State of Louisiana
Coastal Protection and Restoration Authority

2016 Operations, Maintenance, and Monitoring Report

for

Bayou Sauvage National Wildlife Refuge Hydrologic Restoration, Phase 1 (PO-16)

State Project Number PO-16
Priority Project List 1

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Preface

The Bayou Sauvage National Wildlife Refuge Hydrologic Restoration, Phase 1 (PO-16) project was funded through the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA) on the 1st Project Priority List with the United States Fish and Wildlife Service (USFWS) as the federal sponsor. The 2016 Operations, Maintenance, & Monitoring (OM&M) report for PO-16 is the first and final OM&M report for this project, which includes monitoring data collected throughout the life of the project (1993-2015) and Operations and Maintenance activities through 2016. Additional documents pertaining to the PO-16 project may be accessed on the Coastal Protection and Restoration Authority (CPRA) website at http://coastal.la.gov/ resources/library/ .

I. Introduction

The Bayou Sauvage National Wildlife Refuge Hydrologic Restoration, Phase 1 (PO-16) project is located within the Bayou Sauvage National Wildlife Refuge (NWR), approximately 13 miles (21 km) from downtown New Orleans. The 3,706-ac (1,500 ha) project area is bounded by U.S. Highway 90 to the north, the Lake Pontchartrain Hurricane Protection Levee to the east and south, and the Maxent Canal levee to the west, and is hydrologically separated into two units by a railroad embankment (Figure 1). These two units encompass Water Management Units 5 (North Unit) and 6 (South Unit) of the Bayou Sauvage NWR, which is managed by the United States Fish and Wildlife Service (USFWS) (USFWS 2013).

As a result of construction of the Lake Pontchartrain Hurricane Protection Levee in 1956, the project area became hydrologically isolated from the surrounding estuary, thereby creating a large impoundment with precipitation as the major water source. Flap-gated culverts, which required significant head differential to operate, were installed but were inefficient at draining the area (USFWS 1994). Approximately 95 ac/yr (38 ha/yr) of marsh habitat were lost from 1952 to 1991 within the 13,000 impounded acres of the refuge for a total loss of 3,800 acres (1,538 ha) (USFWS 1992). These losses were directly attributed to impounded rainfall and loss of daily tidal exchange which resulted in extended periods of inundation during the growing season. The PO-16 project was proposed in 1991 as a means for removing excess water throughout the year, particularly during spring and summer, to promote the re-establishment of emergent marsh vegetation and reduce the mortality of black willow (*Salix nigra*), which provides rookery habitat for wading birds.

Prior to impoundment, the area containing the PO-16 project was described as ‘brackish three-cornered grass marsh’ by O’Neil (1949); however, a shift from brackish to fresh/intermediate marsh had occurred by 1988 as observed through aerial surveys (Chabreck and Linscombe 1978, 1988, and 1997). By the time of PO-16 project development, the project area was classified as impounded fresh marsh (USFWS 1991) with dominant species including *Spartina patens* (marshhay cordgrass), *Alternanthera philoxeroides* (alligatorweed), *Ludwigia spp* (water primrose), and *Panicum spp* (panicgrass). Bottomland hardwood species including black willow were found on the higher elevations within the project area. A 1993 habitat analysis showed that the PO-16 project area contained approximately 57% open water, 17% fresh marsh, 11% forested wetland, and 7% scrub shrub. Management Unit 6 (South Unit) showed significantly greater marsh loss presumably due to an extended period of dewatering immediately following levee construction, which led to sediment oxidation, subsidence, and compaction (USFWS 1991). Management Unit 5 was not exposed to this drainage, and therefore experienced more gradual marsh loss.

The main objective of the PO-16 project was to reduce water levels in order to enhance fresh marsh and willow regrowth. The project-specific goals were to (1) promote the reestablishment of emergent marsh vegetation; (2) lower water levels to -0.5 - 0 ft below marsh elevation during the spring and summer and to within +0.5 ft above marsh elevation during the fall and winter; and (3) preserve *Salix nigra* (black willow) habitat in order to maintain wading bird rookeries. To reach this objective, two pump stations were installed, one in each of the two units, each consisting of a 30-inch diameter Patterson single stage axial flow vertical drainage pump, with 36 inch diameter discharges, 22,000 GPM capacity, and a 36" diameter smooth-steel discharge pipeline. A weir was also installed at Bayou Thomas to allow independent management of the two units. Construction was completed in May 1996 and subsequent operation of the pumps has been conducted by USFWS personnel.

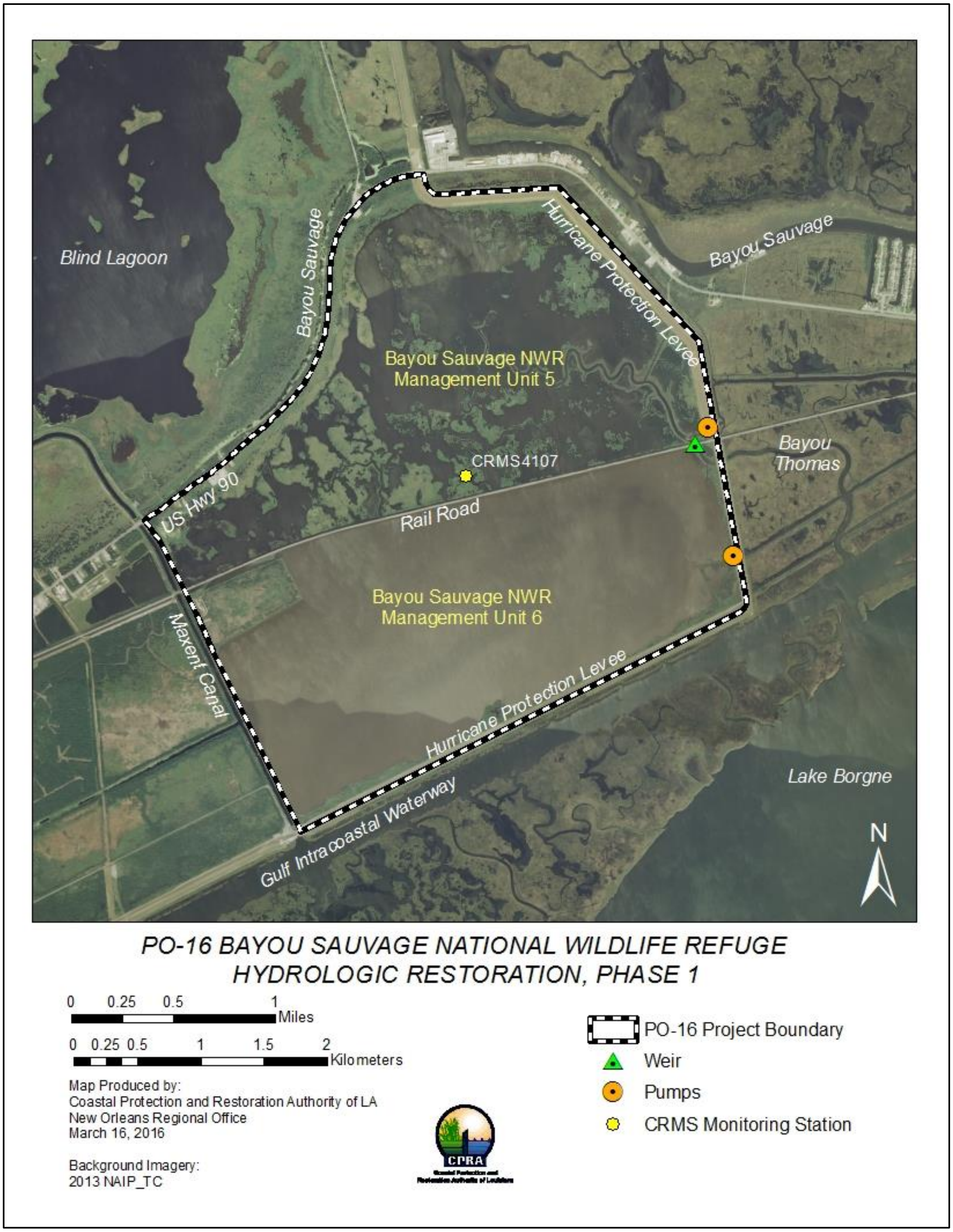

Figure 1. Bayou Sauvage National Wildlife Refuge Hydrologic Restoration (PO-16) project area and features.

II. Maintenance Activity

a. Project Feature Inspection Procedures

The purpose of the annual inspection of the Bayou Sauvage NWR Hydrologic Restoration Phase I Project (PO-16) is to evaluate the constructed project features, to identify any deficiencies, and to prepare a report detailing the condition of project features and recommended corrective actions. Should it be determined that corrective actions are needed, the CPRA shall provide a detailed cost estimate for engineering, design, supervision, inspection, and construction contingencies, and an assessment of the urgency of such repairs (LDNR 2004).

The most recent inspection of the Bayou Sauvage Refuge Restoration Phase I Project (PO-16) was held on April 23, 2014 by Melissa Hymel and Barry Richard of CPRA and James Harris and Neil Lalonde of USFWS. Photographs of that inspection are included in Appendix A of this report.

b. Inspection Results

<u>Pump #5</u>

Pump #5 is working as designed.

<u>Pump #6</u>

Pump #6 is working as designed.

c. Maintenance Recommendations

At this time only preventative maintenance is needed.

i. Immediate/ Emergency Repairs

- None at this time.

ii. Programmatic/ Routine Repairs

- Periodically check pump stations for any maintenance needs.

d. Maintenance History

Due to the Hurricane and Storm Damage Risk Reduction System (HSDRRS) work to improve the levee system in this area, the discharge pipes and pumps were replaced by the US Army Corps of Engineers (USACE). The project paid $50,000 toward this work and the USACE paid the remaining costs. These improvements were completed in 2013.

The USFWS and CPRA requested a 6 year time extension on the Project Life due to the inoperability of the pumps after being damaged by Hurricane Katrina and during the repair work by the USACE. CWPPRA granted this extension which moves the end of project life to the year 2023.

III. Operation Activity

Operation of the PO-16 pumps began in April 1996 and was conducted by USFWS personnel for the duration of the project life. CPRA has received limited operations records from the USFWS to determine if operations were conducted in accordance with the O&M Plan (LDNR 2004). Operations records were sent to CPRA (then LDNR) for the periods from April 1996 to March 1998 and from December 2009 to January 2010, which showed that the pumps were run for the durations shown in Table 1. These are the only *known* operations, not a complete record of operations. Per the USFWS, post-Hurricane Katrina operations have mainly consisted of regular maintenance operations to ensure the equipment was in working order. There were two extended periods during the project life when the pumps were not operational: 1) August 2005 to August 2006 due to Hurricane Katrina damage, and 2) October 2010 to April 2015 due to HSDRRS levee enlargement by the USACE (Figure 2). Therefore, the pumps were not operational for a total of 67 months or approximately 28% of the project life.

Table 1. Known operations (# days) of the PO-16 pumps in the North and South Units. Operations during other time periods are unknown except for periods when pumps were not operational. The # of days shown were not consecutive.

Known Operations of the PO-16 Pumps (# Days)		
	North Unit	South Unit
Spring/Summer1996	38	18
Fall/Winter1996-97	9	4
Spring/Summer1997	12.5	23
Fall/Winter1997-98	23	30
Fall/Winter2009-10	9	8

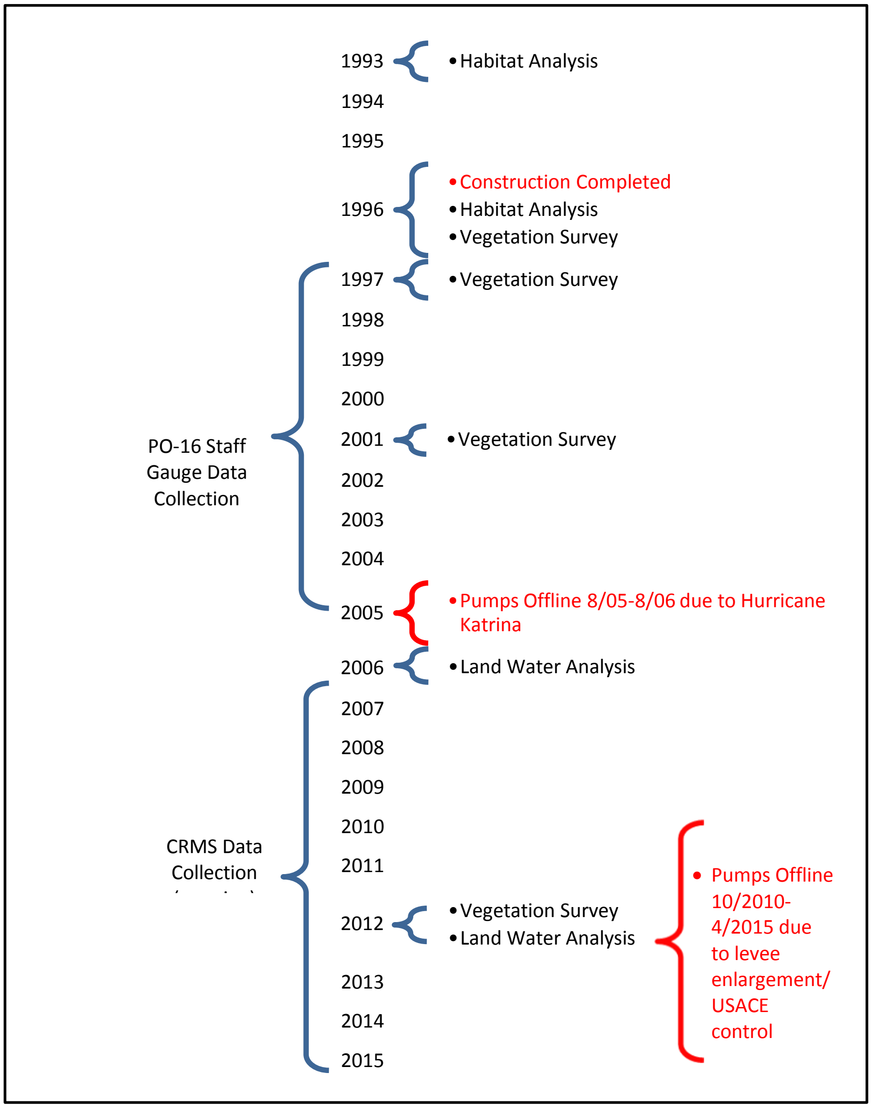

Figure 2. Timeline of construction and monitoring events associated with the Bayou Sauvage National Wildlife Refuge Hydrologic Restoration, Phase 1 (PO-16) project from 1993 to present.

IV. Monitoring Activity

Pursuant to a CWPPRA Task Force decision on August 14, 2003 to adopt the Coastwide Reference Monitoring System-*Wetlands* (CRMS) for CWPPRA, updates were made to the PO-16 Monitoring Plan to merge it with CRMS and provide more useful information for modeling efforts and future project planning while maintaining the monitoring mandates of the Breaux Act. There is one CRMS sites located in the PO-16 project area, CRMS4107, which will be used to supplement existing project-specific data to further evaluate the effectiveness of the project. Further information on data collection methods at the CRMS sites can be obtained in Folse et al. 2012.

a. Monitoring Goals

The following measurable goals were established to evaluate the effectiveness of the project:

1. Promote the reestablishment of emergent marsh vegetation.
2. Lower water levels within the impounded areas to -0.5 ft to 0.0 ft of marsh sediment elevation in the spring and summer and to within +0.5 ft of marsh sediment elevation throughout the rest of the year via the installation of pumps.
3. Maintain black willow habitat in order to promote wading bird rookeries.

b. Monitoring Elements

The following monitoring elements will provide the information necessary to evaluate the goals listed above. A timeline of data collection events associated with these monitoring elements is shown in Figure 2.

Reference Area

An area north and west of I-10 and east of a levee along Paris Road was chosen as a reference area for the PO-16 project because it was impounded, had open-water areas with water levels within 1 to 2 feet, had fresh/intermediate marsh, bottomland hardwood and willow habitat, and had Clovelly and Lafitte muck soils similar to the project area (Figure 3); however, some differences between the reference area and the project area do exist. The reference area is sometimes subjected to tidal influence during the spring via gates connecting the area with Lake Pontchartrain. Also, the willow habitat within the reference area is not inundated year round and the willows present are alive and in good condition similar to the higher areas within the project area.

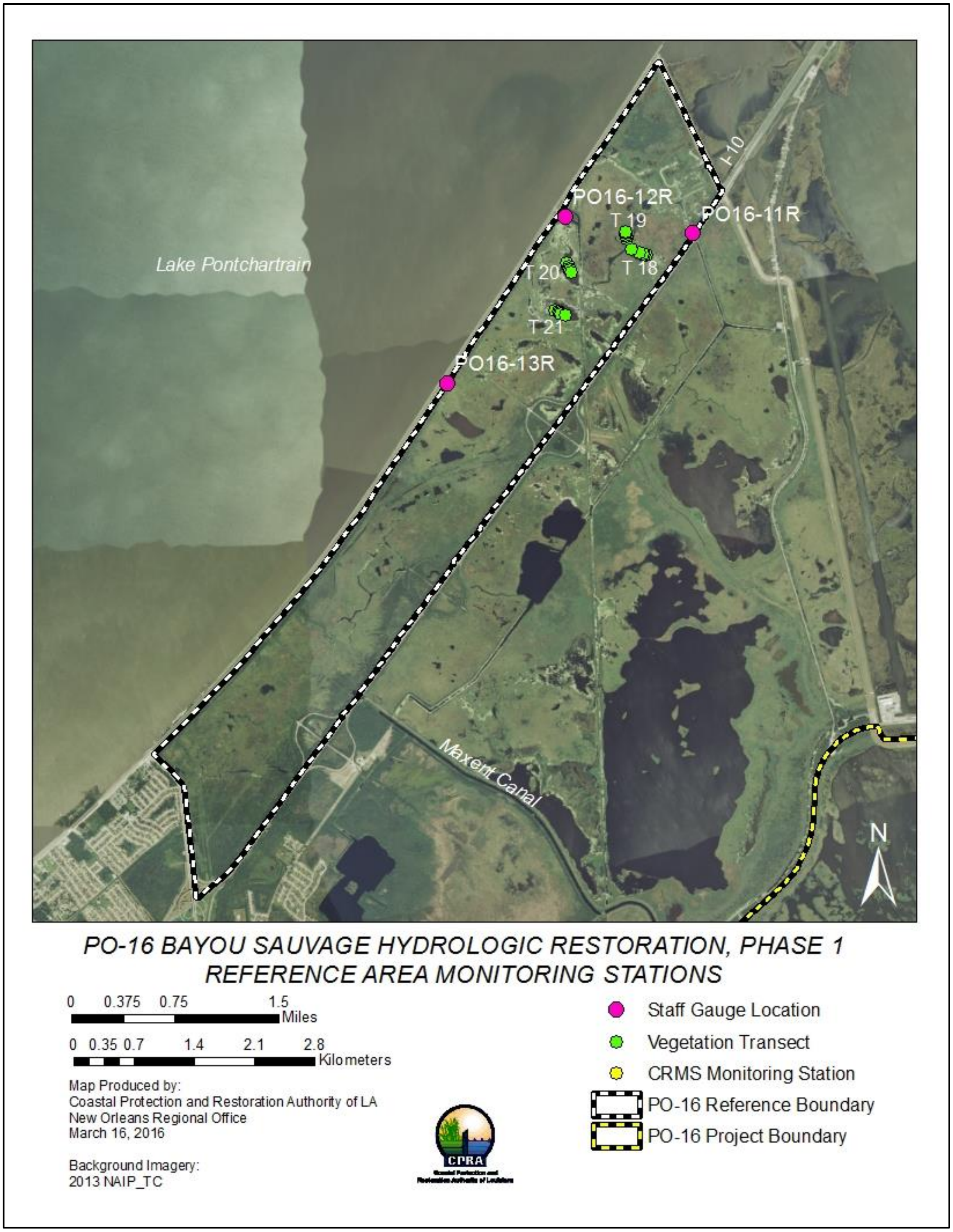

Figure 3. The PO-16 reference area and associated monitoring stations.

Aerial Photography

To document marsh to open water ratios in the PO-16 project and reference areas, aerial photography was obtained in 1993, 1996, 2006 and 2012. Near-vertical, color-infrared aerial photography (1:12,000 scale, with ground control markers) was acquired and analyzed for changes in habitat type in 1993 and 1996 and for land to water ratios only in 2006 (Steyer et al. 1995, revised 2000). All remaining habitat analyses were changed to land/water analyses upon the implementation of CRMS in 2003. In 2012, land to water ratios within the project and reference areas were derived from digital imagery with 1-meter resolution, acquired in October 2012 through the CRMS program. In addition to the PO-16-specific analyses described above, land change between 1985−2010 was also evaluated for the PO-16 project area and within a 1-km^2 at CRMS4107 within the northern project unit using Landsat Thematic Mapper (TM) data (Couvillion et al. 2011).

Vegetation

Emergent marsh vegetation sampling stations were established along four transects within the project area and four transects within the reference area (Figures 3 and 4). The two transects in the northern unit of the project area were chosen to represent fresh marsh and *Spartina patens*-dominated intermediate marsh habitat and the two transects in the southern unit were chosen to represent fresh marsh and open water. In the reference area, two transects were representative of *Spartina patens*-dominated intermediate marsh and two transects were open water. Five stations were located along each transect for a total of 20 project stations and 20 reference stations. Three of the four transects (Transects 7, 8, and 9) within the project area were first established and sampled using the line-intercept method by the USFWS in 1989 (Harris 1989). During the post construction period, species composition, percent cover, and relative abundance were evaluated at all project and reference transects within 4-m^2 plots using a modified Braun-Blanquet sampling method (Mueller-Dombois and Ellenberg 1974) in 1996, 1997, 2001, and 2012. Emergent marsh vegetation was also sampled annually at CRMS4107 within the project area from 2007 to present. At CRMS4107, ten 4-m^2 sampling plots were randomly located along a 288-m transect and sampled using the same method described above. Percent coverage data from the PO-16 stations and CRMS stations were summarized according to the Floristic Quality Index (FQI) method utilized by CRMS (Cretini et al. 2011), where cover is qualified by scoring species according to their tolerance to disturbance and stability within specific habitat types.

Marsh Inundation

Water level was measured using staff gauges at five locations within the project area (two in the northern unit, and three in the southern unit, Figure 4) and at three locations within the reference area (Figure 3). The location and number of staff gauges were determined by USFWS personnel using information gathered during field investigations of water flow throughout the areas, and the collection of weekly staff gauge readings was the responsibility of USFWS personnel. Staff gauges and marsh surface elevation within the project and reference areas were surveyed relative to

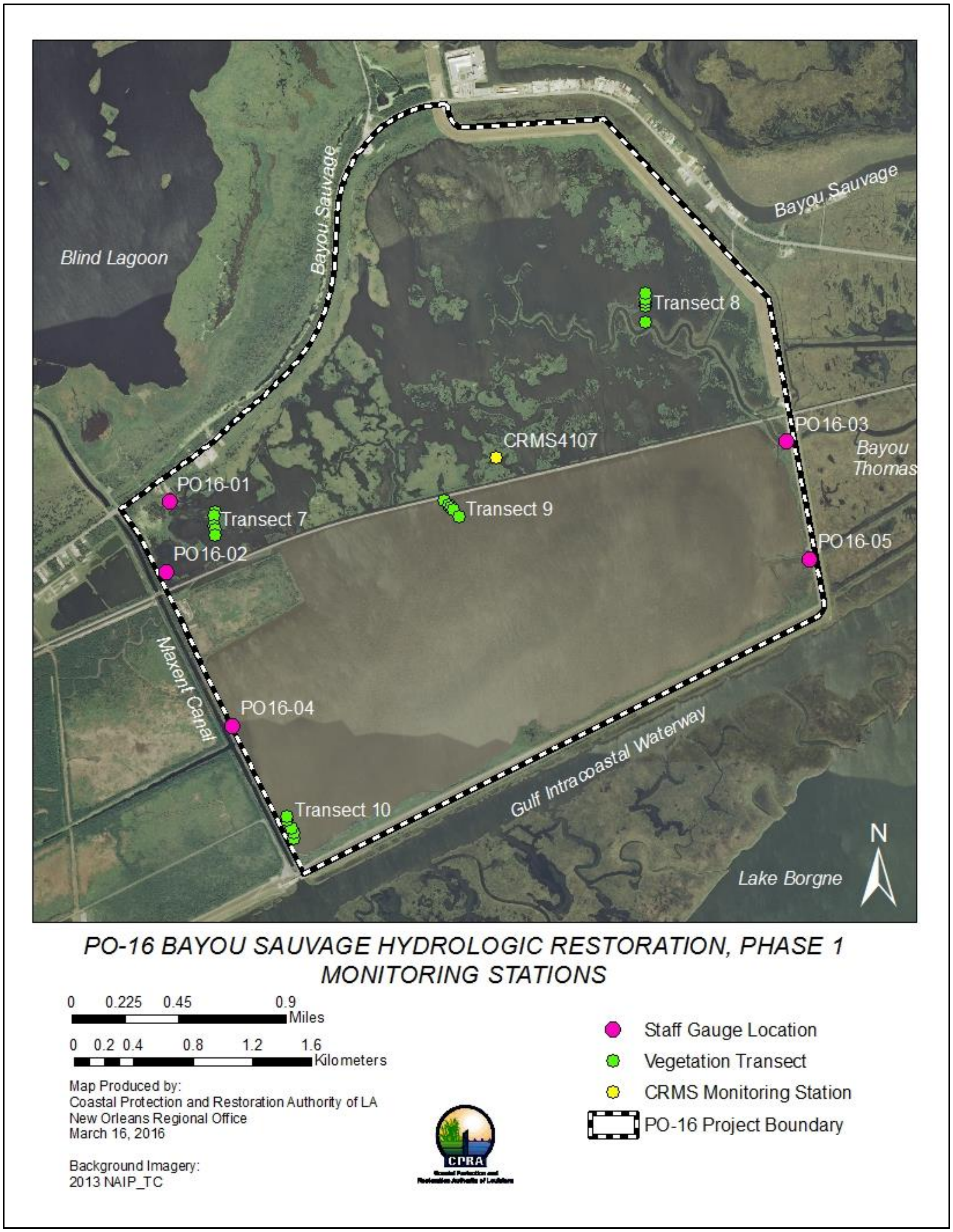

Figure 4. Location of monitoring stations within the PO-16 project area.

NAVD 88, feet (Geoid99) in 2003 (John Chance Land Surveys 2004). An earlier survey of the gauges was deemed to be suspect. Weekly gauge readings began in February 1997 and were to be continued through 2004, although intermittent gauge readings continued to be collected through 2014.

Hourly water level and salinity has been sampled at CRMS4107 from November 2007 to present using methods described in Folse et al. 2012. The continuous recorder is mounted on a wooden post in open water with sufficient water depths to inundate the recorder year round. The station is serviced approximately once every month to clean and calibrate the recorder and to download the data. A staff gauge is installed next to the continuous recorder to compare recorded water levels to a known datum (NAVD88, ft). During processing, the data are examined for accuracy and loaded to the CPRA database, and are available for download from the CRMS website (http://www.lacoast.gov/crms2).

c. Monitoring Results and Discussion

i. Aerial Photography

Land/water analyses of photography obtained of the PO-16 project and reference areas in 1993 (pre-construction), 1996 (as-built), 2006 (10 years post-construction), and 2012 (16 years post-construction) are presented in Appendix D. Habitat analyses are also presented for years 1993 and 1996. Considerable variability may exist in habitat and land/water classifications due to 1) clarity of the image; 2) water level at the time the image was taken; 3) seasonality; 4) difficulty in distinguishing submerged, floating, and emergent vegetation; and 5) in the case of floating marshes, variable mat buoyancy and frequent vegetative changes. Photography was always acquired in fall to early winter which adjusts for some seasonality differences.

One of the specific goals of the project was to promote the reestablishment of emergent marsh vegetation within the project area. It was anticipated that the project would allow for the maintenance of existing emergent marsh and for the conversion of 1,050 acres of shallow open water to emergent marsh over the life of the project (USFWS 1991, USFWS 1992); however, this goal was not met during the 16 year post-construction period (1997 to 2012) included in the analysis. Trends in land change were compared between the project and reference areas from 1993 to 2012 (Figure 5, Table 2). Land/water analyses showed an overall loss of 42% (647 acres) of the initial land area in the PO-16 project area from 1993 (pre-construction) to 2012 (Year 16). Percent land within the project area decreased from 41% in 1993 to 24% in 2012 (Figure 5). Alternatively, land acreage was relatively stable within the reference area, with an overall loss of 1% (32 acres) of the initial land acreage from 1993 to 2012. The period of greatest land loss in the project area occurred from 1996 to 2006 (-887 ac, -48% land loss), while the reference area showed a small land loss of 6

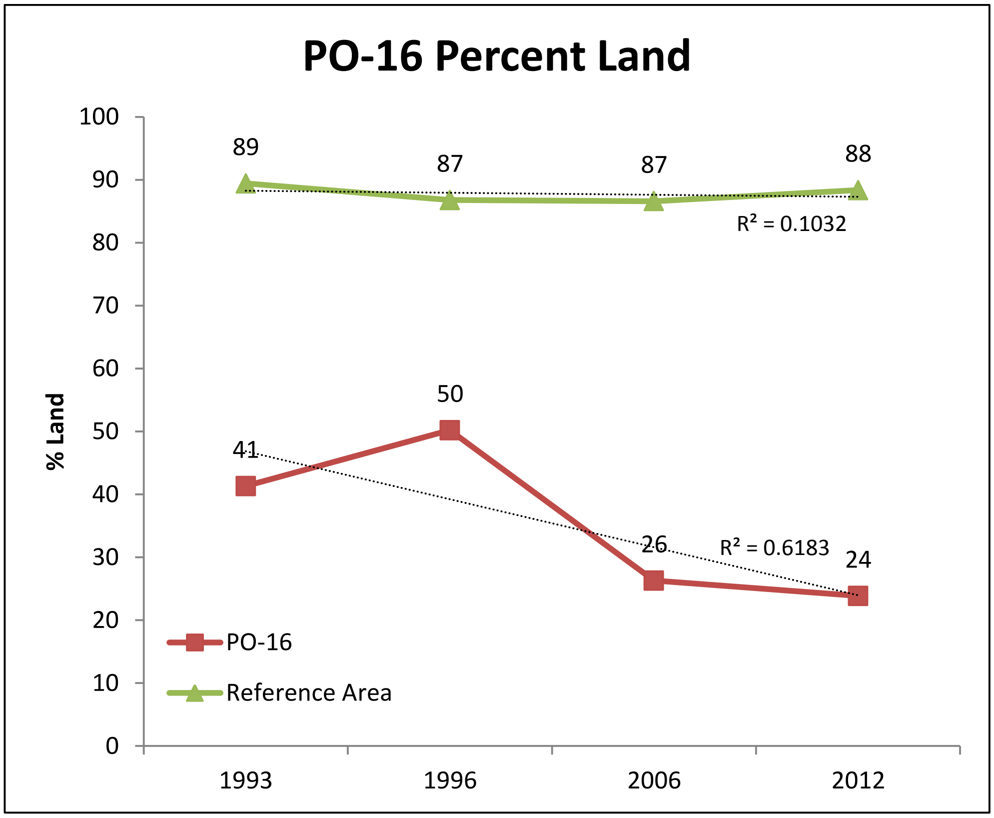

Figure 5. Trends in % land change within the PO-16 project and reference area from 1993 to 2012.

Table 2. Land acreage changes within the PO-16 project and reference area from 1993 to 2012.

Time Period	Project Area			Reference Area		
	Land Change (ac)	% Change	Change Rate (ac/yr)	Land Change (ac)	% Change	Change Rate (ac/yr)
1993—1996 (Pre-construction)	+330	+22%	+110	-85	-3%	-28
1996—2006 (Year 1 through 10)	-887	-48%	-89	-6	-<1%	-<1
2006—2012 (Year 10 through 16)	-90	-9%	-15	+59	+2%	+10
Overall (1993—2012)	-647	-42%	-34	-32	-1%	-2

acres. Extreme climatological events occurring during this period included a severe drought in 1999 through early 2000 and Hurricane Katrina in 2005, which may have accelerated land loss in the project area; however, negative impacts from these events were not reflected similarly in the reference area.

Land/water analyses may be confounded by differing water levels at the time of photo acquisition. No water level readings were taken within the project area at the time of the 1993 or 2006 photo, but staff gauge readings were taken in 1996 at PO16-01 a few days before and after the photo acquisition date. These readings suggest that water level was approximately 0.2—0.3 feet below marsh level. At the time of the 2012 photo, hourly continuous water level readings were being collected at CRMS4107, which show that the water level was more than a foot higher than in 1996 and 0.9 ft above marsh level (*Note:* This is relative to PO-16 average marsh elevation, not CRMS4107 site-specific marsh elevation. See 'Marsh Inundation' discussion, pg 22.). Precipitation data are not available for the PO-16 project area, but NOAA gauge data from nearby Lakefront Airport show that the total spring/summer precipitation in 2012 was the highest measured from 1993 to 2015 (Figure 6). Low water levels in the project area during the time of the 1996 photo may have artificially inflated the total 1996 land acreage, thereby increasing the subsequent % land loss in the following period. Alternatively, high water levels during the 2012 photo may have caused an underestimation of land acreage within the project area. Water level readings are not available within the reference area on or near the four photo acquisition dates.

Despite the confounding effects of water level on the PO-16 aerial analyses, an analysis of multi-temporal satellite data from 1985 to 2010 also reveals a negative trend (r^2=0.63) in % land within the PO-16 project area (Figure 7). Land/water data derived using techniques described in Couvillion et al. 2011 show an even greater loss of land acreage between 1995 and 2006 of 1,258 acres. Total % change in land from 1985 to 2010 was -71%, with a total 2010 land acreage of 984 acres. Water level data at CRMS4107, however, show that the marsh was flooded during each of the last three analysis years (2008, 2009, and 2010) which may have led to an underestimation of land acreage in those years. Although there is uncertainty in the exact acreage lost within the project area, it appears that the existing land acreage was not maintained and land gain did not occur as expected. Although the pumps were operational in 13 of the 16 post-construction years included in the analysis, the lack of operations data make it impossible to determine whether land loss occurred despite being operated as intended or because operations did not occur as intended.

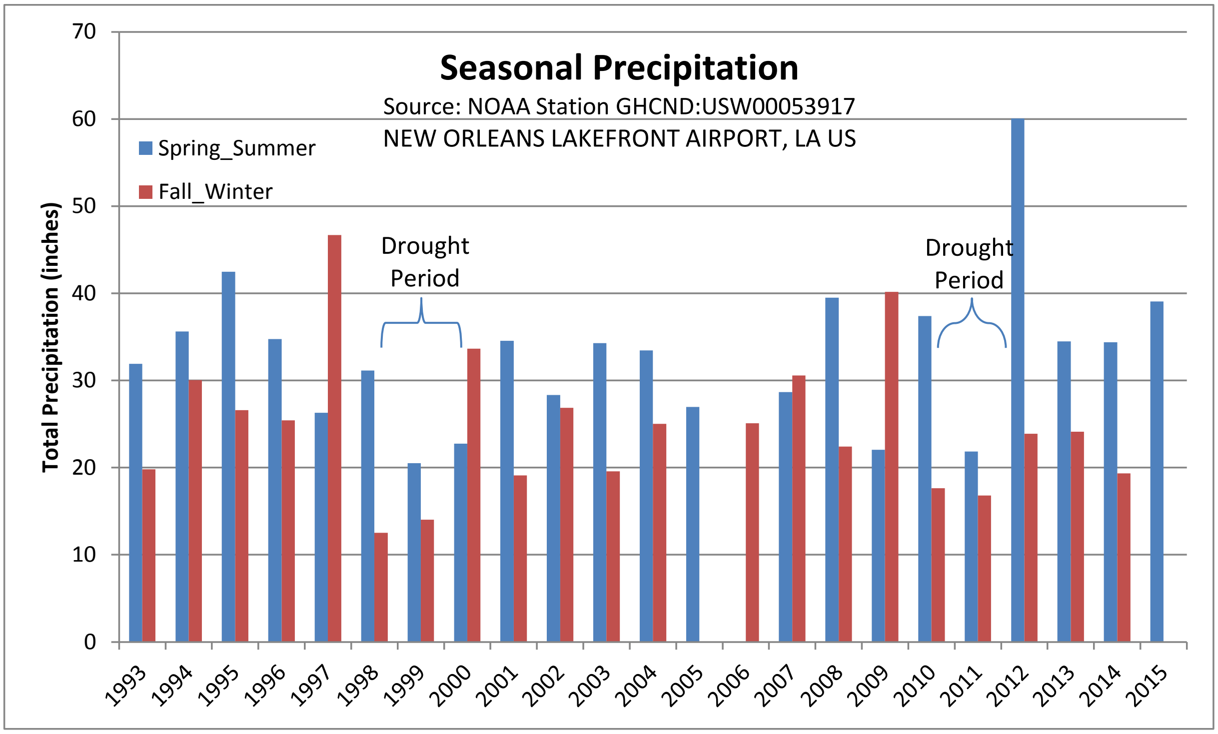

Figure 6. Total seasonal precipitation (in) from 1993 to 2015 observed at Lakefront Airport, New Orleans, LA (NOAA, GHCND:USW00053917).

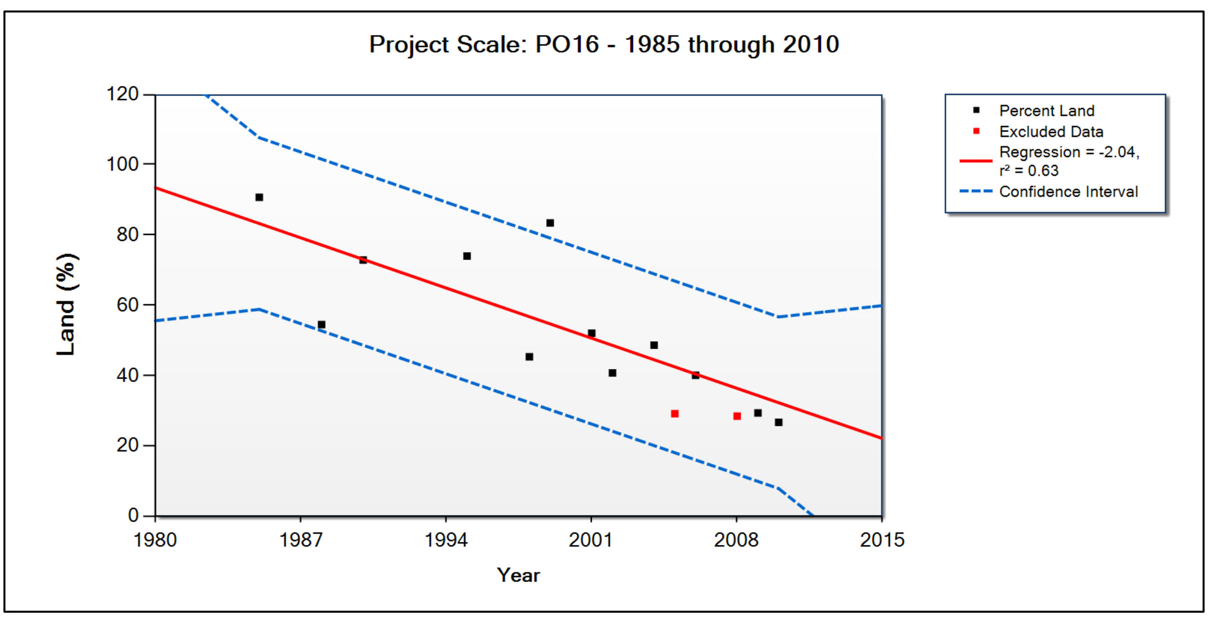

Figure 7. Trends in % land change within the PO-16 project area from 1985 to 2010 based on land/water analyses of multi-temporal satellite data (Couvillon et al. 2011).

ii. Vegetation

The goal to promote reestablishment of emergent marsh vegetation within the PO-16 project area was not achieved based on the vegetative sampling conducted from 1996 to 2012. The intent of the project was that drawdown of water levels during optimal periods via the installed pumps would promote germination of marsh vegetation seeds on exposed mudflats. In 1996, four vegetation transects were established in both the project and reference areas with 5 sample plots per transect for a total of 20 sample plots in each area. Several transects were placed in shallow, open water with the expectation that these areas would become vegetated, but this did not occur. All five plots on Transect 9, two plots on Transect 7 (Figure 4), and all plots on Transects 20 and 21 in the reference area (Figure 3), remained open water through the entire sampling period from 1996 to 2012. Six additional plots converted to open water between 2001 and 2012 in the project area, while only one additional plot converted to open water in the reference area (Figure 8). For the purpose of describing changes in the vegetative community over time within the project and reference areas, plots which were open water for the entire sample period were not included in the analysis. The remaining plots included in the analysis within the project area (n=13) were located on Transect 7 (n=3) and Transect 8 (n=5) in the north unit, and Transect 10 (n=5) within the south unit (Figure 4). Plots included in the reference area (n=10) were located on Transect 18 (n=5) and Transect 19 (n=5) (Figure 3).

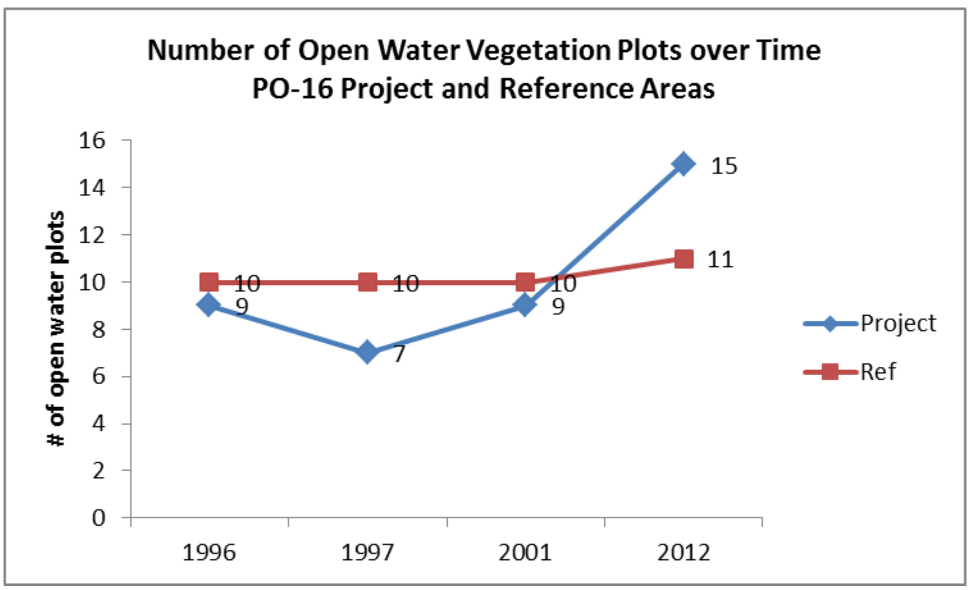

Figure 8. Number of open water plots over time within the PO-16 project (n=20) and reference (n=20) areas.

In 1996 and 1997, the vegetation community within the project area plots was a diverse fresh to intermediate marsh (Figure 9). Major species in the project area in 1996 and 1997 were *Panicum dichotomiflorum*, *Cyperus odoratus*, *Bacopa monnieri*, *Ludwigia leptocarpa*, and *Spartina patens*. Total percent cover of vegetation within the project area plots increased from 1996 to 1997, but then showed sharp declines in 2001 and 2012. By 2012, only four plots contained live vegetation, all within the north unit: two on Transect 7 and two on Transect 8. Transect 10, which was located on a thin strip of vegetation on the western side of the south unit had converted to open water by 2012. There were distinct differences in the vegetative community between the three project area transects. While Transect 7 was dominated by *S. patens* in 1996 and 1997, *S. patens* was not present at Transect 8 until 2012 (Figures 10 and 11). Transect 8 was a more diverse community dominated by *P. dichotomiflorum* and *B. monnieri*, but showed a steady decline of *P. dichotomiflorum* over the four sample years. Transect 10 was dominated by *L. leptocarpa* in 1996, *C. odoratus* in 1997, and *Panicum repens* in 2001 before converting to open water by 2012 (Figure 12).

The vegetative community within the reference area plots was typical of a *Spartina patens*-dominated intermediate marsh and was most similar to Transect 7 in the project area. Unlike the project area, percent cover in the reference area continued to increase through 2001 before declining in 2012. Species richness in the project area was initially twice as high as the reference area, but then decreased in 2012 as a result of the conversion of plots to open water rather than change in community within vegetated areas (Figure 13a). If total number of species is expressed in relation to the number of vegetated plots per sample year, there was actually an increase in the number of species per vegetated plot within the project area over time (Figure 13b).

Several climatic events occurred during the study period which potentially induced vegetative stress within the Bayou Sauvage marshes. Extreme drought occurred in southeastern Louisiana in 1999-2000 and in 2011 (Figure 6) causing excessive drying and oxidation of soils. Salinity was not measured within the project area during the 1999/2000 drought, but salinity measured at CRMS4107 in July 2011 reached a high of 25 ppt as evaporation occurred. By comparison, salinity at nearby CRMS3626 and CRMS3650 outside of the impoundment was less than 3 ppt during the same time period. Several major storms also impacted the project area including Hurricane Katrina in August 2005, which led to an influx of brackish water into the impounded areas. Retention of storm surge floodwaters for up to 3 weeks within the Bayou Sauvage impoundments was estimated to cause nearly 68% mortality of overstory and understory trees (Howard 2012). Differences in the plant community between the project and reference areas may explain the differing response to these events over the study period. In 1996 and 1997, 70 and 85% of the project area plots were characterized as fresh based on the species present (Figure 14), but by 2001 all plots on Transects 7 and 10 had transitioned to intermediate. The percentage of intermediate plots in the reference area, however, has ranged from 60-90% for all years sampled. The more intermediate species within the reference area may have been more resilient to salinity stressor events during the sample period.

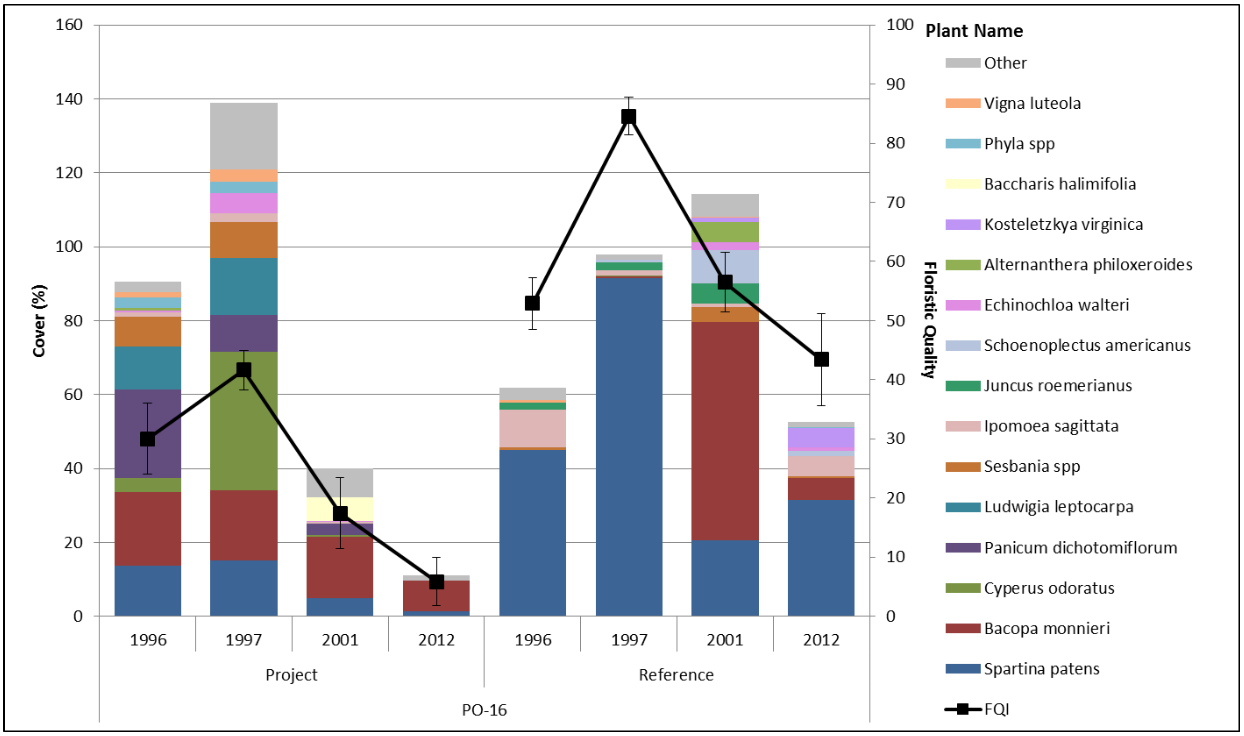

Figure 9. Mean percent cover of species within the PO-16 project and reference areas and the Floristic Quality Index (FQI) score for each year sampled.

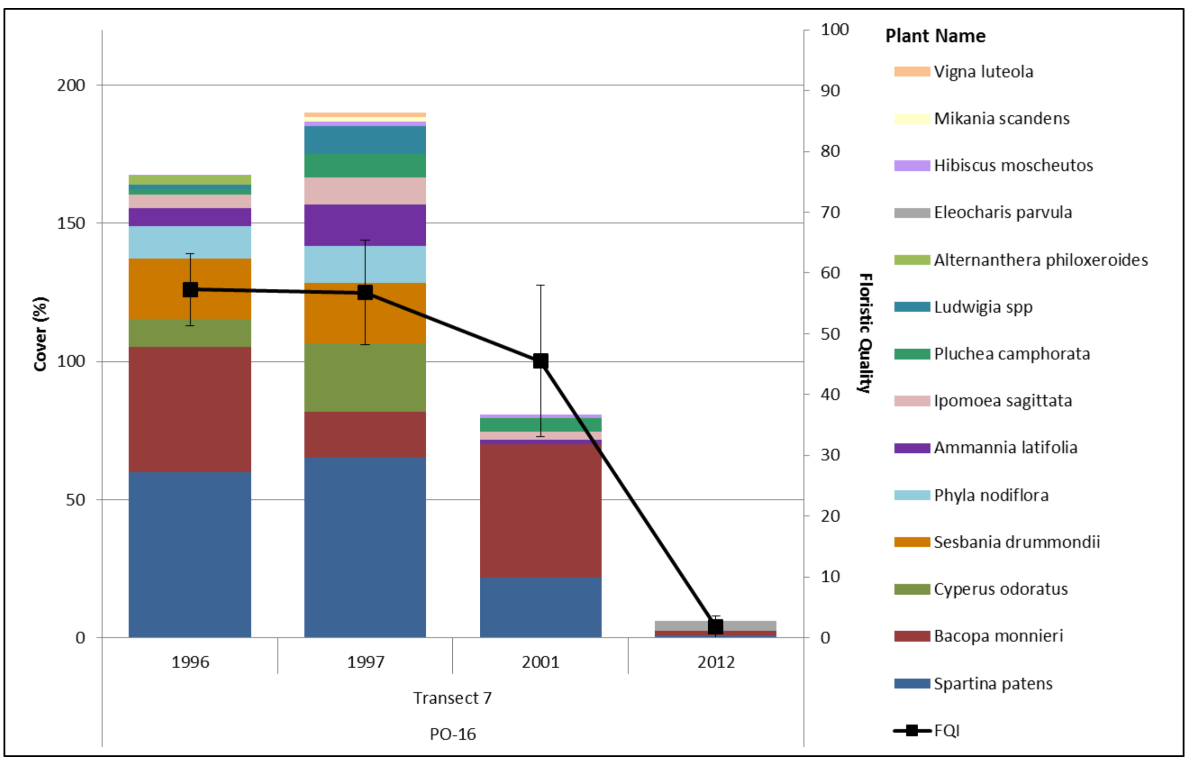

Figure 10. Mean percent cover of species along Transect 7 within the north unit of the PO-16 project area and the Floristic Quality Index (FQI) score from 1996 to 2012.

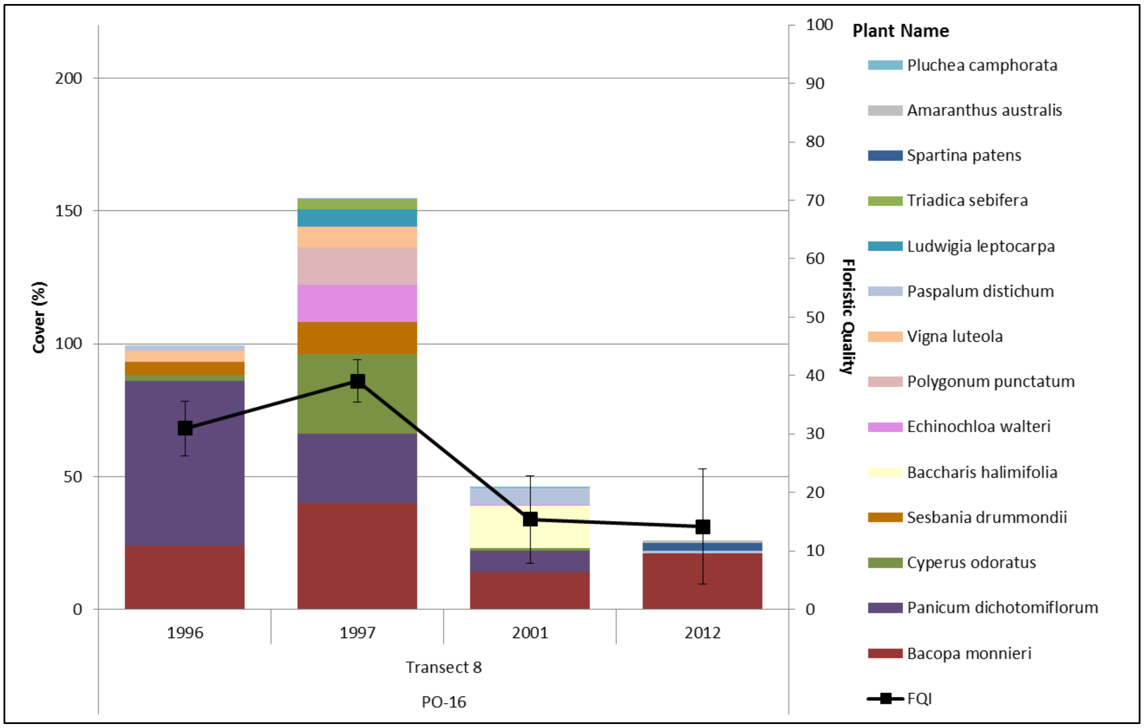

Figure 11. Mean percent cover of species along Transect 8 within the north unit of the PO-16 project area and the Floristic Quality Index (FQI) score from 1996 to 2012.

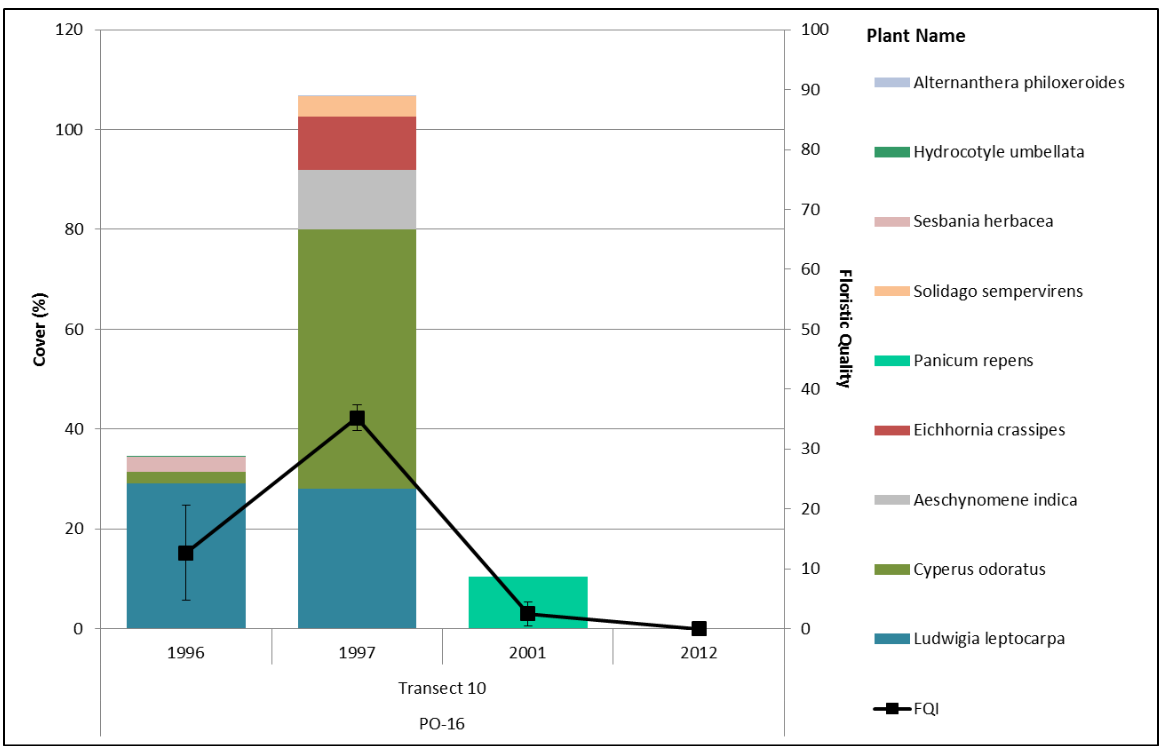

Figure 12. Mean percent cover of species along Transect 10 within the south unit of the PO-16 project area and the Floristic Quality Index (FQI) score from 1996 to 2012.

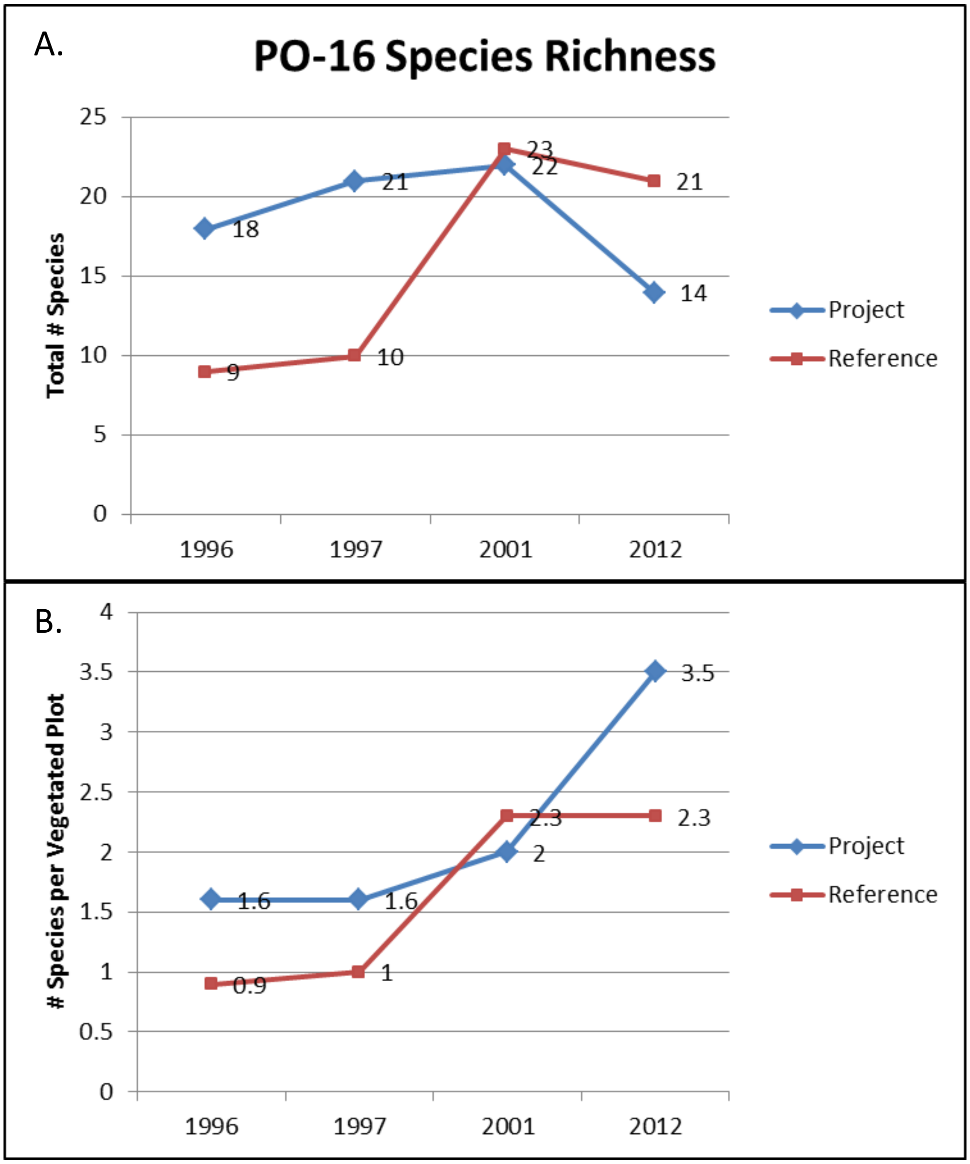

Figure 13. A) Total number of species within the PO-16 project and reference areas over time. ; B) Number of species per vegetated plot within the PO-16 project and reference areas over time.

Vegetation sampled annually at CRMS4107 (Figure 4) from 2007 to present indicates that areas of stable, intermediate marsh remain within the PO-16 North Unit. The vegetative community at CRMS4107 is highly dominated by *S. patens* with a mean total cover of *S. patens* ranging from 47 to 94% (Figure 15). One tool that has been used to assess the quality of the vegetation community at the CRMS sites is the Floristic Quality Index (FQI) (Cretini et al. 2011). The FQI score is calculated by assigning each species a CC score, or coefficient of conservatism, which is scaled from 1 to 10 and reflects a species' tolerance to disturbance and habitat specificity. The modified FQI equation for Louisiana's wetland plant species takes into account not only the CC scores, but also the percent covers of species at a site, and the resulting FQI score is scaled from 0 to 100. FQI scores greater than 71 are classified as 'good', less than 39 are 'poor', and between 39 and 71 are considered 'fair'. Mean FQI at CRMS4107 from 2007 to 2015 was 65, and ranged from 42 in 2012 (post-drought) to 84 in 2014. Although considered 'fair', the FQI at CRMS4107 in 2015 was higher than the mean FQI for all intermediate CRMS sites and for all CRMS sites within the Pontchartrain basin indicating that the vegetation community at CRMS4107 is relatively robust and stable (Figure 16).

Mean FQI scores were calculated for the PO-16 project and reference areas for each of the sampling years (Figures 9-12). FQI scores were generally higher for the reference area plots due to the high occurrence of *S. patens* which has a high CC score of 9. However, FQI scores were still below the ideal range of 80-100 for fresh/intermediate marsh in all years except in 1997 within the reference area. The presence of fresher species, some of which are associated with disturbance and therefore have lower CC scores, resulted in a lower FQI within the PO-16 project area plots. FQI in the project area reached a high of 42 in 1997, but then dropped sharply in 2001 and 2012 due to the loss of vegetative cover and the eventual conversion of most plots to open water.

Together, the vegetation sampling conducted at the PO-16 plots and the CRMS4107 plots demonstrate that although there are areas of robust marsh within the PO-16 project area, current land loss trends threaten the marsh community. The 42% loss of land acreage observed through the aerial land/water analysis was reflected in the conversion of most PO-16 plots to open water. While the PO-16 plots were established in 1996, the CRMS4107 plots were established more recently (2006) in intermediate marsh that for now appears to be stable and healthy. The high percentage of *S. patens* at CRMS4107 may continue to provide some resilience to future high salinity events and the plots at CRMS4107 will continue to be sampled annually to monitor the ongoing condition of the marsh community.

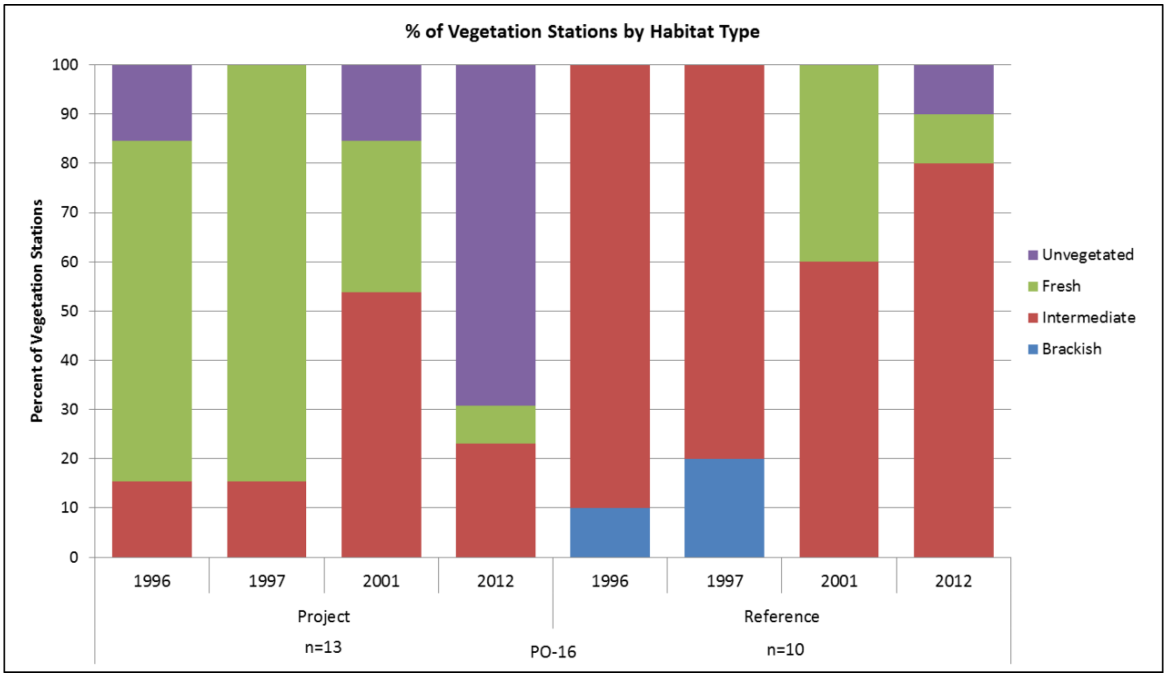

Figure 14. Percent of vegetation stations by habitat type as determined by species present in the PO-16 project and reference areas from 1996 to 2012.

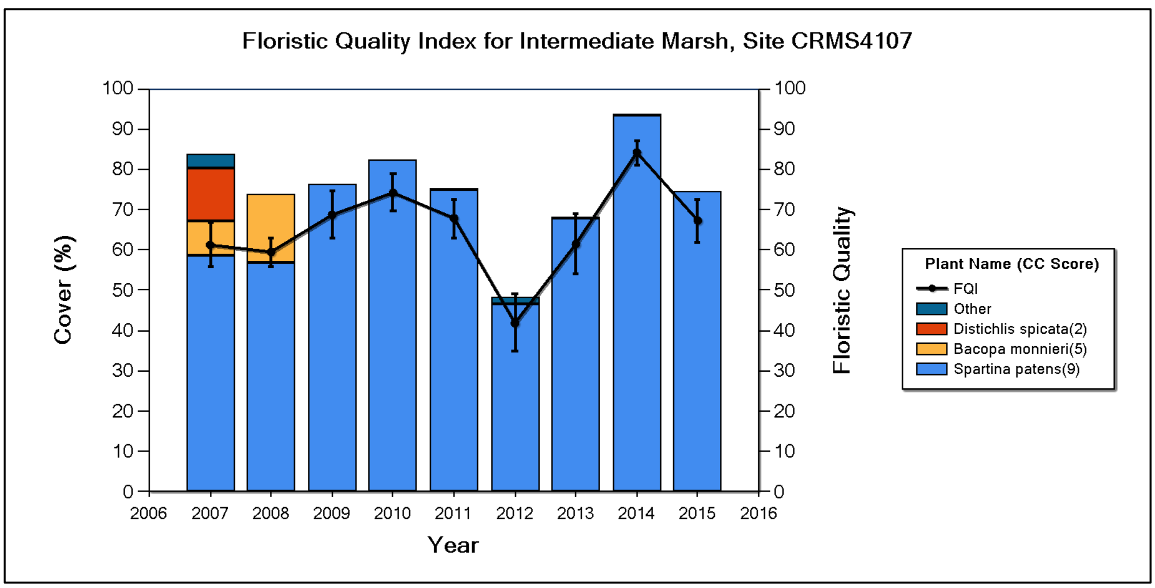

Figure 15. Mean percent cover of species and the Floristic Quality Index (FQI) score at CRMS4107 within the north unit of the PO-16 project area from 2007 to 2015.

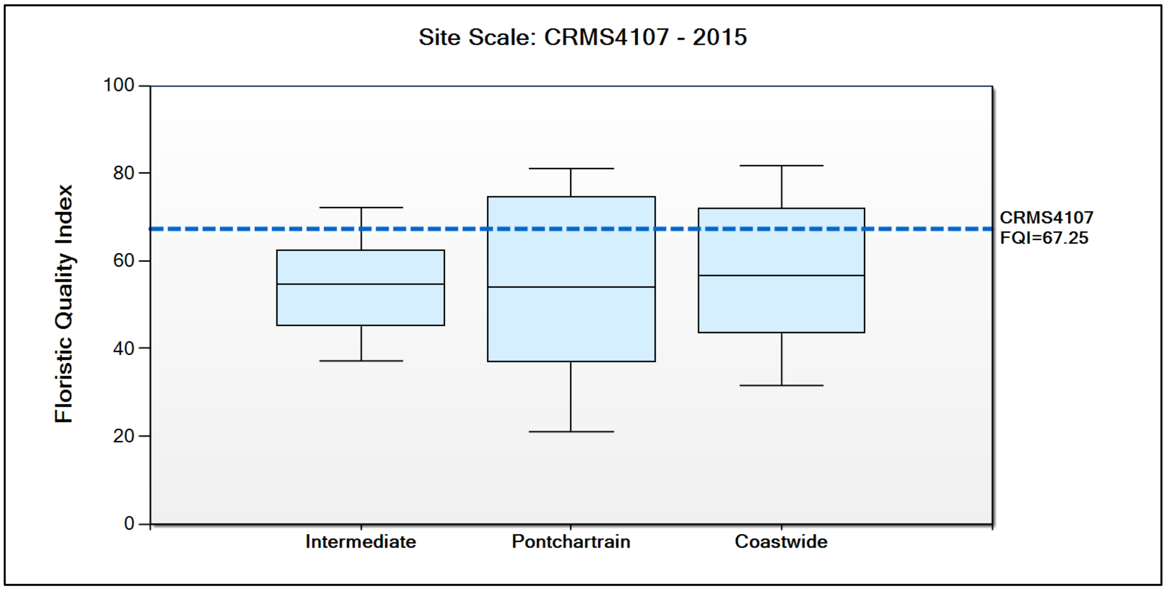

Figure 16. Floristic Quality Index (FQI) of CRMS4107 in 2015 compared to mean FQI of CRMS sites at multiple spatial scales. From left to right, box plots represent mean FQI of CRMS sites within the intermediate marsh type, within the Pontchartrain basin, and coastwide.

iii. <u>Marsh Inundation</u>

Water level and operations data are essential in determining whether the PO-16 project has successfully met the target inundation levels stated in the project goals, which were to lower water levels within -0.5 ft to 0.0 ft of marsh sediment elevation in the spring and summer and within +0.5 ft of marsh sediment elevation in the fall and winter. During the staff gauge data collection period from 1997—2004, problems were encountered with data quality issues and frequency of staff gauge readings. Annual data completeness of staff gauge readings was acceptable from 1997-1999 at 92% or greater and several meetings were held between then-LDNR and USFWS to address data quality. From 2000 to 2004, however, annual data completeness ranged from 15% to 73%. The lack of pump operation records during the period of staff gauge data collection also hinders the evaluation of the project. Operations data were only provided for two periods: 1) April 1996 to March 1998 and 2) October 2009 to April 2010 (Table 1), although it is known that the pumps were offline for two extended periods: 1) August 2005 to August 2006 following Hurricane Katrina and 2) October 2010 to April 2015 for USACE levee enlargement.

Additional problems were encountered with the initial survey of the project and reference area staff gauges to NAVD (ft), which was determined to be suspect. Weekly gauge readings began in February 1997 but a follow-up survey to correct the gauges did not occur until October 2003 (John Chance Land Surveys 2004). A correction factor was provided by the surveyor for the existing gauges, which was used to correct the 1997-2003 data. PO16-01 and PO16-05, located in the North and South Units respectively (Figure 4), were both knocked over prior to the 2003 survey and therefore those data could not be back-corrected. PO16-04 showed a suspiciously high correction factor of 1.44 ft at the time of the 2003 survey. It appears that this gauge was compromised sometime prior to June 2001 because the application of the correction factor prior to that date causes the data to diverge significantly from the other sites. The data collected at PO16-04 past June 2001, however, is shown to not be significantly different from PO16-03, also located in the South Unit (matched pairs t-test, $p=0.76$). Due to the issues with these three sites (PO16-01, PO16-04, and PO16-05), the analysis will focus only on PO16-02 in the North Unit and PO16-03 in the South Unit.

Mean marsh elevation was surveyed in 2003 along transects in the North Unit, South Unit, and Reference Area, and was calculated by averaging all points described by the surveyor as 'Vegetated Marsh'. The North Unit and Reference Area had similar mean marsh elevations of -0.20 ft NAVD and -0.16 ft NAVD, respectively. All points along the two South Unit transects were described by the surveyor as either 'Sub Mud Flat' or 'Sub Pond Bottom' and showed a mean elevation of -1.43 ft NAVD; therefore, the North Unit marsh elevation was used for inundation calculations for both units. A 2007 survey of mean marsh elevation at CRMS4107 in the North Unit showed a 0.59 ft higher marsh elevation of 0.39 ft NAVD, and the most recent survey in 2014 showed a mean marsh elevation of 0.43 ft NAVD (Geoid99). The higher marsh elevation observed at CRMS4107 may be due to localized elevation variation and also due to differences in the CRMS survey methodology in which points are taken at both the vegetative crown height and sediment surface height. Because the 2003 survey transects represented the overall project area and because the goal of the project was to bring water levels down to sediment level for purposes of seed germination, the 2003 elevation of -0.20 ft was used for inundation calculations.

Mean seasonal inundation was calculated from the weekly gauge readings for the North Unit (PO16-02), South Unit (PO16-03), and reference area (Figure 17). The shaded area in Figure 17 represents the target area of -0.5 – 0 ft inundation in the spring/summer and 0 – 0.5 ft inundation in fall/winter relative to a marsh elevation of -0.20 ft NAVD. Inundation was not calculated for seasons with less than three weekly readings. Trends in seasonal inundation were similar between the project and reference areas. A comparison of the weekly gauge readings using the matched pairs t-test (JMP 11.0.0) showed that there was no significant difference in inundation between the North and South Units (PO16-02 and PO16-03) and no significant difference between the project stations and the two reference stations PO16-11R and PO16-12R (Table 3a). PO16-13R was significantly different from all other stations.

Operations data show that the pumps were run regularly from April 1996 to March 1998 for the durations presented in Table 1. A matched pairs t-test limited to this known operations period shows that water levels were significantly lower in the

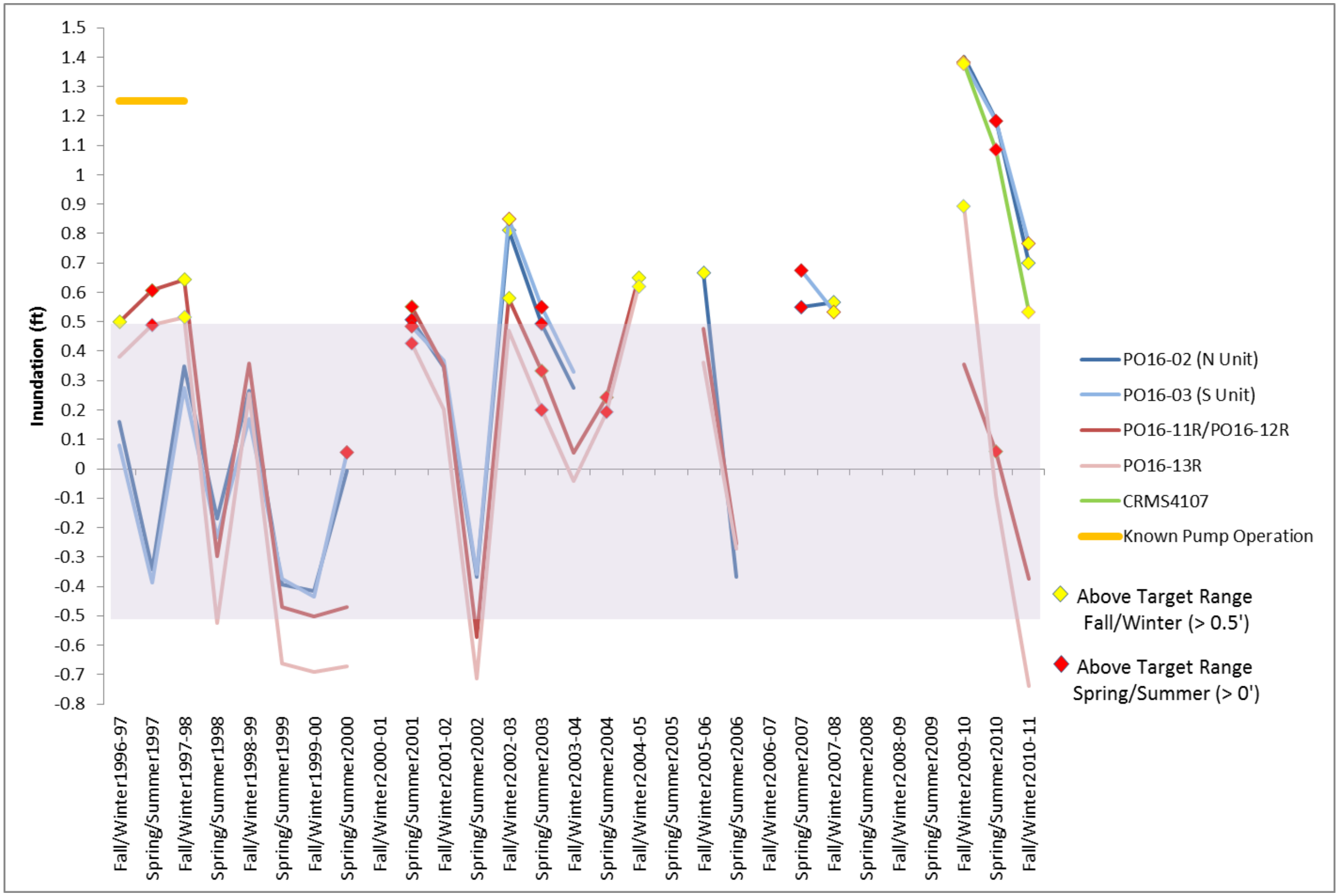

Figure 17. Mean seasonal inundation within the North Unit (PO16-02), South Unit (PO16-03), and reference area of the Bayou Sauvage NWR Hydrologic Restoration project, Phase 1 (PO-16) based on weekly gauge readings. The shaded area represents the target inundation of -0.5 – 0 ft in the spring/summer and 0 – 0.5 ft in the fall/winter relative to a marsh elevation of -0.20 ft NAVD.

project area than in the reference area (Table 3b). During this period of pump operation, precipitation during the Fall/Winter season of 1997-98 was the second highest recorded (47 inches) at the Lakefront Airport from 1993 to present (Figure 6), and it appears that the pumps were successful in lowering water levels during this time by over half a foot. Following this early successful period of operation, it is unknown how often the pumps were operated except for periods where the pumps were known to be offline. Within the project area there were 5 spring/summer seasons and 5 fall/winter seasons identified where the mean inundation was above target range and presumably could have triggered pump operation. Two of these seasons occurred during offline periods. The percentage of weeks relative to the inundation target was calculated from an average of inundation at the two project sites and the three reference sites (Figure 18). Although there was a high percentage of missing data since 2001, the staff gauge readings were normally collected at project and reference gauges on the same day. During the early period of known operation from 1997 to 1999, the percentage of weeks above target level was higher in the reference area than in the project area. However, in 8 out of the following 11 spring/summer seasons with available data, the % of weeks above target level (inundation>0) was higher in the project area. The % of weeks above target level in the project area was also higher than the reference area in 9 out of 10 fall/winter seasons from 2001 to 2014.

Table 3. Results of Matched Pairs t-test comparisons of weekly gauge data between PO-16 project and reference stations. The p-values in red indicate significantly different results ($p<0.05$).

Matched Pairs t-test Results--*p* values

a) All Weekly Gauge Data, 1996-2014 (n=262)

	PO16-02	PO16-03	PO16-11R	PO16-12R	PO16-13R
PO16-02		1.00	0.55	0.65	0.0002*
PO16-03			0.57	0.66	0.0003*
PO16-11R				0.42	<.0001
PO16-12R					<.0001
PO16-13R					

b) Known Operation Period Only, Spring 1996-Winter1998 (n=54)

	PO16-02	PO16-03	PO16-11R	PO16-12R	PO16-13R
PO16-02		0.02*	<.0001	<.0001	<.0001
PO16-03			<.0001	<.0001	<.0001
PO16-11R				0.74	<.0001
PO16-12R					<.0001
PO16-13R					

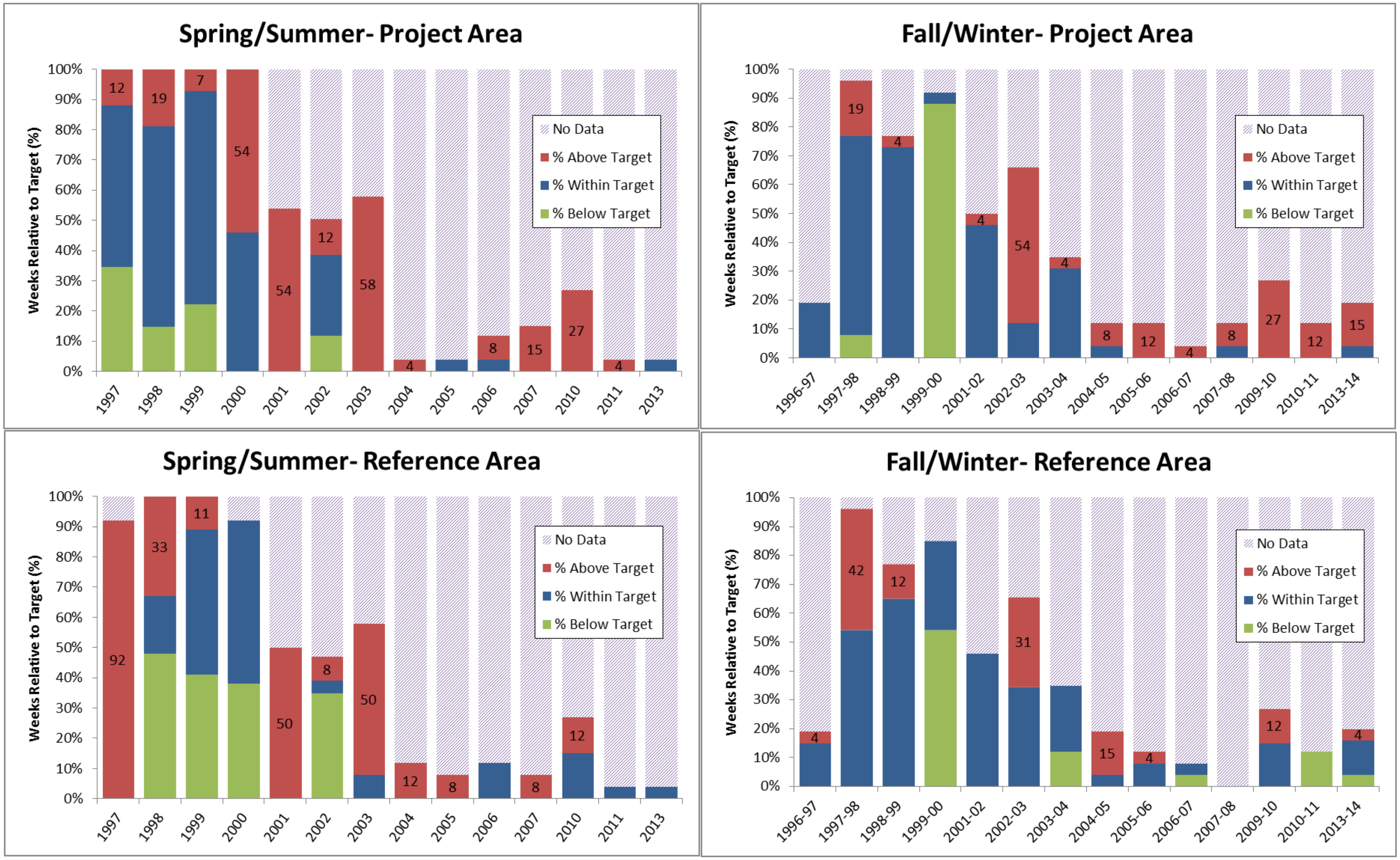

Figure 18. The percentage of weeks relative to the inundation target (within -0.5 to 0 ft in spring/summer and within 0 to 0.5 ft in fall/winter) within the PO-16 project and reference areas relative to a marsh elevation of -0.2 ft.

Water level has been sampled continuously at CRMS4107 since November 2007; however the pumps were not operational for 4.5 years (fall 2010 to spring 2015) during that period due to the USACE levee enlargement (Figure 19). The marsh was flooded approximately 62% of the time relative to the CRMS4107 mean marsh elevation and 89% of the time relative to the PO-16 mean marsh elevation. Inundation was above the seasonal target level 45% of the time relative to the CRMS4107 marsh elevation of 0.39 ft. During only the periods where the pumps were operational, inundation was above the seasonal target level 60% of the time. The operations activity conducted in the fall/winter season of 2009 (Figure 19) appear to be associated with maintenance activities (addition of fuel conditioner). The fall/winter season of 2009 was a period of relatively high precipitation (Figure 6) and the CRMS4107 water level was still above the fall/winter target level (>0.5 inundation) when the pumps were turned off in January 2010 (relative to CRMS4107 or PO-16 marsh elevation).

Trends in soil elevation data at several CRMS sites within the Bayou Sauvage NWR indicate that marshes within the PO-16 impoundment may be increasingly vulnerable to submergence in the future. Over five years of RSET (rod-surface elevation table) and accretion data were used to calculate elevation trends at CRMS4107 and at three unimpounded sites (CRMS0002, CRMS3626, CRMS3650) within the Bayou Sauvage NWR. Data show that accretion rates are nearly double at sites outside of the impoundment (Figure 20). RSET measurements at the three unimpounded sites also showed positive elevation change rates of 0.4-0.5 cm/yr, while CRMS4107 had a negative elevation change rate of -0.71 cm/yr. Proper management and operation of the PO-16 pumps may be increasingly critical for the health of the PO-16 marsh community if these trends continue. In summary, it appears that although there was some success in lowering water levels through PO-16 pump operation early in the project life, inundation in the project area was above target range more often than the reference area in a majority of seasons where data are available. In addition to the pumps being offline for approximately 28% of the project life, it appears that there were several seasons where pump operation could potentially have occurred to reduce water levels within the project area.

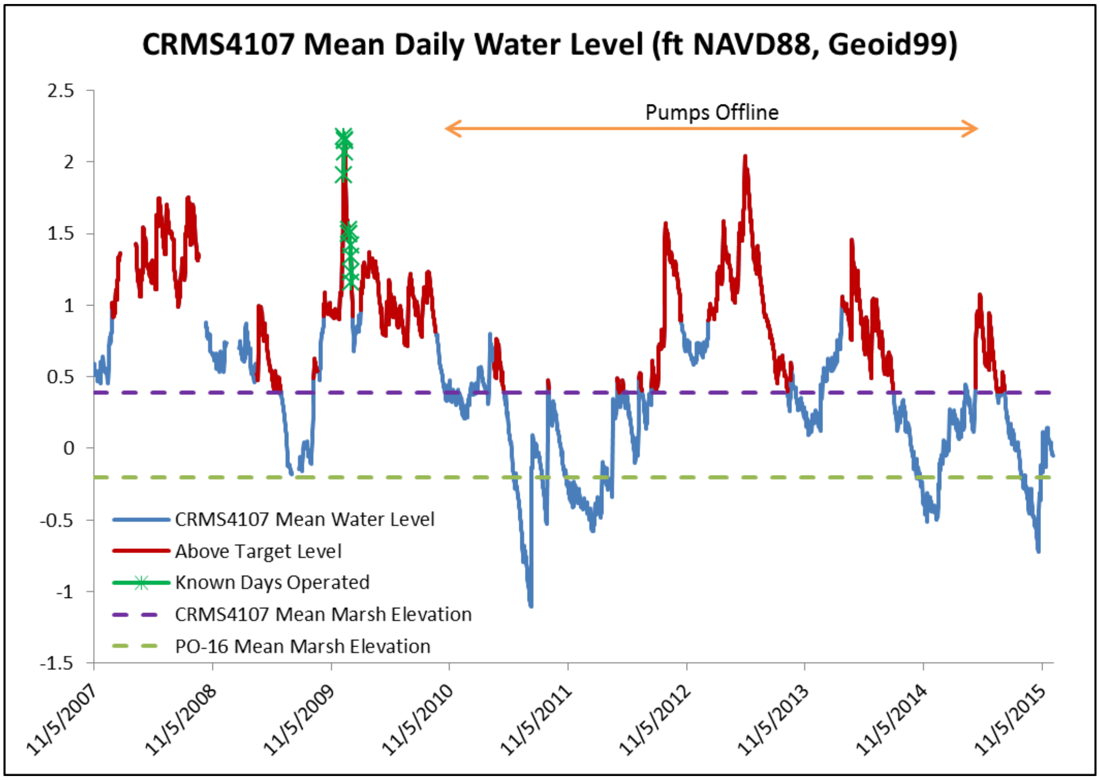

Figure 19. Mean daily water level at CRMS4107 from November 2007 to December 2015 relative to CRMS4107 marsh elevation (0.39 ft) and overall PO-16 marsh elevation (-0.20 ft). Mean water level above target inundation level (in red) is relative to the CRMS4107 mean marsh elevation.

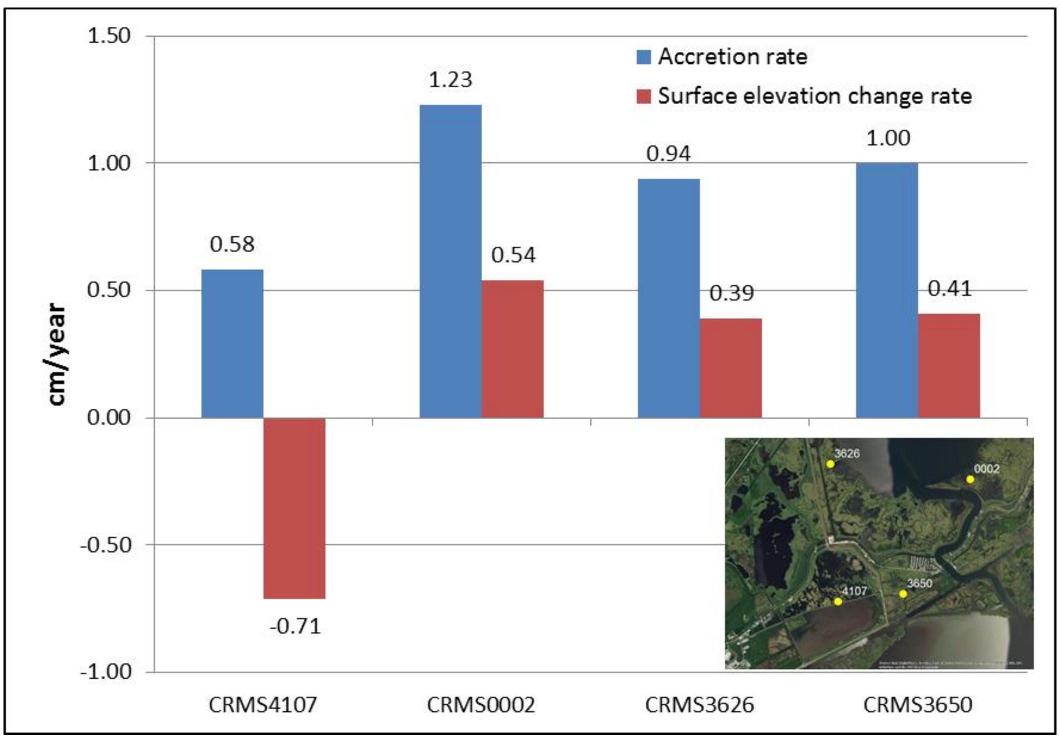

Figure 20. Long-term accretion and surface elevation change rates (cm/yr) at four CRMS sites within the Bayou Sauvage NWR. CRMS4107 is the only impounded site.

V. Conclusions

a. Project Effectiveness

The ability to measure the effectiveness of the PO-16 project was compromised by a lack of operations data for much of the project life. Changes in monitoring variables were evaluated over time, but those changes cannot be definitively attributed to project operations, or lack thereof. The first project goal, to promote the reestablishment of emergent marsh vegetation, was not met during the project life. Total percent cover of vegetation within the project area increased from 1996 to 1997, but then showed a sharp decline in 2001 and 2012. By 2012, only four plots contained live vegetation. A decline was also observed in the reference area but was less pronounced. Vegetation sampled at CRMS4107 within the North Unit indicates that areas of stable, intermediate marsh remain within the PO-16 project area; however, the remaining marsh is threatened by a high land loss rate and negative elevation change rate within the project area. From 1993 to 2012, 42% of the land acreage was lost within the project area (32 ac/yr) while only 1% was lost within the reference area.

Based on the available staff gauge and operations data, it does not appear that water levels were consistently lowered within the impounded areas to -0.5 ft to 0.0 ft of marsh sediment elevation in the spring and summer and to within +0.5 ft of marsh sediment elevation throughout the PO-16 project life. A two year period of operation early in the project life showed that the pumps were successful in reducing water levels compared to the reference area following a period of high precipitation. However, in the years that followed the percentage of weeks above the target inundation level was more often higher in the project area than the reference area. Water level measured continuously at CRMS4107 showed that water level was above target level 60% of the time during the period that the pumps were known to be potentially operational. This was relative to the CRMS4107 site-specific marsh elevation which is higher than the general PO-16 marsh elevation. An analysis of long term trends in soil surface elevation at CRMS sites within the Bayou Sauvage NWR showed that soil surface elevation is decreasing within the impoundment and increasing outside the impoundment; therefore, flooding potential is expected to increase over time within the impoundment.

b. Recommended Improvements

The following action items are recommended to improve the future operation of the PO-16 pumps:

1) Marsh Elevation/ Staff Gauge Survey – An updated survey of average marsh elevation of the PO-16 project area and PO-16 staff gauges is recommended. Average marsh elevation at CRMS4107 was most recently surveyed in 2014 but may not be representative of the entire project area based on earlier marsh elevation surveys. The CRMS4107 gauge is now set at NAVD ft, Geoid12A and other gauges should be updated to the current geoid. Based on the consistency of

water levels readings between gauges, only two gauges should be necessary (one in each unit).

2) Define Water Level Trigger — Based on the updated marsh elevation, a target water level reading should be defined that would trigger pump operation in the spring/summer and fall/winter seasons. Until an updated survey can be conducted, results from the recent survey of CRMS4107 should be used. Marsh elevation was determined to be 0.01 ft NAVD (Geoid12A)/0.43 ft NAVD (Geoid99). Pumps should be operated in fall/winter when water level is above 0.93 ft NAVD (Geoid99) and in spring/summer when water level is above 0.43 ft NAVD (Geoid99). The target should be re-evaluated every 3-5 years due to surface elevation changes within the project area over time.

3) Documentation of Operations — A detailed log should be kept of all operations activity including the water level at the beginning and end of each operation period.

Based on the rate of land loss and negative elevation change within the PO-16 project area, more direct restoration efforts such as dedicated dredging of sediments would be recommended for this area in the future, particularly in the South Unit.

c. Lessons Learned

Evaluation of the PO-16 project was hindered by lack of operations records which should have been addressed early on through increased communication between the USFWS and CPRA. Target inundation levels consistent with the PO-16 project goals are listed in the Habitat Management Plan for the Bayou Sauvage NWR (USFWS 2013) but it is unknown how often the pumps were operated to achieve these targets. Greater collaboration between the USFWS and the CPRA regarding specific target water levels being used to trigger pump operations may have improved management of pump operations.

VI. References

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Appendix A
(Inspection Photographs)

PHOTO 1: Trash Rake

PHOTO 2: Pump 5

PHOTO 3: Pump 5

Appendix B
(Field Inspection Notes)

FIELD INSPECTION CHECK SHEET

Project No. / Name: Bayou Sauvage Refuge - Phase 1 (PO-16)

Date of Inspection: 4/23/2014 Time: 11:00 AM

Structure No. **Pump No. 5**

Inspector(s): LDNR: Richard, Hymel
USFWS: Harris, Lalonde

Structure Description: Pump Platform

Water Level: Normal Outside: Normal

Type of Inspection: Annual

Weather Conditions: Clear skies, mild

Item	Condition	Pysical Damage	Corrosion	Photo #	Observations and Remarks
Platform	Good	None	Light		
Trash rack	Good	N/A	N/A		
Fuel Tank	Good	None	Some		
Pump Drive Engine	Good	None	Light		
Pump Gear Box	Good	None	Some		
Piping	Good	None	None observed		
Lake Pont. Inlet System	Good	None	None observed		

FIELD INSPECTION CHECK SHEET

Project No. / Name:	PO-16 Bayou Sauvage Refuge	Date of Inspection:	4/23/2014	Time:	11:00 AM
Structure No.	**Pump No. 6**	Inspector(s):	LDNR: Richard, Hymel USFWS: Harris, Lalonde		
Structure Description:	Pump Station	Water Level:	Normal	Outside:	Normal
Type of Inspection:	Annual	Weather Conditions:	Clear skies, mild		

Item	Condition	Pysical Damage	Corrosion	Photo #	Observations and Remarks
Pump Platform	Good	None	None		
Trash Rack	Good	None	N/A		
Fuel tank	Good	None	Some		
Pump Drive Engine	Good	None	Some		
Pump gear box	Good	None	Some		
Piping	Good	None	None		

Appendix C
(Three Year O&M Budget Projection)

Bayou Sauvage Refuge Wetland Restoration Phase I (PO-16)

Federal Sponsor: USFWS

Construction Completed : May, 1996

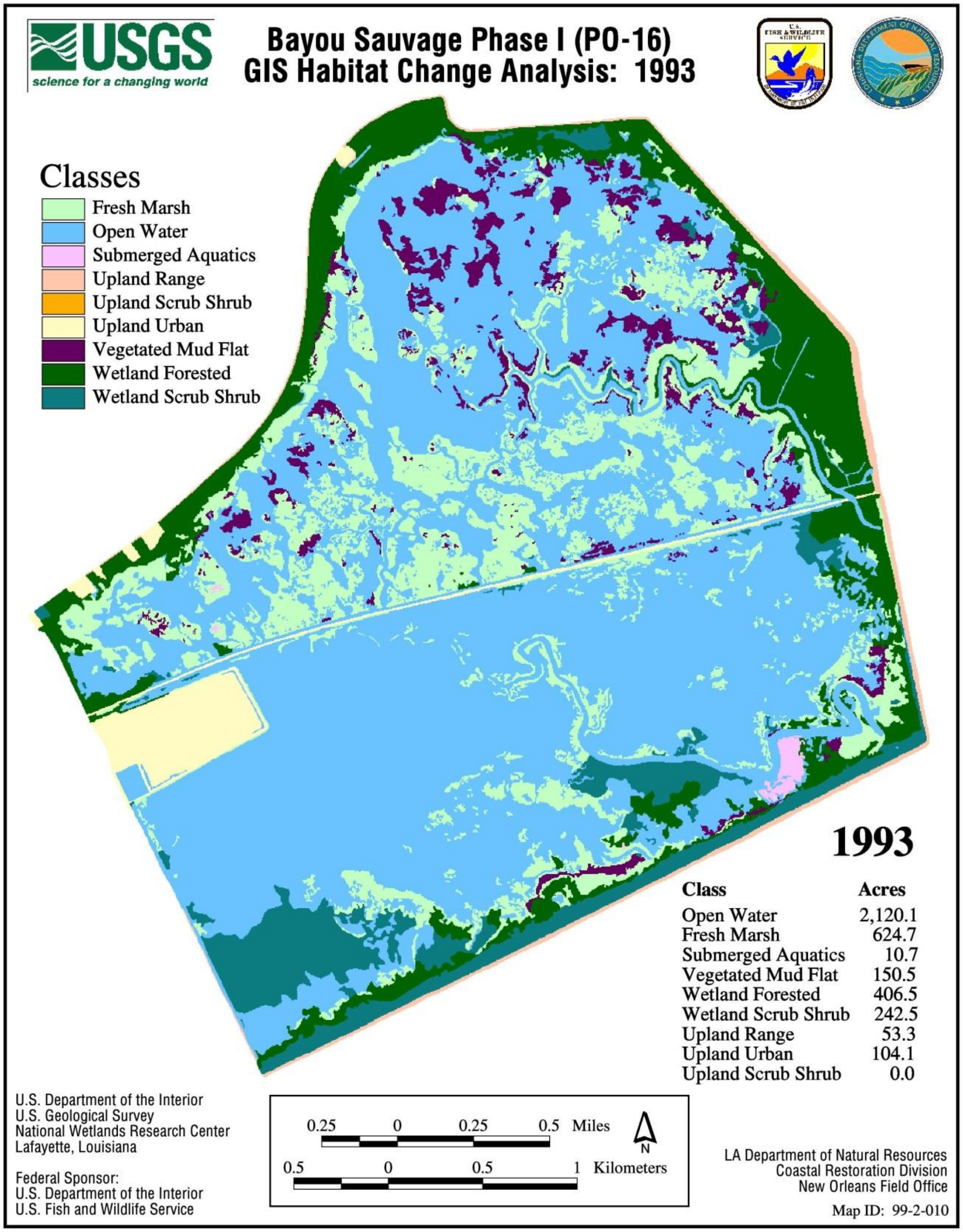
PPL 1

Current Approved O&M Budget	Year 0	Year - 1	Year -2	Year -3	Year -4	Year -5	Year -6	Year -7	Year -8	Year -9	Year -10	Year -11	Year -12	Year -13	Year -14	Year -15	Year -16	Year - 17	Year -18	Year -19	Year -20	Year -21	Year -22	Year -23	Year -24	Year -25	Project Life	Currently
January, 2005	FY97	FY98	FY99	FY00	FY01	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	FY22	Budget	Funded
State O&M																											$294,364	$294,364
Corps Admin																											$0	$0
Federal S&A																											$0	$0
Total																											$294,364	$294,364

																											Remaining	Current 3 year
Projected O&M Expenditures																											Project Life	Request
Maintenance Inspection									$3,174.00	$3,257.00	$3,341.00	$3,426.00	$3,517.00	$3,609.00	$3,702.00	$3,799.00	$3,897.00	$3,999.00	$4,103.00	$4,209.00	$4,209.00	$4,209.00	$4,209.00	$4,209.00	$4,209.00	$4,209.00	$25,254	$12,627
General Operations and Maintenance									$13,245.00	$13,589.00	$13,942.00	$14,305.00	$14,677.00	$15,058.00	$15,450.00	$15,851.00	$16,264.00	$16,686.00	$17,121.00	$17,568.00	$17,568.00	$17,568.00	$17,568.00	$17,568.00	$17,568.00	$17,568.00	$105,408	$52,704
Surveys																											$0	$0
Sign Replacement																											$0	$0
Federal S&A																											$0	$0
Maintenance/Rehabilitation																											$0	$0
E&D																											$0	$0
Construction																											$0	$0
Construction Oversight																											$0	$0
Total					$0	$0	$0	$0	$16,419	$16,846	$17,283	$17,731	$18,194	$18,667	$19,152	$19,650	$20,161	$20,685	$21,224	$21,777	$21,777	$21,777	$21,777	$21,777	$21,777	$21,777	$130,662	$65,331

O&M Expenditures from COE Report	$124,276	Current O&M Budget less COE Admin	$294,364	Current Project Life Budget less COE Admin	$294,364
State O&M Expenditures not submitted for in-kind credit	$0	Remaining Available O&M Budget	$170,088	Total Projected Project Life Budget	$254,938
Federal Sponsor MIPRs (if applicable)	$0	**Incremental Funding Request Amount FY12-FY14**	**-$104,757**	**Project Life Budget Request Amount**	**-$39,426**
Total Estimated O&M Expenditures (as of April 2010)	$124,276				

Appendix D
(Aerial Photography Analyses)



Habitat data were derived from 1:12,000 scale color-infrared photography. Preconstruction photography was obtained November 7, 1993. Classes are based on "Classification of Wetlands and Deepwater Habitats of the United States," Cowardin et. al. 1979, as modified for National Wetland Inventory Mapping Conventions.

Figure D-1. 1993 habitat analysis of the Bayou Sauvage NWR Hydrologic Restoration, Phase 1 (PO-16) project area.

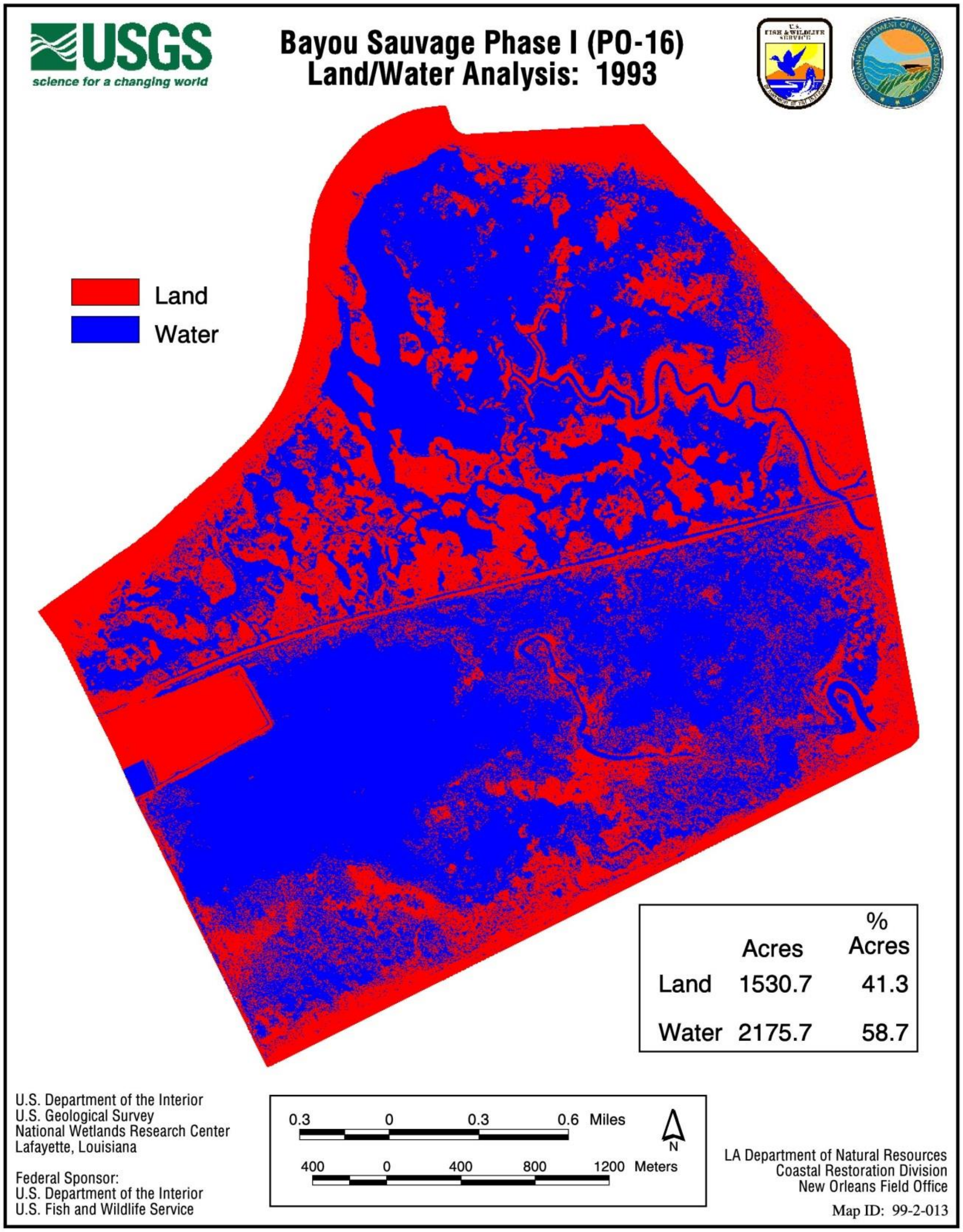
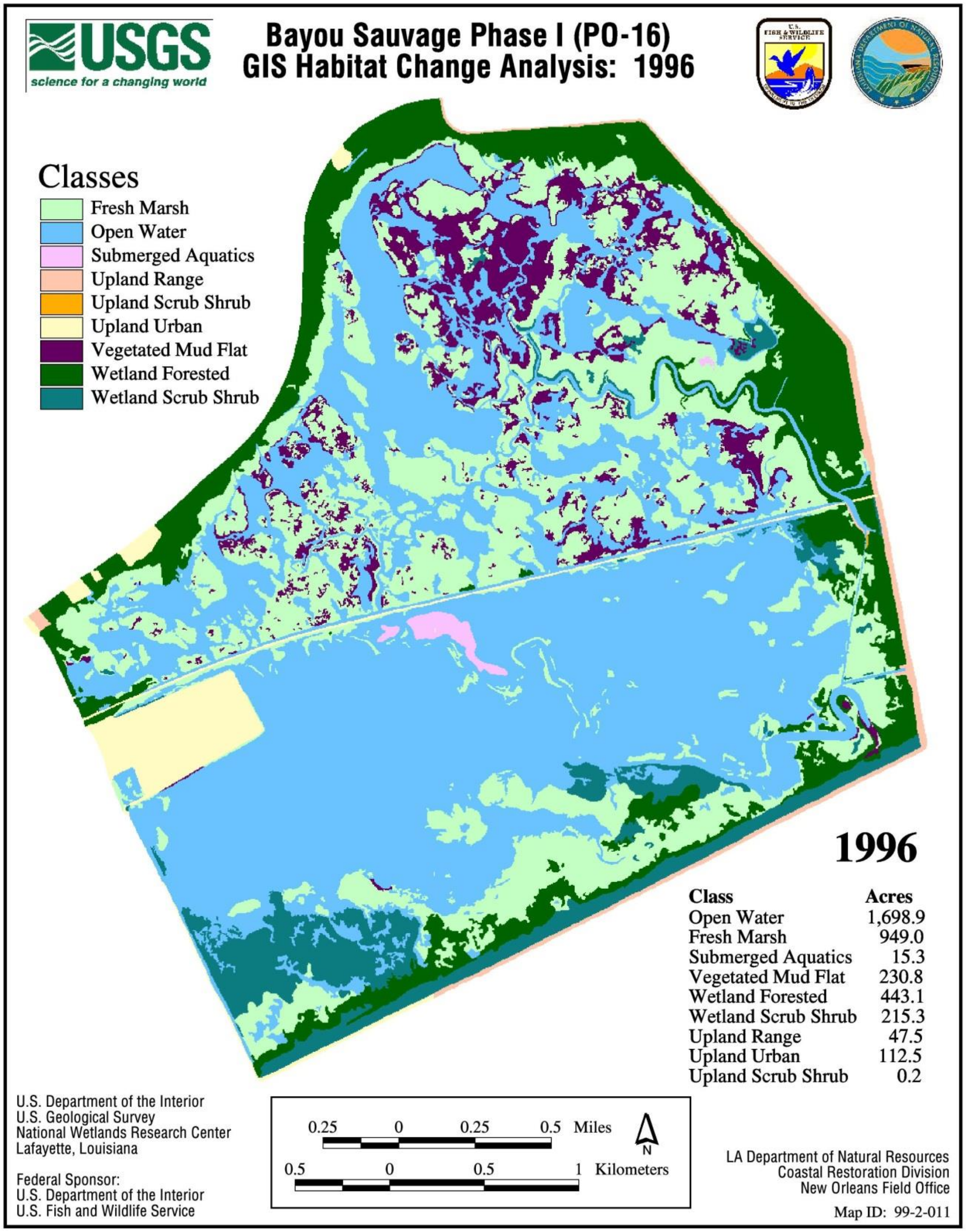


Figure D-2. 1993 land/water analysis of the Bayou Sauvage NWR Hydrologic Restoration, Phase 1 (PO-16) project area.



Habitat data were derived from 1:12,000 scale color-infrared photography. Postconstruction photography was obtained December 20, 1996. Classes are based on "Classification of Wetlands and Deepwater Habitats of the United States," Cowardin et. al. 1979, as modified for National Wetland Inventory Mapping Conventions.

Figure D-3. 1996 habitat analysis of the Bayou Sauvage NWR Hydrologic Restoration, Phase 1 (PO-16) project area.

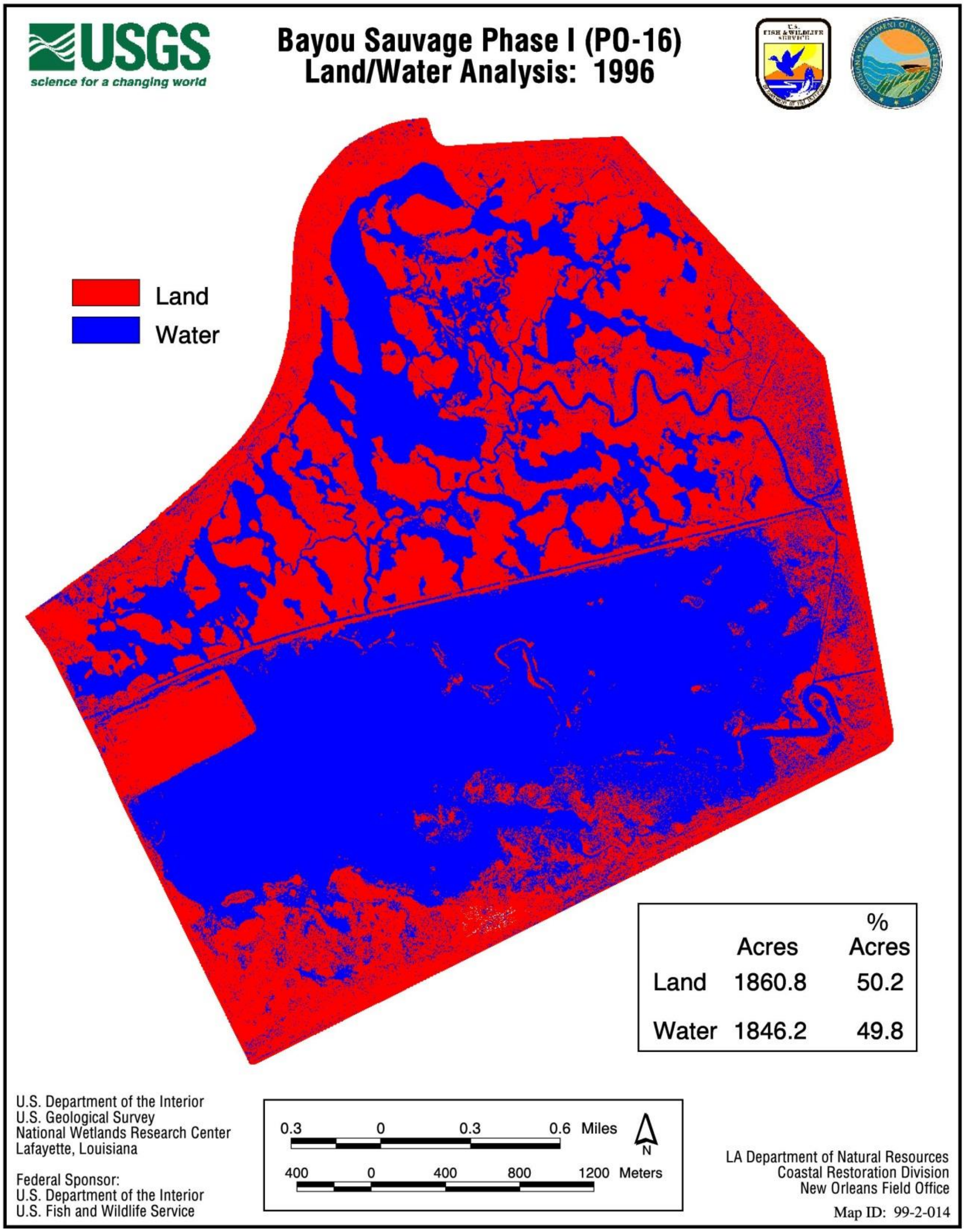


Figure D-4. 1996 land/water analysis of the Bayou Sauvage NWR Hydrologic Restoration, Phase 1 (PO-16) project area.

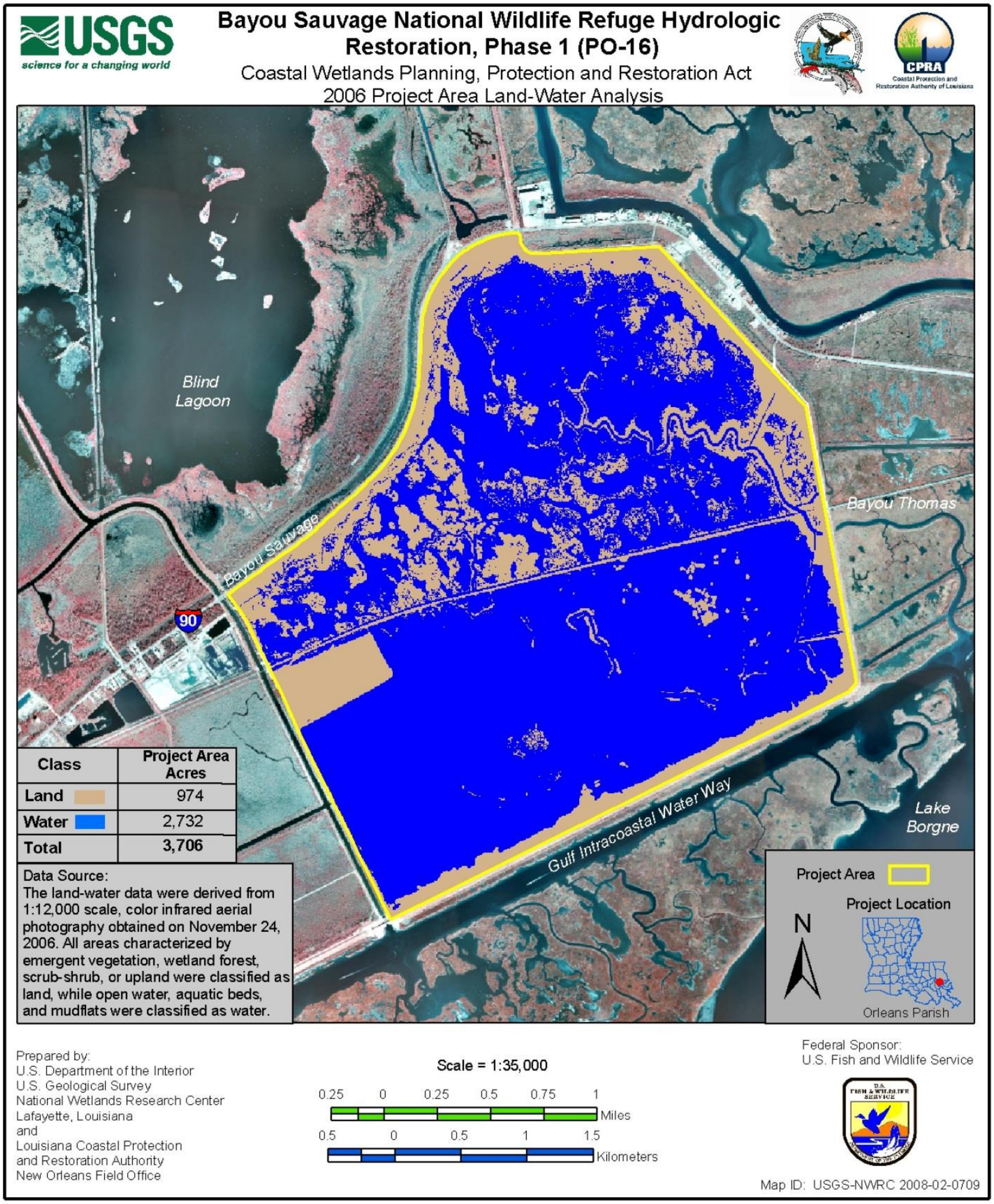


Figure D-5. 2006 land/water analysis of the Bayou Sauvage NWR Hydrologic Restoration, Phase 1 (PO-16) project area.

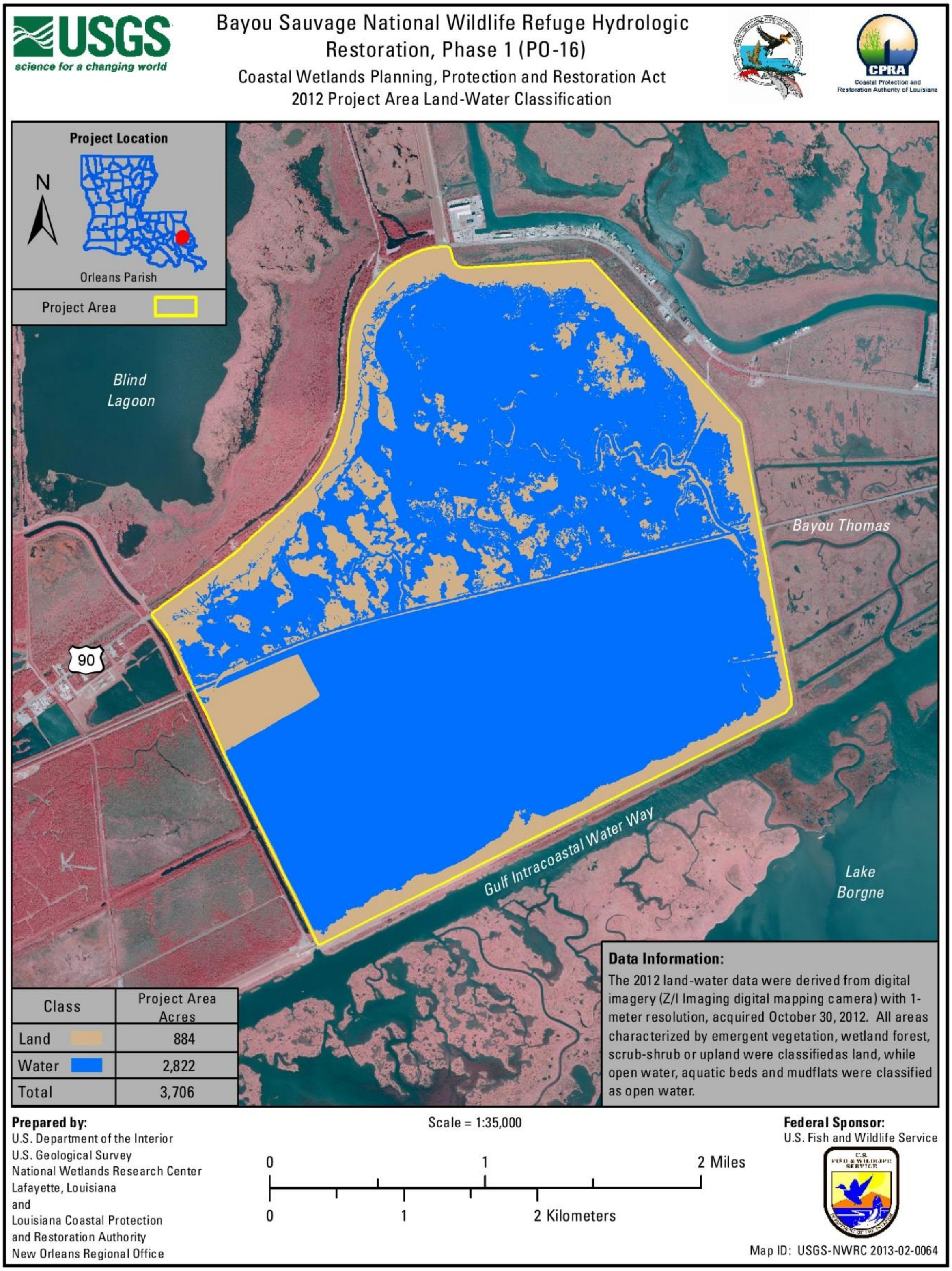


Figure D-6. 2012 land/water analysis of the Bayou Sauvage NWR Hydrologic Restoration, Phase 1 (PO-16) project area.

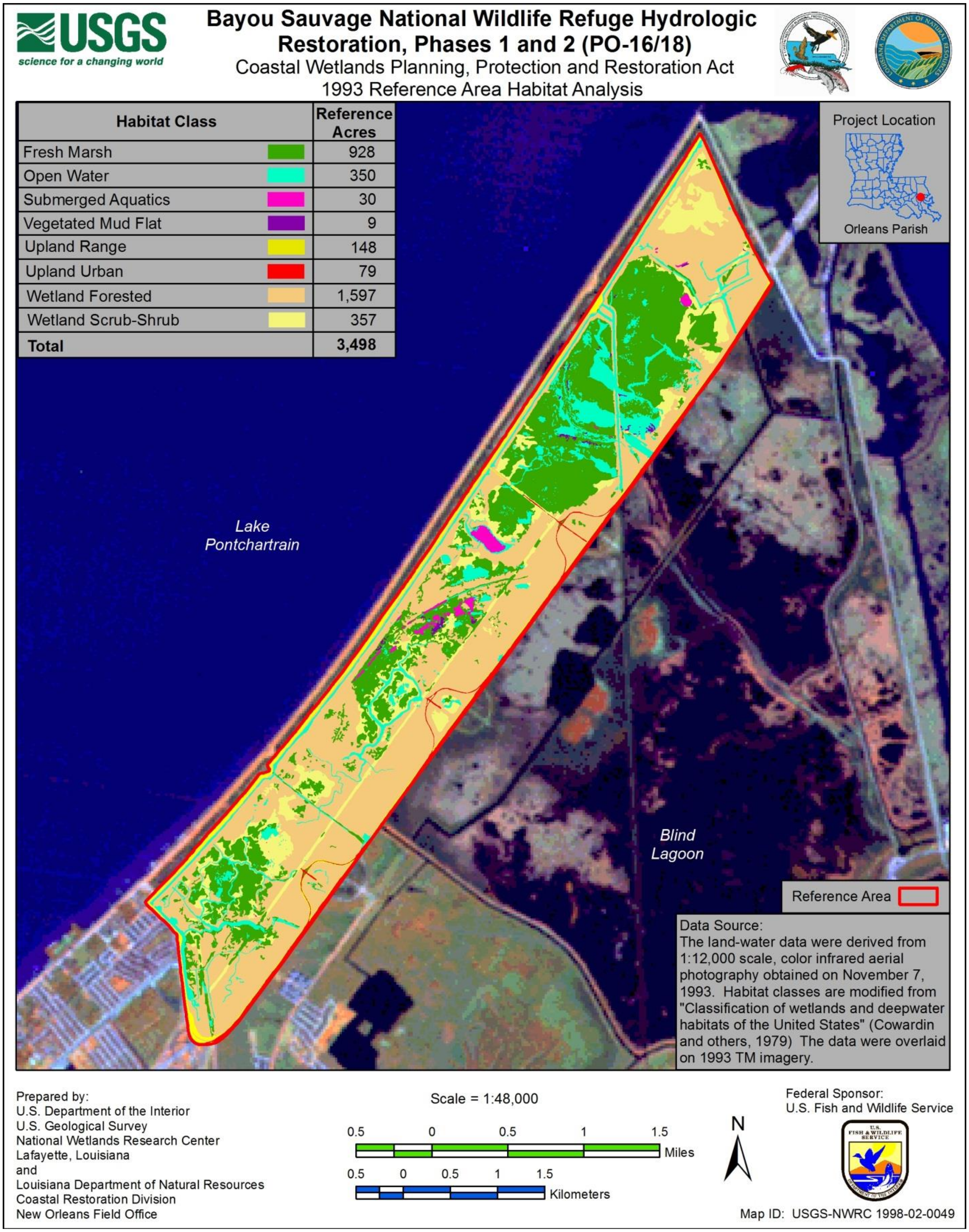


Figure D-7. 1993 habitat analysis of the Bayou Sauvage NWR Hydrologic Restoration, Phase 1 (PO-16) reference area.

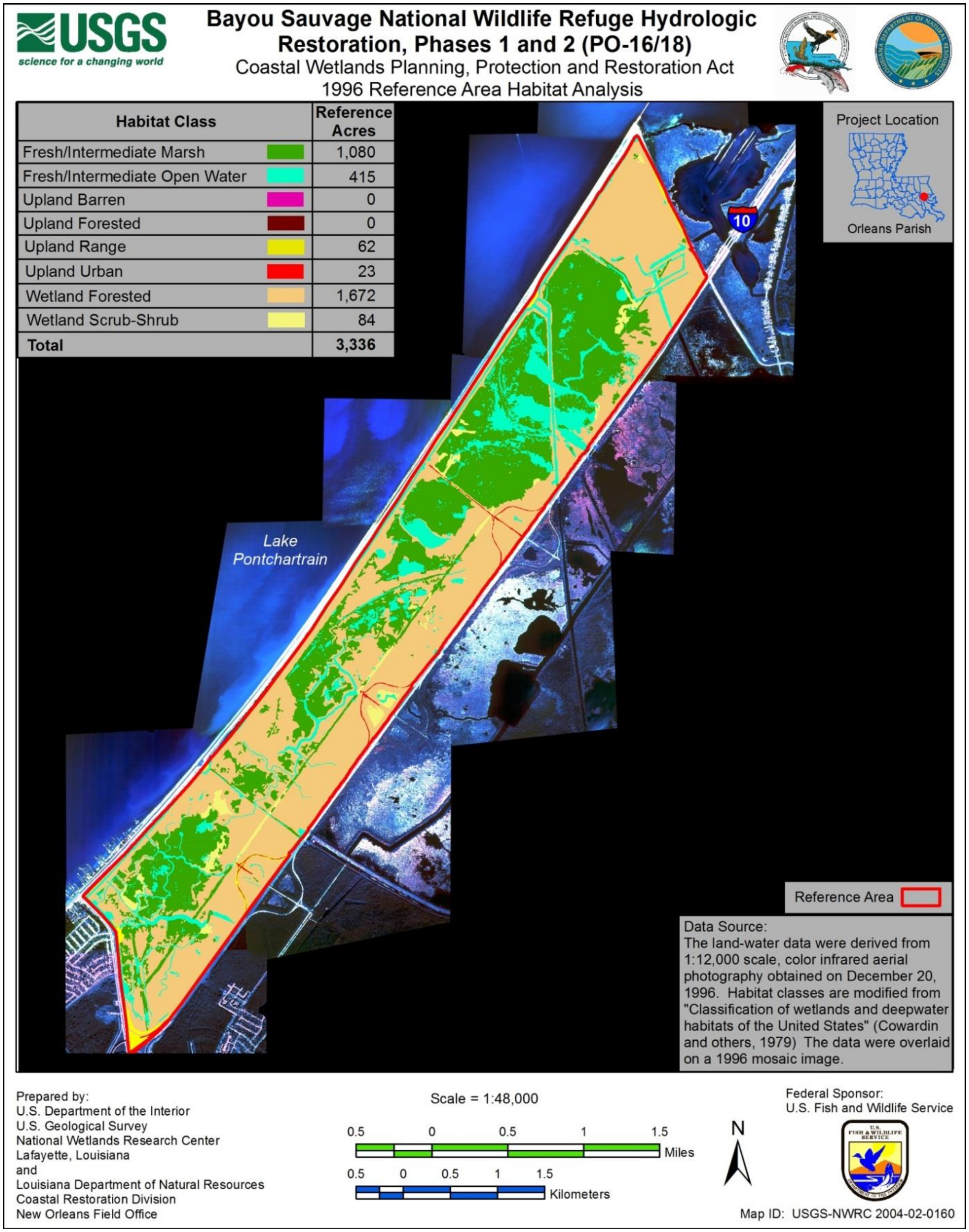


Figure D-8. 1996 habitat analysis of the Bayou Sauvage NWR Hydrologic Restoration, Phase 1 (PO-16) reference area.

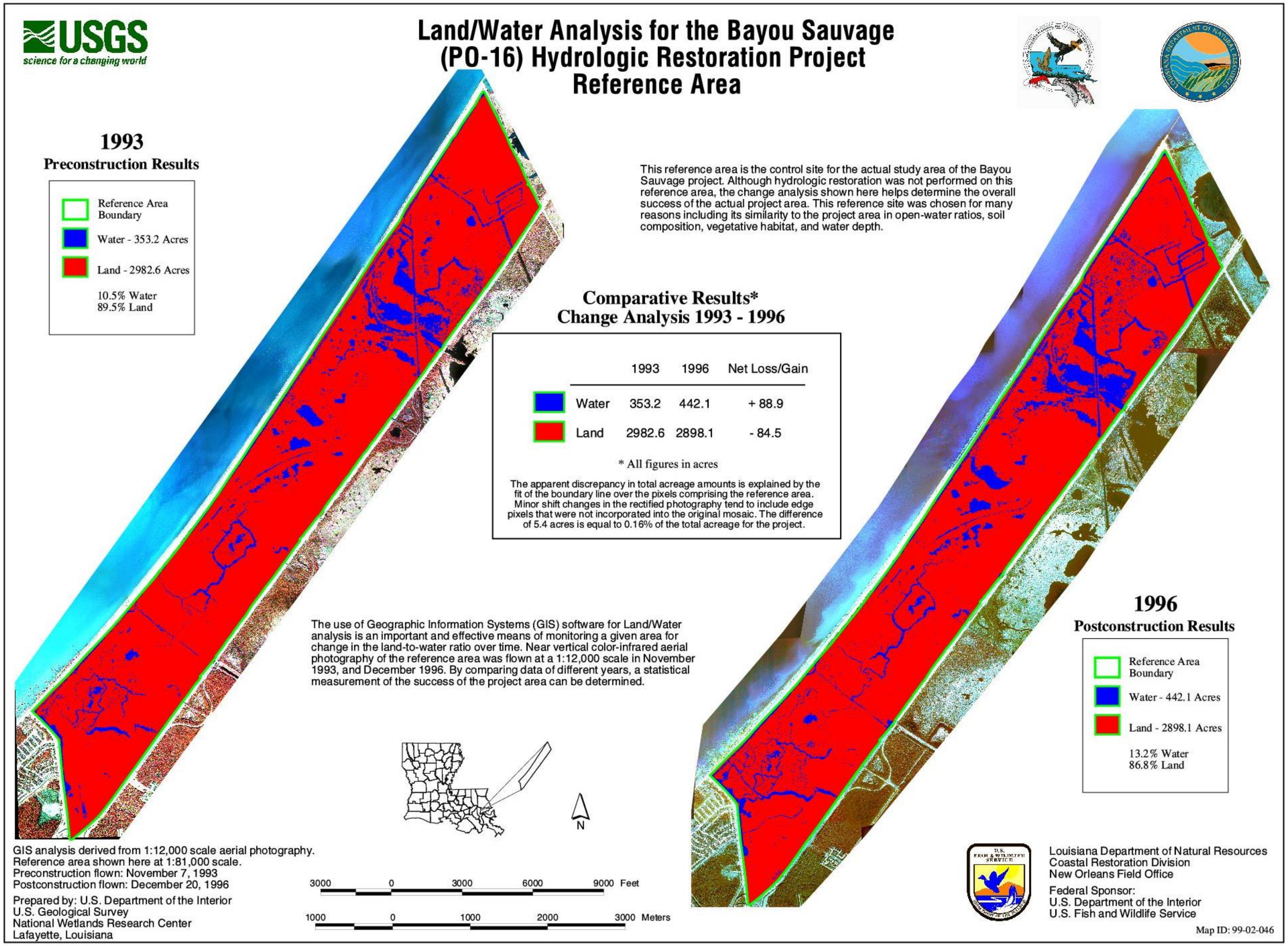


Figure D-9. 1993 and 1996 land/water analyses of the Bayou Sauvage NWR Hydrologic Restoration, Phase 1 (PO-16) reference area.

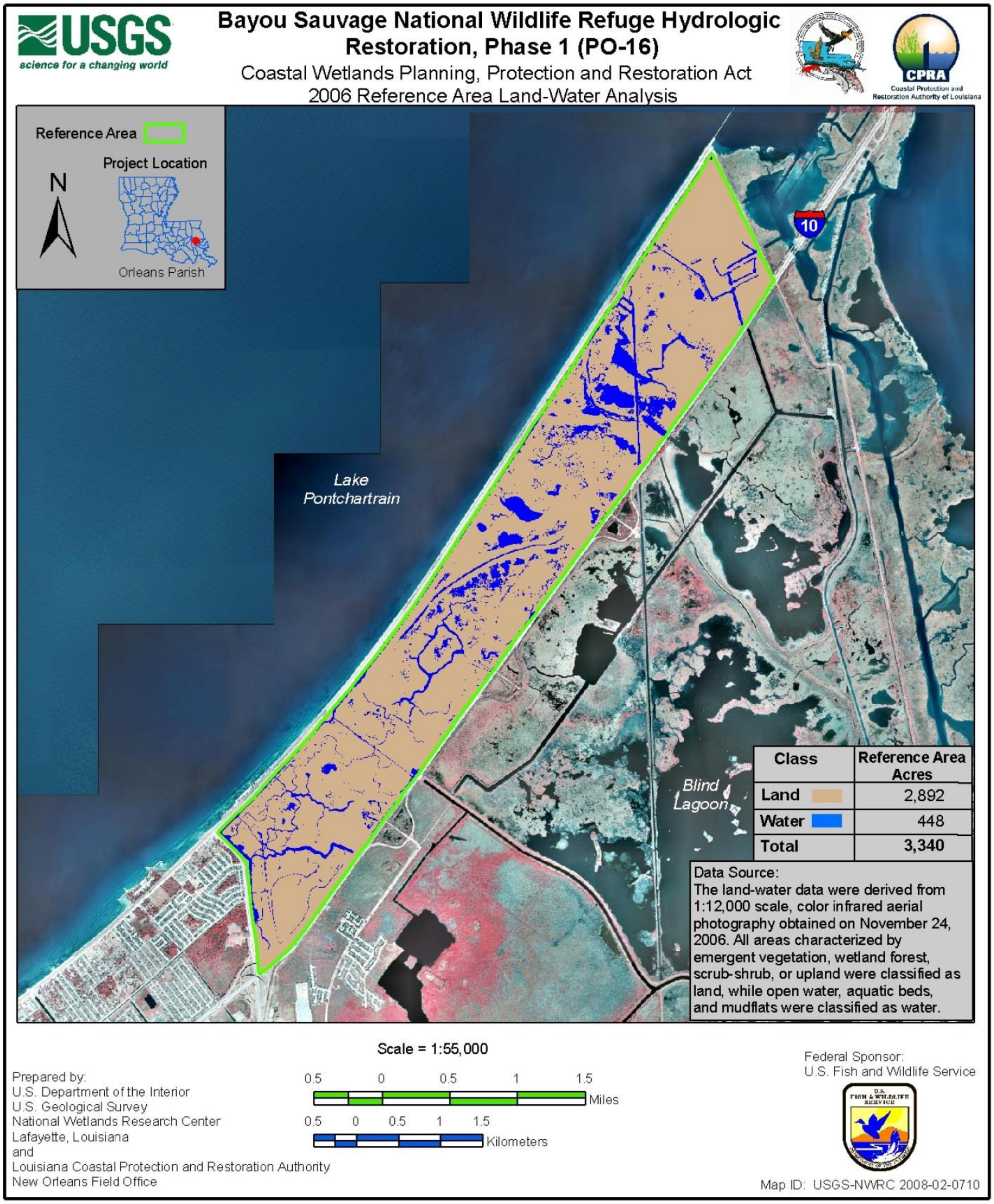
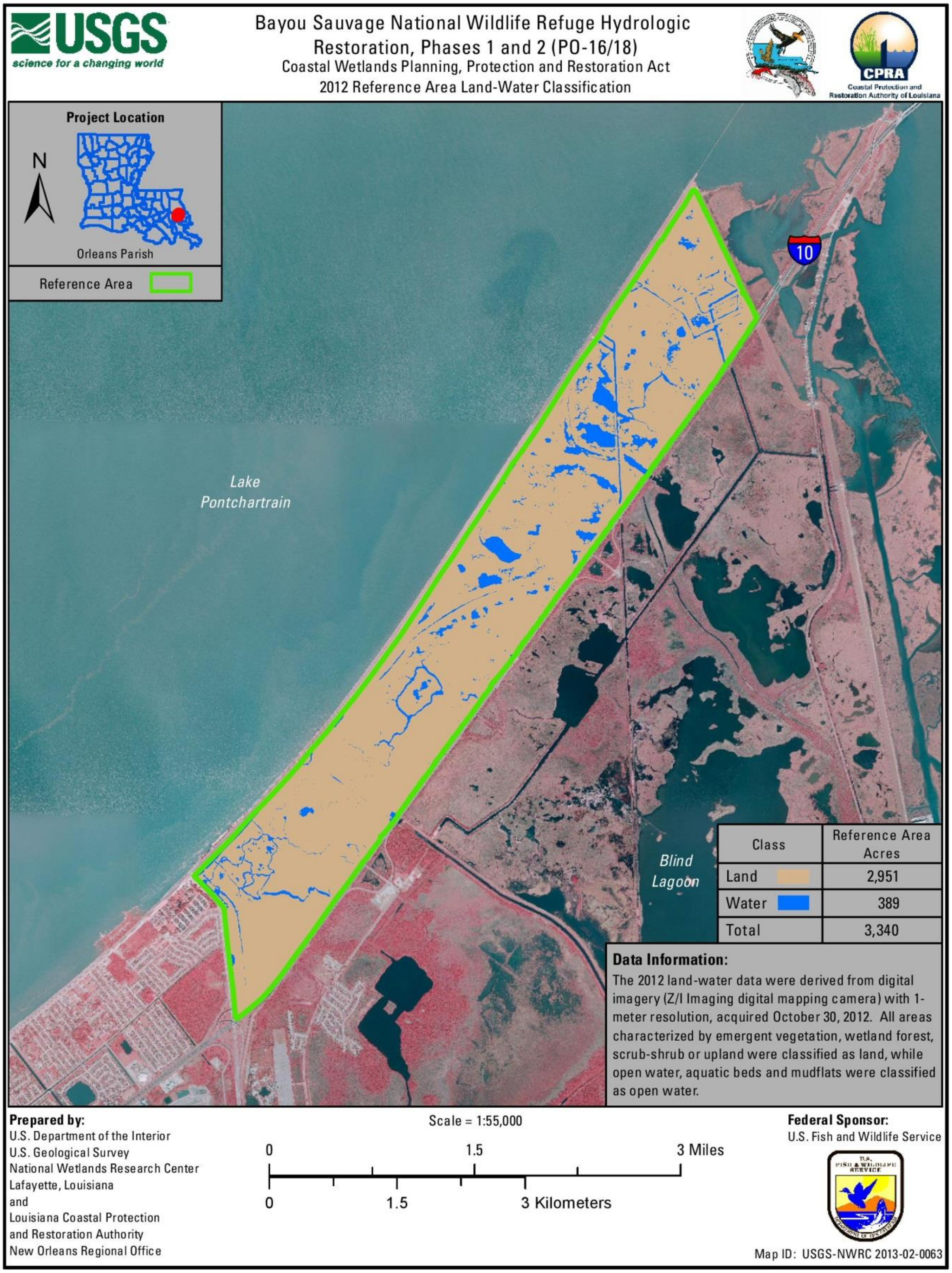


Figure D-10. 2006 land/water analysis of the Bayou Sauvage NWR Hydrologic Restoration, Phase 1 (PO-16) reference area.



Class	Reference Area Acres
Land	2,951
Water	389
Total	3,340

Figure D-11. 2012 land/water analysis of the Bayou Sauvage NWR Hydrologic Restoration, Phase 1 (PO-16) reference area.