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

Four-Mile Canal Terracing and Sediment Trapping
CWPPRA Priority Project List 9
State No. TV-18

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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 October 9, 2003.

ECOLOGICAL REVIEW
Four-Mile Canal Terracing and Sediment Trapping

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

The Four-Mile Canal Terracing and Sediment Trapping project is located south of Intracoastal City in Vermilion Parish, Louisiana, and includes Little White Lake and the portion of Little Vermilion Bay immediately west of Four-Mile Canal (Figure 1). Ecological problems that exist within the project area include shoreline erosion, impaired water quality, and subsidence. Wind- and wake- generated wave action is believed to be the main cause of marsh loss in this area (National Marine Fisheries Service and State of Louisiana 1999). The erosion rate for the northern shoreline used in the Little Vermilion Bay (TV-12) Wetland Value Assessment ([WVA]; CWPPRA Environmental Working Group 1994) was 8 ft/yr. Subsidence, at a rate of 1.1 to 2.0 ft/century, has made only a minimal contribution to interior wetland loss (LCWCRTF & WCRA 1999). In addition, Four-Mile Canal is a manmade channel, constructed to provide a direct discharge of the Vermilion River into Vermilion Bay (HNTB Corporation 2002). Materials excavated to build the channel were deposited in spoil banks along the canal, which prevented river water from nourishing existing marsh adjacent to the canal. As a result, the marsh deteriorated and converted to open water.

There has been a gradual conversion of marsh north of Little Vermilion Bay from brackish to intermediate (O'Neil 1949; Chabreck et al. 1968; Chabreck and Linscombe 1978; Chabreck and Linscombe 1988; Chabreck and Linscombe 1997). This may be attributed to increased freshwater input to the area that resulted from the construction of the Gulf Intracoastal Waterway (GIWW; completed in 1944) and increased flow of the Atchafalaya River. However, sediment introduced from these freshwater sources has not resulted in land building in the area because wave energies are too great to promote subaerial development. In addition, sediment resuspension in Little Vermilion Bay and increased sediment introduction from the Atchafalaya River have increased turbidity in the bay, thereby inhibiting growth of submerged aquatic vegetation (SAV). An SAV survey of Little Vermilion Bay conducted by LDNR on October 28, 1999 found that only 6% (26 of 435) of rake samples contained SAV (Castellanos 2000).

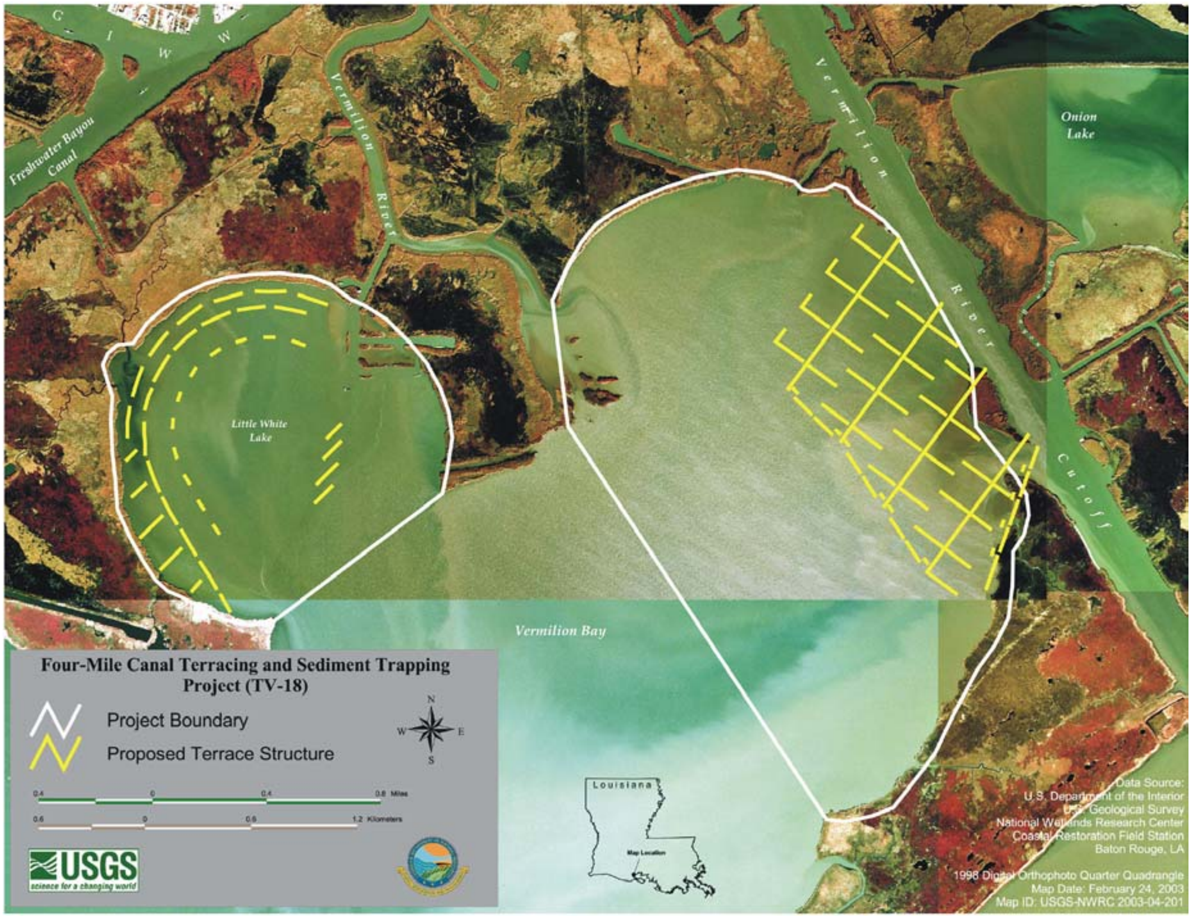

Figure 1: Map of project area (outlined in white), and terrace fields. Note that the configuration of the terraces has been revised. See figure 2 for the revised layouts.

II. Goal Statement

The goals of this project are to:

- create 52 acres of earthen terraces within the project area immediately after construction;
- reduce shoreline erosion rates by 50% over the 20 year project life;
- as a result of goals 1 and 2, achieve a 9% (approximately 17 acres) net increase in marsh habitat by the end of the 20 year project;
- increase submerged aquatic vegetation (SAV) coverage from 0% to 25% of the project area by the end of the 20 year project life;

and,

- increase fisheries utilization of the project area.

III. Strategy Statement

Project goals will be achieved using the following design features:

- use dredged material from borrow canals to construct earthen terraces in a "fish-net" orientation in the open water areas of Little Vermilion Bay, and in a shoreline contour configuration in Little White Lake; and,
- plant *Spartina alterniflora* (smooth cordgrass) along the slopes of the terraces.

IV. Strategy-Goal Relationship

The construction of terraces will buffer existing marsh against shoreline erosion by reducing wave and wake energy. Marsh will immediately be created by planting *S. alterniflora* along the slopes of the constructed terraces. Additionally, new marsh will be created in Little Vermilion Bay as freshwater and suspended sediments introduced from Four Mile Canal are dispersed through the terrace field, and trapped in the shallow open water adjacent to the terraces. To a lesser extent, the terraces in Little White Lake are also expected to trap sediment during storm events. In doing so, terraces will indirectly reduce water-column turbidity within the project area which will, in conjunction with decreased wave and wake energy, create habitat suitable for colonization by SAV. Fisheries habitat will be enhanced through creation of marsh edge and propagation of SAV.

V. Project Feature Evaluation

Components of the proposed TV-18 project include construction of borrow canals and vegetated terraces in Little Vermilion Bay and Little White Lake (Figure 1). The canals will be dredged approximately 10 feet below the current water bottom, and dredged sediment will be gently piled to reach the final construction elevation of +5 feet NAVD-88. The terraces in Little Vermilion Bay will have 20-foot crowns and 4 (H):1(V) side slopes. The terraces in Little White Lake will have 15-foot crowns and 4(H):1(V) side slopes. The terrace slopes will be planted with *Spartina alterniflora* (smooth cordgrass) as soon as weather and soil conditions permit, in order to minimize erosion (Talbot 1995; LDNR 1998). The terraces will be constructed and planted in the summer, in order to provide the plants the greatest opportunity for survival.

Four rows of terraces will be constructed in Little White Lake, roughly following the shoreline contour (Figure 2). This configuration was chosen to avoid problems with a pipeline that runs through the middle of the lake and because of land rights issues. The rows will be staggered so that the openings between terraces in any one row are located approximately in the middle of the terraces in the adjacent row, in order to minimize the wave energy reaching the currently existing shoreline (Talbot 1995). It is expected that this terrace configuration will also trap sediment resuspended from the lake-proper during storm events and, in doing so, provide episodic opportunities for subaerial land growth. In order to facilitate trapping of sediment being delivered to the area from the Vermilion River, four additional terraces will be constructed along the left descending side of the channel that connects Little White Lake to the river (Figure 2). The terraces in Little White Lake will be 28,150 feet in total, and will immediately create 31 acres of emergent land.

Terraces in Little Vermilion Bay will be constructed in an open "fish-net" design (Figure 2). This configuration is expected to operate as a baffle system which will slow the flow of water entering from Four Mile Canal, thereby allowing sediment to fall out of suspension within the terrace field. The primary terraces will be constructed in a NW-SE orientation, in order to provide the existing shoreline maximum protection from south-westerly winds to which the area is currently vulnerable. Existing land protects this area from south-easterly and northerly winds, but not to south-westerly winds that may dominate in the summer months. Further, the terrace configuration will reduce saltwater intrusion into Four Mile Canal, thereby protecting existing brackish and intermediate marsh along the Canal from further degradation. This design will also minimize the

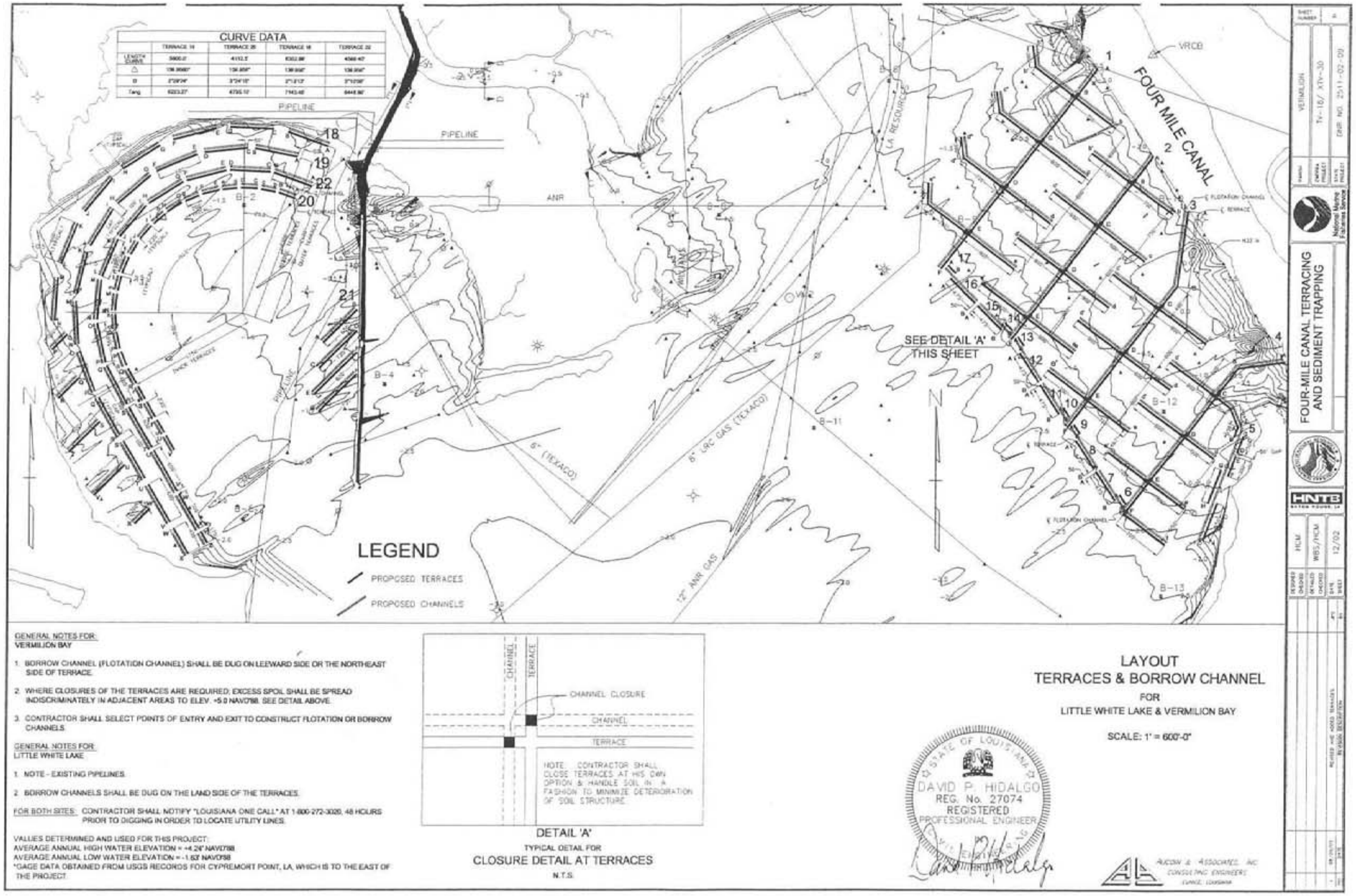

Figure 2: Layout of terrace fields in Little White Lake and Little Vermilion Bay (HNTB 2003).

fetch distance within the terrace field which will reduce wind-wave sediment resuspension, increase water clarity, and provide the opportunity for SAV establishment. Finally, maximizing the marsh edge within the terrace field will benefit the goal of increasing fisheries utilization in the area. The terraces in Little Vermilion Bay will be 42,400 feet in total, and will immediately create 52 acres of emergent land.

Terraces will be surveyed on a regular schedule to determine their susceptibility to excessive settlement and erosion (details may be found in the project's Operation, Maintenance, and Rehabilitation Plan). The outer-most terraces are considered "sacrificial" and are expected to erode as they are exposed to wave energy. However, if interior terraces do not remain at a height suitable for plant growth and survival, a contingency plan is in place to restore the terraces to the desired height in year 10 of the project's 20-year life.

VI. Assessment of Goal Attainability

The potential for creating and restoring wetlands depends upon a number of factors including proximity to available freshwater and sediment sources. Where these sources are inadequate, wetlands must be restored and created with techniques such as bay bottom terracing (LDNR 1993). Terraces are ridges, or discontinuous levees, of sediment constructed at marsh elevation using subtidal bottom sediments that have been excavated on site. Terrace fields are developed by arranging a series of these ridges in some pattern that maximizes intertidal edge and minimizes fetch between ridges (LDNR 1993). While this is a relatively new concept in coastal restoration efforts, it combines several long-existing techniques (baffle systems of ridges, breakwaters, vegetation planting) into one conservation tool (Underwood et al. 1991, LDNR 1993). Baffle systems of ridges, designed to encourage sedimentation, have been an essential component of sedimentation fields for hundreds of years in the Netherlands (Wagret 1968). Breakwaters have been used around the world to reduce wave erosion of shorelines, and vegetation has long been used to stabilize dunes or dredged material deposits (Woodhouse et al. 1974). When combined to create terrace fields, these techniques are expected to enhance deposition and retention of suspended sediments, reduce turbidity, increase marsh-edge habitat, increase overall primary and secondary production, and maximize access for aquatic organisms (Underwood et al. 1991; LDNR 1993; Turner and Streever 2002).

<u>State- or CWPPRA-funded Terrace Projects in Louisiana:</u>

The first terracing project in the United States was constructed in 1990 in the Sabine National Wildlife Refuge (SNWR), Louisiana. Within two ponds, 128 terraces were constructed in an open checkerboard pattern, and were planted with *Spartina alterniflora*. This design was chosen in order to reduce wave erosion of existing marsh fringes by reducing fetch, and to maximize the length of marsh-water interface. The post-project shoreline analysis indicated that the shoreline was prograding, most likely because tidal surges and wind-generated waves were reduced by the presence of the terraces (LDNR 1993). One year after planting, the marsh:water interface increased by 38,570 feet; after two years it had increased by 52,493 feet compared to before construction conditions (LDNR 1993). After two growing seasons, all terraces had 100% vegetative cover, and as of 1999, *S. alterniflora* was the dominant vegetation species (Rozas and Minello 2000). In addition, the vegetated terraces reduced fetch distance, increased soil organic matter content by supporting growth of *S. alterniflora*, and acted as wave-damping buffers for the surrounding marsh environment (LDNR 1993).

Attempts to establish SAV were not so successful (Rozas and Minello 2000). Three species of wild-collected SAV, *Ruppia maritima* (widgeon grass), *Halodule beaudettei* (shoal grass), and *Thalassia testudinum* (turtle grass), were planted in randomly selected ponds within each terrace field. Only *H. beaudettei* remained just two months after planting, with a survival rate of 22-24% in the terrace ponds. Low survival rates were attributed to substantial epiphytic growth on SAV and to continued high water-column suspended sediment concentrations, both of which reduced the amount of light available for plant production (LDNR 1993).

Rozas and Minello (2001) examined nekton utilization of the SNWR terrace fields in 1999. They found that while terraced marshes provided habitat that was equivalent in function to natural marshes for some species (e.g., white shrimp *Litopenaeus setiferus*), they were not functionally equivalent to natural marshes for most species (e.g., brown shrimp *Farfantepenaeus aztecus*, blue crab *Callinectes sapidus*, grass shrimp *Palaemonetes spp*.). However, terraced marshes did support higher standing crops of these nekton species than the adjacent shallow open-water ponds. It was further noted that penaeid shrimp and blue crabs are strongly attracted to shoreline vegetation. As a result, they should benefit from the increased length of marsh-open water interface which results when terrace fields are built in shallow open-water ponds.

Since the construction of the first terrace fields in the SNWR, several more projects that utilize terraces exclusively or incorporate them into a larger plan have been constructed in coastal Louisiana. Terrace projects that have been constructed include Plowed Terraces Demonstration (CS-25), Little Vermilion Bay Sediment Trapping (TV-12), and GIWW-Perry Ridge West Bank Stabilization (CS-30). Similar to the proposed TV-18 project, it is expected that terraces in these projects will reduce wave energy and turbidity which will in turn reduce shoreline erosion, create marsh, increase marsh edge, and promote SAV growth.

Little information is available regarding the performance of these recently constructed projects; however, limited unpublished data exist for the Little Vermilion Bay Sediment Trapping (TV-12) project, located immediately west of the proposed project site. Project features include 23 terraces totaling 23,300 linear feet of earthen terraces constructed to an elevation of 4.6 feet (NAVD-88), with plantings of *S. alterniflora*. A nested "V" pattern was selected to take advantage of sediment-laden water flowing from two entrances to Little Vermilion Bay from Freshwater Bayou Canal. Data indicate that this project is achieving the goal of trapping sediments, and the terraces appear to be persisting in the high-energy environment of Little Vermilion Bay (HNTB Corporation 2002). In addition, most are completely covered with vegetation, predominantly by the spread of the original *S. alterniflora* plantings (D. Castellanos, pers. comm. Aug 2001).

<u>Biotic Considerations for Terrace Projects</u>

The Sabine Terracing project was largely successful in attaining its biological goals; however, some lessons were learned that may be applied to future terracing projects. In the Sabine Terracing Project Final Report (LDNR 1993) it was concluded that environmental factors such as tidal amplitude, wind driven wave heights, water depth, existing marsh elevations, and salinity regime should be considered in other project designs. Design features such as terrace length, spacing, and configuration may be tailored to the site in order to maximize the benefits to the project area.

In order to maintain hydrologic integrity and permit ingress and egress of marine organisms it is critical to leave openings between terraces (LDNR 1993). In addition, future terracing plans could enhance the habitat value of projects for fishery species by increasing the proportion of marsh to open water ratio within terrace fields (Rozas and Minello 2001). Based on a study in a Galveston, Texas marsh, Rozas and Zimmerman (2000) recommended constructing low marsh edge by creating large areas of low marsh interspersed with a dense network of shallow channels and interconnected ponds in order to promote nekton use.

Poor survival of SAV in the Sabine Terracing project was attributed to difficult site conditions combined with the conflicting goal of retention of suspended sediments (LDNR 1993). Despite this conclusion, it is still believed that it is possible to establish SAV within terrace ponds (LDNR 1993), provided that suspended sediment concentrations can be reduced sufficiently to allow for adequate light penetration. To this end, terrace fields should be designed in a way that balances the need for sediment-laden freshwater to maintain and create marsh with the need to minimize fetch and discharge rates to reduce suspended sediment concentrations.

The height of the terraces after settling is important to the survival of *S. alterniflora*, and thus, to the success of the terraces. Relative to other marsh species, *S. alterniflora* is generally tolerant of flooding conditions that do not cause excessively low soil redox conditions (Gleason and Zieman 1981), possibly because it possesses an efficient mechanism to transport oxygen to its roots (DeLaune and Pezeshki 1991). However, continuous soil waterlogging may lower soil Eh to the point where oxygen deficiencies in the root zone allow sulfide and other reduced compounds to accumulate to concentrations that are toxic to the plants (Koch and Mendelssohn 1989; Mendelssohn and McKee 1988; DeLaune and Pezeshki 1991). Such conditions have been shown to reduce growth and productivity of *S. alterniflora*, and have the potential to cause vegetative diebacks (Mendelssohn and McKee 1988; Mendelssohn et al. 1981).

<u>Geomorphological Considerations for Terrace Projects</u>

Because the post-settlement height of terraces is important to the survival of desirable marsh species, engineering properties and geomorphology such as soil/water content, soil bearing capacities, and sediment particle size should be investigated during the project design phase. Soil-bearing capacity has been identified as the greatest influence on terrace structural integrity and post-construction settlement, and so sediments with extremely high water content or organic matter content may not be suitable substrate for terrace construction (LDNR 1993). For these reasons, proposed terracing projects are generally located in the western part of Louisiana, rather than, for example, in the Balize Delta. Yet, as found in the Little Vermilion Bay Sediment Trapping (TV-12) project, problems related to soil characteristics can arise anywhere in the state.

Despite indications that the TV-12 project is attaining its biotic goals, structural problems were encountered. Layers of very soft peat, clays and organic clays from the sediment surface to depths of 5 to 15 feet were found, leading to the conclusion that the soils were of poor quality for terrace construction (Soils and Foundations Engineers, Inc 1998). This caused the original construction design to be reevaluated, and a cross-sectional configuration was designed to provide an adequate berm distance to minimize the potential for shearing and subsequent terrace failure. Multiple lifts, sediment piled in any given area two to three times over one to two weeks, were also required to build the terraces (PENSCO 2000). Building the terraces in multiple lifts allowed the first lift of each terrace some time to consolidate before applying the second and, in some cases a third, lift. This technique also ensured that the terraces were constructed to the initial desired height.

A staged construction was also recommended for the TV-12 project, with a lapse of four to five years between stages, in order to allow adequate time for soil compaction before building to the desired height. This recommendation was not employed because it was believed that the potential for some slumping of the terraces was an acceptable risk when compared to the immediate biological benefits that may be achieved by proceeding with a single-staged construction schedule. Indeed, settlement did occur within just a few months after construction was completed. As a result, the crests are now narrower than when constructed, and the height above sea level is now +2.3 to +4.5 feet, rather than the design height of +5 feet (HNTB Corporation 2002). While these structural issues will not result in failure of the project, they may reduce the project's effectiveness in attaining its biological goals (HNTB Corporation 2002). Although these post-settlement elevations are acceptable for survival of emergent marsh vegetation, the engineering summary report for this project noted that if sediment deposition proceeds at a rate slower than future terrace settlement, it could become necessary to reconstruct the terraces in order to reestablish the desired elevation and cross-section (PENSCO 2000).

The stratigraphy of the TV-12 project area is similar to that of the proposed TV-18 site. Soil characteristics were compared graphically between the proposed TV-18 project, the constructed TV-12 project, and two proposed terracing projects (PO-25 and PO-28) that were not constructed (Figure 3). The Bayou Bienvenue Terracing (PO-25) project was not constructed because of poor soil conditions which, in the relatively deep water of the project area, compromised the potential success of the project. Additionally, there were several anticipated logistical problems associated with construction. In addition to the similarly poor soil conditions, the La Branche Terracing (PO-28) project was not built because of land-rights issues. Compression strengths are poor for the two projects that were not constructed, but are similar between Little Vermilion and Four Mile Canal. The moisture content and dry unit weight data for the top 15 feet of soils at the proposed TV-18 site are less desirable than found at the Little Vermilion site.

The engineering analysis performed for the proposed TV-18 project concluded that terraces, if built as proposed, would cause compression of native soils by 15-25% under the weight of the berms, and that the crest will settle due to consolidation within the fill. As a result, future addition of height may be required (HNTB Corporation 2002). It was further recommended that consideration be given to constructing the project in two stages, where the initial height of the terraces would be 1-3 feet above average high water. One to two years later, a second stage of construction could commence to reach the desired crest elevation.

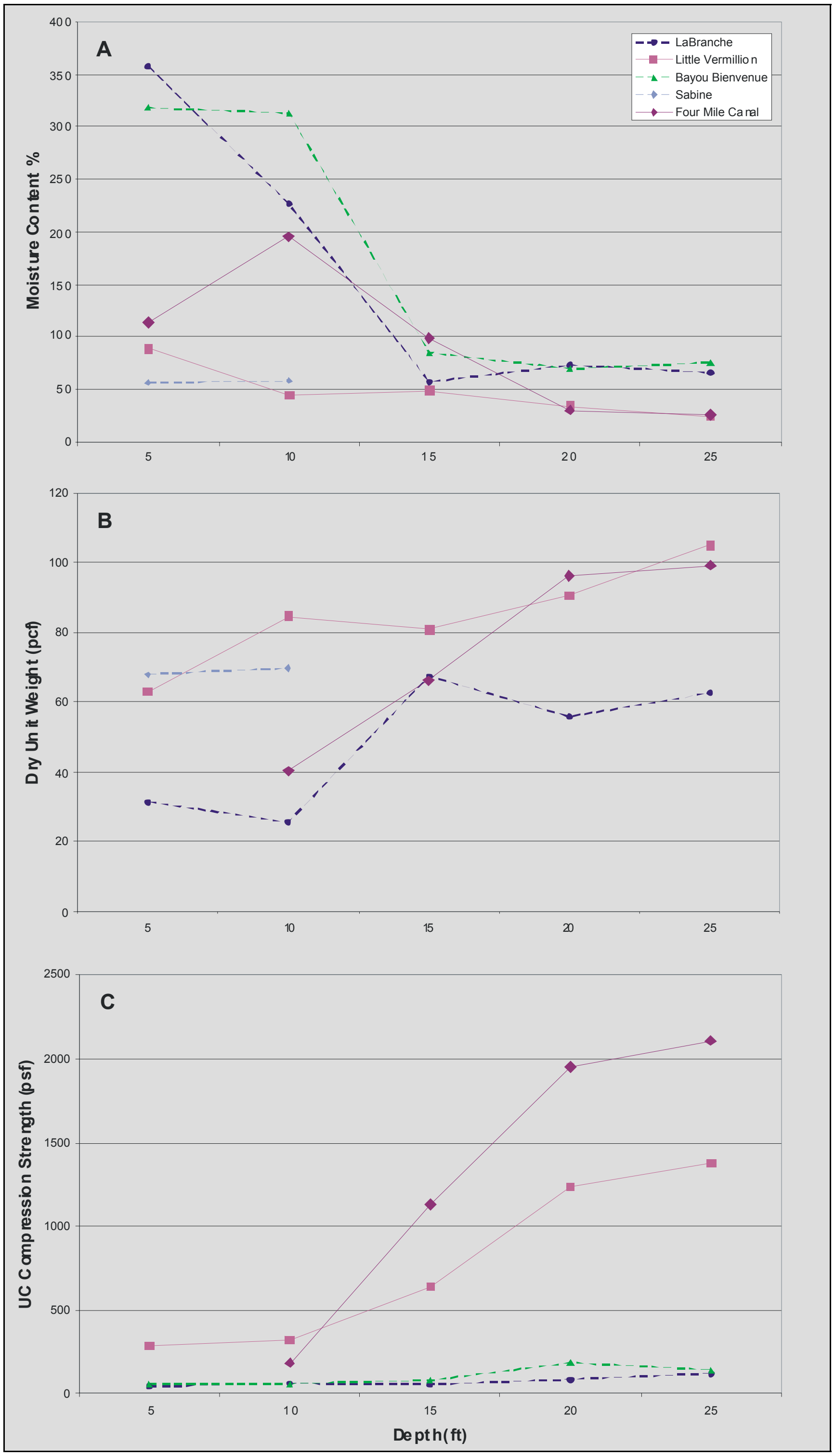

Figure 3: Comparison of soil characteristics among proposed terracing project sites.

Summary/Conclusions

The project was designed to achieve the desired goals. Reduction of shoreline erosion will be achieved by the buffering capacity of the constructed terraces. Results from the Sabine Terracing project show that marsh terracing can reduce fetch, wave energy, and shoreline erosion within coastal water bodies. Marsh habitat will be created in two ways. First, marsh will immediately be built by creating terraces from dredged material and planting them with *S. alterniflora*. This action alone will create 68 acres of subaerial land. Second, by reducing fetch and wave energy, terraces will promote the deposition of suspended sediments in the shallow water adjacent to the terrace edges in Little Vermilion Bay. This will slowly build marsh over the life of the project, as subaerial land is built and plants naturally become established.

This restoration technique also appears to increase the standing crop of nekton species relative to similarly sized shallow open-water ponds. The goal of establishing SAV within the project area is less certain, as SAV was not established in the SNWR; however, terracing could provide favorable conditions within ponds for establishment and growth of SAV, provided that concentrations of suspended sediments can be decreased to provide adequate light penetration into the water column. The "fish net" design for Little Vermilion Bay may be conducive to SAV growth. Water velocity should decrease quickly as freshwater enters the terrace field. As a result, sediments should drop out of suspension shortly after water enters the field, which will increase water clarity in the terrace field ponds further from Four Mile Canal.

VII. Recommendations

Based on the evaluation of similar projects, the conceptual design for Four-Mile Canal Terracing and Sediment Trapping project appears to be an acceptable design to proceed to construction.

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