State of Louisiana

Coastal Protection and Restoration Authority (CPRA)

2016 Operations, Maintenance, and Monitoring Report

for

Little Vermilion Bay Sediment Trapping

State Project Number TV-12
Priority Project List 5

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Vermilion Parish

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Preface

This report includes monitoring data collected through spring 2016, and the annual maintenance inspection from April, 2016. The Little Vermilion Bay Sediment Trapping (TV-12) project is a 20-year Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA, Public Law 101-646, Title III, Priority List 5) project administered by the Natural Marine Fisheries Service (NMFS) and the Coastal Protection and Restoration Authority of Louisiana (CPRA).

The 2016 report is the final report in a series of reports. For additional information on lessons learned, recommendations and project effectiveness please refer to the 2004 and 2005 Operations, Maintenance, and Monitoring Reports and prior O&M annual inspection reports on the CPRA web site at http://coastal.Louisiana.gov/. These reports will be made available for download at the following website: http://cims.coastal.la.gov.

I. Introduction

Little Vermilion Bay is a shallow western extension of Vermilion Bay, located in south-central Vermilion Parish, Louisiana (figure 1). Prior to 1900, marshes surrounding Little Vermilion Bay were brackish or saline. By 1952, fresh water from the Atchafalaya Basin began reaching Atchafalaya Bay and reduced salinities in the area (Adams and Baumann 1980). With strong southeasterly winds, the fresh sediment-rich waters from Atchafalaya Bay and Gulf Intracoastal Waterway (GIWW) reach Little Vermilion Bay and deposit sediments in the project area.

Perhaps the most important hydrologic change within this region was the dredging of the GIWW. Construction of the GIWW was authorized by the Rivers and Harbors Act of 1925 (Louisiana Coastal Wetlands Conservation and Restoration Task Force, LCWCRTF 1993). Multiple studies, involving satellite imagery and turbidity measurements, indicate that northwest winds (resulting from cold fronts) are largely responsible for re-suspending sediments in Little Vermilion Bay and that the GIWW and Freshwater Bayou are significant sources of fresh water and sediment into the area (Walker 1998). Sediment availability is a fundamental component to the projects success. The recognition of the potential for subaerial development in Little Vermilion Bay stimulated interest in designing a plan to enhance this development (National Marine Fisheries Service, NMFS 1998).

At mean tide levels, water depth in Little Vermilion Bay ranges from 1 to 3 ft (0.3 - 0.9 m). Soil types surrounding Little Vermilion Bay are classified as Clovelly-Lafitte (NRCS 1996). Clovelly soils consist of continuously flooded, very poorly drained, and very slowly permeable organic matter formed in moderately thick accumulations of herbaceous plant material, overlying very fluid clayey alluvium (NRCS 1996). Lafitte soils consist of mostly flooded, very poorly drained, and moderately rapidly permeable, organic matter from herbaceous plant material, overlying clayey alluvium (NRCS 1996). Marshes surrounding Little Vermilion Bay have been classified as brackish by O'Neil (1949) and Chabreck and Linscombe (1962, 1968, 1978, 1988). But more recent surveys of the project area indicate the vegetation type to be mostly intermediate with some brackish habitat. The primary plant species include *Phragmites australis* (common reed), *Spartina patens* (saltmeadow cordgrass), *S. alterniflora* (smooth cordgrass), *Sagittaria lancifolia*. (Bulltongue arrowhead), *Schoenoplectus californicus* (California bulrush), *Typha* sp. (cat-tail), *Juncus romerianus* (needlegrass rush), and *Cladium mariscus* (Jamaica swamp sawgrass).

The marshes west of Vermilion Bay continues to be fresher than those to the east and along the Acadiana Bays as the areas west of Vermilion Bay are more heavily influenced by higher salinity Gulf of Mexico waters via Southwest Pass. Even though these marshes benefit from the Atchafalaya River water flowing through the GIWW and the bay itself the occasional salinity pulse can reach even isolated interior marshes during prolonged droughts due to the constant tidal exchange with Southwest Pass and the multitude of oil and gas canals.

The Little Vermilion Bay Sediment Trapping Project area will affect 964 ac (390 ha), of which 67 ac (27 ha) are intermediate marsh and 897 ac (363 ha) are shallow open water (figure 1). It is located in the northwestern corner of Little Vermilion Bay at its confluence with Freshwater Bayou.

The project includes multiple features that classify it not only as a sediment trapping project but also a vegetative planting and shoreline protection project. Construction was completed in September 1999. The features include:

1. Approximately 14,000 to 19,900 linear feet (4,267 - 6,065 m) of distributary channels 100 ft (30.5 m) wide and 10 ft (3.0 m) deep were dredged.

2. Created approximately 68 acres (8.9 - 12.5 ha) of terraces.

3. Vegetative plantings of gallon containers and sprigs of *S. alterniflora* were planted at the base of terraces and along the existing shoreline.

Figure 1. Little Vermilion Bay Sediment Trapping (TV-12) project and reference area map.

II. Maintenance Activity

a. Project Feature Inspection Procedures

The purpose of the annual inspection of the Little Vermilion Bay Sediment Trapping Project (TV-12) is to evaluate the constructed project features to identify any deficiencies and prepare a report detailing the condition of project features and recommended corrective actions needed. Should it be determined that corrective actions are needed, LDNR shall provide, in the report, a detailed cost estimate for engineering, design, supervision, inspection, and construction contingencies, and an assessment of the urgency of such repairs (O&M Plan, 2004). The annual inspection report also contains a summary of maintenance projects which were completed since completion of constructed project features and an estimated projected budget for the upcoming three (3) years for operation, maintenance and rehabilitation. The three (3) year projected operation and maintenance budget is shown in Appendix B.

An inspection of the Little Vermilion Bay Sediment Trapping Project (TV-12) was held on April 21, 2016 under mostly cloudy skies and mild temperatures. In attendance were Stan Aucoin of CPRA and John Foret, and Rick Hartman of NOAA. The annual inspection began at the terrace field in Little Vermilion Bay.

The field inspection included a complete visual inspection of the entire project site. Staff gauge readings were used to determine approximate elevations of water and earthen terraces. Photographs were taken at each project feature (see Appendix A) and Field Inspection notes were completed in the field to record measurements and deficiencies (see Appendix C).

b. Inspection Results

<u>Site 1—Earthen Terraces</u>

The terraces appear to be in excellent condition. The opening to the terrace field at the intersection of Little Vermilion Bay and Freshwater Bayou continues to widen. The erosion of terraces nearest Freshwater Bayou, however, has not gotten significantly worse. Bayou Backer Erosion Control has begun installing their product around the inside points of the two terraces closest to Freshwater Bayou, but installation is moving very slowly. Protected terraces continue to provide protection from waves allowing sediment delivered through the channels to continue to accrete. Planting of bullwhips performed by others in the areas between the terraces continues to expand. Submerged and emergent vegetation is evident throughout the project area. Narrowing the opening to Freshwater Bayou should still be considered as a way to protect this developing marsh. (Photos: Appendix A, Photos 1-5)

Site 2—Vegetative Plantings

Vegetation continues to expand from the original plantings and appears strong. Native emergent vegetation between the terraces has become established and should continue to expand with the additional protection provided by the plants mentioned above.

II. Maintenance Activity (continued)

c. Maintenance Recommendations

i. Immediate/ Emergency Repairs

None

ii. Programmatic/ Routine Repairs

The opening at Freshwater Bayou continues to expand. Limiting the widening of Freshwater Bayou into the terrace field should be considered.

d. Maintenance History

General Maintenance:

Below is a summary of completed maintenance projects and operation tasks performed since August 20th 1999, the construction completion date of the Little Vermilion Bay Sediment Trapping Project (TV-12).

December 2011 Staff Gauge:

Installed a staff gauge on Channel Marker #1 at N 29°44'51.26", W 92°11'59.14".

February 2012 Survey:

Acadian Engineering and Environmental Consultants, Inc. performed surveys on this project as well as on TV-18 Four Mile Canal in order to more accurately estimate quantities of material needed for a possible maintenance event. Costs of this survey effort that were charged directly to this project were $18,006.34.

III. Operation Activity

a. Operation Plan

There are no water control structures associated with this project; therefore, no Structural Operation Plan is required.

b. Actual Operations

There are no water control structures associated with this project, therefore no required structural operations.

IV. Monitoring Activity

Pursuant to a CWPPRA Task Force decision on August 14, 2003 to adopt the Coastwide Reference Monitoring System-*Wetlands* (CRMS-*Wetlands*) for CWPPRA, updates were made to the TV-12 Monitoring Plan to merge it with CRMS-*Wetlands* and provide more useful information for modeling efforts and future project planning while maintaining the monitoring mandates of the Breaux Act.

a. Monitoring Goals

The objectives of the Little Vermilion Bay Sediment Trapping Project are to enhance the amount of wetlands created by natural sediment deposition where confined flow of Atchafalaya River water enters the project area through the dredging of distributary channels, protect the existing wetlands of the project area by reducing wave energy through the creation of terraces, create emergent marsh on terraces along distributary channels and on newly deposited soils, and to encourage colonization by submerged aquatic vegetation between and around terraces.

The following specific goals will contribute to the evaluation of the above objectives:

1. Increase sediment deposition in the project area conducive to the establishment of emergent vegetation.
2. Create and enhance emergent marsh by planting on terraces and along suitable existing shorelines.
3. Increase the occurrence of submerged aquatic vegetation in shallow open water within the project area.
4. Reduce shoreline erosion rate in the project area.

b. Monitoring Elements

<u>Aerial Photography:</u>
In order to evaluate shoreline movement, terrace stability, and the extent of interior emergent marsh creation (direct and indirect) in the project area, near-vertical, color-infrared aerial photography (1:12,000 scale) was obtained once prior to construction in 2000, and was obtained post-construction in 2002 and 2009. The original photography was checked for flight accuracy, color correctness, and clarity and was subsequently archived. Aerial photography was scanned, mosaicked, and georectified by USGS/NWRC personnel according to standard operating procedures (Steyer et al. 1995, revised 2000).

Percent land trends were calculated using Landsat Thematic Mapper (TM) data for 1985 - 2010. Linear regressions were calculated for the period of record. The variability in percent land data points around the slope illustrates the influence of various sources of environmental variance or classification error. Positive slopes indicate increasing percent land or historical land gain and negative slopes indicate decreasing percent land or historical land loss (Couvillion et al., 2011).

Bathymetry/Topography

Sediment deposition was monitored along existing transects used in bathymetry map creation (for engineering purposes). Several transects encompassing an array of terrace and channel formations was selected for development of elevation profiles (figure 2). Elevation of the water bottom sediments was determined along each transect in a similar fashion to that in the initial survey. Average elevations for terraces, bay bottom around and among terraces, and channels were computed using select points from the 1999 and 2003 surveys that were found to be at most 1.6 ft. apart. These points were then ploted to create a pseudo cross sectional comparison between the 1999 and 2003 data sets. Surveys were conducted by a professional engineering firm in 1999 (as built) and in 2003.Additional survey years may be added to gather additional information throughout the project life.

Emergent Vegetation:

The plantings and naturally colonized vegetation on the terraces were evaluated and classified into a wetland indicator status based on a plant species frequency of occurrence in wetlands. Data was collected using line intercept methodology on a minimum of two and a maximum of four transects per terrace (dependent upon length), with samples taken at one meter intervals (figure 2). All plants that were in the horizontal plane of the line were identified, assigned a prevalence index number, and averaged for each 3.28 ft (1 m) segment. Measurements were taken across the terraces from vegetated edge to vegetated edge and differential Global Positioning System (dGPS) readings were recorded for consistency of sampling location for each sampling date. The transects duplicated the elevation survey cross section lines. This data was used to generate Frequency of Occurrence by species throughout the project area using a subset of the terraces and transects monitored in 2002, 2004, and after Hurricane Rita in 2005. The presence or absence of vegetation was recorded for each sample to determine the percent occurrence on a transect (% occurrence = (number of samples with emergent marsh species/number of samples) × 100). When vegetation was present, the species present was recorded in order to determine the frequencies of individual species.

Shoreline Change:

To document shoreline movement along the existing marsh shoreline, shoreline stations were established along the marsh edge in both the project and reference area using historical Google Earth photography. In all 37 stations were established corresponding to just before construction in 2/28/1998, these stations where sampled when photography was available post construction on 8/9/2003 and again on 4/9/2014 in both the project and reference areas. The shoreline position relative to shoreline markers was measured using Google Earth and annual rates calculated for both the project and reference locations. Along with this the 1999 and 2003 shoreline positions where compared in the project and reference area by continuous differential GPS of the vegetated edge at the land water interface. The distance and rates of change where then calculated by area and mapped for interpretation.

Submerged Aquatic Vegetation:

To evaluate the effects of earthen terraces on SAV habitat, a modification of the rake method (Chabreck and Hoffpauir 1962) was used to estimate SAV occurrence. The project and reference areas were monitored along multiple transects representative of the overall habitat type (figure 3). Each transect had a minimum of 50 sampling stations. At each station, aquatic vegetation was sampled by dragging a garden rake on the pond bottom for about 1 second. The presence of vegetation was recorded to determine the frequency of aquatic plant occurrence (frequency = number of occurrences/number of stations x 100). When vegetation was present, the species present was recorded in order to determine the frequencies of individual species (Nyman and Chabreck 1996). SAV abundance was sampled prior to construction in 1999 immediately post-construction in 2003. SAV data collection was suspended in 2004 when the reference area became the project area for TV-18.

CRMS Supplemental

Additional data collected at CRMS-*Wetlands* stations can be used as supporting or contextual information for this project. Data types collected at CRMS sites include hydrologic from continuous recorder, vegetative, physical soil characteristics, discrete porewater salinity, surface elevation change, vertical accretion and land:water analysis of 1 km^2 area encompassing the station (Folse et al., 2012, revised 2014). For this report hydrologic, vegetation, and elevation change data were used to provide contextual information for the project. Data from CRMS2041 near the project area was used to add additional information. Hourly salinity and water levels (ft, NAVD88) are monitored with a continuous recorder at each CRMS-*Wetlands* site. Average annual salinity and percent time flooded are used to develop a Hydrologic Index (HI) score (Snedden and Swenson 2012) based on the suitability of the site in maximizing vegetation productivity according to its specific marsh class (swamp, fresh, intermediate, brackish, and saline). Vegetation composition and cover are estimated from 10 permanent 2x2 m plots that are randomly distributed along a transect in the emergent marsh within each of the 1 km^2 CRMS-*Wetlands* sites. Individual species' cover data are summarized according to the Floristic Quality Index (FQI) method (Cretini and Steyer 2011) where cover is qualified by scoring species according to whether they are generally associated with disturbance or stability. Elevation change data is calculated from rod sediment elevation tables (RSET) and accretion measurements biannually in the spring and fall. These measurements are collected for five years before rates or trajectories are calculated and developed for the Submergence Vulnerability Index (SVI) method (Stagg and Sharp 2013).

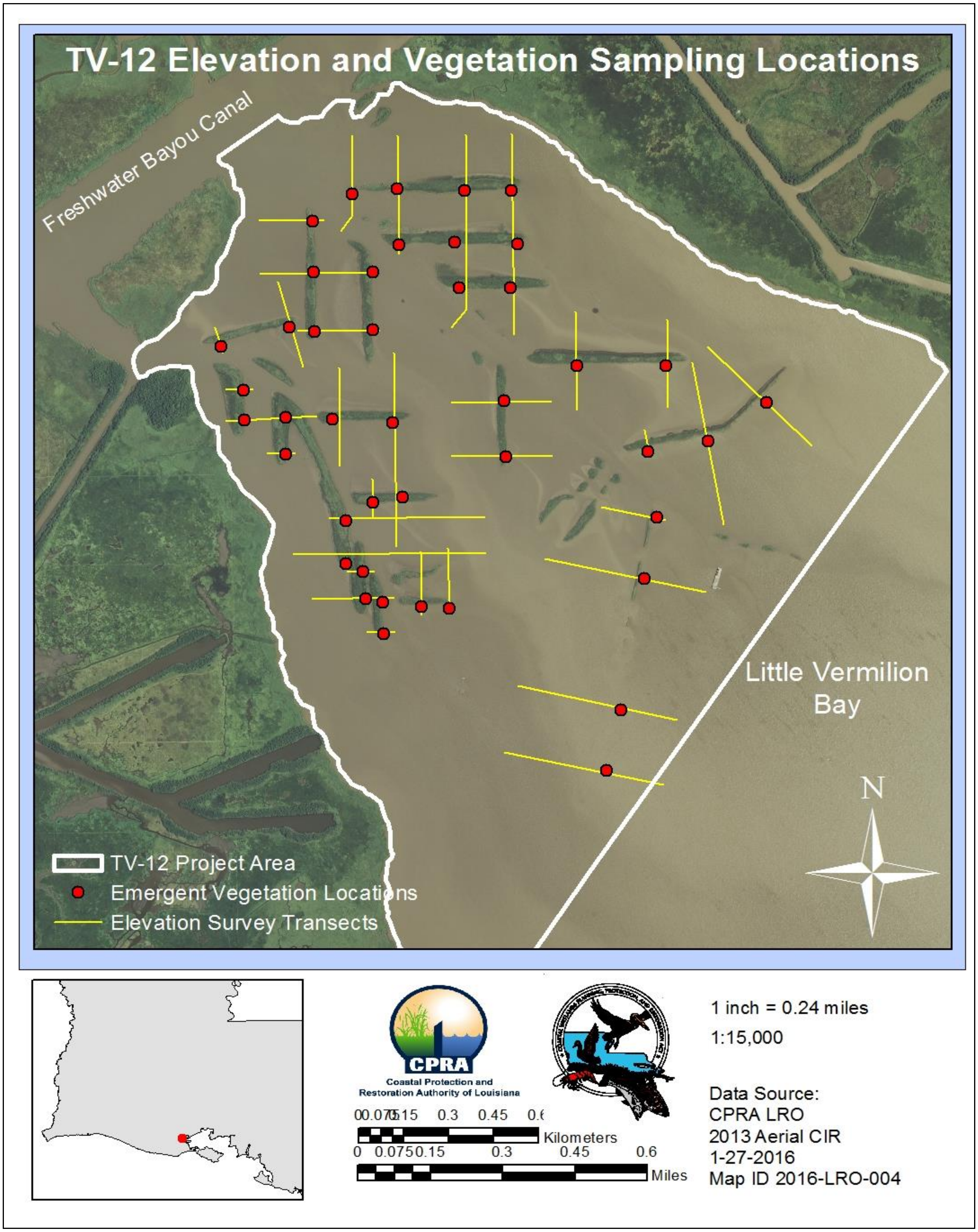

Figure 2. Little Vermilion Bay Sediment Trapping (TV-12) emergent marsh and elevation sampling locations.

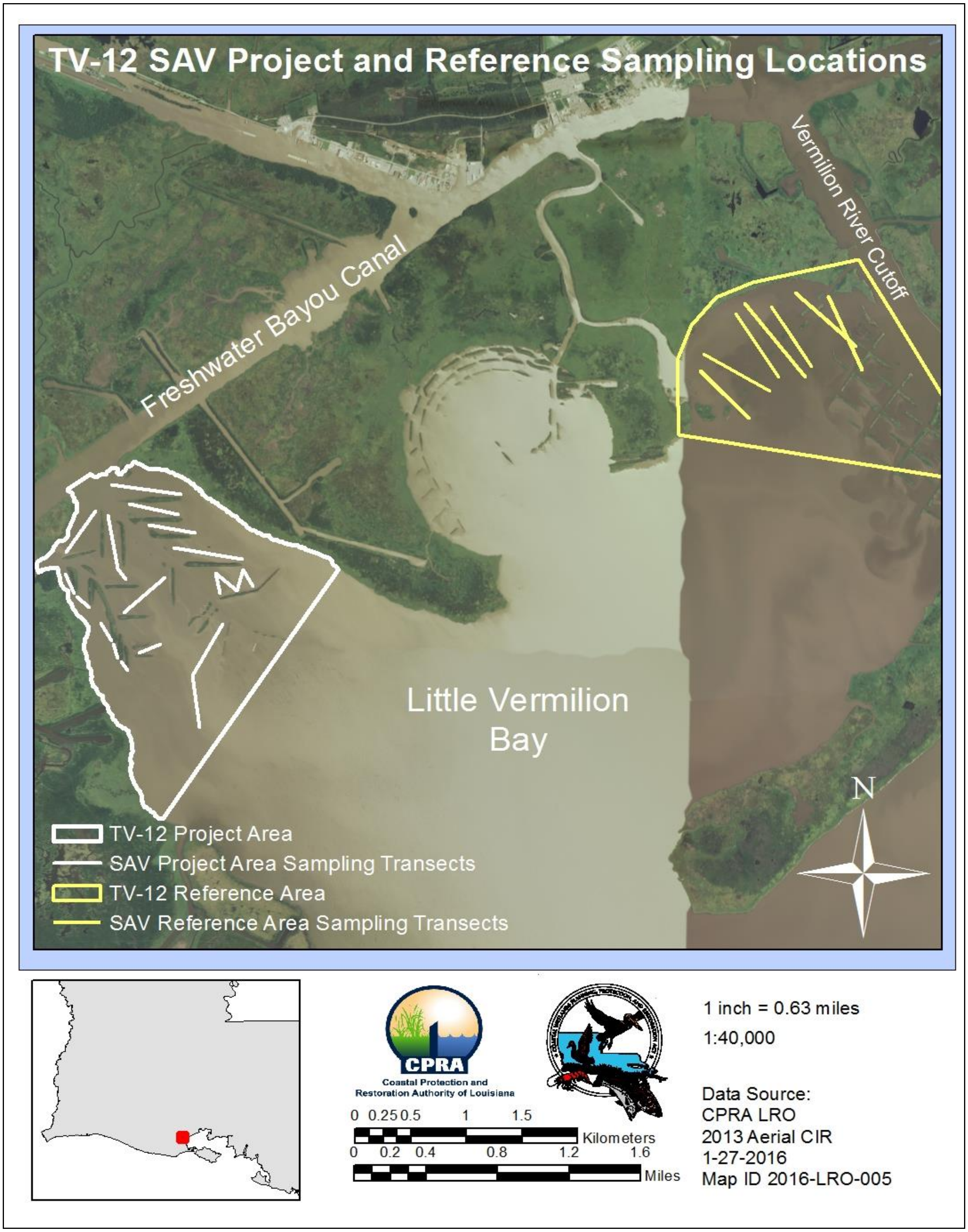

Figure 3. Little Vermilion Bay Sediment Trapping (TV-12) SAV sampling locations.

c. Monitoring Results and Discussion

Aerial Photography:

Historically, the project area contained the open waters of Little Vermilion Bay and the land was mostly comprised of the east and west shores of this bay. Starting in the late seventies to early eighties, the confluence of the Freshwater Bayou Canal (FBC) and Little Vermilion Bay was periodically dredged for access between the two water bodies and to nearby oil infrastructure. Some of this spoil was present prior to the construction of the project terraces and the conveyance channels.

Based on the photography analysis, the project and reference areas have slowly lost land post construction, while greatly increasing tidal mud flat acreages over the same period (table 1, figure 4, 5, and 6). The project area was further analyzed to identify specific locations of land loss or gain between the 2000 and 2002 data sets (figure 7). There were no general patterns of land gain, which were limited to a few terraces, whereas losses were evenly distributed among the edges of all terraces due to wave and wake erosion. In addition to the land and water classes, a tidal flats class was added in 2002 and 2009 to describe areas of very shallow water mostly in between the terraces (figure 8). This was necessary as post construction the inter terrace areas silted in substantially and became subaerial on both meteorological and astronomical low tides. The periodically exposed tidal flats have continued to build from sediment deposition in the project area but have substantially slowed in formation between the 2002 to 2009 land area analyses. The reference area increased over this period but this was largely due to the construction of the TV-18 project which was very similar to the TV-12 project (Thibodeaux et al., 2008). The reduction in the rate of tidal flat formation in the project area was in large part due to the lack of additional inter terrace space for sediment to settle out of the water column. The remaining project area appeared to be too deep or the water currents too strong for the rapid siltation of ultrafine clay particles without the addition of more terraces.

The existing tidal flats may eventually become permanently subaerial and contribute to the land component of the analysis but that process appears to take more time and or some environmental stimulus that is not yet present in the project area. The same pattern of rapid subaqueous tidal flat formation has been seen in TV-15 and TV-18 project areas with the same very slow recruitment of subaerial marsh (Wood et al., 2012). It is interesting to note the speed of tidal flat formation in the project area as all sediment deposition appears to be near the project features, indicating the utility of the terraces across multiple projects locations with sediment inputs. The overall trend in the project area has been an increase in acreage of about 2.5 acres per year from 1985 through 2010 which includes the construction of the project and the decline of the overall project land area due to wave and wake erosion since project construction (figure 9).

Table 1. Land, water, and tidal flat acreages from 2000, 2002 and 2009 in the project and reference area. The reference area in 2009 was contaminated due to the construction of TV-18 in this location before the data was collected.

Little Vermilion Bay Sediment Trapping (TV-12)												
	Project						Reference					
	2000		2002		2009		2000		2002		2009	
	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%
Land	69.6	6.3	62.7	5.7	54	4.9	74.5	8.4	73.5	8.2	115	12.9
Water	1035.8	93.7	842.7	76.3	833	75.4	816.8	91.6	705.9	79.2	608	68.2
Tidal Flats	0	0	199.5	18.1	218	19.7	0	0	111.6	12.5	168	18.9
Total	1105.4		1104.9		1105		891.3		891		891	

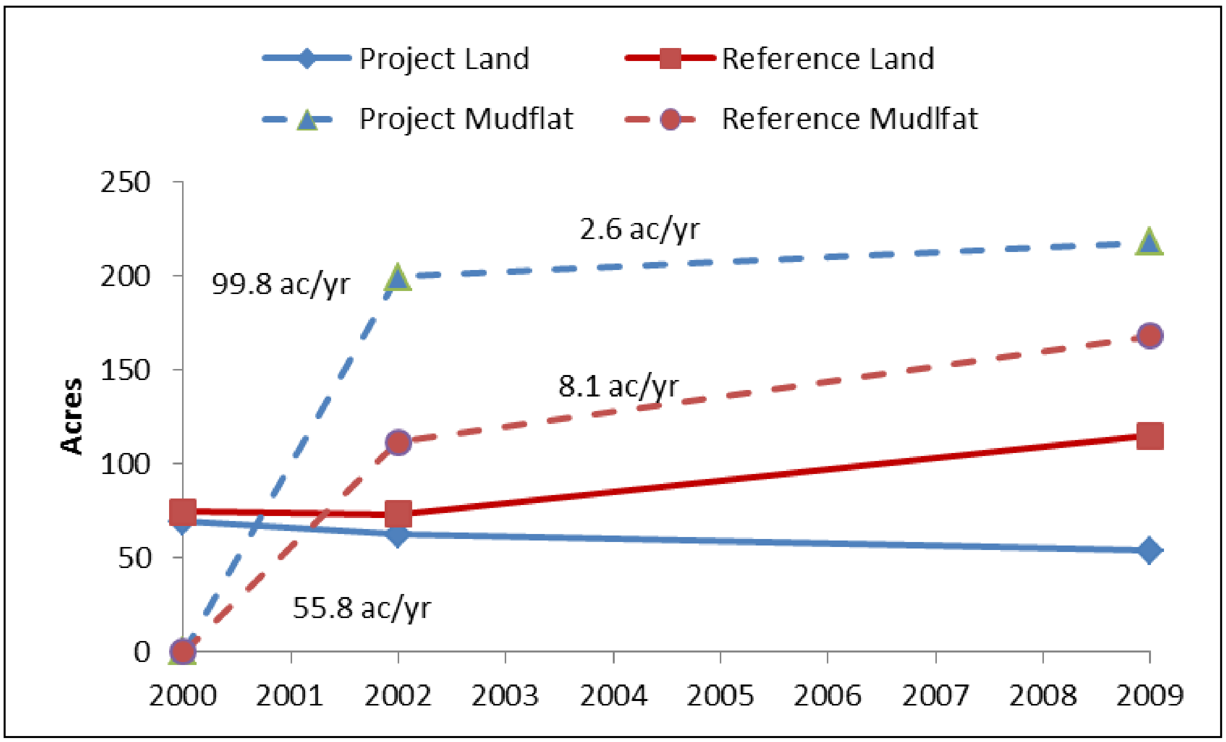

Figure 4. Little Vermilion Bay Sediment Trapping (TV-12) land and tidal flat acreage change over time in the project and reference areas. The reference area is no longer valid as of 2009 when the presences of TV-18 nullified the comparison.

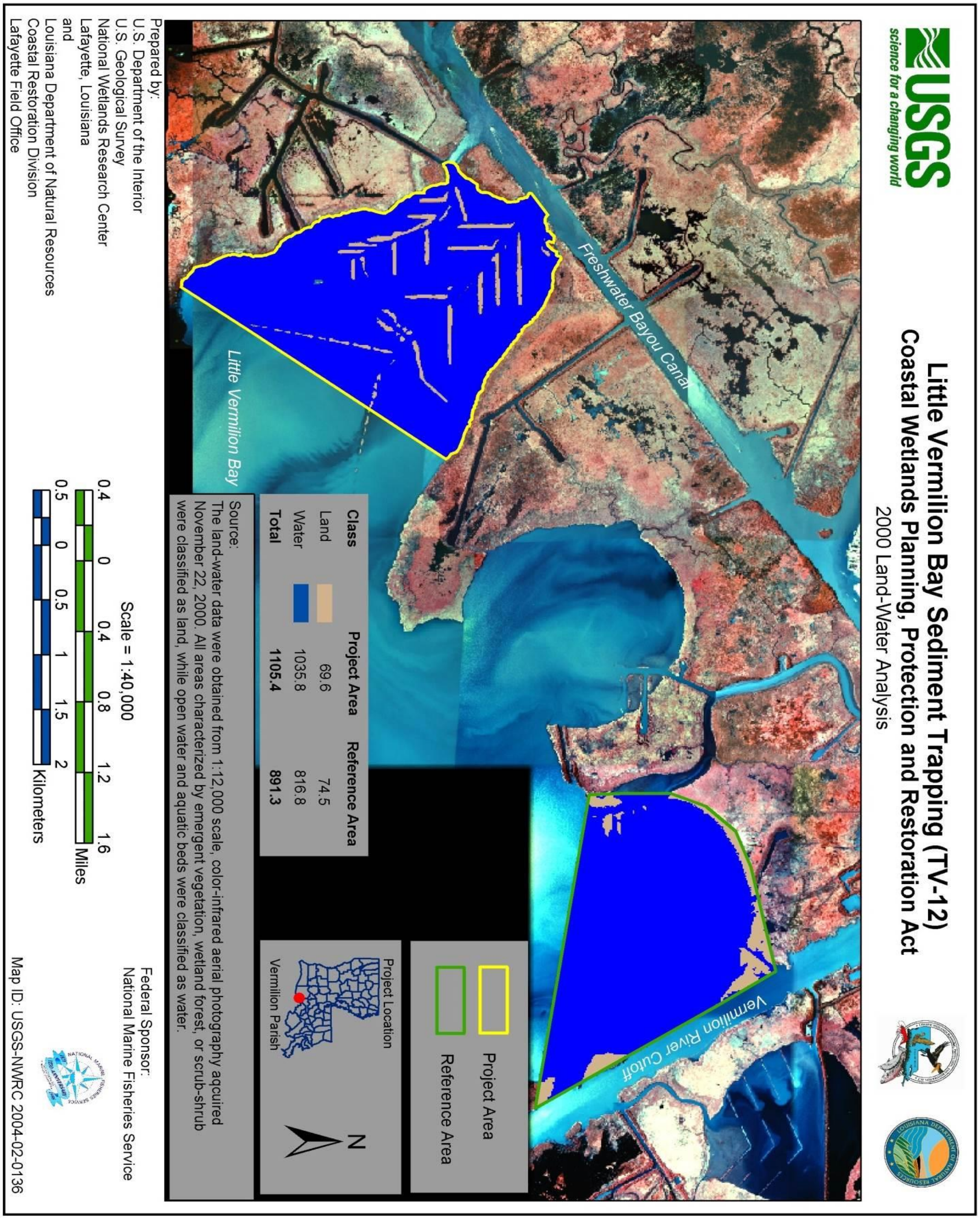

Figure 5. Little Vermilion Bay Sediment Trapping (TV-12) Land: Water analysis in 2000.

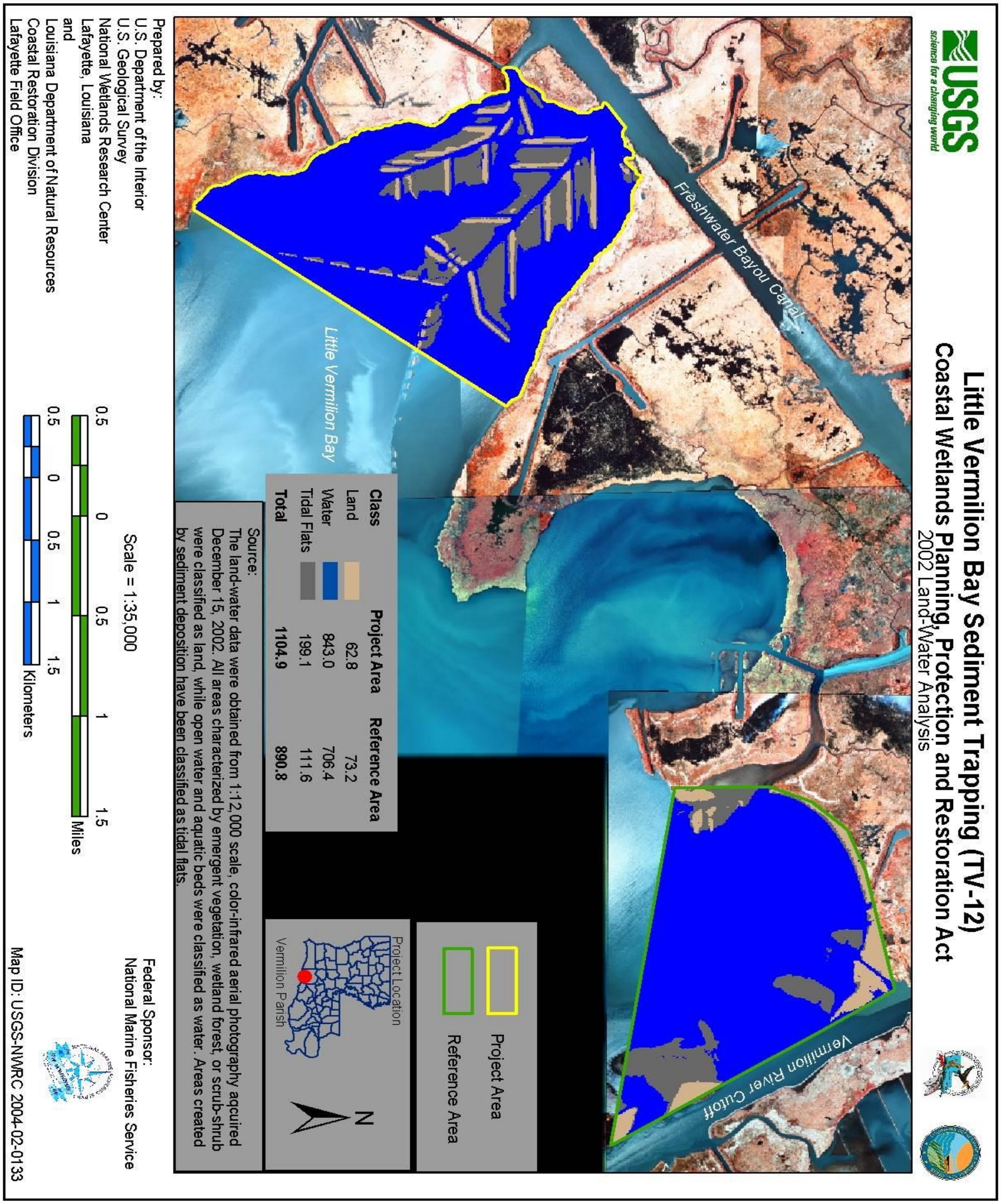

Figure 6. Little Vermilion Bay Sediment Trapping (TV-12) Land: Water analysis in 2002.

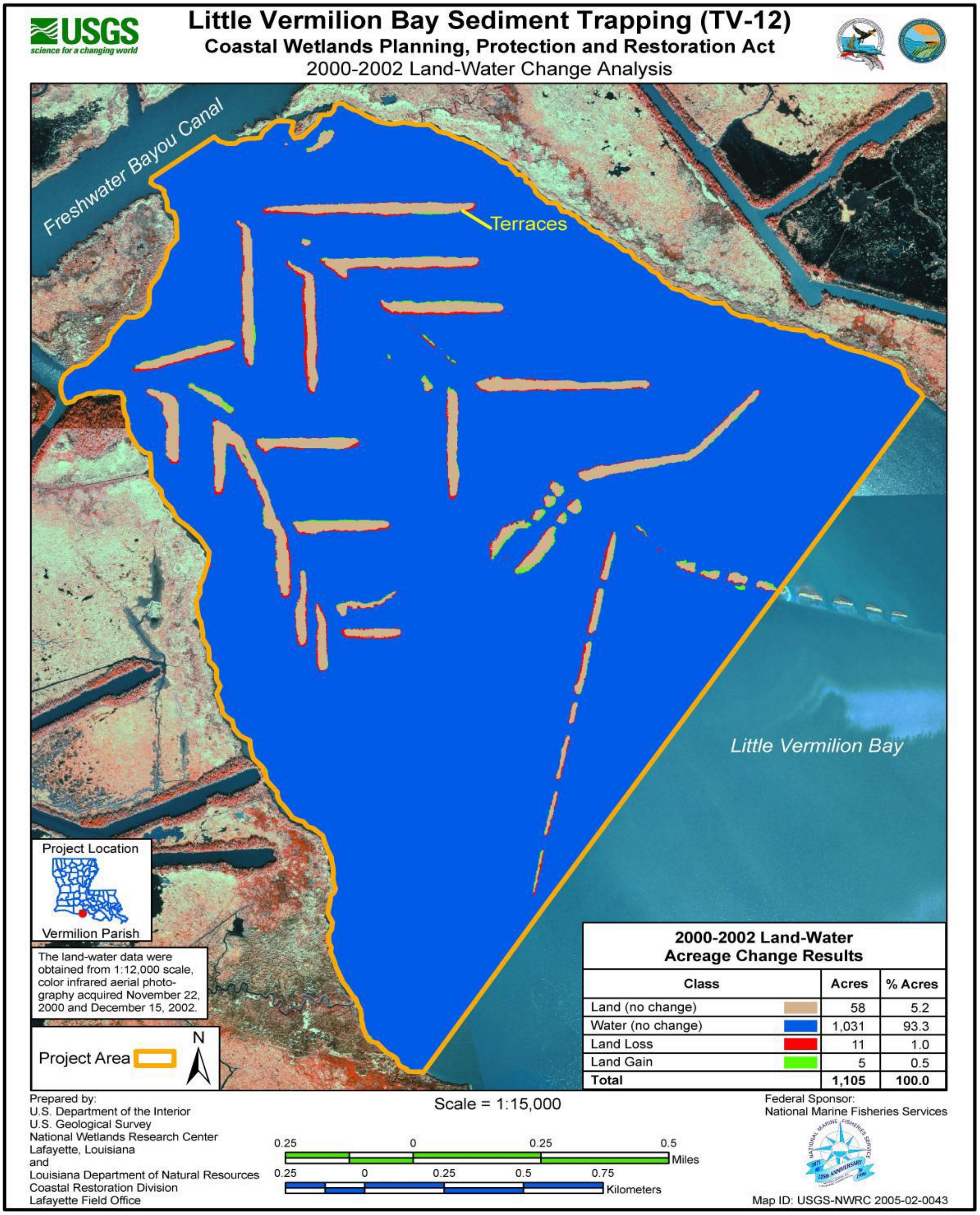

Figure 7. Little Vermilion Bay Sediment Trapping (TV-12) Land: Water change between 2000 and 2002.

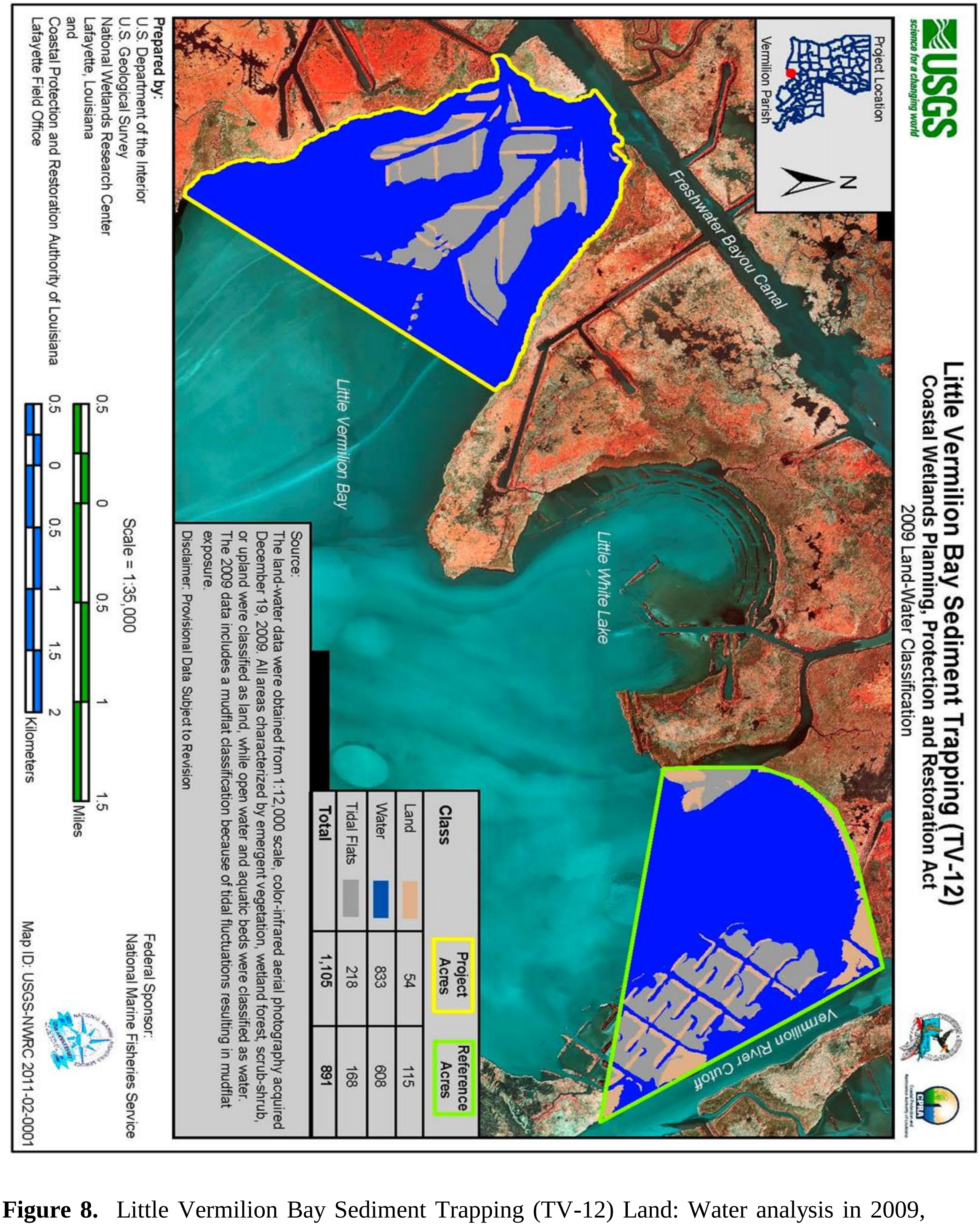

Figure 8. Little Vermilion Bay Sediment Trapping (TV-12) Land: Water analysis in 2009, note the constructed TV-18 project in the reference area.

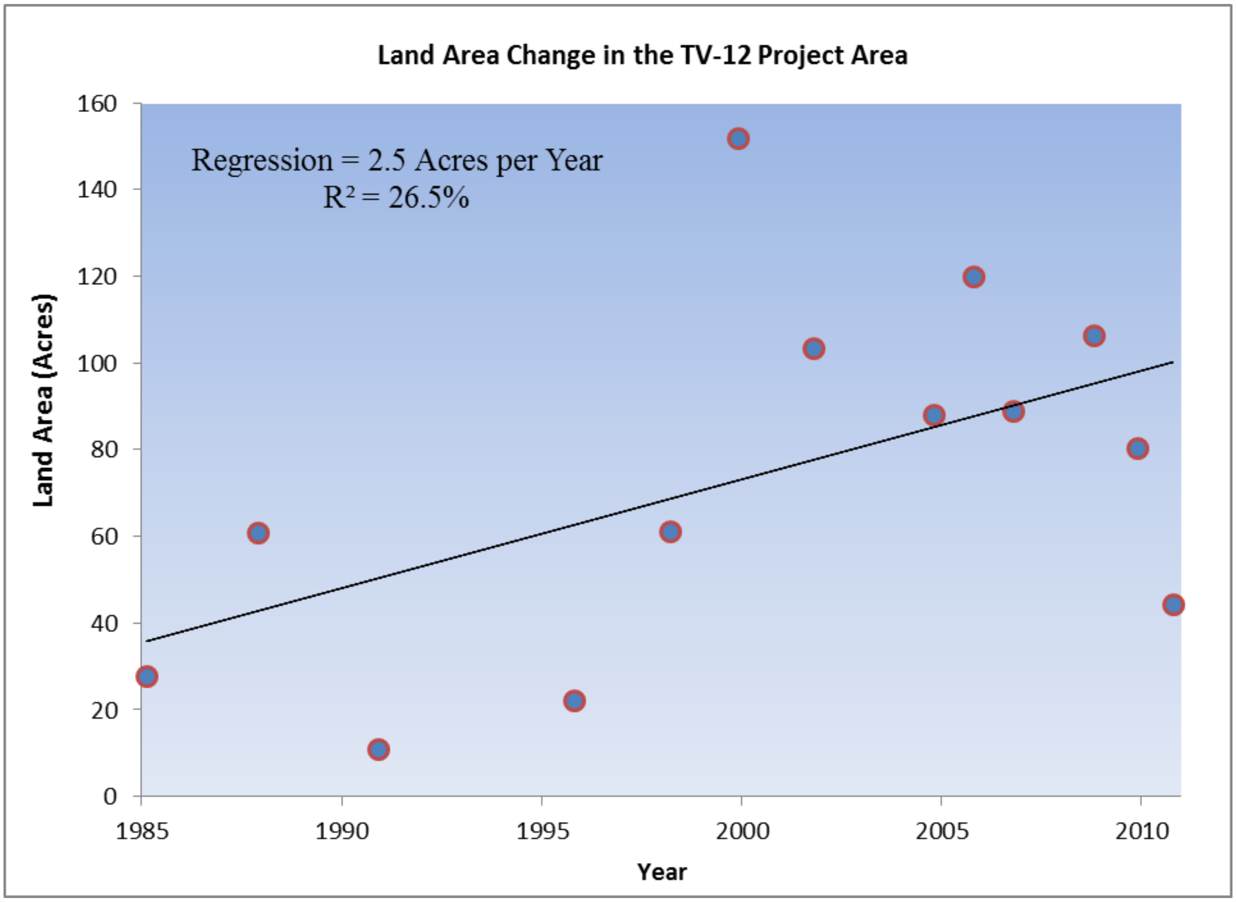

Figure 9. Project scale land change for TV-12. Acres of land are displayed for all cloud free TM images available for 1984-2010. The line depicts the land gain trend for the entire period of record.

Bathymetry/Topography:

An elevation survey was conducted immediately after the construction of TV-12 in September of 1999. A later construction elevation survey containing only a subset of the original transects was completed in August 2003. There was substantial sediment deposition between the two elevation surveys, specifically in the channel and borrow ditches. The mean channel bottom elevation in 2003 was 1.37 ft higher than in the same locations in 1999 (figure 10). The bay bottom in the vicinity of the terraces had a mean elevation increase of 0.5 ft over the same time period. During this period, the average terrace elevation loss was 0.018 ft, a difference within the survey error.

The transect specific cross sectional data generally showed some elevation increases on the bay bottoms and in channels and borrow canals as of 2003 (figure 11). However some channels were actually scoured to greater depth since 1999, likely due to the reduced hydrologic capacity of the overall project area from sedimentation. When a channel or tidal bay losses depth it also losses the ability to convey water efficiently. In the specific instance of the TV-12 project area the hydrodynamic forces between Vermilion Bay and the FBC are substantial enough to maintain certain project channels as tidal and floodwaters exchange conduits. It is evident in the 2009 Land: water analysis that all but the two main north south channels are completely filled in and the main conveyance channel through the center of the project area have continued to maintain their capacity as they now carry the vast majority of the water between the two waterways.

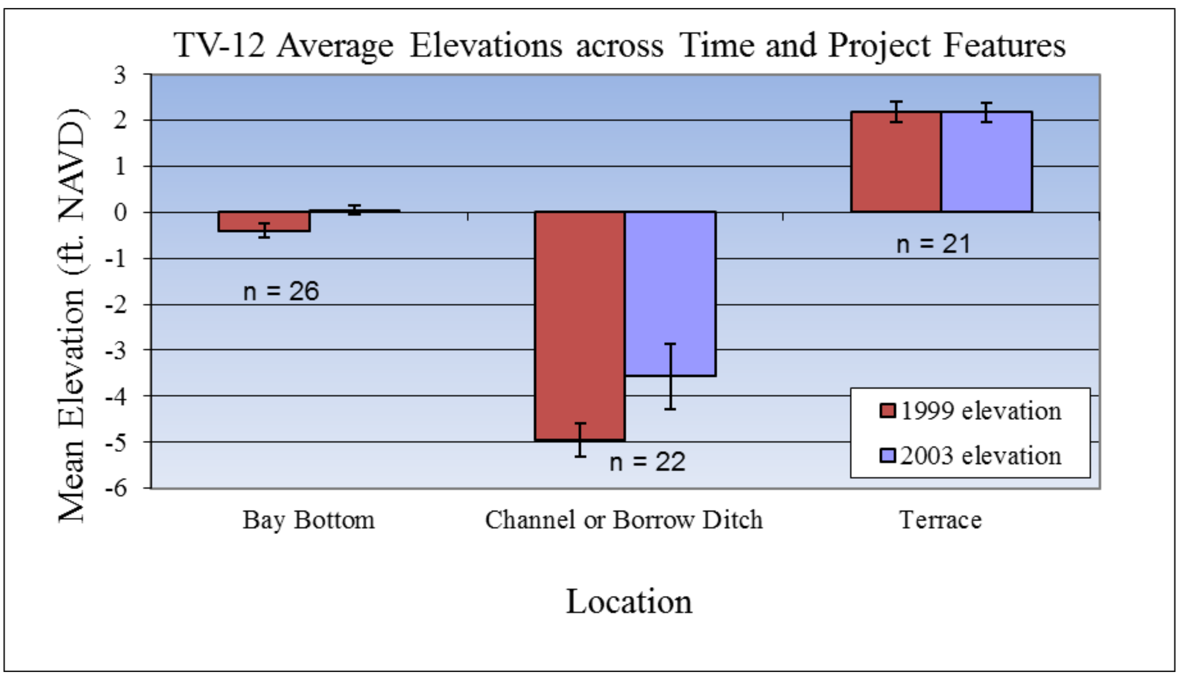

Figure 10. Mean elevation of three major project feature classes from the 1999 and 2003 elevation surveys. Each location mean was calculated from 21 to 26 points that were measured in the same place during both surveys.

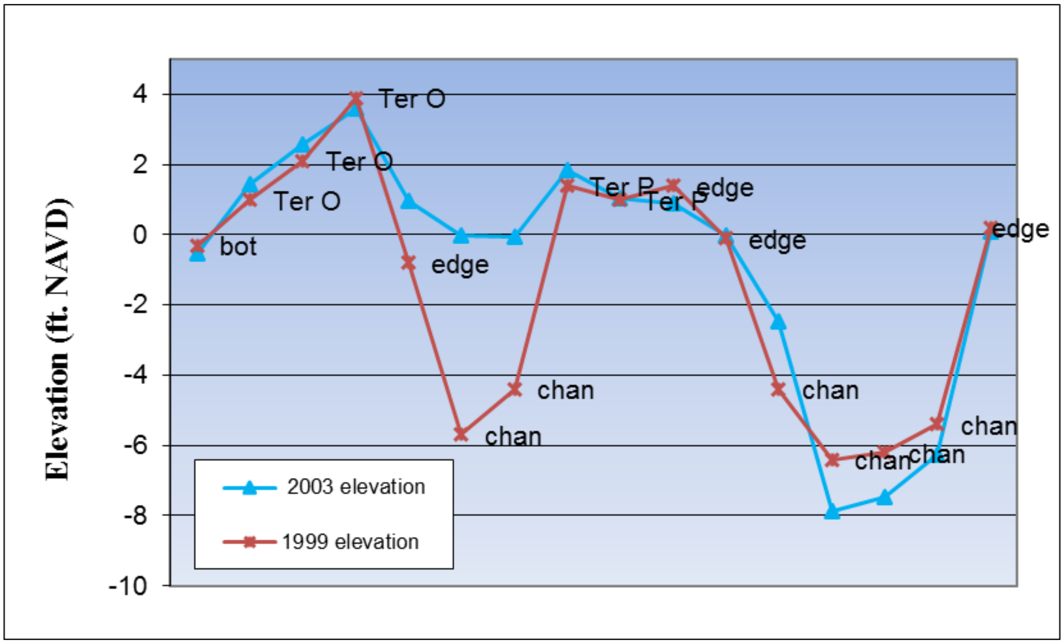

Figure 11. Elevation transects of selected paired points along cross TV-12 terraces from the 1999 and 2003 surveys. Bot = Bay Bottom, Ter = terrace, chan = channel, and edge = edges between terraces, channels, and bottoms. Points are equidistant along the x axis on the chart and the distance between them does not reflect an actual distance.

Emergent Vegetation:

In 1999 immediately after construction, the terraces were devoid of vegetation except for the *Spartina alterniflora* plantings. By 2000, the *Spartina alterniflora* plantings covered much of the terraces edge with a thick hedgerow at the water land interface. Vegetative cover, both recruited and the expansion of the plantings increased and completely covered parts of some terraces by 2001. In the summer of 2002 the emergent vegetation sampling documented that the *S. alterniflora* plantings continued their expansion, dominating the intertidal frame on the edge of the terraces. Many other species also recruited to and colonized the terraces by 2002. The concern over what cohort of vegetation would colonize and thrive on the higher elevations of the TV-12 terraces has been thoroughly documented as dominated by obligate wetland species even up to the crown at near 4 ft NAVD elevation (Castellanos et al., 2004).

Vegetation data was collected in 2002, 2004, and post Hurricane Rita in 2005. The 2005 survey revealed that the majority of the dominant crown and intertidal vegetation was unaffected by Hurricane Rita. There was little change in the frequency of occurrence (%) of *Spartina alterniflora* from 2002 through 2005, though there was a slight reduction in 2005.

This was more likely the effect of competition from the maturing vegetation community on the terraces than any hurricane effects. A consistent increase in the occurrence of *Paspalum vaginatum* over the surveys shows the succession of the higher elevation of the terraces from early colonizers to stable late stage high marsh species (figure 12). Hurricane Rita did have an obvious and notable effect on *Vigna luteola.* The overall frequency of *Vigna luteola* and *Solidago sempervirens* plummeted from 63.5% to 3.7% and 25.0% to 2.0%, while other species were already in decline due to competition. *Aster tenuifolius* and *Echinochloa walteri* had already begun to decrease drastically in 2004 by 24.4% and 24.3% respectively from the previous survey. The overall trend in the species frequency of occurrence vegetation data shows that the terraces where being colonized by dominant late stage vegetation that will be difficult to out compete by early stage successional species even after an ecological disturbance.

More recently the project area has been host to several dedicated plantings of various species and measures. This is in large part directly attributable to project features preforming as designed, the large subaqueous tidal flats are an excellent platform to plant deeper colonizing emergent vegetation. The NRCS soil and water conservation district office (SWCD), NMFS, and CPRA observational data documented emergent species starting to colonize the non-terraced project area, albeit slowly, which directly led to these planting efforts. Starting in approximately 2008 the area has experienced multiple plantings in small areas by the NRCS SWCD and in 2014 by the CPRA LA-39 coastwide planting project (LA-39 year three planting). The NRCS SWCD plantings consisted of *Spartina alterniflora* and *Schoenoplectus californicus*, while the CPRA LA-39 plantings where all trade gallons of *Schoenoplectus californicus.* As of the writing of this report the planting by all sources from 2012 through 2015 have had excellent survivorship and growth, with minimal mortality. The LA-39 plantings in the TV-12 project area have been monitored from deployment through one year and have shown notable expansion. The plantings have expanded from the initial coverage of approximately 3% to 50% of the sample plots in less than one year. This expansion is expected to continue but at a slower pace, as plants experience increasing intraspecific competition for resources and space.

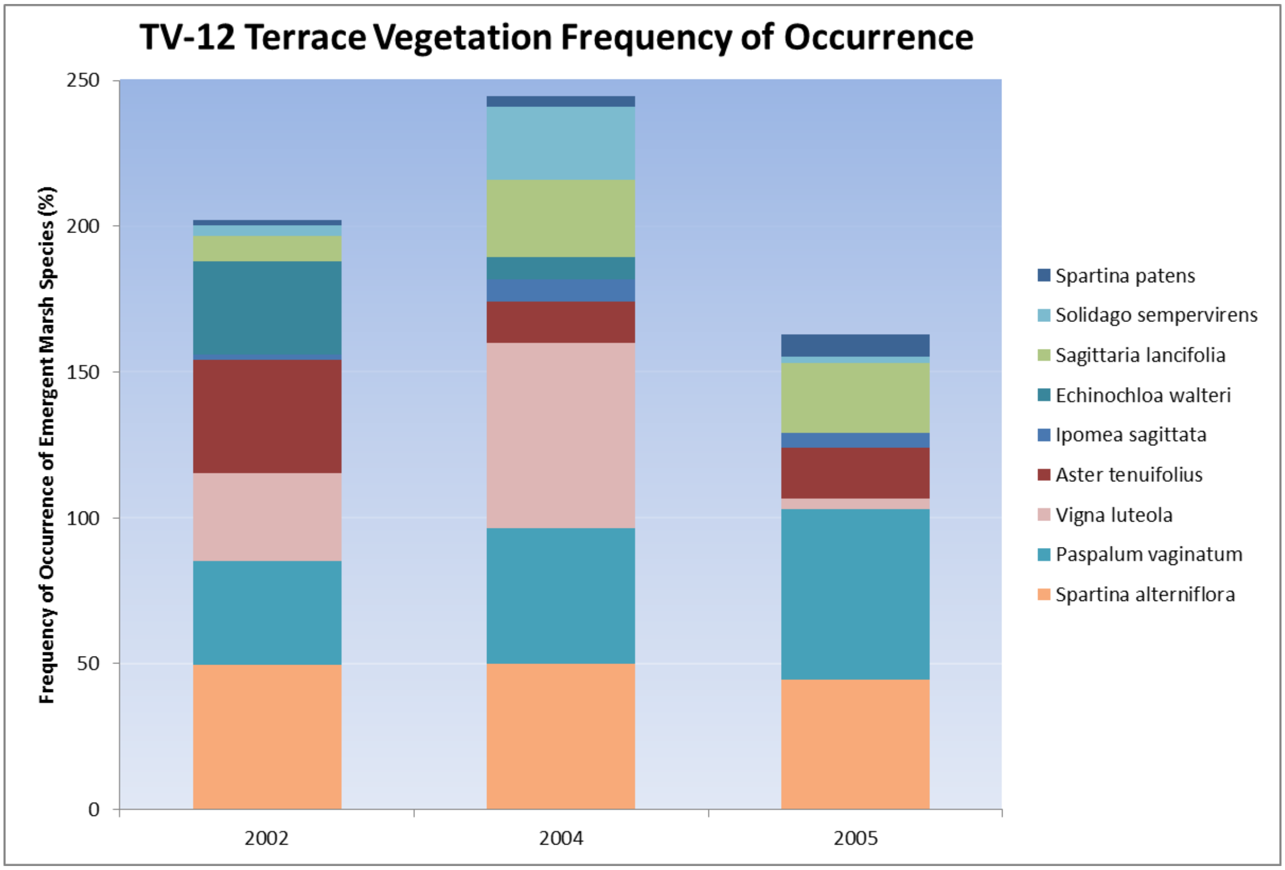

Figure 12. The frequency of occurrence of dominant emergent marsh species within the TV-12 project area in 2002, 2004, and 2005.

<u>Shoreline Change:</u>

The TV-12 project has successfully achieved the shoreline protection component of the project design by substantially reducing the shoreline erosion rate compared to the pre TV-18 reference shoreline (Table 2) (Thibodeaux et. al. 2008). On average the project shoreline eroded -16.8 ft during the period of direct comparison to an exposed reference shoreline (1998-2003), which retreated over -37.1 ft. From just prior to construction in 1998 through 2014 the erosion rate in the reference area was -3.03 ft/yr while the project area was -2.01 ft/yr using Google Earth photography comparison methods. Much of this difference occurred during the initial sampling period when the project reference comparison was uncontaminated by the construction of TV-18. The time period in which both areas had protective terraces, 2003-2014, are nearly equal with the project area eroding at -1.50 ft/yr SE± 0.23 and the reference area at -1.05 ft/yr SE± 0.49. The reference area shoreline was further bolstered by the placement of spoil parallel to the shoreline during the construction of an access channel in 2011, drastically reducing the wind fetch that could reach the reference shoreline. The DGPS mapping of both the project and reference shorelines and the corresponding differences between 1999 and 2003 yielded very similar results to the Google Earth photograph methodology. The DGPS data between 1999 and 2003 resulted in an annual rate of -3.12 ft/yr

SE± 0.13 in the project area while the reference area lost -6.46 ft/yr SE± 0.82 (figure 13 and 14). The location of the highest shoreline losses in the project area was in the southwestern portion of the project shoreline that received little protection from the terraces. The DGPS data revealed several more intense areas of loss in the reference area spread across all shoreline orientations which were mitigated after the construction of the TV-18 project.

Table 2. TV-12 Google Earth photography shoreline change rates and associated events.

	Shoreline Change Rate (ft/yr)		
Time Period	**2/28/1998 - 8/9/2003**	**8/9/2003 – 4/9/2014**	**2/28/1998 – 4/9/2014**
Project	-2.99 SE± 0.50	-1.50 SE± 0.23	-2.01 SE± 0.28
Reference	-6.63 SE± 0.51	-1.05 SE± 0.49	-3.03 SE± 0.38
Notable Events	Period of direct project reference comparison	Period in which the reference became TV-18	Life of the project rates

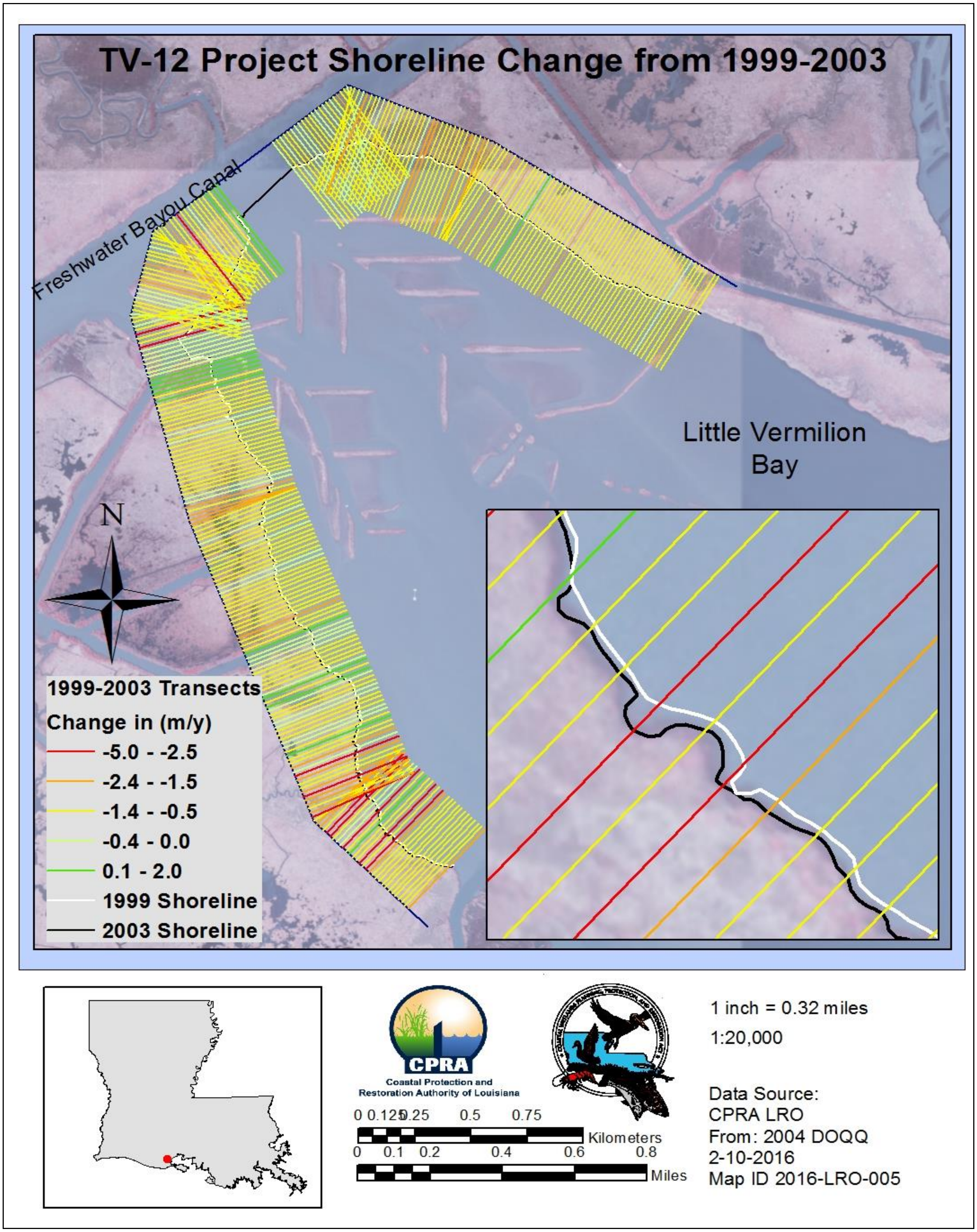

Figure 13. Shoreline position change for the TV-12 project area using 1999 and 2003 DGPS data.

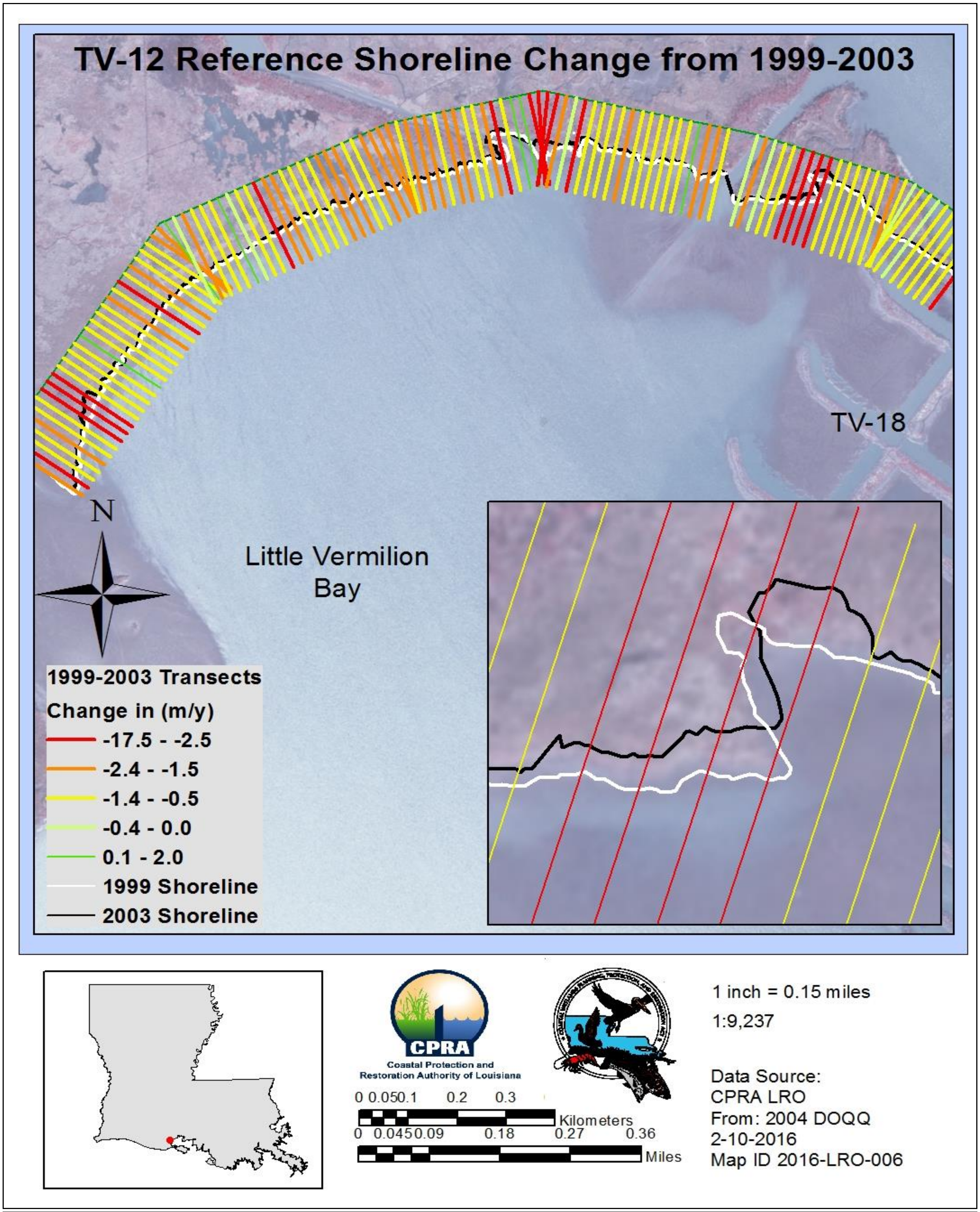

Figure 14. Shoreline position change for the TV-12 reference area using 1999 and 2003 DGPS data.

Submerged Aquatic Vegetation:

Significant amounts of SAV were not collected during sampling at construction or nearly three years later (spring 2003). The mean percent cover for all SAV in the reference area in 1999 was 5.4% and less than 1% in the project area (figure 15). In 2003, the mean percent cover of SAV was less than 3% in the reference area and less than 1% in the project area. SAV is generally most abundant in late summer or fall; therefore it may have been underestimated in the 2003 spring sampling. The 2003 SAV sampling was conducted in spring because of the imminent construction of the TV-18 project in the area between Little White Lake and Vermilion River Cutoff which has since effectively eliminated the reference area. Several samples of SAV were found on some of the terrace edges during the emergent vegetation survey completed in the summer of 2002, indicating some benefit from the increased elevation and protection from the terraces. The increase in bottom elevation between the terraces has created tidal flats that are more habitable for emergent vegetation than submerged vegetation as these locations are subaerial for extended periods during the winter months. However anecdotally there are some locations in the project area that maintain small populations of SAV even through 2015.

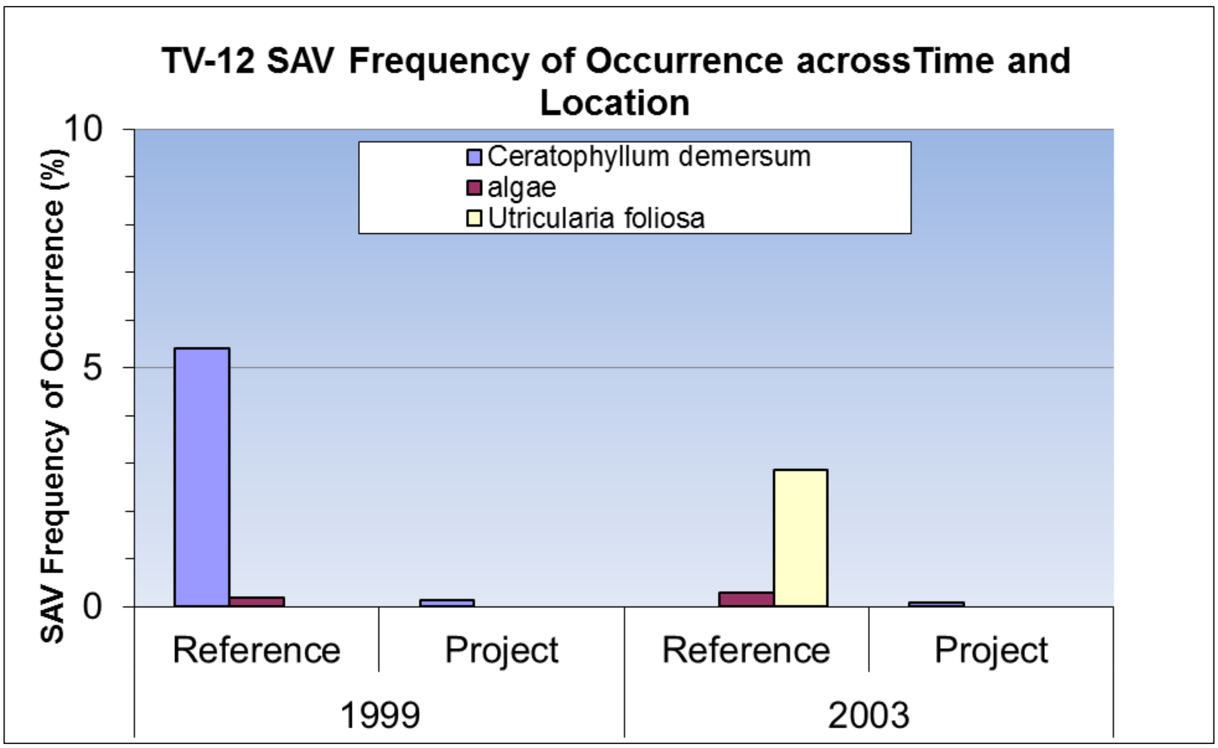

Figure 15. Total percent cover of SAV in the TV-12 project and reference areas between 1999 and 2003.

CRMS Supplemental:

Hydrologic:

CRMS site 2041 is approximately two miles east of the project area and experiences very similar hydrologic conditions to the project as it is located between Little White Lake and the old Vermilion River Channel which still conveys water between the Vermilion River Cutoff and Vermilion Bay via Little White Lake and Little Vermilion Bay. The monthly average salinities at CRMS2041 have rarely exceed 4ppt from 2013-2015 which corresponds to the major *Schoenoplectus californicus* plantings in the project area, which coupled with a lack of tropical activity in part explains the plantings success (figure 16). During the severe drought of 2010 and 2011 monthly average salinities were as high as 12ppt and routinely over 5ppt at CRMS2041 and likely very similar in the project area. Despite these longer term chronically high salinities, the original district plantings performed well and much of these original areas still remain vegetated. Water levels documented at CRMS2041 also show that the terrace crowns are rarely inundate at this temporal scale, though tropical events certainly overtop them for brief periods. The marsh platform at CRMS2041 is quite high in elevation when compared to many of the coastal marshes statewide in both GEOID 99 and 12A. The terraces of the TV-12 project area are similar if not higher in elevation and as such there vegetative community should resemble one another over time.

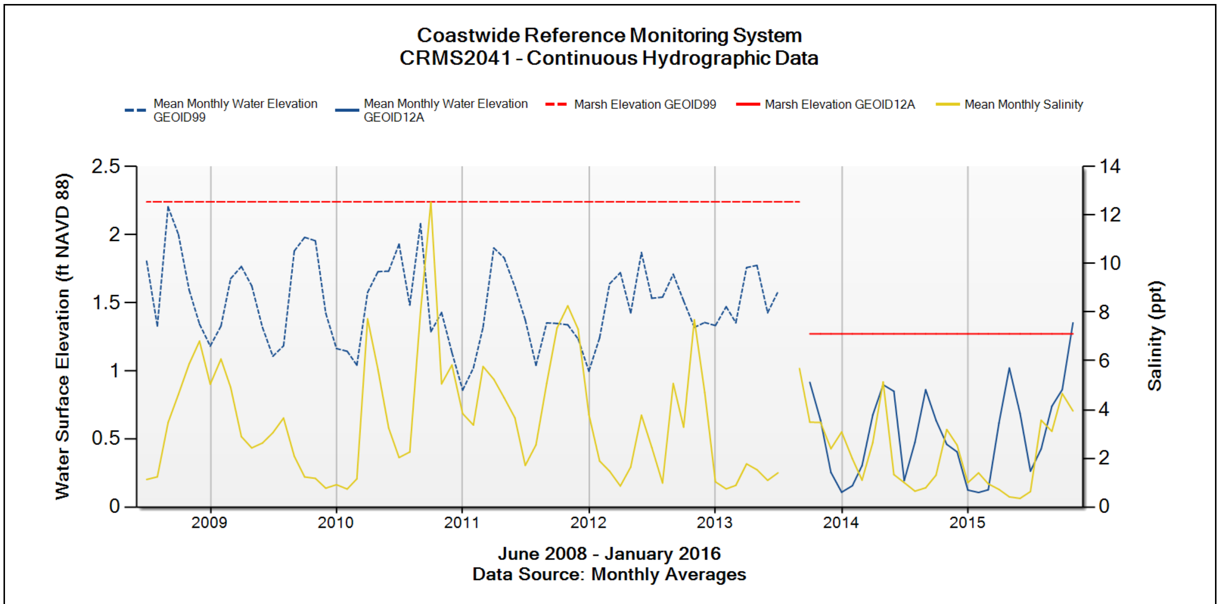

Figure 16. Continuous hydrologic data from CRMS2041 which experiences similar conditions to the TV-12 project area.

Vegetation:

The vegetative community at CRMS2041 has rebounded from both, hurricanes in 2008 and the drought in 2011, which manifested itself in the 2012 data. As of the 2015 data collection the site was continuing to increase in both total cover and FQI from the 2008 lows in both categories (figure 17). Similar responses would be expected in the TV-12 project area terraces if data was available, anecdotal data from the LA-39 sampling and observation lend credence to this assumption. However there are some species composition differences between the two areas based on amount of land water interface. The terraces have a healthy intertidal growth of *Spartina alternaflora* which is absent in the interior location of CRMS2041. Both locations are likely trending toward a more mature stable late stage successional community after the previously mentioned disturbances.

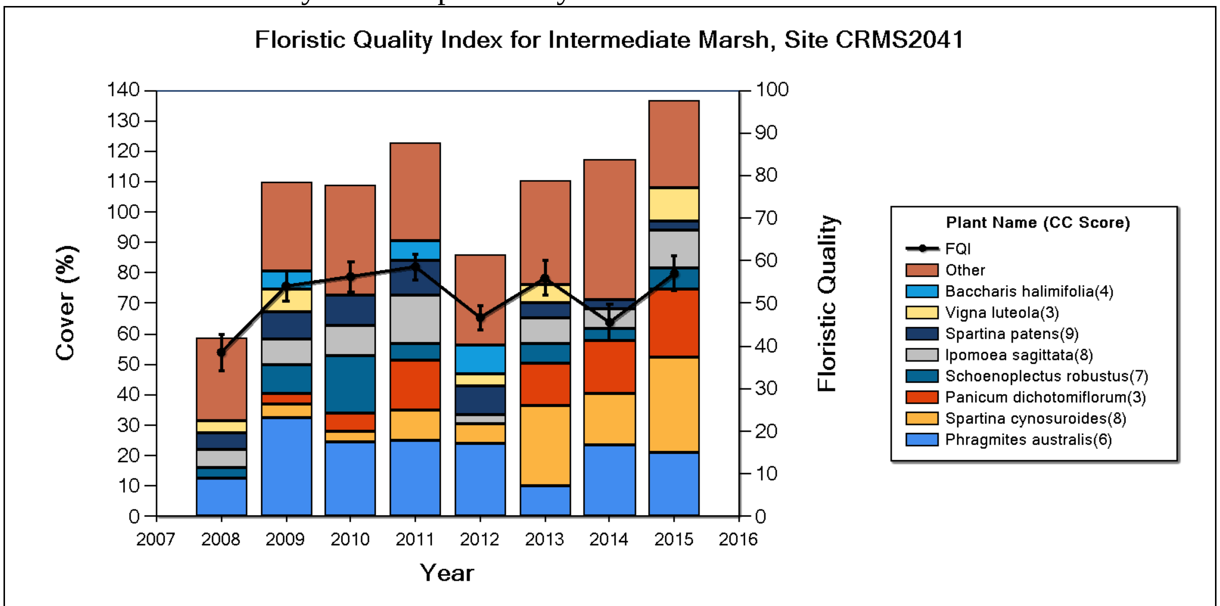

Figure 17. Percent coverage and floristic quality index of species collected from CRMS2041. The CC scores represent the quality of individual species from 1 to 10 where 1 represents disturbance species and 10 indicates stability.

Marsh Elevation Change:

Subsidence and accretion data collected at CRMS 2041 from site installation through the beginning of 2016 displays stability in elevation change in the vicinity of TV-12 (figure 18). The site was experiencing substantial elevation loss during the 2010-2011 drought, as severe dewatering of the soil lead to highly negative rates. The long term average elevation change rate was 0.06 cm/yr. The overall pattern of elevation change has been very stable from initial measurements through the spring 2016. This is however somewhat deceiving as there have be dynamic negative and positive rate swings depending on the local water budget.

The soil elevation change, compared to the original marsh elevation and hydrologic prism, are used to generate individual CRMS site Submergence Vulnerability Index (SVI) values (figure 19). The SVI at CRMS2041 is very high and above the 90th percentile of the hydrologic datum suggesting that the site rarely has surface flooding under normal water levels. This local SVI score is then compared at larger spatial scales such as by basin, by marsh type, and coastwide to give context to local CRMS sites or project observations (figure 20). CRMS site 2041 is near the top the SVI values within its own marsh type and coastwide, but as you get into the generally very high marshes of the Teche Vermilion basin the site ranks well but is not at the top of the distribution. This is probably very similar to the upper portion of the terraces flood regime in the TV-12 project area, where flooding is limited to high water events yet wetland vegetation is still dominant. This is likely due to the constantly saturated soils and the episodic flooding which select for wetland species in both locations.

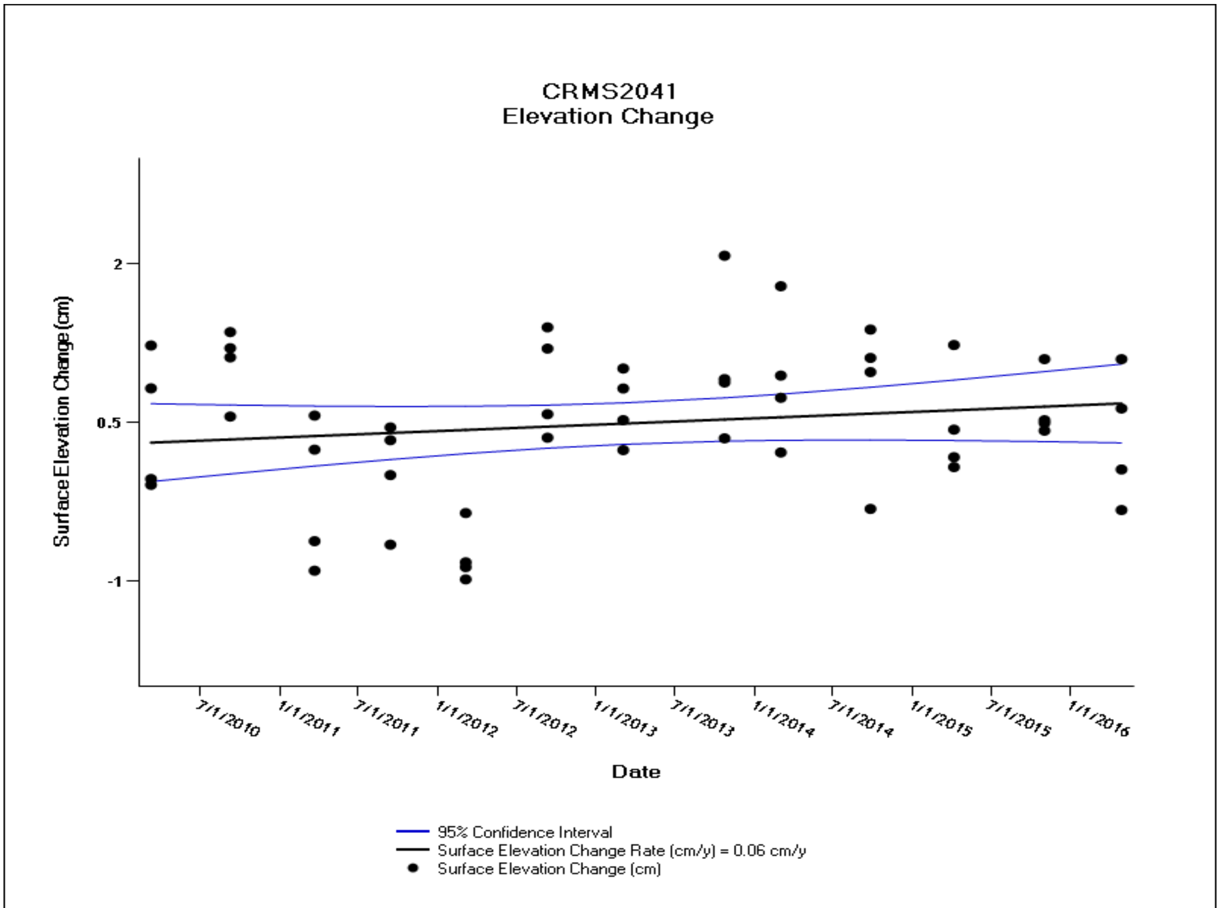

Figure 18. Elevation change per year in the nearby CRMS site 2041, which is representative of the project area marsh. Note the elevation change drop during the drought of 2010-2011.

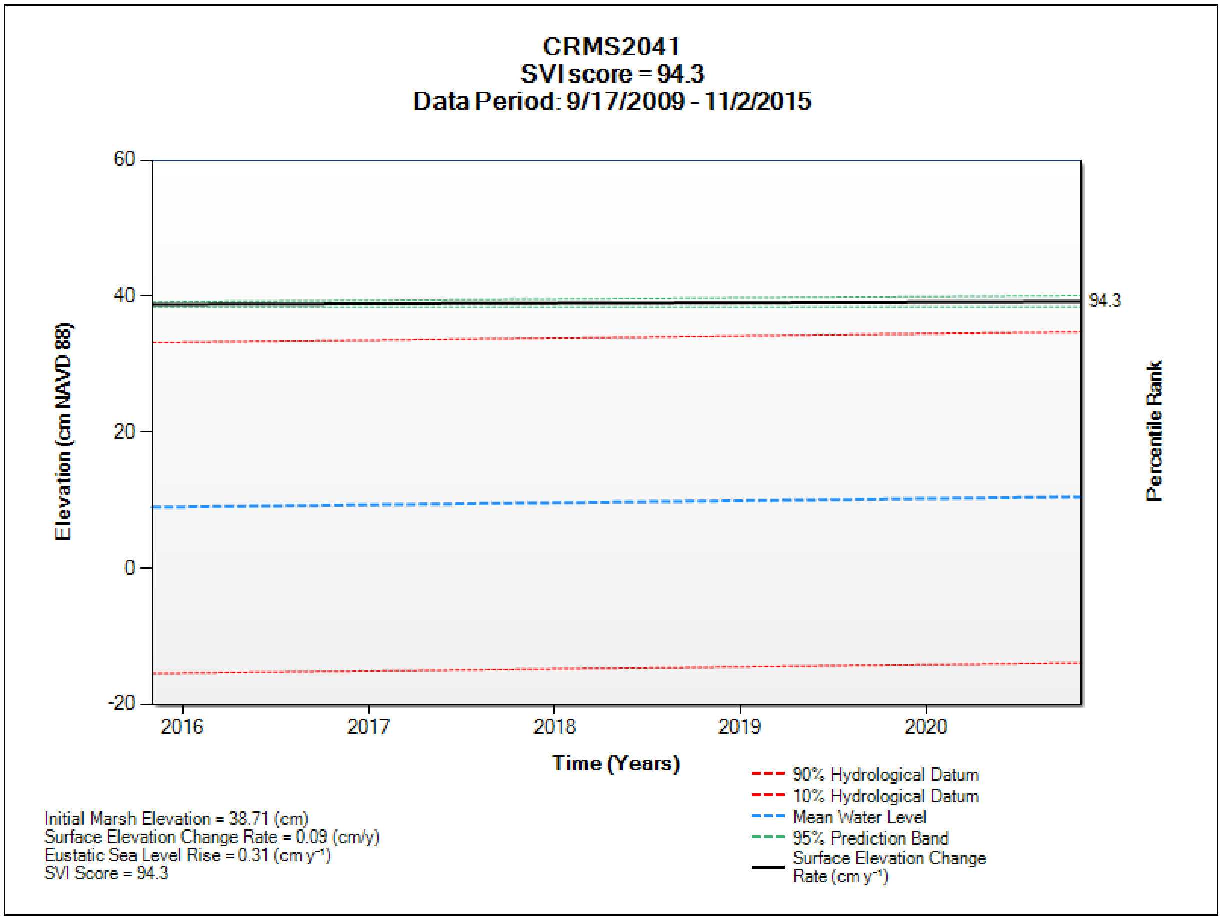

Figure 19. Submergence Vulnerability Index of the CRMS site 2041 which is near the project area based on data collected from site installation through 2016.

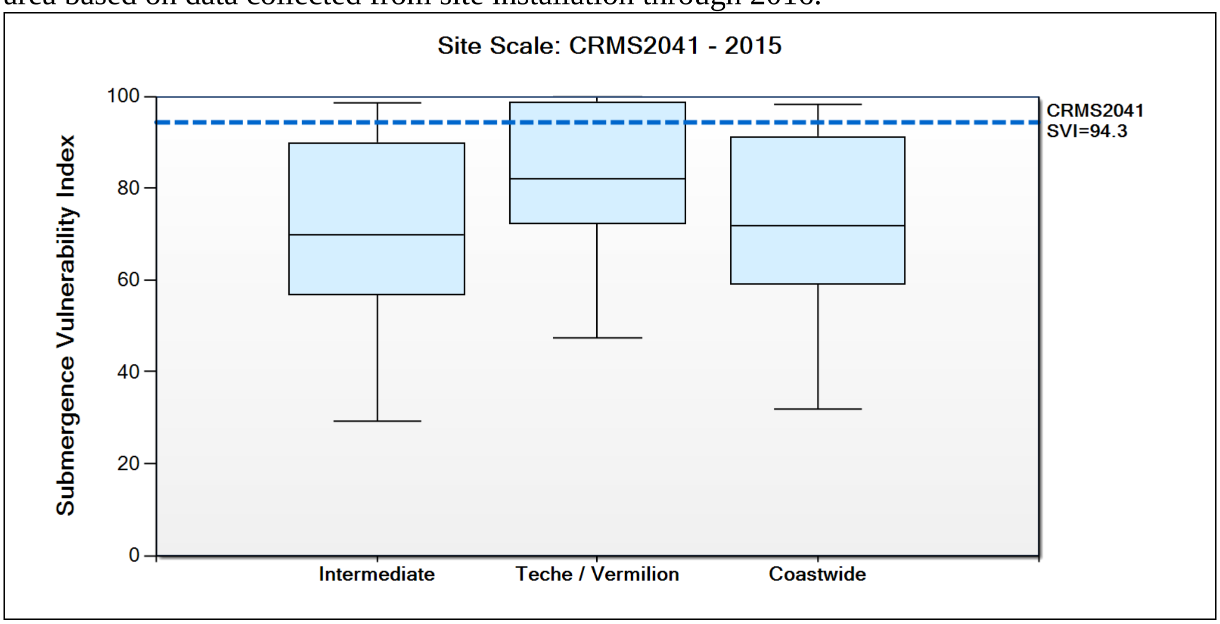

Figure 20. Submergence Vulnerability Index of the CRMS site 2041 compared to multiple spatial scales to provide a reference for site performance.

V. Conclusions

a. Project Effectiveness

The terraces were very effective at creating emergent marsh habitat. The speed at which the terraces vegetated, including not only planted species but coverage from locally recruited emergent species was impressive. The terraces also reduced the amount of shoreline erosion in the project area to half that of the reference area. This shoreline protection feature is however possibly isolated to low wave energy systems and would likely not be reproducible in a larger bay or lake rim.

The rate of sedimentation has also increased as a result of the terrace construction, though much of this was immediate and most of the inter terrace areas transitioned from a shallow bay bottom to and intermittently exposed tidal flat soon after construction. This tidal flat has not become completely subaerial to date but much of the project area now has the necessary elevation to support emergent marsh species that occupy more flooded habitats. A series of successful non-project related plantings have taken place in the project recently due to the slow natural colonization of emergent vegetation. This could be the required catalyst that helps transition the tidal flats to emergent marsh.

The SAV population of the project area has remained low likely due to several factors, the turbidity of the water being of utmost importance among those. The location of the project area was chosen due to the high availability of suspended sediments in the water column. As such there is little light penetration during periods of high sediment input into the system. As sediment was trapped in the project area the elevation quickly increased, also limiting the habitat availability for SAV growth. As emergent vegetation is established on the tidal flats, pockets of remaining open water may achieve the necessary requirements for increased SAV production.

b. Recommended Improvements

The armoring of the southernmost terraces in the project area and reducing the opening at Freshwater Bayou Canal would likely lead to an extended functional project life and enhanced project performance over the life of the project. Sacrificial terraces built at the perimeter of a terrace field when exposed to wind and wave energy are designed to fail, but once this has occurred the next group of non-sacrificial terraces is subjected to these forces and will also fail. By armoring the outer terraces the project features are allowed to function as designed unaffected by the exterior wave energies.

c. Lessons Learned

The shallow bay bottom and borrow canals in the project area quickly silted in and became tidal flats early on in the project life, this was in part due to hurricane activity shortly after project construction. As this siltation occurred the cross-sectional area available for hydrologic exchange was reduced. The opening at Freshwater Bayou into the terrace field grew wider. All of this in turn caused the main conveyance channels to become deeper to facilitate the exchange of water between Freshwater Bayou Canal and Vermilion Bay via Little Vermilion Bay. After this occurred much of the sediment laden water passes through the project area and out into Vermilion Bay where it is lost to deeper waters. To maximize the sediment load passing through the project area a larger foot print could have been selected to maximize more of the areas sediment budget. A larger project foot print with armored southern terraces could have spent years transforming the shallow bay bottoms into tidal flats, and possibly emergent marshes. This would still be possible by extending the terrace field along the bay rim and into the bay itself, south of the original project area. Along with this expansion armoring the southern face of the terraces would help to keep constructed and created land loss to a minimum over the life of the project.

The rapid creation of tidal flats in the project area followed by a very slow transition to emergent marsh is not isolated to the TV12 project area; it has also been documented at TV15 and TV18. All three of these projects have been recently planted with non-project funds in an effort to expedite the transition from tidal flats to emergent marsh. In future sediment trapping projects it might be wise to include vegetative plantings after tidal flat formation has occurred and stabilized in order to generate the successional catalysts necessary to transition to an emergent marsh. The species planted in the three projects listed above was *Schoenoplectus californicus*, which is widely renowned for its ability to thrive in deep intermediate waters.

d. End of Project Life

The terraces at the confluence of Little Vermilion Bay and Freshwater Bayou Canal have been highly successful at eliminating shoreline erosion while capturing sediment in formerly open water areas around the terraces. This feature should, under normal environmental conditions including hurricanes, continue to mature and potentially create emergent marsh with the continued non-project efforts to plant the intertidal flats that have developed. The terraces have needed little maintenance over the 20 year project life and this trend is expected to continue into the foreseeable future. However of the seven sacrificial southern terraces only two and fragments of a third remain due to the wind and wave energy of Vermilion Bay and Freshwater Bayou Canal. These terraces may be repaired in conjunction with the construction of the Cole's Bayou project in the area to avoid equipment mobilization costs. These repairs would likely take place by the end of project life in 2019, as TV-63 is scheduled for construction beginning in 2017. If efforts to create sustainable emergent marsh around the terraces are successful then this will help to mitigate the erosive forces received by the project area, thus prolonging its economic life well beyond the twenty year threshold.

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Appendix A

Inspection Photographs

Photo No. 1—Bayou Backer installation equipment (2016)

Photo No. 2—terrace field view from opening at Freshwater Bayou (2016)

Photo No. 3—bullwhip plantings between terraces (2014)

Photo No. 4—Emergent vegetation (2014)

Photo No. 5—vegetation growing between terraces (2013)

Appendix B

Three Year Budget Projection

LITTLE VERMILION/ TV12 / PPL 5

Three-Year Operations & Maintenance Budgets 07/01/2016 - 06/30/2019

Project Manager	O & M Manager	Federal Sponsor	Prepared By
Pat Landry	*Stan Aucoin*	*NMFS*	*Stan Aucoin*

	2016/2017 (-17)	2017/2018 (-18)	2018/2019 (-19)
Maintenance Inspection	$ 7,057.00	$ 7,269.00	$ 7,487.00
Structure Operation			
State Administration		$ -	$ -
Federal Administration		$ -	$ -

Maintenance/Rehabilitation

16/17 Description:

	2016/2017 (-17)
E&D	
Construction	
Construction Oversight	
Sub Total - Maint. And Rehab.	$ -

17/18 Description

	2017/2018 (-18)
E&D	$ -
Construction	$ -
Construction Oversight	$ -
Sub Total - Maint. And Rehab.	$ -

18/19 Description:

	2018/2019 (-19)
E&D	$ -
Construction	$ -
Construction Oversight	$ -
Sub Total - Maint. And Rehab.	$ -

	2016/2017 (-17)	2017/2018 (-18)	2018/2019 (-19)
Total O&M Budgets	**$ 7,057.00**	**$ 7,269.00**	**$ 7,487.00**

O &M Budget (3 yr Total)	**$ 21,813.00**
Unexpended O & M Budget	**$ 120,987.00**
Remaining O & M Budget (Projected)	**$ 99,174.00**

OPERATION AND MAINTENANCE BUDGET WORKSHEET

LITTLE VERMILION SNT / PROJECT NO. TV-12 / PPL NO. 5 / FY 2016-2017

DESCRIPTION	UNIT	EST. QTY.	UNIT PRICE	ESTIMATED TOTAL
O&M Inspection and Report	EACH	1	$7,057.00	**$7,057.00**
General Structure Maintenance	LUMP	0	$0.00	**$0.00**
Engineering and Design	LUMP	0	$0.00	**$0.00**
Operations Contract	LUMP	0	$0.00	**$0.00**
Construction Oversight	LUMP	0	$0.00	**$0.00**

ADMINISTRATION

LDNR / CRD Admin.	LUMP	0	$0.00	$0.00
FEDERAL SPONSOR Admin.	LUMP	0	$0.00	$0.00
SURVEY Admin.	LUMP	0	$0.00	$0.00
OTHER				$0.00
			TOTAL ADMINISTRATION COSTS:	**$0.00**

MAINTENANCE / CONSTRUCTION

SURVEY

SURVEY DESCRIPTION:	Set staff gage.				
	Secondary Monument	EACH	0	$0.00	$0.00
	Staff Gauge / Recorders	EACH	0	$0.00	$0.00
	Marsh Elevation / Topography	LUMP	0	$0.00	$0.00
	TBM Installation	EACH	0	$0.00	$0.00
	OTHER				$0.00
				TOTAL SURVEY COSTS:	**$0.00**

GEOTECHNICAL

GEOTECH DESCRIPTION:					
	Borings	EACH	0	$0.00	$0.00
	OTHER				$0.00
				TOTAL GEOTECHNICAL COSTS:	**$0.00**

CONSTRUCTION

CONSTRUCTION DESCRIPTION:						
	Rip Rap	LIN FT	TON / FT	TONS	UNIT PRICE	
	Rock Dike	0	0.0	0	$0.00	$0.00
	Bank Paving	0	0.0	0	$0.00	$0.00
		0	0.0	0	$0.00	$0.00
	Filter Cloth / Geogrid Fabric		SQ YD	0	$8.00	$0.00
	Navigation Aid		EACH	0	$0.00	$0.00
	Signage		EACH	0	$0.00	$0.00
	General Excavation / Fill		CU YD	0	$0.00	$0.00
	Dredging		CU YD	0	$0.00	$0.00
	Sheet Piles (Lin Ft or Sq Yds)			0	$0.00	$0.00
	Timber Piles (each or lump sum)			0	$0.00	$0.00
	Timber Members (each or lump sum)			0	$0.00	$0.00
	Hardware		LUMP	0	$0.00	$0.00
	Materials		LUMP	0	$0.00	$0.00
	Mob / Demob		LUMP	0	$0.00	$0.00
	Contingency		LUMP	0	$0.00	$0.00
	General Structure Maintenance		LUMP	0	$0.00	$0.00
	OTHER				$0.00	$0.00
	OTHER				$0.00	$0.00
	OTHER				$0.00	$0.00
					TOTAL CONSTRUCTION COSTS:	**$0.00**

TOTAL OPERATIONS AND MAINTENANCE BUDGET: **$7,057.00**

OPERATION AND MAINTENANCE BUDGET WORKSHEET

LITTLE VERMILION SNT / PROJECT NO. TV-12 / PPL NO. 5 / FY 2017-2018

DESCRIPTION	UNIT	EST. QTY.	UNIT PRICE	ESTIMATED TOTAL
O&M Inspection and Report	EACH	1	$7,269.00	**$7,269.00**
General Structure Maintenance	LUMP	0	$0.00	**$0.00**
Engineering and Design	LUMP	0	$0.00	**$0.00**
Operations Contract	LUMP	0	$0.00	**$0.00**
Construction Oversight	LUMP	0	$0.00	**$0.00**

ADMINISTRATION

LDNR / CRD Admin.	LUMP	0	$0.00	$0.00
FEDERAL SPONSOR Admin.	LUMP	0	$0.00	$0.00
SURVEY Admin.	LUMP	0	$0.00	$0.00
OTHER				$0.00
			TOTAL ADMINISTRATION COSTS:	**$0.00**

MAINTENANCE / CONSTRUCTION

SURVEY

SURVEY DESCRIPTION: Set staff gage.

Secondary Monument	EACH	0	$0.00	$0.00
Staff Gauge / Recorders	EACH	0	$0.00	$0.00
Marsh Elevation / Topography	LUMP	0	$0.00	$0.00
TBM Installation	EACH	0	$0.00	$0.00
OTHER				$0.00
			TOTAL SURVEY COSTS:	**$0.00**

GEOTECHNICAL

GEOTECH DESCRIPTION:

Borings	EACH	0	$0.00	$0.00
OTHER				$0.00
			TOTAL GEOTECHNICAL COSTS:	**$0.00**

CONSTRUCTION

CONSTRUCTION DESCRIPTION:

Rip Rap	LIN FT	TON / FT	TONS	UNIT PRICE	
Rock Dike	0	0.0	0	$0.00	$0.00
Bank Paving	0	0.0	0	$0.00	$0.00
	0	0.0	0	$0.00	$0.00
Filter Cloth / Geogrid Fabric		SQ YD	0	$8.00	$0.00
Navigation Aid		EACH	0	$0.00	$0.00
Signage		EACH	0	$0.00	$0.00
General Excavation / Fill		CU YD	0	$0.00	$0.00
Dredging		CU YD	0	$0.00	$0.00
Sheet Piles (Lin Ft or Sq Yds)			0	$0.00	$0.00
Timber Piles (each or lump sum)			0	$0.00	$0.00
Timber Members (each or lump sum)			0	$0.00	$0.00
Hardware		LUMP	0	$0.00	$0.00
Materials		LUMP	0	$0.00	$0.00
Mob / Demob		LUMP	0	$0.00	$0.00
Contingency		LUMP	0	$0.00	$0.00
General Structure Maintenance		LUMP	0	$0.00	$0.00
OTHER				$0.00	$0.00
OTHER				$0.00	$0.00
OTHER				$0.00	$0.00
				TOTAL CONSTRUCTION COSTS:	**$0.00**

TOTAL OPERATIONS AND MAINTENANCE BUDGET: **$7,269.00**

OPERATION AND MAINTENANCE BUDGET WORKSHEET

LITTLE VERMILION SNT / PROJECT NO. TV-12 / PPL NO. 5 / FY 2018-2019

DESCRIPTION	UNIT	EST. QTY.	UNIT PRICE	ESTIMATED TOTAL
O&M Inspection and Report	EACH	1	$7,487.00	**$7,487.00**
General Structure Maintenance	LUMP	0	$0.00	**$0.00**
Engineering and Design	LUMP	0	$0.00	**$0.00**
Operations Contract	LUMP	0	$0.00	**$0.00**
Construction Oversight	LUMP	0	$0.00	**$0.00**

ADMINISTRATION

LDNR / CRD Admin.	LUMP	0	$0.00	$0.00
FEDERAL SPONSOR Admin.	LUMP	0	$0.00	$0.00
SURVEY Admin.	LUMP	0	$0.00	$0.00
OTHER				$0.00
			TOTAL ADMINISTRATION COSTS:	**$0.00**

MAINTENANCE / CONSTRUCTION

SURVEY

SURVEY DESCRIPTION:	Set staff gage.				
	Secondary Monument	EACH	0	$0.00	$0.00
	Staff Gauge / Recorders	EACH	0	$0.00	$0.00
	Marsh Elevation / Topography	LUMP	0	$0.00	$0.00
	TBM Installation	EACH	0	$0.00	$0.00
	OTHER				$0.00
				TOTAL SURVEY COSTS:	**$0.00**

GEOTECHNICAL

GEOTECH DESCRIPTION:					
	Borings	EACH	0	$0.00	$0.00
	OTHER				$0.00
				TOTAL GEOTECHNICAL COSTS:	**$0.00**

CONSTRUCTION

CONSTRUCTION DESCRIPTION:						
	Rip Rap	LIN FT	TON / FT	TONS	UNIT PRICE	
	Rock Dike	0	0.0	0	$0.00	$0.00
	Bank Paving	0	0.0	0	$0.00	$0.00
		0	0.0	0	$0.00	$0.00
	Filter Cloth / Geogrid Fabric		SQ YD	0	$8.00	$0.00
	Navigation Aid		EACH	0	$0.00	$0.00
	Signage		EACH	0	$0.00	$0.00
	General Excavation / Fill		CU YD	0	$0.00	$0.00
	Dredging		CU YD	0	$0.00	$0.00
	Sheet Piles (Lin Ft or Sq Yds)			0	$0.00	$0.00
	Timber Piles (each or lump sum)			0	$0.00	$0.00
	Timber Members (each or lump sum)			0	$0.00	$0.00
	Hardware		LUMP	0	$0.00	$0.00
	Materials		LUMP	0	$0.00	$0.00
	Mob / Demob		LUMP	0	$0.00	$0.00
	Contingency		LUMP	0	$0.00	$0.00
	General Structure Maintenance		LUMP	0	$0.00	$0.00
	OTHER				$0.00	$0.00
	OTHER				$0.00	$0.00
	OTHER				$0.00	$0.00
					TOTAL CONSTRUCTION COSTS:	**$0.00**

TOTAL OPERATIONS AND MAINTENANCE BUDGET: **$7,487.00**

Appendix C

Field Inspection Notes

MAINTENANCE INSPECTION REPORT CHECK SHEET

Project No. / Name: TV-12 Little Vermilion Bay

Date of Inspection: April 21, 2016 Time:

Structure No. N/A

Inspector(s): Stan Aucoin (CPRA)
John Foret and Rick Hartman(NMFS)

Structure Description: Terraces/Vegetation

Water Level

Type of Inspection: Annual

Weater Conditions: Mostly cloudy and mild

Item	Condition	Physical Damage	Corrosion	Photo #	Observations and Remarks
Steel Bulkhead / Caps	N/A				
Steel Grating	N/A				
Stop Logs	N/A				
Hardware	N/A				
Timber Piles	N/A				
Timber Wales	N/A				
Galv. Pile Caps	N/A				
Vegetation	Good				Submergent and Emergent vegetation is evident throughout the project
Signage /Supports	N/A				
Rip Rap (fill)	N/A				
Earthen Terraces	Excellent			1,2	Terraces are in good condition. The erosion nearest Freshwater Bayou has not worsened; however, the opening to the terrace field at Freshwater Bayou is now 1,800 feet wide and continues to widen.

What are the conditions of the existing levees?
Are there any noticeable breaches?
Settlement of rock plugs and rock weirs?
Position of stoplogs at the time of the inspection?
Are there any signs of vandalism?