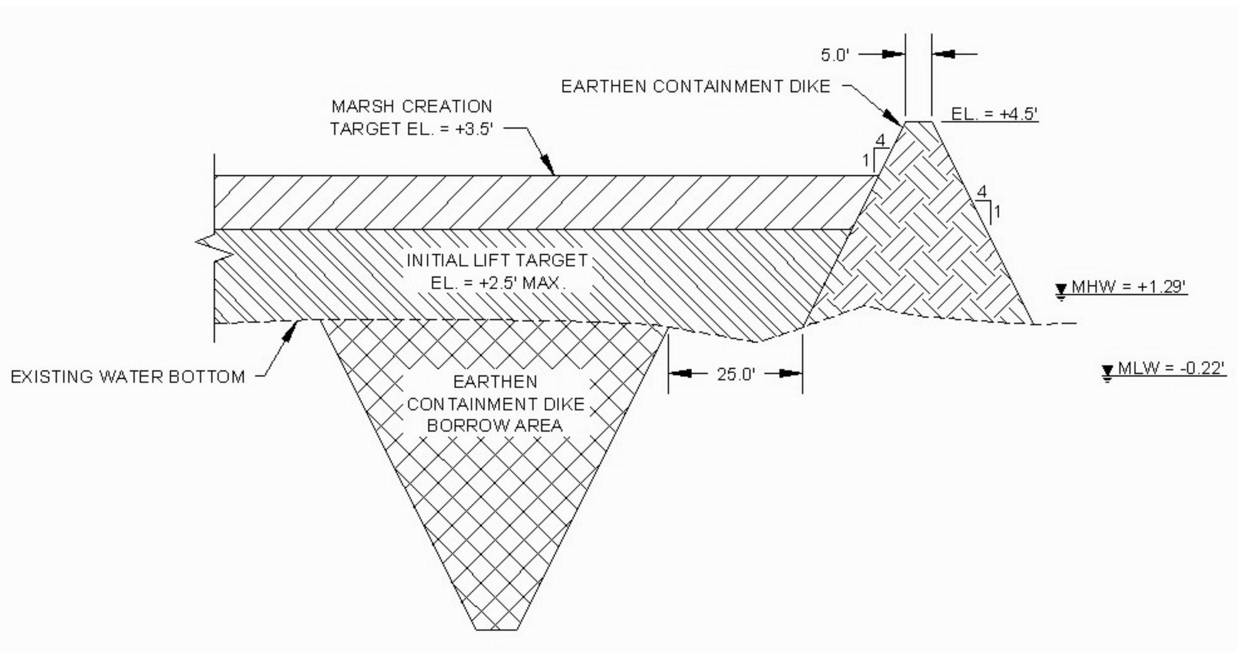

Figure 4. Design of the earthen containment dike, containment dike borrow area, and marsh fill. (Gillen 2008).

Earthen Plug Design

An earthen plug will be constructed from in situ material borrowed from within the project area in order to close a breach in the spoil bank at the southern end of the north-south oriented oil canal on the eastern perimeter of the project area that has led to significant erosion of the adjacent marsh (Figure 2; Gillen 2008). The plug will be built to a crown elevation of +6.0 feet NAVD 88 to allow for settlement, which will bring the crown elevation close to that of existing spoil banks, which ranges from +3.0 to +4.0 feet NAVD 88 (Gillen 2008). The plug is expected to settle 2.1 feet within the first year following construction and a total of 3.8 feet in the 20 year project life, resulting in a final elevation of +2.2 feet NAVD 88 (Gillen 2008). The plug will be constructed with a crown width of 20 feet to be consistent with existing canal spoil banks (Gillen 2008). Side slopes of 1(V):5(H) were selected to maintain a factor of safety of 1.3 (Gillen 2008). A total of approximately 9,300 cubic yards of material will be needed to construct the earthen plug (Gillen 2008).

Borrow Area for Marsh Fill

Following bathymetric, magnetometer, sidescan sonar, and sub-bottom profile surveys of a 25 square mile area in East Cote Blanche Bay, two potential sediment sources were identified and further investigated with more detailed surveys and vibracore sampling (Finkl et al. 2008). One of the potential borrow areas was at the north end of the search area and the second was at the south end (Finkl et al. 2008). The southern area was eliminated as an alternative based on the material collected in the vibracores (Finkl et al. 2008). Approximately 4.0 million cubic yards of suitable marsh fill, composed predominantly of soft clays, was identified in the northern area (Finkl et al. 2008). A final cut to fill ratio of 1.5:1 and a two-lift construction plan will require a total of 2,821,000 cubic yards of sediment and a depth of cut of -16.0 feet NAVD 88 to fill the marsh creation and marsh nourishment areas to +3.5 feet NAVD 88 (Gillen 2008). Although it is not anticipated that extra material will be necessary, the borrow area will be permitted to -20.0 feet NAVD 88 to ensure adequate material is available (Gillen 2008). Sediment will be hydraulically dredged from the borrow area and transported to the project area via pipeline.

A two-dimensional model called Simulating Waves Nearshore (SWAN; developed by Delft University of Technology, The Netherlands) was run in order to determine the potential impacts of the borrow area on the local wave climate, specifically to evaluate any differences in wave height with and without the potential borrow area (Gillen 2008). The maximum change in wave height measured by the model within the borrow area was less than 0.5 feet; however, this change did not propagate a significant distance away from the borrow area (Gillen 2008). The wave model was run with a borrow depth of -20.0 feet NAVD 88, prior to the final selection of the -16.0 feet NAVD 88 depth (Gillen 2008). However, the -20.0 feet depth represents the worst case scenario, and it is expected that wave heights will decrease slightly with the -16.0 feet depth of the final borrow area (Gillen 2008). No negative impacts are expected as a result of borrow area construction (Gillen 2008).

VI. Assessment of Goal Attainability

When addressing the likelihood that the proposed project features will provide the desired ecological response, it is important to evaluate the lessons learned from scientific research and previous projects that are similar in scope to the East Marsh Island Marsh Creation (TV-21) project. The findings of this review follow.

Marsh Creation

Marsh creation through the use of dredged material has been practiced in the United States for decades (Streever 2000). Despite years of experience with this technique, there is still ongoing debate concerning the success of marsh creation projects because created marshes may not be functionally equivalent to natural marshes (Moy and Levin 1991, Streever 2000). Project success is often measured by the establishment of marsh vegetation, such as *Spartina alterniflora*, because dense vegetation protects the site from erosion and may promote accretion (Streever 2000). However, many created marshes have been shown to significantly differ from natural marshes in physical and biological parameters such as bird species composition (Darnell and Smith 2004); nekton and benthic infaunal densities (Craft et al. 2003, Craft and Sacco 2003, Minello and Webb 1997, Moy and Levin 1991, Posey et al. 1997, Streever 2000); aboveground and belowground biomass (Shafer and Streever 2000, Streever 2000); primary productivity (Edwards and Mills 2005); sediment properties such as soil nutrient content and sediment grain size (Craft et al. 2003, Moy and Levin 1991, Poach and Faulkner 1998, Streever 2000); and geomorphological features such as elevation, water edge to marsh area ratios, and tidal connectivity (Delaney et al. 2000, Edwards and Mills 2005, Shafer and Streever 2000).

Some research indicates that as created marshes age, they progress to a level of habitat function similar to that of natural marshes; however, not all of the measured parameters have become increasingly similar to natural marshes over time (Delaney et al. 2000, Havens et al. 2002, Streever 2000, Minello and Webb 1997, Moy and Levin 1991). For example, results of a study in North Carolina indicated that although macrofaunal densities resembled those of a natural marsh within 6 months, the created marsh was not functionally equivalent to a natural marsh because species composition was not similar to a natural marsh, even after 27 months (Levin et al. 1996). A study conducted in Galveston Bay indicated that due to differences in elevation and tidal flooding, fish and decapod crustacean densities were lower in created marshes 3 to 15 years in age, and there was no obvious trend of increased nekton use with marsh age (Minello and Webb 1997). Havens et al. (2002) measured significant differences in habitat function in sediment organic carbon at depth, saltbush density, and bird utilization in a 12-year-old marsh constructed in Virginia. A study conducted in North Carolina found that biological and physical parameters developed at different rates, with plant biomass achieving equivalence in the first 5 years, followed by benthic infaunal community composition 5-10 years later (Craft et al. 1999). However, even after 20-25 years, soil nutrient reservoirs continued to be smaller in the constructed marshes (Craft et al. 1999).

Vegetation and soil development in created brackish marshes have been found to be related, in part, to tidal inundation (Craft et al. 2002). In a study conducted in North Carolina, aboveground biomass of *Spartina alterniflora* reached levels comparable to natural marshes within 3 years after marsh creation (Craft et al. 2002). This vegetation was found in the lowest elevations (along tidal creeks) of the created marsh and was inundated much of the time (Craft et al. 2002). Vegetation growing in the interior marsh, where elevations were higher and inundation was less frequent, took longer to reach levels of productivity comparable to that of natural marshes (Craft et al. 2002). Above-ground biomass of *Spartina patens*, which was planted at the highest elevation along the upland border of the marsh, was infrequently inundated and never attained equivalence to natural marsh (Craft et al. 2002). Soil development was also correlated with increased inundation (Craft et al. 2002). They estimated that, depending on elevation and tidal inundation, it could take 30-200 years for the created marsh soil to become equivalent to the natural marsh (Craft et al. 2002).

There have been a number of marsh creation projects constructed in Louisiana under such programs as CWPPRA, the United States Army Corps of Engineers (USACE) dredged material beneficial use program (USACE 1995), and the LDNR Dedicated Dredging program (LDNR 2000). Design parameters of some of these projects are summarized in Appendix A, and selected projects are discussed below.

- The Queen Bess Island Restoration (BA-05b) project (constructed in 1993 through the USACE Beneficial Use of Dredged Material Program) involved pumping dredged material into an area of open water surrounded by containment dikes in order to create vegetated wetlands and increase the size of the island. The objectives of the project included enhancing and creating nesting habitat for the Brown Pelican (*Pelecanus occidentalis*) and other colonial birds (Curole 2001). The size of the island was nearly doubled from 17 to 32.3 acres, vegetation growth has been vigorous, and the number of Brown Pelican nests on the island has increased dramatically post-construction (Curole

2001). However, Brown Pelican populations have also increased in other areas along the coast, indicating that factors other than project construction have also contributed to Brown Pelican reproductive success (Curole 2001).

- The Bayou LaBranche Wetland Creation (PO-17) project, located on the southwestern shore of Lake Pontchartrain, was the first project constructed through the CWPPRA program, with construction completed on April 1, 1994. Due to significant land loss, the project area prior to construction was mostly shallow, open water habitat, and only a narrow band of marsh along the shoreline separated the project area from Lake Pontchartrain (Boshart 2004). The project was designed to create approximately 305 acres of marsh and to reach a minimum 70% emergent marsh to 30% open-water ratio 5 years after construction. In 1997, the project area was approximately 82% land and 18% water (Boshart 2004). However, because most of the project was constructed in the upper target elevation range, which was not suitable for the establishment of marsh vegetation, only 51% of land was emergent marsh, with the rest classified as scrub-shrub and upland habitat (Boshart 2004, NRCS 2004). The target range of sediment elevation for this project, after 5 years of consolidation, was between +0.65 and 1.62 feet NAVD 88. As of August 2002, elevations at 11 of 19 staff gauge stations were within this target range (Boshart 2004). In addition, as sediment elevation has decreased over time, soil properties and vegetation communities have continued to develop toward characteristic wetland habitat for the region (Boshart 2004).

- The Barataria Bay Waterway Wetland Restoration (BA-19) CWPPRA project, completed in November 1996, was intended to complement the state-funded BA-05b project by creating an additional 9 acres of vegetated wetlands on Queen Bess Island using sediment from maintenance dredging of the Barataria Bay Waterway. The elevation of the marsh platform was projected to be +1.22 feet NGVD 29 after settlement and consolidation; however, two years after construction the elevation was +0.79 feet NGVD 29 (Curole 2001). Because of the low elevation, the project area is constantly flooded and no appreciable vegetation growth has occurred (Curole 2001).

- The Atchafalaya Sediment Delivery (AT-02) CWPPRA project, constructed in 1998, was designed to utilize sediment dredged from two channels in the Atchafalaya Delta to create 230 acres of delta-lobe islands suitable for the establishment of emergent marsh vegetation (Rapp et al. 2001). However, inaccurate elevation surveys made prior to construction caused the dredged material to be piled too high (Raynie and Visser 2002). As a result of the lower flooding frequency and duration produced by this elevation, the created islands have become dominated by wetland forest vegetation rather than the targeted emergent marsh species that colonize nearby natural crevasse splays (Raynie and Visser 2002).

- The goal of the West Belle Pass Headland Restoration (TE-23) CWPPRA project, completed in 1998, was to reduce the encroachment of Timbalier Bay into marsh on the west side of Bayou Lafourche and Belle Pass by creating 184 acres of marsh using sediment dredged from Bayou Lafourche (Curole and Huval 2005). However, failed containment dikes allowed a large quantity of sediment to be washed out of the marsh creation sites before the material had settled/consolidated (Curole and Huval 2005). Furthermore, large sections of the project area were filled to levels significantly higher or lower than the targeted +1.7 feet NAVD 88 elevation (Curole and Huval 2005). As a result, only 31 acres of saline marsh were created by this project, with the remainder classified as upland, scrub/shrub, beach/bar/flat, and subaqueous habitat (Curole and Huval 2005).

- The goal of the Lake Chapeau Sediment Input and Hydrologic Restoration, Point Au Fer Island (TE-26) project, constructed under the CWPPRA program in 1999, was to convert 260 acres of open water to marsh, which would act as a hydrologic barrier between two watersheds in the project area (Lear and Triche 2004, Raynie and Visser 2002). The marsh platform was designed to have a construction elevation of +1.5 feet NGVD 29, and a target elevation of +0.5 feet NGVD 29 (or existing marsh elevation) after settlement and consolidation (Raynie and Visser 2002). However, portions of the project area were not filled to the correct elevation, and some of the sediment was removed by tidal flow coming through containment dike failures and the dredge pipeline corridor (Raynie and Visser 2002). Consequently, the created marsh has a lower elevation than adjacent natural marsh, leading to more frequent and longer inundation than optimal for healthy marsh (Raynie and Visser 2002). The TE-26 project created only 139.5 acres of new land (Lear and Triche 2004).

- The Sabine Refuge Marsh Creation, Cycle 1 (CS-28-1) CWPPRA project is part of an overall effort to create approximately 1,120 acres (in a total of 5 cycles) of emergent marsh using sediment from maintenance dredging of the Calcasieu Ship Channel. The goal of the first cycle, completed in February 2002, was to create approximately 125 acres. The marsh was designed to have an elevation of +3.08 feet NAVD 88 at construction and +1.08 feet NAVD 88 after 5 years (Sharp and Juneau 2005). Although post-construction elevation surveys have not been conducted, Cycle 1 has been highly successful (Sharp and Juneau 2005). Vegetation surveys found that the created marsh was densely covered by emergent vegetation within two years (Sharp and Juneau 2005). In 2005, Hurricane Rita negatively impacted vegetation cover, species richness, and plant height in the project area, but vegetation generally recovered by 2006 (Ed Haywood, CPRA, personal communication, May 2008).

<u>Marsh Nourishment</u>

Marsh nourishment is a relatively new restoration strategy that has not been widely used in CWPPRA-funded projects. Marsh nourishment is a restoration technique that can refer to either the direct placement of a thin-layer of sediment through spray or hydraulic dredging or from the "spilling" of a thin-layer of sediment over marsh that is adjacent to an uncontained restoration project (LaPeyre et al. 2006). The concept behind marsh nourishment is that the addition of sediment would increase plant growth by improving the conditions within the growing environment by adding a mineral and nutrient source, increasing oxygen levels through soil aeration, and reducing the frequency and duration of flooding via an increase in elevation (Mendelssohn and Kuhn 2003). Interest in marsh nourishment as a coastal restoration technique began with studies evaluating the environmental effects of thin layer disposal of dredged material in marshes as an alternative to bucket dredging and its associated negative impacts from spoil bank creation, such as the impoundment of wetlands and the creation of upland habitat

(Cahoon and Cowan 1988, Ford et al. 1999, Wilber 1992, Wilber 1993). Because these studies concluded that dredged material disposed in thin layers did not permanently negatively impact existing healthy marshes, thin-layer sediment deposition has been proposed as a method for restoring soil elevations in deteriorated marshes to counteract sea-level rise, subsidence, and weather related disturbances (Cahoon and Cowan 1988, Ford et al. 1999, Kuhn and Mendelssohn 1999, Leonard et al. 2002, Mendelssohn and Kuhn 2003, Schrift 2006, Slocum et al. 2005, Wilber 1992, Wilber 1993, Wilsey et al. 1992).

Cahoon and Cowan (1988) concluded that although dredged material may have provided nourishment to recolonizing vegetation and adjoining marsh, it did not provide any benefits to the existing marsh because most of the vegetation was killed immediately following disposal of the material, and complete re-vegetation did not occur for at least 3 years in areas that received the most sediment (sediment deposition ranged between 10 and 38 cm). Other studies have also shown that marsh nourishment requires an initial recovery period; however, these studies found that the deposition of a thin-layer of sediment in deteriorated marshes resulted in an increase of both plant biomass and percent cover (Ford et al. 1999, Kuhn and Mendelssohn 1999, Leonard et al. 2002, Mendelssohn and Kuhn 2003, Slocum et al. 2005, Wilsey et al. 1992). Wilber (1993) concluded that the duration of the initial recovery period varies according to the thickness of sediment placement and the extent of soil modification. If a thinner layer of sediment is deposited, vegetation can recover more quickly via the production of new shoots from surviving roots and rhizomes; however, a thicker layer of sediment must be recolonized by seeds from adjacent marshes and will require a much longer recovery period (Wilber 1993).

In a study conducted in dieback areas of salt marsh near Caminada Bay, Louisiana, *Spartina alterniflora* transplanted into elevated plots had more than twice the aboveground and belowground biomass than plants transplanted into non-elevated plots after three months of growth (Wilsey et al. 1992). Ford et al. (1999) found that increased elevation through the deposition of a 2 cm layer of dredged material in a deteriorated Louisiana marsh increased percent cover of *Spartina alterniflora* three-fold within one year. Kuhn and Mendelssohn (1999) conducted a study in a deteriorated *Spartina alterniflora* marsh near Venice, Louisiana in which they evaluated the effect of varying thicknesses of sediment addition from minimal to more than 30 cm. Plant biomass was 30-50% greater in the areas that received greater than 15 cm of sediment, and percent cover increased by 50% in the areas nourished with greater than 30 cm of sediment, compared to the reference areas (Kuhn and Mendelssohn 1999). A study conducted in North Carolina evaluated the effect of the addition of 0 to 10 cm of sediment to deteriorated and non-deteriorated *Spartina alterniflora* marshes (Leonard et al. 2002). This study concluded that the healthy marshes did not benefit from the soil addition, but a two-fold increase in vascular plant stem density was observed when 2-10 cm of dredged material was added to the surface of the deteriorated marsh (Leonard et al. 2002). This study was unable to determine the optimal thickness of sediment (addition of 10 centimeters was the maximum application) that could be added to deteriorated marsh to provide benefits to the marsh without causing detrimental effects (Leonard et al. 2002).

Mendelssohn and Kuhn (2003) investigated the effects of differing thicknesses of sediment addition resulting from the accidental overflow of hydraulically dredged material being used to fill a gas pipeline canal adjacent to the marsh. The study was divided into five sites based on the amount of sediment that each area received: 1) no sediment addition, 2) trace amounts of sediment that were not quantifiable, 3) sediment addition not greater than 15 cm, 4) sediment addition between 15 and 30 cm, and 5) sediment addition between 30 and 60 cm

(Mendelssohn and Kuhn 2003). Areas receiving greater than 15 cm of sediment (4 and 5 above) showed increased plant production after two years (Mendelssohn and Kuhn 2003). Mendelssohn and Kuhn (2003) concluded that the addition of an intermediate to high amount of sediment (between 15 and 60 cm) to deteriorated marshes can improve plant height and biomass after an initial recovery period by increasing soil aeration, mineral content, and available nutrients, and that marsh nourishment could play a positive role in marshes where rates of sea level rise are greater than the rates of vertical accretion.

Because most studies conducted so far have been conducted immediately after sediment addition, it is possible that the observed increase in plant productivity may be a short-term result that decreases with time (LaPeyre et al. 2006). In order to examine whether the positive effects of marsh nourishment endured over the long-term in the same marsh examined by Mendelssohn and Kuhn (2003), Slocum et al. (2005) examined plant growth over a 7 year period. They found that percent cover had initially been greater than 90% soon after sediment deposition, but that this nutrient-enriched growth spurt faded after about 3 years. However, they also found that the positive effects of increased elevation were longer lasting and that even after 7 years, sediment enriched areas had 55% cover compared to only 20% cover in areas that did not receive sediment (Slocum et al. 2005).

Marsh nourishment is a relatively new restoration strategy that provides an opportunity for further research. Although most marsh nourishment studies conducted so far have shown that the goal of increasing plant productivity in deteriorated marsh can be achieved with the deposition of 5 to 15 cm of sediment (LaPeyre et al. 2006), Mendelssohn and Kuhn (2003) found that sediment additions greater than 30 cm also positively affected plant biomass. LaPeyre et al. (2006) suggests that the proper thickness can be easily determined by calculating how much sediment needs to be added to return the deteriorated marsh back to the elevation of nearby healthy marsh. However, there is still a need for further study on the optimal thickness of sediment that should be used for marsh nourishment. Additionally, in the placement of unconfined dredged material for marsh creation, there is little data available that addresses the distance surrounding the creation sites that is nourished by the flow of material (NRCS 2004). Furthermore, most marsh nourishment studies have been conducted in *Spartina alterniflora* marshes, and little data exists for the effects of nourishment in other types of marsh. The long term effects of marsh nourishment as a restoration technique in all types of marsh should be further studied (LaPeyre et al. 2006).

In addition to the LDNR Dedicated Dredging Program (LDNR 2000), a marsh nourishment component has been included in a couple CWPPRA-funded marsh creation projects that have been constructed in coastal Louisiana. These projects provide an opportunity to further evaluate the success and potential of the marsh nourishment technique. Design parameters of previously constructed marsh nourishment projects are summarized in Appendix A.

<u>Summary/Conclusions</u>

Achieving proper elevation is critical to the success of marsh creation projects. The elevation of the marsh surface controls the frequency and duration of flooding, which in turn affects vegetation zonation and productivity (Broome et al. 1988). Marsh platforms built too high may become dominated by upland vegetation, whereas platforms built too low may be excessively-inundated and therefore unsuitable for vegetation establishment. Regarding the TV-21 project, the elevation of the marsh platform would be approximately +1.8 feet NAVD 88 for a majority of the project life. At this elevation, the platform would be inundated approximately

6.5% of the time, based on 7 years of hourly water level data from the TV14-01 gage, located nearby in Lake Sand approximately two miles west of the project area (29°34'15.68"N, 91°45'14.53"W) (Figure 5). Although this level of inundation is lower than optimal for many species of emergent vegetation, it should be suitable for the locally-dominant *Spartina patens*, which is less tolerant of flooding and more productive in irregularly-inundated habitats (Burdick and Mendelssohn 1987, Broome et al. 1995, Nyman et al. 1995). Furthermore, the marsh elevation survey indicated that the average marsh elevation measured at the top of the root mass of existing plants was +1.72 feet NAVD 88 (Fenstermaker 2007), and field investigations revealed that the project area is currently supporting healthy marsh vegetation at this elevation (Cassidy Lejeune, LDWF, personal communication, February 2008).

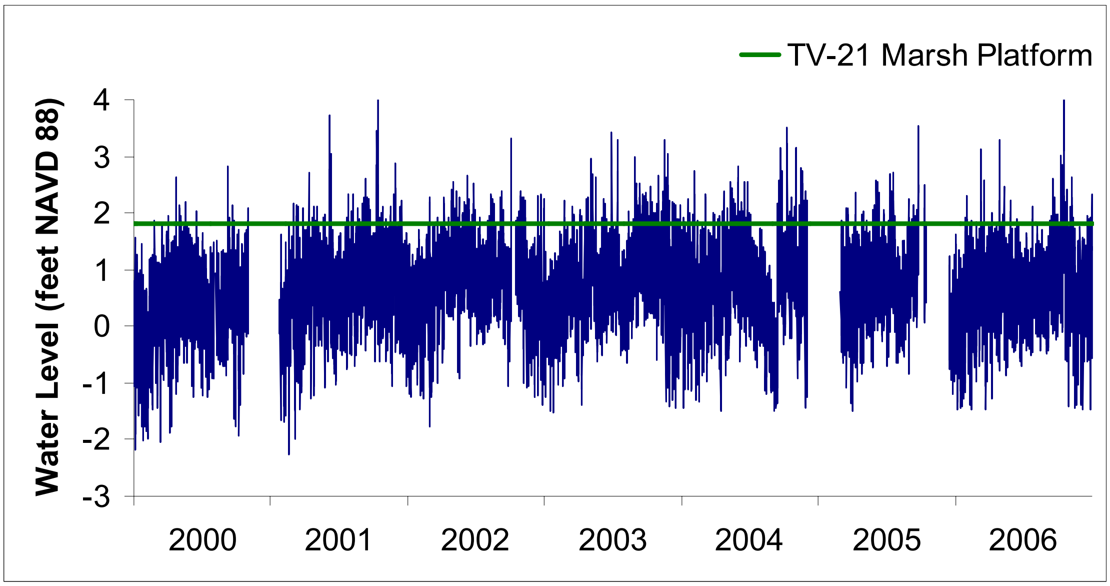

Figure 5. **Water level at the TV-14-01 gage for the years 2000 to 2006 (from CPRA data).**

It is important to quickly establish vegetation on created marsh platforms to stabilize the sediment and prevent its loss from erosive processes. The rate at which marsh vegetation naturally colonizes bare sediment is dependent on substrate characteristics and the availability of recruits (Broome et al. 1988). The borrow material that will be used in the TV-21 project is predominantly soft clay (Finkl et al. 2008). This fine textured material is more likely to have adequate nutrient concentrations necessary for rapid plant establishment than the sandy substrates often available for use in marsh creation projects (Broome et al. 1988). However, plantings may be necessary to accelerate vegetation establishment and development, particularly along the edges of the marsh platform which are more susceptible to erosion. Furthermore, because there is broken marsh in the TV-21 project area and existing vegetation will initially be smothered by nourishment with a thin layer of sediment; there may be a limited supply of propagules (i.e., seeds or plant fragments) available to colonize the newly created marsh platform. Under these circumstances, plantings can greatly accelerate vegetative establishment and development (Broome et al. 1988). It has been proposed to initially plant the perimeter and other vulnerable areas of the created marsh, followed by a second phase of vegetation planting in the large interior portions of the marsh platform that have not yet revegetated naturally. Once established, these plantings should provide a source of propagules for the remainder of the marsh platform, so that vegetative colonization can occur on a more natural progression. However, if development is inadequate, then additional plantings may be warranted.

Based on the results of the fill area and marsh elevation surveys, approximately 5 to 30 centimeters (after initial dewatering and consolidation) of dredged material will be placed over existing marsh areas for nourishment. The amount of dredged material that will be placed over existing marsh is consistent with the range of dredged material placement found in the literature. Existing vegetation nourished with the least amount of sediment will likely recover within 1 to 3 years after construction via the production of new shoots from surviving roots and rhizomes (Wilber 1993). Although it has been estimated that vegetation will only need to be planted on the 165 acres of created marsh (Gillen 2008), existing marsh areas receiving a thicker layer of sediment nourishment would need to be recolonized by seeds from adjacent marshes and would thus require a much longer recovery period (Wilber 1993). Additional plantings may be warranted on any portion of the 197 acres of nourished marsh that does not revegetate naturally in order to accelerate colonization of the entire project area.

The long-term sustainability of the created marsh is dependent on maintaining natural hydrologic exchange between the marsh and adjacent water bodies. Levees and canal spoil banks interrupt this exchange, resulting in prolonged flooding and drying events, reduced sediment and nutrient inputs, and ultimately marsh degradation and loss (Swenson and Turner 1987, Turner 1987, Kuhn et al. 1999). To prevent impoundment of the marsh platform, the containment dikes will be degraded down to marsh elevation, or +1.8 feet NAVD 88 approximately 1 year following construction (Gillen 2008). If there is differential settlement and the marsh platform settles more quickly than the containment dikes, the dikes could remain above the marsh platform, act as hydrologic barriers, and interrupt the transport of sediment and nutrients into the project area. If the containment dikes are found to impound the marsh, mechanical-gapping may be warranted.

Aerial photography of Marsh Island has revealed that marsh loss has occurred via the expansion of interior broken marsh into surrounding unbroken marsh and the conversion of broken marsh into open water due to the lateral erosion of unconsolidated sediments beneath the living root zone (Nyman et al. 1994). Without action, the land loss rate in the East Marsh Island Marsh Creation (TV-21) project area will likely continue to increase. Filling of the open water areas in the TV-21 project area will prevent the process of lateral erosion and will therefore protect existing habitat and increase the longevity of the island.

VII. Recommendations

Based on the evaluation of available ecological, geological, and engineering information, as well as scientific literature and environmental data, and a review of similar restoration projects, the proposed strategies of the East Marsh Island Marsh Creation (TV-21) project will likely achieve the desired ecological goals. At this time, it is recommended that this project be considered for Phase 2 authorization.

Appendix B of this document contains the responses to issues that were identified in the 30% Ecological Review.

References

Aquaterra Engineering, LLC (Aquaterra). 2008. Geotechnical Investigation: East Marsh Island Marsh Creation Project (TV-21) Iberia Parish, Louisiana. Baton Rouge, Louisiana. 22 pp. + appendices. (Prepared for C.H. Fenstermaker, Inc.).

Boshart, W.M. 2004. 2004 Operations, Maintenance, and Monitoring Report for Bayou LaBranche Wetland Creation (PO-17), Louisiana Department of Natural Resources, Coastal Restoration Division, New Orleans, Louisiana. 22 pp.

Broome, S.W., I.A. Mendelssohn, and K.L. McKee. 1995. Relative growth of *Spartina patens* (Ait.) Muhl. and *Scirpus olneyi* Gray occurring in a mixed stand as affected by salinity and flooding depth. Wetlands 15:20-30.

Broome, S.W., E.D. Seneca, and W.W. Woodhouse. 1988. Tidal salt marsh restoration. Aquatic Botany 32:1-22.

Burdick, D.M. and I.A. Mendelssohn. 1987. Waterlogging responses in dune, swale, and marsh populations of *Spartina patens* under field conditions. Oecelogia 74:321-329.

Cahoon, D.R. Jr. and J.H. Cowan Jr. 1988. Environmental impacts and regulatory policy implications of spray disposal of dredged material in Louisiana wetlands. Coastal Management 16:341-362.

C.H. Fenstermaker and Associates, Inc (Fenstermaker). 2007. Survey Report for Topographic, Bathymetric, and Magnetometer Surveying Services for the East Marsh Island Marsh Creation Project (TV-21). Lafayette, Louisiana. 178 pp. + appendices. (Prepared for Louisiana Department of Natural Resources)

Coastal Protection and Restoration Authority of Louisiana (CPRA). 2007. Integrated Ecosystem Restoration and Hurricane Protection: Louisiana's Comprehensive Master Plan for a Sustainable Coast. Baton Rouge, Louisiana. 117 pp.

Craft, C., S. Broome, and C. Campbell. 2002. Fifteen years of vegetation and soil development after brackish-water marsh creation. Restoration Ecology 10(2):248-258.

Craft, C., P. Megonigal, S. Broome, J. Stevenson, R. Freese, J. Cornell, L. Zheng, and J. Sacco. 2003. The pace of ecosystem development of constructed *Spartina alterniflora* marshes. Ecological Applications 13(5):1417-1432.

Craft, C., J. Reader, J.N. Sacco, and S.W. Broome. 1999. Twenty-five years of ecosystem development of constructed *Spartina alterniflora* (Loisel) marshes. Ecological Applications 9(4):1405-1419.

Craft, C. and J. Sacco. 2003. Long-term succession of benthic infauna communities on constructed *Spartina alterniflora* marshes. Marine Ecology Progress Series 257:45-58.

Curole, G. 2001. Comprehensive Monitoring Report No. 1 for the period October 1, 1996 to November 1, 1999: Barataria Bay Waterway Wetland Creation (BA-19). Louisiana Department of Natural Resources, Coastal Restoration Division, Thibodaux, Louisiana. 17 pp.

Curole, G.P. and D.L. Huval. 2005. Comprehensive Report No.1 for the period November 8, 1997 to February 18, 2004: West Belle Pass Headland Restoration (TE-23). Louisiana Department of Natural Resources, Baton Rouge, Louisiana. 47 pp.

Darnell, T.M. and E.H. Smith. 2004. Avian use of natural and created salt marsh in Texas, USA. Waterbirds 27(3):355-361.

Delaney, T.P., J.W. Webb, and T.J. Minello. 2000. Comparison of physical characteristics between created and natural estuarine marshes in Galveston Bay, Texas. Wetlands Ecology and Management 5:343-352.

Edwards, K.R. and K.P. Mills. 2005. Aboveground and belowground productivity of *Spartina alterniflora* (smooth cordgrass) in natural and created Louisiana salt marshes. Estuaries 28(2):252-265.

Environmental Protection Agency (EPA). 2008. East Marsh Island Marsh Creation (TV-21). Revised Project Information Sheet for Wetland Value Assessment. 12 pp.

Finkl, C.W., B.M. Forrest, J.L. Andrews, and M. Larenas. 2008. Geophysical and Geotechnical Investigations Conducted for the East Marsh Island Marsh Creation Project, Louisiana. Boca Raton, Florida: Coastal Planning & Engineering, Inc. 18 pp. + appendices.

Ford, M.A., D.R. Cahoon, and J.C. Lynch. 1999. Restoring marsh elevation in a rapidly subsiding salt marsh by thin-layer deposition of dredged material. Ecological Engineering 12:189-205.

Gillen, Dain. 2008. Final Design Report East Marsh Island Marsh Creation Project (TV-21) Iberia Parish, Louisiana. Coastal Protection and Restoration Authority. Baton Rouge, Louisiana. 27 pp. + appendices.

Havens, K.J., L.M. Varnell, and B.D. Watts. 2002. Maturation of a constructed tidal marsh relative to two natural reference tidal marshes over 12 years. Ecological Engineering 18:305-315.

Kuhn, N.L. and I.A. Mendelssohn. 1999. Halophyte sustainability and sea level rise: Mechanisms of impact and possible solutions. *In*: H. Lieth et al. (editors). Halophyte uses in different climates. Backhuys Publishers, Leiden, The Netherlands. 13 pp.

Kuhn, N.L., I.A. Mendelssohn, and D.J. Reed. 1999. Altered hydrology effects on Louisiana salt marsh function. Wetlands 19:617-626.

LaPeyre, M., B. Piazza, and B. Gossman. 2006. Short and long-term effects of thin layer deposition of dredged material on marsh health (1434-05HQRU1561, RWO No. 77). NMFS – USGS Interagency Agreement No. HC-119. Year 1 Report. 32 pp. + appendices.

Lear, E and S. Triche. 2004. 2004 Operations, Maintenance, and Monitoring Report for Lake Chapeau Sediment Input and Hydrologic Restoration, (TE-26) Point Au Fer Island. Louisiana Department of Natural Resources, Coastal Restoration Division, Thibodaux, Louisiana. 38 pp.

Leonard, L. A., M. Posey, L. Cahoon, T. Alphin, R. Laws, A. Croft, and G. Panasik. 2002. Sediment recycling: marsh renourishment through dredged material disposal. The NOAA/UNH Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET). 49 pp.

Levin, L.A., D. Talley, and G. Thayer. 1996. Succession of macrobenthos in a created salt marsh. Marine Ecology Progress Series 141:67-82.

Louisiana Coastal Wetlands Conservation and Restoration Task Force and the Wetlands Conservation and Restoration Authority. 1999. Coast 2050: Toward a Sustainable Coastal Louisiana. Appendix E-Region 3 Supplemental Information. Louisiana Department of Natural Resources. Baton Rouge, Louisiana. 173 pp.

Louisiana Department of Natural Resources (LDNR). 2000. Closure Report: Initial Funding Allocation, DNR Dedicated Dredging Program (LA-1). Louisiana Department of Natural Resources, Coastal Restoration Division. Baton Rouge, Louisiana. 8 pp.

Mendelssohn, I. A. and N. L. Kuhn. 2003. Sediment subsidy: effects on soil-plant responses in a rapidly submerging coastal marsh. Ecological Engineering 21:115-128.

Minello, T.J. and J.W. Webb, Jr. 1997. Use of natural and created *Spartina alterniflora* salt marshes by fishery species and other aquatic fauna in Galveston Bay, Texas, USA. Marine Ecology Progress Series 151:165-179.

Merino, J.H., J.A. Nyman, and T. Michot. 2005. Effects of season and marsh management on submerged aquatic vegetation in coastal Louisiana brackish marsh ponds. Ecological Restoration 23(4):235-243

Moy, L.D. and L.A. Levin. 1991. Are *Spartina* marshes a replaceable resource? A functional approach to evaluation of marsh creation efforts. Estuaries 14(1):1-16.

Natural Resources Conservation Service (NRCS). 2004. East Marsh Island Marsh Creation (TV-21). Project Information Sheet for Wetland Value Assessment. 10 pp.

Nyman, J.A., M. Carloss, R.D. DeLaune, and W.H. Patrick, Jr. 1994. Erosion rather than plant dieback as the mechanism of marsh loss in an estuarine marsh. Earth Surface Processes and Landforms 19:69-84.

Nyman, J.A., R.D. DeLaune, S.R. Pezeshki, and W.H. Patrick, Jr. 1995. Organic matter fluxes and marsh stability in a rapidly submerging estuarine marsh. Estuaries 18 (18):207-218.

Poach, M.E. and S.P. Faulkner. 1998. Soil phosphorous characteristics of created and natural wetlands in the Atchafalaya Delta, LA. Estuarine, Coastal and Shelf Science 46:195-203.

Posey, M.H., T.D. Alphin, and C.M. Powell. 1997. Plant and infaunal communities associated with a created marsh. Estuaries 20(1):42-47.

Rapp, J.M., M. Fugler, C.K. Armbruster, and N.S. Clark. 2001. Progress Report No. 1 for the period February 1, 1998 to March 28, 1999: Atchafalaya Sediment Delivery (AT-02). Louisiana Department of Natural Resources, Baton Rouge, Louisiana. 38 pp.

Raynie, R.C. and J.M. Visser. 2002. CWPPRA Adaptive Management Review – Atchafalaya Sediment Delivery Project (AT-02). Prepared for the CWPPRA Planning and Evaluation Subcommittee, Technical Committee, and Task Force. Baton Rouge, Louisiana. 23 pp.

Schrift, A.M. 2006. Salt marsh restoration with sediment-slurry amendments following a drought-induced, large scale disturbance. Masters Thesis, Louisiana State University, Baton Rouge. 54 pp.

Shafer, D.J. and W.J. Streever. 2000. A comparison of 28 natural and dredged material salt marshes in Texas with emphasis on geomorphological variables. Wetlands Ecology and Management 8(5):353-366.

Sharp, L.A. and H. Juneau. 2005. 2005 Operations, Maintenance, and Monitoring Report for Sabine Refuge Marsh Creation (CS-28). Louisiana Department of Natural Resources, Coastal Restoration Division, Lafayette, Louisiana. 15 pp. + appendices.

Slocum, M.G., I.A. Mendelssohn, and N.L. Kuhn. 2005. Effects of sediment slurry enrichment on salt marsh rehabilitation: plant and soil responses over seven years. Estuaries 28(4):519-528.

Streever, W.J. 2000. *Spartina alterniflora* marshes on dredged material: A critical review of the on-going debate over success. Wetlands Ecology and Management 8(5):295-316.

Swenson, E.M. and R.E. Turner. 1987. Spoil banks: effects on a coastal marsh water-level regime. Estuarine, Coastal and Shelf Science 24:599-609.

Turner, R.E. 1987. Relationship between canal and levee density and coastal land loss in Louisiana. U.S. Department of the Interior, Fish and Wildlife Service, National Wetlands Center, Biological Report 85 (14). 58 pp.

United State Army Corps of Engineers (USACE). 1995. Dredged material: Beneficial use monitoring program. New Orleans, Louisiana. 14 pp.

Wilber, P. 1992. Case studies of the thin-layer disposal of dredged material – Gull Rock, North Carolina. Environmental Effects of Dredging, D-92-3. Waterway Experiment Station, U.S. Army Corps of Engineers. 5pp.

Wilber, P. 1993. Managing dredged material via thin-layer disposal in coastal marshes. Environmental Effects of Dredging Technical Bulletin, EEDP-01-32. Waterway Experiment Station, U. S. Army Corps of Engineers. 14 pp.

Wilsey, B.J., K.L. McKee, and I.A. Mendelssohn. 1992. Effects of increased elevation and macro- and micronutrient additions on *Spartina alterniflora* transplant success in saltmarsh dieback areas in Louisiana. Environmental Management 16(4):505-511.

APPENDIX A

Design parameters of constructed marsh creation and marsh nourishment projects (sorted by construction date).

Project Name	Project Number	Coast 2050 Region	Construction Date	Project Area (acres)	Dredged Material (cubic yards)	Marsh Nourishment (acres)	Nourishment Sediment Thickness (inches)	Marsh Creation (acres)	Constructed Marsh Elevation (ft)	Project Summary	Monitoring Results
Calcasieu River & Pass Phase I - Phase III (WRDA)		4	Phase I 1992 Phase II 1996 Phase III 1999		4.0 million					Dredged material from the Calcasieu Ship Channel was deposited within the Sabine National Wildlife Refuge.	
Queen Bess (State)	BA-05b	2	1993		152,000			8	+3.22 NGVD 29	Dredged material was added to the island, and a rock dike was installed to armor the shoreline in order to restore the island as a brown pelican rookery.	Pelican nests continue to increase and area has become vegetated. The size of the island was nearly doubled from 17 acres (1989) to 32.3 acres (1996).
Bayou LaBranche Wetland Creation (CWPPRA)	PO-17	1	1994	487	2.7 million			305	+2.44 ± 0.19 NAVD 88	Dredged sediment from Lake Pontchartrain was used to create vegetated wetlands in an open water area bounded by I-10, Lake Pontchartrain, and Bayou LaBranche.	The average salinity (5.3 ppt) was statistically higher than the reference area (4.6 ppt) due to less tidal flushing because of the semi-impoundment of the project area. As of January 1999, sediment elevation was within the target range (+0.65 to 1.62 ft NAVD 88) in most of project area. 300 acres of open water were converted to land in 3 years, although only 51% of the project area was classified as marsh in 1997.
Wine Island (FEMA)	DSR-81558	3	1995							The island was repaired to pre-Hurricane Andrew condition with the beneficial use of dredged material from Houma Navigational Canal maintenance, and vegetation was planted to stabilize the sediment.	
Barataria Bay Waterway Wetland Delivery (CWPPRA)	BA-19	2	1996	510				9	+3.72 NGVD 29	The goal of this project was to create wetlands by constructing a 1,650 feet shell dike and filling the containment area with dredged material from the Barataria Bay Waterway (BBWW).	Vegetation has not colonized this project area because of low elevation and persistent inundation with water.
Timbalier Island Repair (FEMA)	DSR-81559	3	1996							A major breach created by Hurricane Andrew was closed, a 300-ft.-wide elevated marsh platform was constructed, and vegetation was planted to stabilize the sand.	

Design parameters of constructed marsh creation and marsh nourishment projects (sorted by construction date).

Project Name	Project Number	Coast 2050 Region	Construction Date	Project Area (acres)	Dredged Material (cubic yards)	Marsh Nourishment (acres)	Nourishment Sediment Thickness (inches)	Marsh Creation (acres)	Constructed Marsh Elevation (ft)	Project Summary	Monitoring Results
East Island Repair Protection (FEMA)	DSR-81560	3	1996							An elevated marsh platform was constructed in an area destroyed by Hurricane Andrew, and vegetation was planted to stabilize the sand.	
Barataria Bay Waterway, Grand Terre Island (Phase I - Phase II) (WRDA)		2	1996 1999		500,000					Dredged material from the Barataria Bay Waterway (BBWW) was placed beneficially to create wetlands on Grand Terre Island.	
Atchafalaya Sediment Delivery (CWPPRA)	AT-02	3	1998	4,248	720,000			280		Dredged material from Natal Channel was placed at elevations mimicking natural delta lobes. By re-establishing water and sediment flow into the eastern part of the Atchafalaya Delta, an additional 1,200 acres of new marsh habitat are expected to be naturally created over the life of the project.	This project created more scrub-shrub habitat than emergent marsh because the sediment was stacked too high during construction. One year post-construction, only 78.4 acres were created.
Big Island Sediment Mining (CWPPRA)	AT-03	3	1998	3,400	3.4 million			922	+1.5 to 3.0 NGVD 29	A new western delta lobe was created behind Big Island to enhance the accretion of land beyond the west bank of the Atchafalaya River. A main stem and five branch channels designed to mimic natural channel bifurcations were dredged, and material was placed at elevations mimicking natural delta lobes. Re-established water and sediment flows are expected to add an additional 2,000 acres over the project life.	The channels are maintaining adequate depth and still delivering sediment into the delta. However, this project created substantially more scrub-shrub and beach/bar/flat habitats than emergent marsh.
West Belle Pass Headland Restoration (CWPPRA)	TE-23	3	1998	2,459	2.7 million			184	+2.0 NAVD 88	Dedicated dredging was used to create marsh on the west side of Belle Pass. A water control structure and 17,000 linear feet of riprap were also used to reduce the encroachment of Timbalier Bay into the marshes on the west side of Bayou Lafourche.	Only a 5.4% increase in saline marsh area was attained as a direct result of construction failures. Only 1.2 million cubic yards was dredged, creating just 31.2 acres. Target elevations were not met. Also, 9.5 acres of vegetated wetlands were damaged by marsh buggies, and disposal of flotation channel refuse buried 8 acres of existing wetland vegetation. In contrast to the marsh creation phase, the shoreline protection phase was successful in reducing the shoreline erosion rate.

Design parameters of constructed marsh creation and marsh nourishment projects (sorted by construction date).

Project Name	Project Number	Coast 2050 Region	Construction Date	Project Area (acres)	Dredged Material (cubic yards)	Marsh Nourishment (acres)	Nourishment Sediment Thickness (inches)	Marsh Creation (acres)	Constructed Marsh Elevation (ft)	Project Summary	Monitoring Results
Isle Dernieres Restoration, East Island (CWPPRA)	TE-20	3	1999	449	3.9 million					Sand dredged from adjacent waters was used to build dunes and an elevated marsh platform. Sand fences were installed and vegetation was planted to stabilize sand and minimize wind-driven transport. A claim submitted to FEMA to repair damage to this project caused by Hurricane Katrina is still pending.	The island increased 187.3 acres in size from 1996 to 2002. Fences have accumulated sand to create dunes. Vegetation survival was high (70%) after one growing season. Non-planted and non-seeded vegetation increased from <1% (2001) to >23% (2003). There has been an increase in species richness and vegetative cover each year.
Isle Dernieres Restoration Trinity Island (CWPPRA)	TE-24	3	1999	776	4.85 million					Sand dredged from adjacent waters was used to build dunes and an elevated marsh platform. Sand fences were installed and vegetation was planted to stabilize sand and minimize wind-driven transport. A claim submitted to FEMA to repair damage to this project caused by Hurricane Katrina is still pending.	The island increased 92.64 acres in size from 1996 to 2002. Fences have accumulated sand to create dunes. Vegetation survival was high (>80%) after one growing season. Vegetative cover decreased from 34.4% (2001) to 7.8% (2003) in dune plots. There has been an increase in overall species richness and bay plot vegetative cover each year.
Lake Chapeau Sediment Input and Hydrologic Restoration, Point au Fer Island (CWPPRA)	TE-26	3	1999	13,024	850,000			160		The objectives of the project are to restore the marshes west of Lake Chapeau, to re-establish the hydrologic separation of the Locust Bayou and Alligator Bayou watersheds, and to re-establish the natural drainage patterns within the Lake Chapeau area. The hydrologic separation of the watersheds was established using dredged material from Atchafalaya Bay and the restoration of island hydrology by plugging oil field access canals and gapping artificial spoil banks.	Plants are vigorously growing and spreading.
Dedicated Dredging Program–Lake Salvador (State)	LA-01a	2	1999		114,089	YES		26		Two sites adjacent to Baie du Cabanage in the Salvador Wildlife Management Area were filled utilizing dredged material to nourish and rebuild marshes.	The southern edge of the fill areas that were nourished with dredged slurry is dominated by willow trees, indicating that the elevation is too high for marsh vegetation. The northern areas that were previously open water are dominated by freshwater marsh.

Design parameters of constructed marsh creation and marsh nourishment projects (sorted by construction date).

Project Name	Project Number	Coast 2050 Region	Construction Date	Project Area (acres)	Dredged Material (cubic yards	Marsh Nourishment (acres)	Nourishment Sediment Thickness (inches)	Marsh Creation (acres)	Constructed Marsh Elevation (ft)	Project Summary	Monitoring Results
Barataria Bay Waterway, Mile 31 to 24.5 (WRDA)		2	1999							Dredged material from miles 31 to 24.5 of the Barataria Bay Waterway (BBWW) was used to create marsh habitat.	
Brown Lake (WRDA)		4	1999		1.6 million			315		Dredged material was pumped to an elevation conducive to marsh creation in the Brown Lake area near Calcasieu River, 16 miles south of Lake Charles.	
MRGO (1999), Mile 14 to 11 (WRDA)		1	1999		3.5 million					Dredged material from miles 14.0 to 11.0 of the Mississippi River Gulf Outlet (MRGO) navigation channel was placed unconfined in shallow water adjacent to the south jetty at mile 15.3.	
Whiskey Island Restoration (CWPPRA)	TE-27	3	2000	4,926	2.9 million			657		Back barrier marsh was created, the breach at Couple Nouvelle was filled, and *Spartina alterniflora* was planted. A claim submitted to FEMA to repair damage to this project caused by Hurricane Katrina is still pending.	The island increased 168.03 acres in size from 1996 to 2002. Vegetation survival was <30% after one growing season due to drought. More than 21,600 cubic yards of sediment was lost from wind and overwash events in 1.5 years due to no sand fencing and no aerial seeding of *Cynodon dactylon*. There was a decrease in species diversity and percent cover from 2001 to 2003 due to the lack of sand fencing.
East Timbalier Island Sediment Restoration, Phase II (CWPPRA)	TE-30	3	2000	9,330	2.8 million			216	+3.0 NGVD 29	Dredged material was placed along the landward shoreline of the island. Additional rock was placed on the existing breakwater in front of the island. A claim submitted to FEMA to repair damage to this project caused by Hurricane Katrina is still pending.	Created habitats are now supporting a range of new, emergent vegetation.
Dedicated Dredging Program-Bayou Dupont (State)	LA-01b	2	2000	29	448,725	YES	6	160		Three sites adjacent to Bayou Dupont and The Pen were filled utilizing dredged material to rebuild marshes. No containment was constructed around the fill area, which allowed material to flow over and nourish adjacent marsh.	
Sabine Refuge Marsh Creation, Cycles 1-5 (CWPPRA)	CS-28	4	Cycle 1 2002 Cycle 3 2007	6,006	1 million 828,767			214 232	+3.08 NAVD 88 +2.03 to 2.71 NAVD 88	Two of five planned cycles have been completed using material dredged from Calcasieu River Ship Channel to create marsh in large, open water areas in order to block wind-induced saltwater intrusion.	The first cycle resulted in densely covered marsh within two years. The next four cycles are expected to produce similar results.

Design parameters of constructed marsh creation and marsh nourishment projects (sorted by construction date).

Project Name	Project Number	Coast 2050 Region	Construction Date	Project Area (acres)	Dredged Material (cubic yards	Marsh Nourishment (acres)	Nourishment Sediment Thickness (inches)	Marsh Creation (acres)	Constructed Marsh Elevation (ft)	Project Summary	Monitoring Results
Dustpan Maintenance Dredging Operations for Marsh Creation in the Mississippi River Delta Demonstration (CWPPRA)	MR-10	2	2002		222,000			40		This project demonstrated the beneficial use of dredged material from routine maintenance of the Mississippi River Navigation Channel by using a dustpan hydraulic dredge to create and restore adjacent marsh that had converted to shallow open water.	Vegetation successfully colonized the marsh creation area one year following project completion.
Brown Marsh (Other)	BRM-01	3	2002			YES	6-12	44		This project consisted of thin layer marsh creation and nourishment in Lafourche Parish.	
MRGO, Mile 14 to 12 (2002) (WRDA)		1	2002		1.6 million					Dredged material from miles 14 to 12 of the MRGO navigation channel was placed at an elevation conducive to marsh vegetation establishment.	
MRGO, Mile 14 to 12 (2003) (WRDA)		1	2003		4.3 million					Dredged material was pumped behind the MRGO jetty to create marsh habitat.	
Timbalier Island Dune and Marsh Creation (CWPPRA)	TE-40	3	2004	663	4.6 million			273	+1.6 NAVD 88	Beach, dunes, and marsh were restored on the eastern end of the island. A claim was submitted to FEMA to repair damage to this project caused by Hurricane Katrina is still pending.	
Dedicated Dredging Program – Pass a Loutre (State)	LA-01c	2	2005					26		Twenty-six acres of sustainable freshwater marsh was created in the vicinity of Pass a Loutre using dredged material.	
Freshwater Introduction South of Highway 82 (CWPPRA)	ME-16	4	2006	24,874	243,390	YES	10	14.5	+2.5 NAVD 88	This project included four water control structures, breaching spoil banks in areas near Highway 82 to allow water to flow across the chenier, removing plugs to facilitate water flow from the lakes subbasin into the chenier subbasin, and 26,000 linear feet of vegetated earthen terraces.	

Design parameters of constructed marsh creation and marsh nourishment projects (sorted by construction date).

Project Name	Project Number	Coast 2050 Region	Construction Date	Project Area (acres)	Dredged Material (cubic yards	Marsh Nourishment (acres)	Nourishment Sediment Thickness (inches)	Marsh Creation (acres)	Constructed Marsh Elevation (ft)	Project Summary	Monitoring Results
South White Lake Shoreline Protection (CWPPRA)	ME-22	4	2006	5,473				172		Segmented breakwaters were constructed to protect 61,500 linear feet of shoreline along the south shore and interior marshes of White Lake. Material dredged to create a flotation channel was placed behind the breakwaters to create marsh substrate.	
Dedicated Dredging Program - Terrebonne Parish School Board (State)	LA-01d	3	2006	30		YES	0-5	40		Forty acres of sustainable marsh were created just north of Lake DeCade along the western bank of Minors Canal using dredged material.	
Little Lake Shoreline Protection/ Dedicated Dredging Near Round Lake (CWPPRA)	BA-37	2	2007	1,373		532	7-14	488	+2.1 NAVD 88	This project will protect approximately 21,000 feet of Little Lake shoreline, create 488 acres of intertidal wetlands, and nourish an additional 532 acres of fragmented, subsiding marsh.	
Dedicated Dredging Program – Grand Bayou Blue (State)	LA-01e	3	2007					38		This project created marsh near Catfish Lake using dredged material from Grand Bayou Blue.	
Dedicated Dredging Program – Point Au Fer (State)	LA-01f	3	2007					67		This project created marsh on Point Au Fer Island adjacent to the TE-26 project using material dredged from Atchafalaya Bay.	

APPENDIX B

The 30% Ecological Review made the following two recommendations. The response that was received to address each issue is included below each of the numbered items.

Recommendation 1
At the end of construction, if the marsh platform has not dewatered and consolidated to the point where it is stable, consideration should be given to leaving the containment dikes in place until the marsh platform is stable. A post-construction O&M event should be considered to fund a separate mobilization to degrade the dikes after the marsh platform has consolidated fully. Furthermore, if the degraded containment dikes remain above and impound the created marsh, then additional mechanical-gapping may be necessary to ensure adequate tidal exchange.

Response
The text below was taken from the 95% Design Report (Gillen 2008) for the East Marsh Island Marsh Creation (TV-21) project:

> "To allow for a functional marsh and to prevent impoundment following construction, Operations and Maintenance funds have been requested for dike degradation as part of the Phase II budget. Approximately one year following construction, or when the marsh platform is determined by the project team to be stable, a contract will be issued to degrade the remaining containment dikes. The dikes will be degraded down to the level of the marsh platform. If the marsh platform at that time is higher than the final target elevation of +1.8', the dikes may be degraded down to an elevation of +1.8'."

Recommendation 2
As with any vegetation planting, consideration should be given to including fertilization of the marsh platform. According to Wilsey et al. (1992), although an increase in elevation alone will result in increased plant growth, marsh restoration projects achieve the most success with the combined addition of elevation and nutrients.

Response
Keith Lovell (OCRM), the designer of the vegetation planting scheme for the East Marsh Island Marsh Creation (TV-21) project, sent an e-mail response on October 15, 2008. The e-mail contained the following information:

> "It is my belief that fertilizer is only beneficial is some instances and in many cases the addition of fertilizer (at the time of planting) can actually be detrimental to the newly planted vegetation. When fertilizer with high Nitrogen (this is what is commercially available) is applied at the time of planting, it causes an "explosion" of bacteria in the growing zone of the plants root system. This explosion of bacteria greatly reduces the amount of oxygen in the soil that is available to the plant root system and actually creates a toxic microenvironment for the newly transplanted plant, especially bare root transplants. (I have witnessed this first hand with experiments that I have conducted in the field on various projects where we fertilized one row of plants and not the adjacent row 10' away. The plants without the addition of fertilizer actually had higher survival and growth rates!)

However, I believe that the addition of macro- and micro-nutrients can be very beneficial to plant growth but only after the plants have been established. Unfortunately, with the way we have to contract the plantings (we only have one shot with a contractor going out to plant during a contract time) it simply does not mesh well with the biology of the plants.

With the above being said, I do include slow release fertilizer tablets on some planting projects with higher planting elevations - dune plants in sandy, nutrient void, well drained soils – where the creation of the aforementioned toxic microenvironment can be avoided. I may include fertilizer tablets on the containerized plants (for example: on the *Spartina patens* on slightly higher elevations.)”