State of Louisiana
Coastal Protection and Restoration Authority

2018 Operations, Maintenance, and Monitoring Close-out Report

for

Brady Canal Hydrologic Restoration (TE-28)

State Project Number TE-28
Priority Project List 3

March 2019
Terrebonne Parish

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Monitoring Report
For
Brady Canal Hydrologic Restoration
(TE-28)

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Preface

This report includes monitoring data collected through January 2018.

This is the fourth and final report in a series of reports. For additional information on historically pertinent lessons learned, recommendations and project effectiveness in prior periods or finer treatment of historical data analyses please refer to previous Operations, Maintenance, and Monitoring Report on the Coastal Protection and Restoration Authority of Louisiana (CPRA) web site.

I. Introduction

The Brady Canal Hydrologic Restoration (TE-28) project consists of 7,653 ac (3,097 ha) located in Terrebonne Parish, within the Bayou Penchant-Lake Penchant Basin. The project is bounded by Bayou Penchant, Brady Canal, and Little Carencro Bayou to the north, Bayou Decade and Turtle Bayou to the south, Superior Canal to the east, and Little Carencro Bayou and Voss Canal to the west (Figure 1). The project was federally sponsored by the Natural Resources Conservation Service (NRCS) and locally sponsored by the Coastal Protection and Restoration Authority (CPRA) under the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA, Public Law 101-646, Title III).

Historically, the Atchafalaya River provided freshwater and sediments to the Penchant Basin through the diversion of flood waters into Bayou Cocodrie via Bayou Boeuf at Morgan City, and into Bayou Penchant via Bayou Shaefer and Bayou Chene (USDA/NRCS 1995). The Atchafalaya River influenced the establishment of freshwater plant species within the Brady Canal Hydrologic Restoration (TE-28) project area (USDA/NRCS 1995). In 1968, the vegetation in the project area was classified as freshwater, intermediate, and brackish marsh (Chabreck et al. 1968). In 1978, the project area was classified as intermediate marsh with a small area of brackish marsh in the southern portion of the project along Bayou Decade (Chabreck and Linscombe 1988). Over time, hydrologic conditions in the Penchant Basin were altered by the construction of numerous canals, levees, local water management structures, and major public works projects, resulting in diminished freshwater input and sediment retention. Additionally, the dredging of numerous canals in the basin resulted in the breaching of natural hydrologic barriers, allowing for a strong tidal influence from the south. These anthropogenic changes have resulted in an acceleration of tidal exchange between freshwater distribution channels and tidal channels, thus reducing freshwater retention, accelerating erosion, and facilitating saltwater intrusion (USDA/NRCS 1995).

The existence of a natural ridge, the Mauvais Bois Ridge, which bisects the Brady Canal Hydrologic Restoration (TE-28) project, further complicates the hydrologic balance in the project area, resulting in different hydrologic regimes to the north and south of the ridge. The northern section of the project area still receives freshwater and sediments which are provided through overbank flow from Bayou Penchant, Little Carencro Bayou, and Brady Canal. However, freshwater and sediment retention has diminished in the southern portion of the

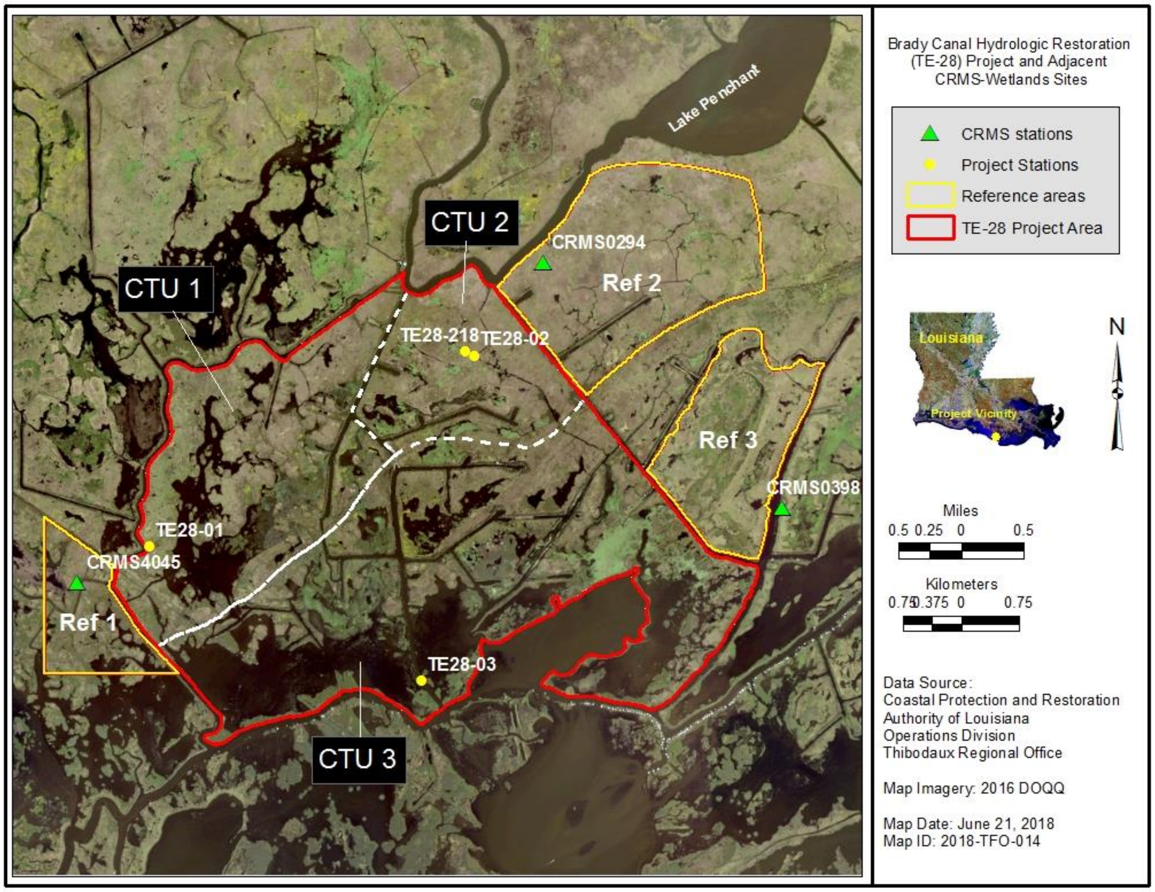

Figure 1. Brady Canal Hydrologic Restoration (TE-28) Project boundary, CTU boundaries, Reference boundaries, Project recorders and CRMS stations used as Reference.

project area due to unimpeded through flow and tidal exchange combined with a decrease in available fresh water and sediment.

Due to differences in marsh type and hydrologic regimes within the project area, the Brady Canal Hydrologic Restoration (TE-28) project was subdivided into conservation treatment units (CTUs) to better evaluate project performance. Three CTUs were established, designated as CTU 1, CTU 2, and CTU 3 (Figure 1). Each CTU was paired with a reference area at the onset of the project to assess its effectiveness; however, in 2003, the Coastwide Reference Monitoring System-Wetlands (CRMS-Wetlands) was adopted by CWPPRA. Subsequently, CRMS monitoring stations were established either inside of or directly adjacent to reference areas to replace the project-specific data recorders that previously characterized them. CTU 1 was paired with reference area 1 (Ref 1), CTU 2 was paired with reference area 2 (Ref 2), and CTU 3 was paired with reference area 3 (Ref 3) (Figure 1).

Land loss data show that during the period from 1932 to 1990, about 1,818 ac (736 ha) of land were converted to open water in the Brady Canal Hydrologic Restoration (TE-28) project area. Approximately 52% of the loss occurred over a 16-year period between 1958 and 1974. The average loss between 1932 and 1958 was approximately 18 ac (7.3 ha) per year while the average loss of 31 ac (12.5 ha) per year occurred between 1983 and 1990.

The increased rate of land loss in the project area was a result of several changes: (1) the hydrology of the Penchant Basin, both natural and anthropogenic, was altered, (2) the natural levee ridge of Bayou Decade had eroded below marsh elevation along the southern end of the project area, (3) higher salinity waters from the south began infiltrating the lower saline environment, (4) the tidal exchange at the southern end of the project area began to increase, and (5) there was a reduction in freshwater and sediment retention.

The infiltration of higher salinity waters and increased tidal exchange can be attributed to the degradation of the natural levee ridge of Bayou Decade along the southern boundary of the project. This has created a direct hydrologic connection between the higher salinity waters from the south and the project area, and has led to decreasing protection from storm surges and tidal scouring. Oilfield access canals extending from within the project area to the Bayou Decade levee ridge have also increased tidal exchange and provided direct routes for saltwater intrusion and reduced freshwater and sediment retention (USDA/NRCS 1995).

The Brady Canal Hydrologic Restoration (TE-28) project involved the installation and maintenance of canal plugs along with the repair, construction, and maintenance of levees, several different types of weirs, rock plugs, earthen and/or rock and earthen embankments, as well as the construction and maintenance of stabilized channel cross-sections. The structures are designed to reduce adverse tidal effects in the project area as well as to better utilize available freshwater and sediment. Project construction began in August 1999 and was completed on July 10, 2000. During this period, the following features were constructed: three fixed crest weirs with variable crest section(s) (figure2, structures 14, 21, and 23), a fixed crest weir with barge bay (figure 2, structure 6), a fixed crest weir (figure 2, structure 24), two rock armored channel liners (figure 2, structures 10 and 20), a rock plug (figure 2, structure 7), and three different embankment types (rock armored earthen embankment, rock dike, and earthen embankment) (Figure 2).

The Penchant Basin Plan (TE-34), a subsequent project authorized under the 6th Project Priority List, encompasses the entire Penchant Basin Project, which includes the Brady Canal Hydrologic Restoration (TE-28) project. Due to the development of this plan at the time, two construction features originally planned to be included under the Brady Canal Hydrologic Restoration (TE-28) project were instead constructed as part of the Penchant Basin Plan in 2011 (TE-34) . These features included the northernmost structure located along Bayou Penchant and the overflow banks along Brady Canal in the northern section of the project. The Brady Canal Hydrologic Restoration (TE-28) project also included provisions for the closure of several large breaches along Bayou Decade between Jug Lake and Turtle Bayou, which were not closed due to budget constraints. However, in August of 2003 CPRA completed the closure of these breaches through the operation, maintenance, and rehabilitation program.

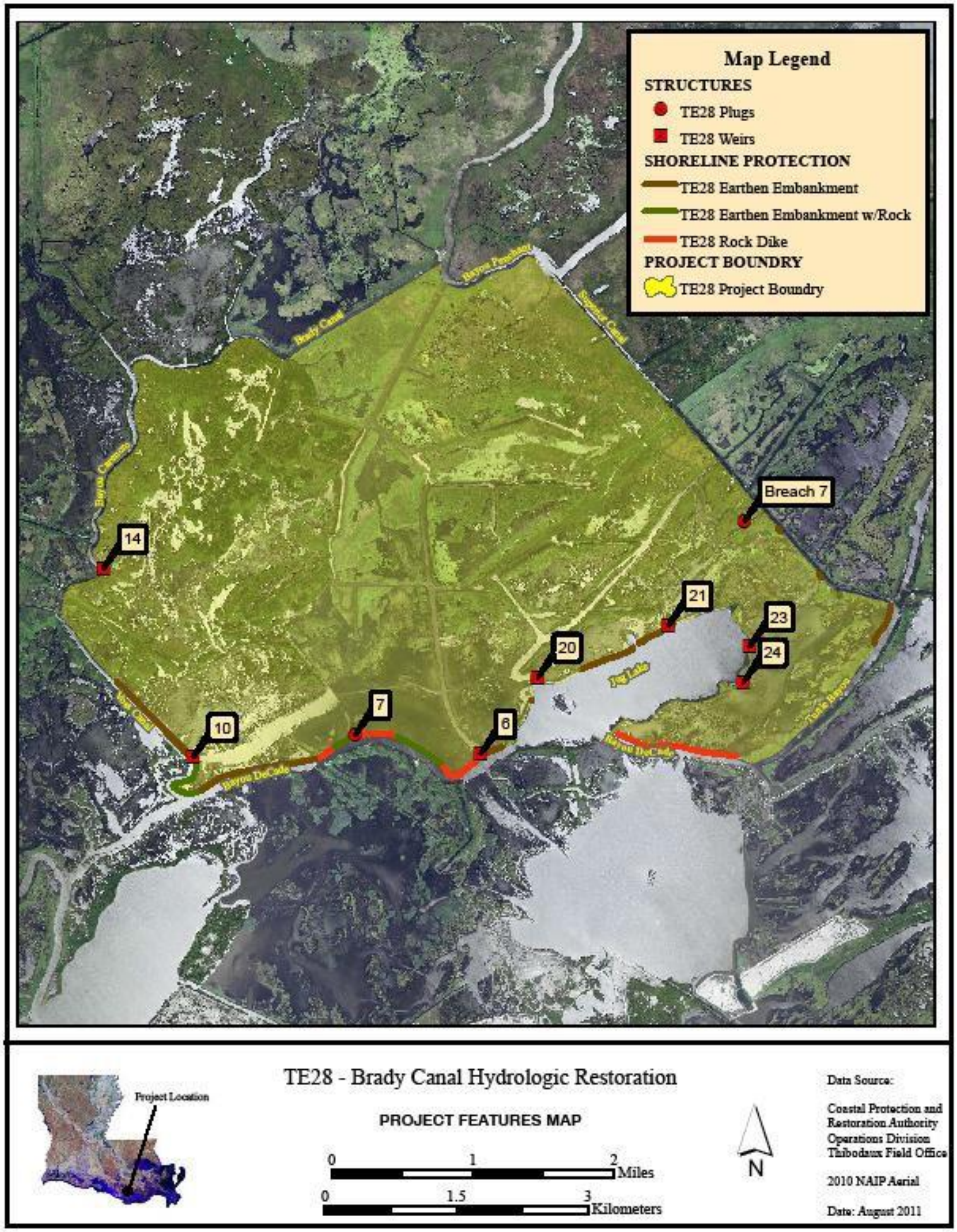

Figure 2. Brady Canal Hydrologic Restoration (TE-28) project features

II. Maintenance Activity

a. Project Feature Inspection Procedures

The purpose of annual inspections of the Brady Canal Hydrologic Restoration Project (TE-28) is to evaluate the constructed project features, identify any deficiencies, and prepare an Annual Inspection report or Operations, Maintenance and Monitoring report detailing the condition of the project features including recommendations for corrective actions, as needed. OM&M reports are prepared periodically and includes results and recommendations based on the inspection of the project features, as well as data collection results and conclusions on the performance of the project. The reports also contain a summary of the completed maintenance projects along with estimated projected budget expenditures including an evaluation of remaining funds available for Operations and Maintenance. Since this project is nearing the end of its twenty (20) year project life, the 2018 inspection was the final inspection of this project. The Brady Canal Hydrologic Restoration project will be entering the close-out phase in year 2020, following the close-out guidelines established by through the CWPPRA program.

The final inspection of the Brady Canal Hydrologic Restoration Project (TE-28) was held on March 27, 2018. In attendance for the inspection were Brian Babin, Todd Hubbell and Josh Sylvest from CPRA, Quin Kinler from NRCS, and Francis Fields with Apache Mineral and Josh Soileau with ConocoPhillips. The inspection began at the intersection of Bayou Decade and Turtle Bayou around 9:30 a.m., progressed along the perimeter of the project area including the lake rim of Jug Lake, and concluded along Brady Canal near the Apache Camp around 12:30 pm.

The inspection included a complete visual inspection of all constructed features within the project area. Photographs of all project features were taken during the field inspection and are shown in Appendix A. Staff gauge readings, where available, were documented and used to estimate approximate water elevations, elevations of rock weirs, earthen embankments, and other project features. The only gauge reading referenced during the inspection was located on the marsh side of Structure 6 and the elevation was approximately 1.7’ NAVD at 10:00 am on March 27, 2018.

b. Inspection Results

Structure 6 – Fixed Crest Weir with Barge Bay

Structure 6 appears to be in good condition. The rock armored bank tie-ins appear to be stable and there are no signs of erosion or breaching around the steel bulkhead. The timber navigational aid supports, signs and lights are visible and appear to be in good condition. Francis Field with Apache did indicate that one of the navigational aid lights was not working properly. Pharo-Marine Automatic Power, the contractor hired to maintain navigational aids for the state, was notified of the possible outage and shall perform test and repair the navigation aid during their upcoming inspection, if needed. The only damaged noted during the inspection of Structure 6 was to the timber pile and warning sign next to the timber bollard on the west side of the barge bay entrance. The timber pile was leaning over and appeared to be broken below the water line. We are recommending that the timber pile and sign be replaced during the next maintenance event. The gauge reading from the CPRA continuous recorder, located just north of Structure 6 indicated that the water elevation was approximately +1.7' NAVD at 10:00 a.m. No other maintenance will be required at Structure 6. (See Appendix A, Photos 33 - 37)

Structure 7 – Rock Plug
Structure 7 appears to be in good condition with no obvious settlement, breaches, or defects other than heavy vegetation on and around the rock plug. The warning signs and supports located on both sides of the structure are in good condition. Currently, there are no recommendations for maintenance (Appendix A, Photos 40 - 41).

Structure 10 – Stabilization Rock Armored Channel Liner
Structure10 appears to be in fair condition. The rock tie-ins to the bank on both sides of the structure appear to be thin and were mostly submerged which is attributed to minor settlement and higher than normal water levels during the inspection. Depths along the center of the rock channel liner taken with a handheld fathometer showed readings between 7.9' and 8.3' with an average of 8.1'. Using the water elevation shown on the staff gauge behind Structure 6, the estimated elevation at the center of the rock channel liner was approximately -6.4 NAVD. The constructed sill elevation was -4.75', indicating that the structure has settled approximately 1.7' feet since it was constructed. All of the timber piling and warning signs appear to be in good condition (See Appendix A, Photo 45)

Structure 14 – Fixed Crest Weir w/ Variable Crest Section
Structure 14 appears to be in fair condition. There was no visible damage to the railings, platform, steel bulkhead or warning signs. The bank tie-in on the north side of the structure is still thin with very little material between the existing bank and the steel bulkhead. The south side of the steel bulkhead connects to a vinyl bulkhead installed by the adjacent camp owner and is in good condition. We are recommending that the eroded earthen embankment connecting the steel bulkhead to the bank on the north side of the structure be refurbished during the next maintenance event. Other than the erosion near the north end of the bulkhead, the structure remains in fair condition. (See Appendix A, Photos 50 - 52)

Structure 20 – Stabilization Rock Armored Channel Liner
Structure 20 is in fair to good overall condition. There appears to be some settlement of the rock riprap on the bank tie-ins and submerged crest of the structure based on elevation depths collected along the crest of the channel liner. Depths along the channel liner crest were approximately 7.7' at the time of this inspection with water levels at 1.7' NAVD. The calculated elevation of the channel liner crest in the center of the opening was approximately -6.0' NAVD with a settlement of approximately 1.2' to 1.5' since the structure was installed. The warning signs and timber supports were also in good condition. At this time, Structure 20 is in good condition and no maintenance will be required. (See Appendix A, Photo 28 - 30)

Structure 21 – Fixed Crest Weir with Three (3) Variable Crest Sections
Overall, Structure 21 is in good condition. There was no visible damage to the steel bulkhead, railings, platform or the warning signs and their timber supports. The rock armored embankments was also in good condition with no signs of settlement since refurbished in 2012. Structure 21 will not require maintenance at this time. (See Appendix A, Photos 22 - 23)

Structure 23 – Fixed Crest Weir with Two (2) Variable Crest Sections
Structure 23 appears to be in good condition as well. There were no visible damage to the steel bulkhead, railings, platform, or the warning signs and their timber supports. The rock armored embankment tie-in to the structure were also in good condition with no obvious settlement or erosion between bank and the structure. Structure 23 will not require maintenance at this time. (See Appendix A, Photos 14 -16)

Structure 24 – Fixed Crest Weir
Overall, Structure 24 is in fair condition. There were no visible damages to the steel bulkhead, platform, or the warning signs and their timber supports. However, as reported in the 2017 inspection report, we did note that one section of the steel handrail had sheared at the welded seam. It is not clear if the steel pipe had been intentionally cut or if the damage was caused by corrosion. The handrail is welded to the top of the steel bulkhead channel cap and does not affect the structure integrity of the weir itself. As noted on previous inspections, there was a hull of a small recreational fishing boat that is lodged against the south bank of the structure near the structure. The hull does not appear to be causing damage or hindering the function of the structure. The rock armored bank tie-ins on both sides of the structure are in good condition with no apparent breaches or erosion. (See Appendix A, Photos 12 - 13)

Bulkhead at head of Brady Canal
The timber bulkhead at the head of Brady Canal is an old existing oilfield structure that is not an original feature of the Brady Canal project. Over time, a small breach had developed on the southern end of the bulkhead. The breach was repaired during the 2012 Maintenance Project with rock riprap to close off the flow around the structure. The riprap material appeared to have settled allowing flow around the structure into Brady Canal. We do not believe that this requires immediate remedial action and will continue to monitor this location on future site visits. (See Appendix A, Photo 55)

Earthen Embankments
The inspection of the earthen embankments included the west bank of Turtle Bayou to Superior Canal (Appendix A, Photos 1, 4-5), the dead end canal connected to Superior Canal, the Jug Lake perimeter (Appendix A, Photos 10-11, 17-21, 24-27 and 31-31), Bayou Decade from Jug Lake to Voss Canal (Appendix A, Photo 43), Voss Canal to Bayou Carencro (Appendix A, Photos 46-49), and Bayou Carencro to Brady Canal (Appendix A, Photos 53-54). The earthen embankments along Turtle Bayou and Superior Canal are in good condition with a couple of recent repairs made by the landowner along Superior Canal (Photos 4-5). The

Jug Lake perimeter was in good condition along the south bank of the existing embankment that was refurbished in 2012. The vegetation was thick and the embankment appears to be stable. The north bank of Jug Lake from Structure 23 around the western perimeter to Bayou Decade was is fair to poor condition. There were large areas of the embankment that were very low with a large breach in the bank south of Structure 21. We also noticed areas of the existing south bank along Bayou Decade that were low and thin near the entrance to Voss Canal (Photo 43). The remaining earthen embankments along Voss Canal, Bayou Carencro and Brady Canal were in fair condition with only two (2) small breaches in the bank along Bayou Carencro north of Structure 14. Since the Brady Canal project is approaching the end of its 20-year life, NRCS and CPRA have decided to proceed with a final maintenance event to refurbish the earthen embankments within the project area that are in need of repairs. The repairs include embankment restoration along the northern and eastern perimeter of Jug Lake, breach closures along Bayou Carencro, and refurbishment of existing embankment along the north bank of Bayou Decade near Voss Canal. The plans and specifications are complete and the bid process should begin by the end of March 2019. It is anticipated that construction will begin by June 2019.

Rock Armored Embankments

The rock plug known as "Breach 7" and located along an existing oil field access canal connected to Superior canal is in good condition. There was no observed settlement along the length of the embankment and no erosion or washouts around the embankment tie-ins. There are no recommendations for corrective action at this time. (Appendix A, Photos 1-3)

The rock armored embankments and rock dikes along the north bank of Bayou Decade (Appendix A, Photos 6-9, 38, 42) and Voss Canal (Appendix A, Photo 44) are in good condition. The rock dike along Bayou Decade between Jug Lake and Turtle Bayou appears to be in fair condition with isolated low areas and moderate displacement of rock riprap. The earthen embankment with rock revetment west of Structure 7 along Bayou Decade appears to be in good condition with no apparent settlement. The earthen embankment with rock revetment beginning at the intersection of Bayou Decade and Voss Canal had some initial settlement after construction but has experienced little change since previous inspections. Despite some minor deficiencies, the rock armored embankments appear to be functioning as intended and no maintenance will be required at this time.

c. Maintenance Recommendations

Overall, the Brady Canal Hydrologic Restoration (TE-28) project was in good condition with isolated deficiencies. In summary, the deficiencies included: a large breach with low and thin areas along the north bank of Jug Lake, erosion and low elevations of the existing north bank along Bayou Decade near Voss Canal, a couple of breaches in the bank line along Bayou Carencro, and a damaged timber piling at the barge bay opening of Structure 6. After discussions with the federal sponsor, NRCS, it was determined that a final maintenance event would be required to address these deficiencies prior to the anticipated end of life of the project in 2020. NRCS has completed the necessary field surveys and data collection to begin the design of the maintenance event. CPRA has tasked All South Engineers, LLC through their current IDIQ contract to prepare plans and specifications to address the deficiencies outlined during the 2018 inspection. The plans and specifications are complete and advertisement for bids should begin by the end of March 2019, with construction to begin in June 2019. All other features inspected during the 2018 annual inspection appear to be in good condition with no other obvious defects that would require immediate attention or action.

d. Maintenance History

General Maintenance: Below is a summary of maintenance projects and operation tasks performed since the completion of the Brady Canal Hydrologic Restoration (TE-28) project.

Under Article II of the Brady Canal Cost Share Agreement, the landowners, ConocoPhillips, formerly Burlington Resources, and the Apache Minerals Corporation were granted in-kind service credits to repair existing earthen embankments within the project area. Below is a description of work and cost associated with the maintenance performed by the landowners:

<u>In Kind Service Credits</u>

7/30/2007 – Apache Corporation contracted Dupre Brothers Construction, Inc. of Houma, La. to repair several breaches along the east bank of Jug Lake and reinforce earthen embankment tie-ins adjacent to variable crest weir structures 21, 23, and 24. The repairs were completed on 7/30/2008 at a total cost of $9,103.12

9/30/2006 – Conoco Phillips contracted Dupre Brothers, Inc. of Houma, La. to repair several breaches along Carencro Bayou, Little Carencro Bayou and Brady Canal using material from adjacent bayous. The total cost for refurbishment and repair of these breaches was $25,890.

9/20/2006 - Apache Corporation contracted Frisco Construction Co. Inc. of Houma, La. to repair breaches and refurbish low areas of the spoil banks along the east bank of Jug Lake and embankment tie-ins adjacent to structures 21, 23 and 24. The repairs were completed on 9/20/2006 at a total cost of $9,265.

10/31/2003 - Apache Corporation contracted Berry Bros. General Contractors to complete 5,050 linear feet of levee refurbishment along the west bank of Jug Lake. The cost for the levee refurbishment including construction oversight was $34,284.87. Following the levee refurbishment, Shaw Coastal performed an as-built survey of the repairs at a cost of $5,100.60. The total project cost for this maintenance event was $39,385.47.

8/15/2003 – ConocoPhillips, formerly Burlington Resources, completed the repair of two (2) large breaches along Little Carencro Bayou following Hurricane Lili. The maintenance project was completed on 8/15/2003 at a total cost of $31,642.57, including construction oversight and administration.

10/21/2002 - Apache Corporation contracted Frisco Construction Co. to repair and restore the existing levee embankment along Turtle Bayou, Superior Canal, and along the west bank of Jug Lake. This work was completed at a total cost of $5,310,.

Brady Canal Breach Repair Project (2003) – LDNR: This maintenance project was completed on August 13, 2003 and included the installation of approximately 9,667 tons of riprap along the north bank of Bayou Decade, 2,325 linear feet of levee refurbishment and earthen breach repair along Turtle Bayou and Superior Canal, and replacement of a timber pile on the navigational aid at structure 6. The cost associated with the engineering, design and construction of the 2003 Brady Canal Breach Repair Project is as follows:

Construction:	$471,329.65
Engineering & Design:	$ 54,473.00
Bidding:	$ 4,100.00
Construction Administration:	$ 8,020.00
Construction Oversight:	$ 49,635.00
As-built Survey and Drawings:	$ 12,873.00
Total Overall Project Costs:	$600,430.65

Brady Canal 2012 Maintenance Project – This maintenance project began in October 2013. It included the refurbishment of 13,900 linear feet of earthen embankment along the perimeter of Jug Lake, rock armoring of the embankment tie-ins adjacent to the three (3) water control structures in Jug Lake, replacement of two (2) timber dolphins at Structure 6, three (3) warning signs at Structure 10, and a breach repair/closure adjacent to an existing timber bulkhead at the intersection of Carencro Bayou and Brady Canal. The total project costs associated with surveying, engineering, design, and construction of the 2012 maintenance project are as follows:

Construction:	$1,353,636.25
Surveying:	$ 60,303.00
Engineering & Design:	$ 99,958.76
Construction Admin/Inspections:	$ 179,386.38
Total Overall Project Costs:	$1,693,284.39

III. Operations Activity

Structure Operations: In accordance with the operation schedule outlined in the Operation and Maintenance Plan, Structures 14, 21, and 23 have been operated twice annually beginning in April 2002. Prior to the scheduled operations in September 2008, the CPRA entered into an agreement with Apache Minerals for the landowner to assume responsibility of operating all water control structures associated with the Brady Canal (TE-28) project. Apache has been providing structure operations services in accordance with terms of their agreement with CPRA since 2008 for $12,000, annually. CPRA renewed Apache's agreement in July 2017 and granted authorization to Apache to operate existing water control structures through June 30, 2020.

Navigational Aids Maintenance:

Currently, CPRA has an agreement with Pharo Marine – Automatic Power, Inc. for inspections, diagnostic testing and repair of the navigation aid lights and signage at Structure 6. The lights are inspected quarterly and repaired as needed.

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 TE-28 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 CWPPRA. There are three CRMS sites located on the edge of the project area: CRMS0294, CRMS0398, and CRMS4045. Previous iterations of the Monitoring Plan included goals of increasing vertical accretion and submerged aquatic vegetation (SAV) in the Project area, but these metrics have since been determined to be unnecessary since the marsh is floating and soils are composed of decaying organic matter. Sampling of these metrics ceased prior to 2006.

a. Monitoring Goals

The objectives of the Brady Canal Hydrologic Restoration (TE-28) project is two-fold: (1) to maintain and enhance existing marshes in the project area by reducing the rate of tidal exchange and (2) to improve the retention of introduced freshwater and sediment.

The following goals will contribute to the evaluation of the above objective:

1. Decrease the rate of marsh loss.
2. Maintain or increase the abundance of plant species typical of a freshwater and intermediate marsh.

3. Decrease variability in water level within the project area.

4. Decrease variability in salinities in the southern portion of the project.

b. Monitoring Elements

The following monitoring elements will provide the information necessary to evaluate the specific goals listed above:

Vegetation

Vegetation stations were established in the Brady Canal Hydrologic Restoration (TE-28) project areas to document species composition and percent cover over time. Plots were placed in CTU 1, CTU 2, and CTU 3. Sites were sampled in 1996 (pre-construction), 1999 (as-built), and in 2002, 2006, 2009, 2012 and 2016 (post-construction) via the semi-quantitative Braun-Blanquet method (Mueller-Dombois and Ellenberg 1974; Sawyer and Keeler-Wolf 1995; Barbour et al. 1999). Plant species inside each $4m^2$ plot were identified and cover values were ocularly estimated using Braun-Blanquet units (Mueller-Dombois and Ellenberg 1974) as described in Steyer et al. (1995). The cover classes used were: solitary, <1%, 1-5%, 6-25%, 26-50%, 51-75%, and 76-100%. After sampling the plot, the residuals within a 5 m (16 ft) radius were inventoried. Mean percent cover was calculated in JMP® version 13 to summarize vegetation data.

Water Level and Salinity

One continuous recorder was located in each CTU to monitor hourly salinity and water levels within the Project area. Data collection was discontinued at project-specific reference recorders in April 2004 due to the implementation of CRMS-Wetlands. Three CRMS sites were subsequently established and used as reference stations. Salinity and water level data were collected from 1996 to 2000 (pre-construction) and from 2000 through January of 2018 (post-construction). Figure 1 illustrates the location of active hourly sampling stations, CRMS reference stations, and previously active reference stations used in salinity and water level analyses described in this report. Statistical analyses of water level and salinity were performed in JMP® version 13.

Marsh Mat Movement

Marsh mat movement was evaluated in CTU 2 using continuous hourly data collected at marsh mat stations TE28-218, located inside the Project area, and CRMS0294, located in the CTU 2 Reference area. Mean daily marsh mat elevations were determined and compared between the Project and Reference areas for the 2010-2017 period (Figure 5). Similar analyses in the earliest reports used data from project-specific Reference area recorder TE28-219R, which was deactivated in 2002 in anticipation of CRMS-Wetlands implementation. CRMS0294 was constructed in late 2005 and its first full year of data was collected in 2006. Weekly means were compared in JMP® version 13.

Habitat Mapping

To document habitat types within the Brady Canal Hydrologic Restoration (TE-28) Project and Reference areas, color infrared (CIR) aerial photography (1:12,000 scale with ground controls) was obtained. The photography was photointerpreted, scanned, mosaicked, georectified and analyzed by National Wetlands Research Center (NWRC) personnel according to the standard operating procedure described in Steyer et al. (1995, revised 2000). The photography was obtained in 1998 (preconstruction) and again in 2002, 2008 and 2016 (post-construction) and the resulting habitat classification maps are presented in Appendix B.

Submerged Aquatic Vegetation (SAV)

Methods described in Nyman and Chabreck (1996) were used to characterize SAV in each CTU and respective reference area by recording presence versus absence at each of 20 random sample points in a given pond. Sampling occurred in the fall of 1996 and 1999 (pre-construction) and again in 2002 (post-construction). This sampling metric was discontinued due to the adoption of CRMS-*Wetlands* and sampling did not occur in 2006, 2012 and 2016. The results from the initial three sampling events are summarized.

Accretion

Accretion was characterized using techniques described by Steyer et al. (1995) in which vertical accretion is determined in triplicate at each of five representative stations within each CTU and respective reference area. Data collection sites coincided with vegetation sampling sites. Data was collected during one pre-construction period in 1997/1998 and two post-construction periods during the 2000/2001 and 2006/2007 timeframes. Reference data, however, were not collected in 2006. Sampling in 2009, 2012 and 2016 did not occur as it had been determined that the marsh was floating and soils were composed of decaying organic matter. The results of the initial three sampling periods are summarized.

b. Monitoring Results and Discussion

Emergent Vegetation

Emergent vegetation data was collected within each CTU of the Project area and from within each corresponding reference area on seven occasions over the life of the Project. These sampling events occurred in 1996 (pre-construction), 1999 (as-built), 2002, 2006, 2009, 2012 and 2016 (post-construction). Data were not available for the CTU 1 reference area in 2006; all other vegetation data that were available from each of these sampling years was used in the statistical analyses of mean cover presented here. Noteworthy trends in the data are also mentioned where they are indicative of fresh and intermediate marsh species promotion, a stated goal of the project. The statistical and descriptive results are corroborative of one another and reveal a vegetation community characterized by plants typical of a fresh or intermediate marsh. *Sagittaria lancifolia*, *Eleocharis* spp. (spikerush species), *Sacciolepis striata*, *Spartina patens*, *Polygonom punctatum* and *Hydrocotyle umbellata* all continue to dominate the majority of vegetation sampling stations (Figures 3 - 5). The Wetland Indicator Status of the most prevalent taxa occurring throughout the Project area are overwhelmingly designated Obligate Wetland species and there are no instances of nonhydrophytic vegetation occurring from either Project or Reference stations.

CRMS – *Wetlands* employs an algorithm to assign fresh, intermediate, brackish or saline marsh type to the marsh from which the vegetation was sampled. These assignments are based on either percent coverages of certain indicator species (where these species are present) or a salinity score derived from species-specific scores of other sensitive species (where indicator species are not present). The aforementioned marsh type indicator species were examined against the vegetation data summarized for each CTU for noteworthy trends not captured in the graphic. While these categorical data types do not lend themselves to the type of statistical analyses conducted to investigate mean percent cover, trends in indicator species corroborate those analyses and further support the success of the project in promoting and maintaining fresh and intermediate marsh species. The species which are represented individually in the vegetation graphics were the most prevalent over all sampling periods. Certain species may not have been prevalent enough over all seven sampling periods to have been listed individually in the summary graphics but are nevertheless indicative of the project's success in maintaining or increasing plants typical of fresh and intermediate marsh as well as overall marsh health. When comparing species richness by CTU, the average number of species encountered over all sampling occasions was highest in CTU 3 at ~30, while the lowest average was encountered in CTU 2 at ~22. The average number of species encountered in CTU 1 was also the overall project average, or ~28.

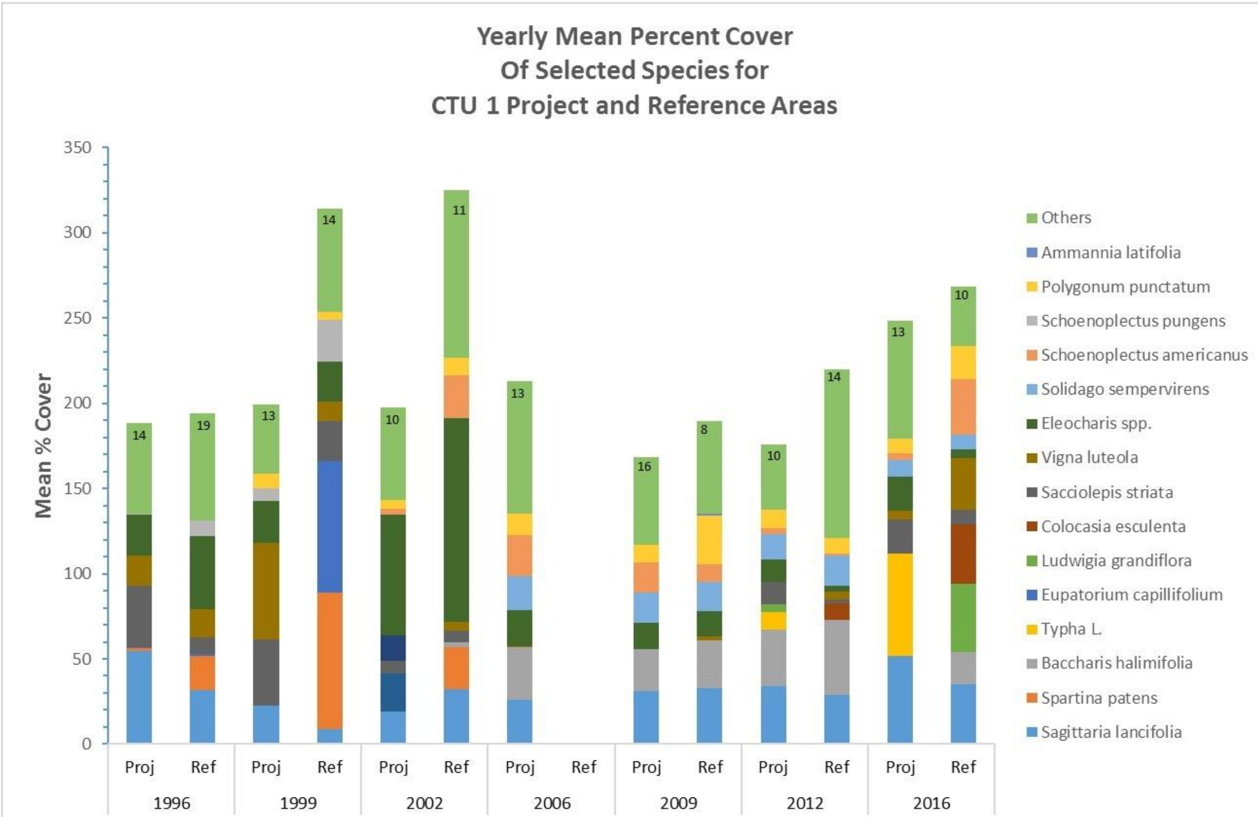

Figure 3. Relative cover of the 15 predominant vegetation taxa in the Brady Canal Hydrologic Restoration (TE-28) Project area over seven sampling periods. Vegetation data are grouped by CTU and year.

In CTU 1, *Sagittaria lancifolia* maintained high percent cover values over all periods and was greater than 50% in the final sampling period. While not captured in the graphic, *Panicum hemitomon* and *Paspalum vaginatum* are additional fresh marsh indicator species that increased in coverage over time in CTU 1, each with their highest cover values in 2016. In Reference area 1, by contrast, *P. vaginatum* showed a general decline over the course of vegetation sampling events and *P. hemitomon* was not present at all. The average number of plants encountered was equal between CTU 1 and its reference area over the life of the project, but the reference area exhibited slightly higher between-year variability.

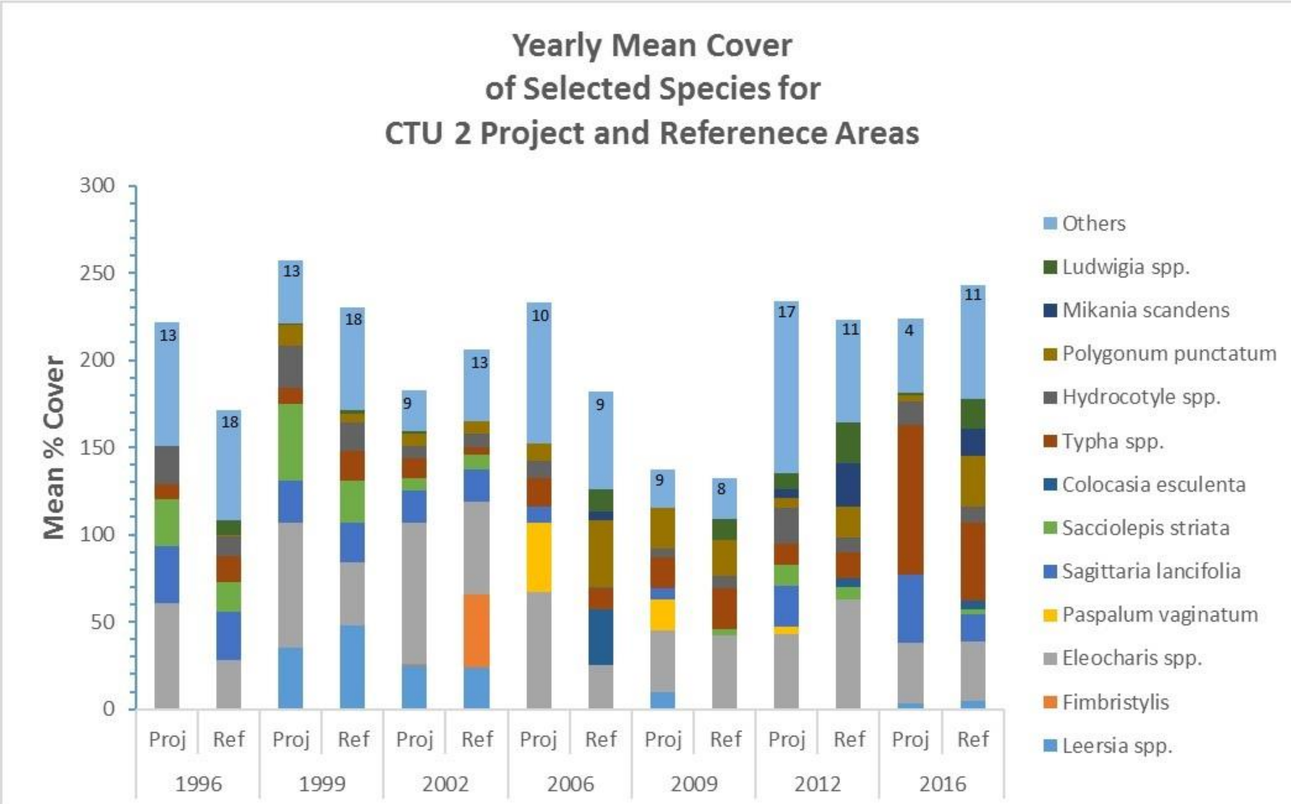

Figure 4. Relative cover of the 12 predominant vegetation taxa in the Brady Canal Hydrologic Restoration (TE-28) Project area over seven sampling periods. Vegetation data are grouped by CTU and year.

In CTU 2, *S. lancifolia* showed appreciable gains in percent cover between 2009 and 2016 (Figure 4), yet trended in the opposite direction inside Reference area 2 where it decreased in coverage over each sampling event. The average number of species encountered in CTU 2 and its reference area were similar over all sampling periods, and there was no appreciable difference in between-year variability.

S. lancifolia also showed positive trends in CTU 3 where it exhibited its highest percent cover in the final year of sampling (Figure 5). Other sensitive species used as fresh and intermediate marsh indicators such as *Colocasia esculenta*, *Paspalum vaginatum* and *Schoenoplectus americanus* were also increasing in coverage in CTU 3 over the project life. While the average number of species encountered between CTU 3 and its reference area were nearly identical, the reference area exhibited much larger swings in the average number of plants recorded for any given year. In CTU 3, the standard deviation (SD) of species encountered over all sampling events was calculated at SD= 4.01 compared to SD= 7.18 in the reference area.

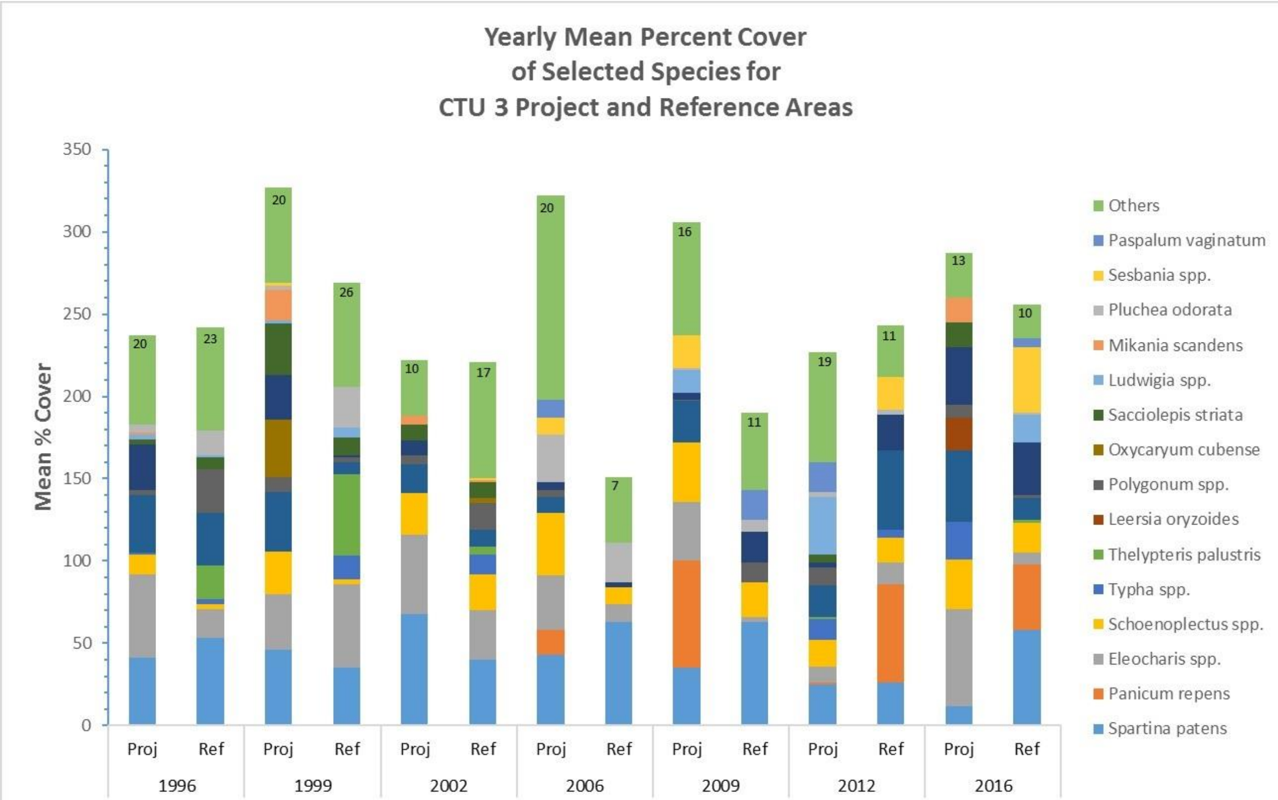

Figure 5. Relative cover of the predominant 15 vegetation taxa in the Brady Canal Hydrologic Restoration (TE-28) Project area over seven sampling periods. Vegetation data are grouped by CTU and year.

Salinity and Water Level

Analyses of both salinity and water level were conducted using project-specific data from continuous recorders within each CTU. These data were compared to reference data captured via project-specific reference recorder, CRMS site, or both. Respective reference pairings used in water level analyses consisted of TE28-01 with CRMS4045, TE28-02 with CRMS0294 and TE28-03 with CRMS0398. Reference stations TE28-04R, TE28-05R and TE2806-R were also used in salinity analyses that partially pre-date the establishment of CRMS sites. Those pairings consisted of TE28-04R, TE28-05R and TE28-06R, respectively, with the project-specific recorders of CTUs one, two and three. The data collection periods of each station are summarized in Table 1.

Table 1. Project- and reference-specific continuous recorder stations, CRMS-Wetlands continuous recorder stations and associated data collection periods for the Brady Canal Hydrologic Restoration (TE-28) project.

Station	Data Collection Period
TE28-01	01/01/1997 - 01/31/2018
TE28-02	01/01/1997 - 01/31/2018
TE28-03	01/01/1997 - 01/31/2018
TE28-04R	02/18/1997 - 04/01/2004
TE28-05R	02/18/1997 - 04/01/2004
TE28-06R	02/18/1997 - 04/01/2004
TE28-07R	02/18/1997 – 03/30/2009
CRMS4045-H01	05/23/2008 - Present
CRMS0294-H01	04/25/2006 - Present
CRMS0398-H01	03/24/2010 - Present

Daily tidal effects on hourly water level readings were controlled by analyzing weekly means for each site; weekly means were likewise used to compare water level data between project and reference areas as well as salinity concentrations between the same. All statistical analyses on salinity and water level data were performed in JMP® version 13.

In order to best characterize the significant amount of previously unanalyzed data, the 7 most recent years of project data were considered in this analysis of mean weekly salinity. Mean weekly salinity was not significantly different between project and reference in CTU 1, but did differ significantly between project and reference in CTUs 2 and 3. Mean weekly salinity values in CTUs 1 and 2 were higher than their respective reference stations between 2010 and 2017, whereas CTU 3 exhibited lower mean weekly salinity readings than its reference area during the 2010-2017 period (Table 2).

Table 2. Mean Weekly Salinity from 2010 through 2017 for TE-28 Project and Reference stations. (Note: Stations not connected by the same letter are significantly different).

Mean Weekly Salinity (2010-2017)

Station					Mean
CRMS0398	A				1.66
TE28-03		B			1.16
TE28-01		B			1.16
CRMS4045		B			1.07
TE28-02			C		0.57
CRMS0294				D	0.30

The range, or difference between maximum and minimum salinities, was also analyzed for each CTU and reference recorder for the 2010 to 2017 period. The weekly salinity range was not significantly different between CTU 2 and its reference station, but CTUs 1 and 3 were significantly different than their corresponding reference stations. The weekly salinity range was higher in CTUs 1 and 3 than in their respective reference areas, while the mean weekly salinity range was lower in CTU 2 than in reference area 2 (Table 3). Note in Tables 2 and 3 that the stations are listed in descending order according to the mean or range value calculated.

Table 3. Range of Mean Weekly Salinity from 2008 through 2017 for TE-28 Project and Reference stations. (Note: Stations not connected by the same letter are significantly different).

Mean Weekly Salinity Range (2010-2017)					
Station					**Mean**
TE28-03	A				2.71
TE28-01	A				2.56
CRMS4045		B			1.94
CRMS0398			C		1.48
CRMS0294				D	0.46
TE28-02				D	0.32

Mean weekly salinity was also analyzed by year for each full year of data collection (1997-2017) inside the project area, and subsequently compared directly between each CTU and its respective reference area. Reference data used in this analyses came from project-specific reference recorders as well as CRMS sites and are absent for CTUs 1 and 2 between 2005 and 2007, the period during the adoption of CRMS-*Wetlands*. Reference data collection in CTU 3 resumed in 2010 with the establishment of CRMS0398. Figures 6 - 8 summarize these yearly means by CTU. Additionally, Table 4 summarizes all salinity data by station (as available) and provides overall values by project versus reference area. Note the station-specific similarity in mean salinities between project and CRMS stations using all available data compared with only the most recent ten years of data.

Table 4. Summary of salinity values for continuous hydrographic stations inside and outside the Brady Canal Hydrologic Restoration (TE-28) project using all available data for each station (1997 – 2017).

Project Stations				
Station	**Mean**	**Minimum**	**Maximum**	**Range**
TE28-01	1.24	0.03	20.58	20.55
TE28-02	0.67	0.05	7.81	7.76
TE28-03	1.24	0.01	22.83	22.82
Overall	1.05	0.01	22.83	22.82
Reference Stations				
TE28-04R	1.27	-0.05	14.76	14.81
TE28-05R	0.67	0.07	6.54	6.47
TE28-06R	1.48	0.21	17.74	17.53
CRMS0294-H01	0.31	0.08	20.91	20.83
CRMS0398-H01	1.65	0.09	17.38	17.29
CRMS4045-H01	1.06	-0.31	21.03	21.34
Overall	1.12	-0.37	21.03	21.34

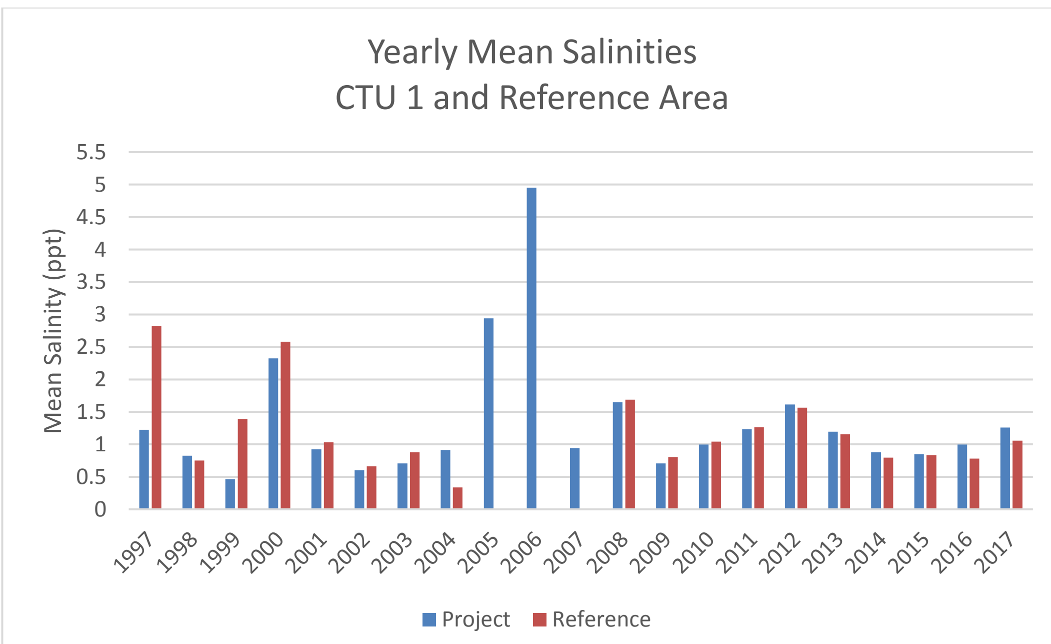

Figure 6. Yearly mean salinities for all open water continuous project and reference recorder stations associated with CTU 1 of the Brady Canal Hydrologic Restoration (TE-28) project. The project area had a higher mean weekly salinity (1.24 ppt) than the reference area (1.17 ppt) but the difference was found to be statistically insignificant.

Natural meteorological events such as drought and tropical cyclones can have varying effects on salinity concentrations in a given area and some of these effects are apparent in the graphed data presented in Figures 6 – 8. Depending on the size, speed, trajectory and geographic proximity, a cyclone may cause an increase or decrease in salinity concentrations. Given that there were over 30 cyclones which affected the project area over the past 20 years, the project area naturally experienced a wide range of variously changing conditions depending on a given storm's characteristics. The salinity spike evident in the 2005-2006 data, for example, is associated with higher salinity concentrations caused primarily by Hurricane Rita in 2005. Drought was the primary driver for similar spikes across all CTUs during the 2000 period. Largescale meteorological phenomena will often cause effects throughout each CTU and reference area, but these effects are relative to one another. Notice, for instance, the difference in the vertical axis scales between each of the CTUs in figures 6 – 8.

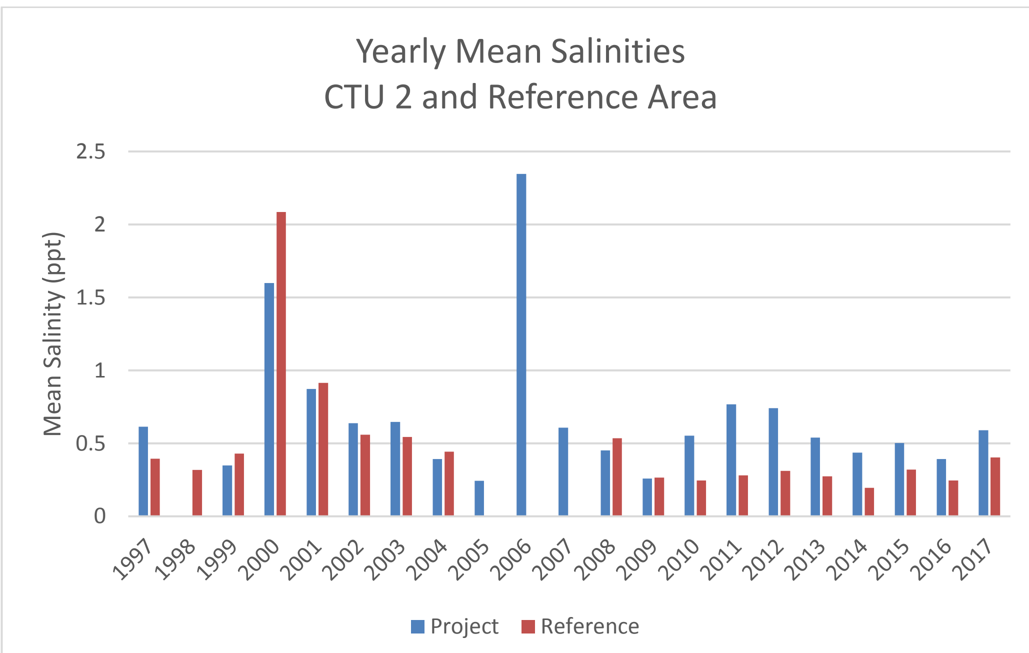

Figure 7. Yearly mean salinities for all open water continuous project and reference recorder stations associated with CTU 2 of the Brady Canal Hydrologic Restoration (TE-28) project. The project area had a higher mean weekly salinity (0.68 ppt) than the reference area (0.43 ppt) and was found to be statistically different.

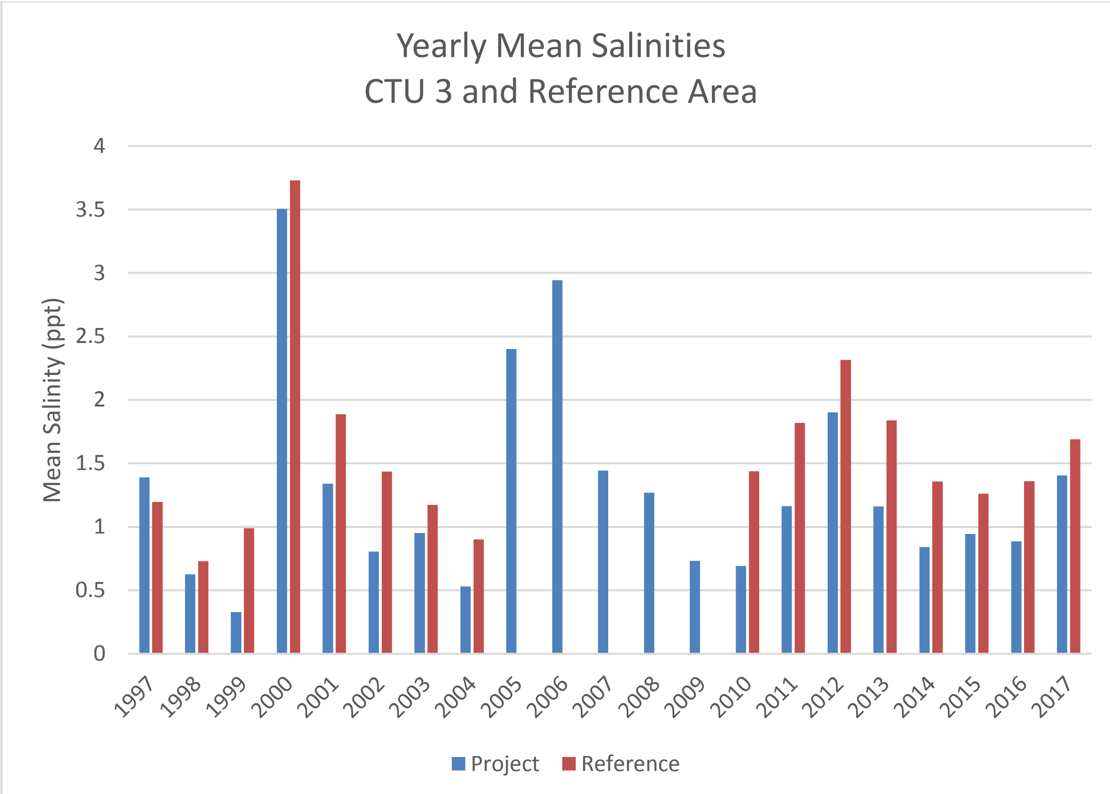

Figure 8. Yearly mean salinities for all open water continuous project and reference recorder stations associated with CTU 3 of the Brady Canal Hydrologic Restoration (TE-28) project. The project area had a higher mean weekly salinity (1.59 ppt) than the reference area (1.25 ppt) and was found to be statistically different.

Frequency distributions were calculated for all available salinity data associated with CTU 3 and its reference area in order to further examine the southernmost area of the project where salinity concentrations may be more heavily influenced by tidal exchange. Five discrete time periods were examined: Pre-construction (February 1997-August 1999), Post 1 (July 2000-April 2004), Post 2 (April 2004-March 2010), Post 3 (March 2010-December 2013) and Post 4 (April 2014-January 2018). These periods were delineated based on a combination of data availability, when which reference recorders were active or inactive, and in an effort to have periods of similar duration. The salinity ranges used correspond with the ecologically significant marsh type categories assigned to marsh sites by CRMS-*Wetlands*. Figure 9 summarizes the results to show the percentage of data points that fell into each of the salinity categories for each of the five periods.

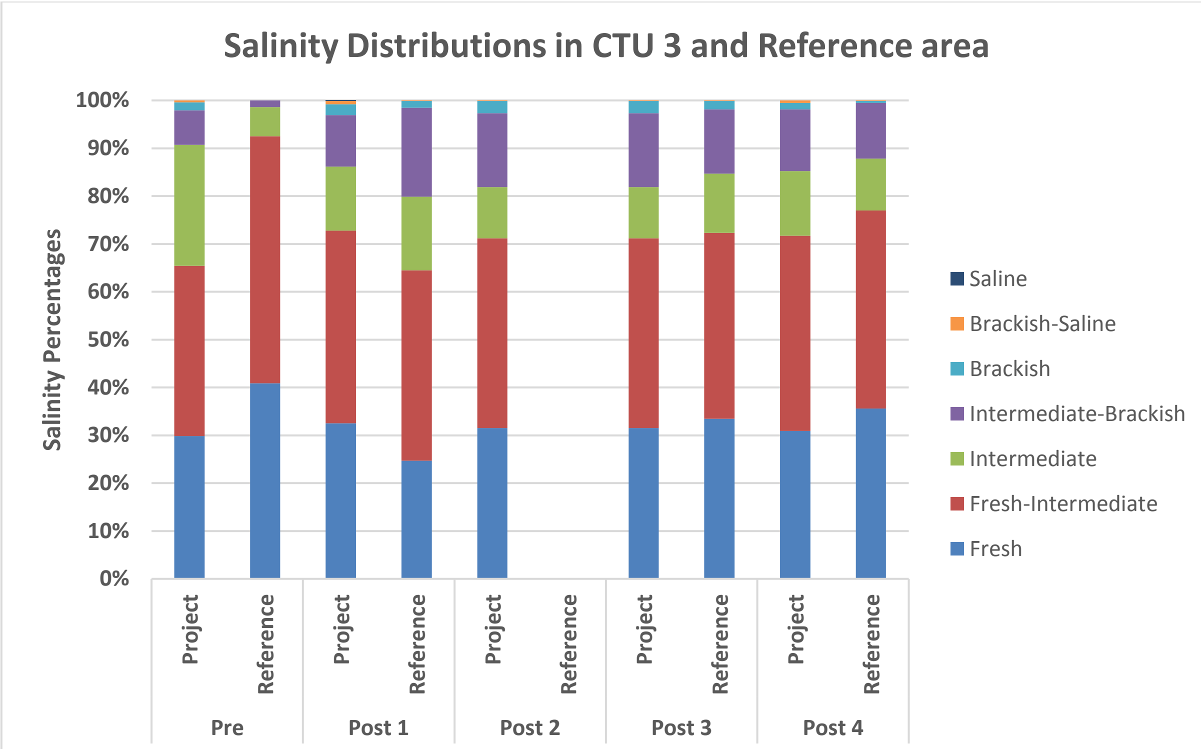

Figure 9. Salinity distributions of CTU 3 and Reference area during Pre-Construction and four Post-Construction time intervals. *Deactivation of Project specific recorders in anticipation of, but prior to, CRMS implementation resulted in a lack of Reference data during the Post 2 period.

The frequency distribution in figure 9 shows the frequency with which a given salinity concentration fell into each of seven salinity categories or subcategories: Fresh, Fresh – Intermediate, Intermediate, Intermediate – Brackish, Brackish, Brackish – Saline, and Saline. While these categories are delineated differently by various sources and authorities, it is nevertheless obvious that the distribution has been relatively constant over time. There are four salinity categories that make up significant portions of the bar graphs: Fresh, Fresh-Intermediate, Intermediate and Intermediate-Brackish. The Intermediate-Brackish category corresponds to the largest salinity concentrations of these (between 7 and 11.5 ppt) but is the least frequent among them. These elevated levels occur periodically and are due primarily to tropical cyclone activity or drought. The areas of the histogram which are marked Fresh, Fresh – Intermediate or Intermediate represent salinity concentrations at or below 2.75 ppt, which account for over 80% of all data points for each time period both inside of CTU 3 as well as its reference area.

Water level data collected from 1997 through 2017 are summarized by station in Table 5. (Note the relevant data collection periods associated with each station presented in Table 1 earlier in this section).

Table 5. Summary of water levels for continuous hydrographic stations inside and outside the Brady Canal Hydrologic Restoration (TE-28) project using all available data for each station from 1997 through 2017. Water levels are presented in (ft) NAVD.

Water Level Summary - Project Stations				
Station	**Mean**	**Minimum**	**Maximum**	**Range**
TE28-01	1.29	-0.71	6.35	7.06
TE28-02	1.55	0.06	6.02	5.96
TE28-03	1.29	-0.31	6.69	7.00
Overall	1.37	-0.71	6.69	7.06
Reference Stations				
TE28-04R	1.06	-0.66	3.47	4.13
TE28-05R	1.26	0.38	2.81	2.43
TE28-06R	1.21	0.00	3.41	3.41
TE28-07R	1.40	-0.37	5.62	5.99
CRMS0294-H01	1.42	-0.41	5.44	5.85
CRMS0398-H01	1.26	-0.74	4.33	5.07
CRMS4045-H01	1.36	-0.85	6.60	7.45
Overall	1.20	-1.04	6.60	7.45

In addition to this summary, statistical analyses including analysis of weekly means and a Tukey-Kramer pairwise test of differences was conducted. Data from project recorders and appropriate CRMS stations were used to compare each CTU with its respective reference area. These analyses focused on the previously unexamined and most recent project and reference data collected between either 2008 through 2017 (CTUs 1 and 2) or 2010 thru 2017 (CTU 3). Weekly mean water levels for each CTU are presented alongside that of their respective reference area in Figures 10 - 12. Mean weekly water level was not significantly different between project and reference in CTU 1 (Figure 10, Table 6), but did differ significantly between project and reference in CTUs 2 and 3 where mean water levels were each higher inside the Project area (Figures 11 and 12; Tables 7 and 8). The mean weekly water level was likewise slightly higher in CTU 1 compared to its reference area, but that difference was negligible and not statistically significant.

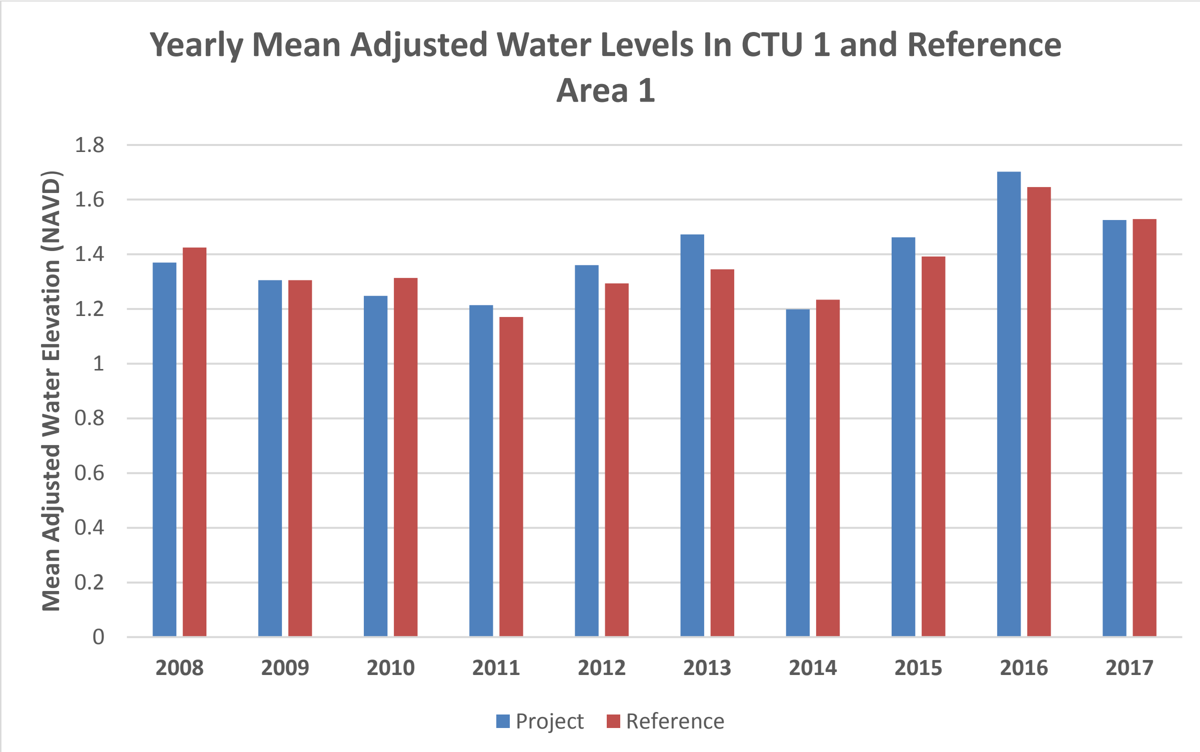

Figure 10. Weekly mean water levels by year for all open water continuous project and reference recorder stations associated with CTU 1 of the Brady Canal Hydrologic Restoration (TE-28) project between 2008 and 2017. The average water elevation to datum (ft) NAVD across all years was ~ 1.38 ft. in the project area and ~1.36 ft. in the reference area.

The mean water level for the 2008 through 2017 period was found to be slightly higher than the mean water level over all available years of project data in CTU 1. This was the case for each project-specific recorder in each CTU and suggests that overall water levels are increasing in the vicinity of the project since the exclusion of pre-2008 data results in slightly higher averages across the board.

Table 6. Connecting letters report from Tukey-Kramer pairwise test of weekly mean water levels in CTU 1 and Reference area 1 for the period 2008-2017.

Connecting Letters Report

Level		Mean
TE28-01	A	1.3812692
CRMS4045-H01	A	1.3641279

Levels not connected by same letter are significantly different.

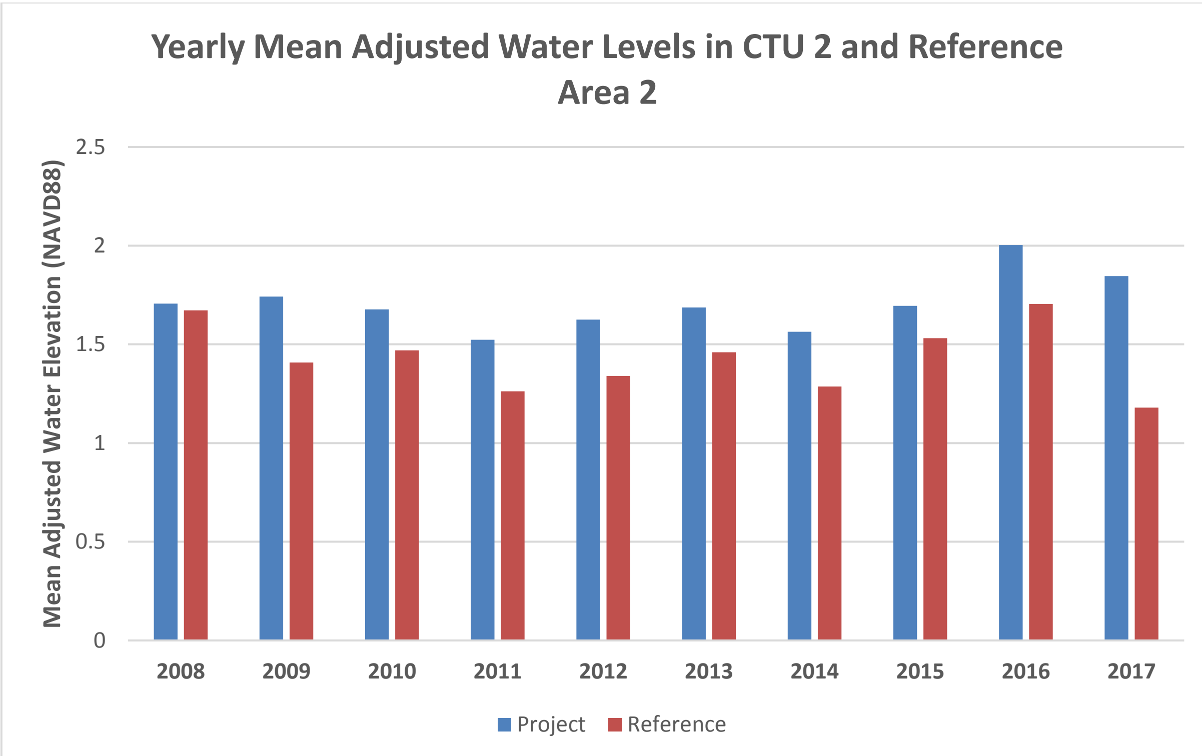

Figure 11. Yearly mean water levels for all open water continuous project and reference recorder stations associated with CTU 2 of the Brady Canal Hydrologic Restoration (TE-28) project between 2008 and 2017. The average water elevation to datum (ft) NAVD across all years was ~ 1.69 ft. in the project area and ~1.42 ft. in the reference area.

The project recorder in CTU 2 consistently reported higher water levels than those reported from its reference area by CRMS0294. They also appeared to remain fairly steady from year to year, while the water levels in the vicinity of CRMS0294 appeared to be slightly more prone to larger fluctuations. The results from a Tukey-Kramer pairwise test of CTU 2 project verses reference area over the 2008 through 2017 period found these results to be statistically significant (Table 7).

Table 7. Connecting letters report from Tukey-Kramer pairwise test of weekly mean water levels in CTU 2 and Reference area 2 for the period 2008-2017.

Connecting Letters Report

Level			Mean
Project	A		1.6915523
Reference		B	1.4191708

Levels not connected by same letter are significantly different.

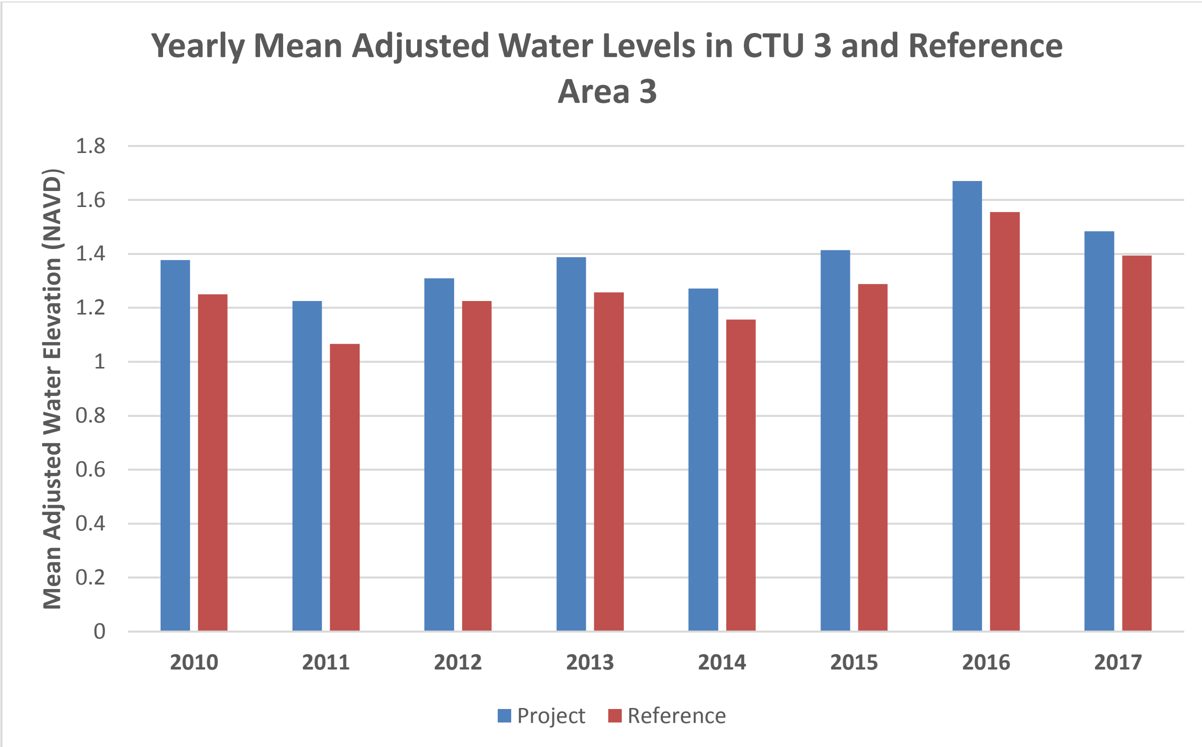

Figure 12. Yearly mean water levels for all open water continuous project and reference recorder stations associated with CTU 2 of the Brady Canal Hydrologic Restoration (TE-28) project between 2010 and 2017. The average water elevation to datum (ft) NAVD across all years was ~ 1.39 ft. in the project area and ~1.27 ft. in the reference area.

While the difference in water level between CTU 3 and its reference area appear to trend very closely to each other and to a similar extent (Figure 12), a Tukey-Kramer pairwise test found the difference in water levels between the two areas to be significantly different during the 2010 to 2017 period (Table 8).

Table 8. Connecting letters report from Tukey-Kramer pairwise test of weekly mean water levels in CTU 3 and Reference area 3 for the period 2010-2017.

Connecting Letters Report

Level			Mean
TE28-03	A		1.3893928
CRMS0398-H01		B	1.2653471

Levels not connected by same letter are significantly different.

All available water level data for each project or reference station was graphed according to the mean water level for a given year and presented in Figure 13. This summary graphic helps to visualize overall trends in water level in the vicinity of and over the life of the project. Visually, the general trend would support slightly higher water levels through time.

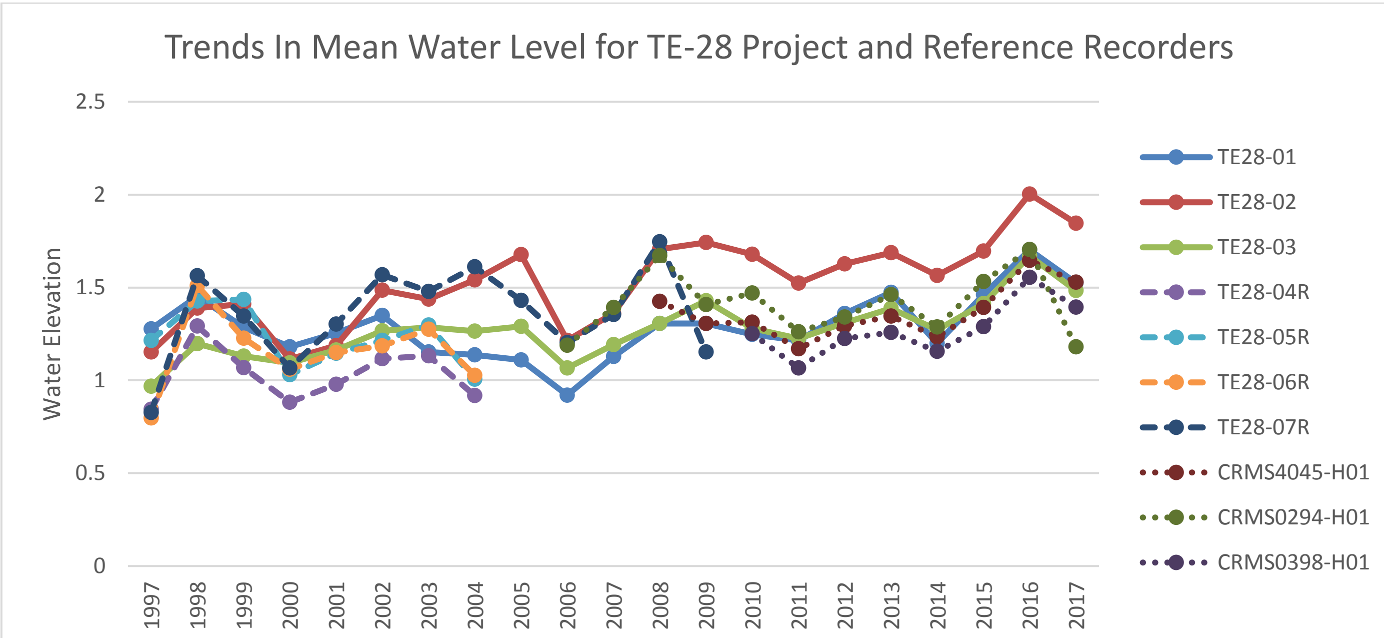

Figure 13. Mean Water Level by year for each project or reference recorder used in analysis of water level for the Brady Canal Hydrologic Restoration (TE-28) project. Note that project recorders are represented by solid lines while reference recorders are represented by dashed lines.

In order to evaluate the variability in water level exhibited by each station in the project area, the range was calculated for each project and reference recorder during the 2010 through 2017 time period for which concurrent data exist. The means of weekly range values were used for the analysis. The range, or difference between maximum and minimum water level, was lower in CTUs 1 and 2 than their corresponding reference areas. In each instance the difference was found to be statistically significant. CTU 3 exhibited slightly higher range values compared with its reference area, but not to a statistically significant degree.

CRMS4045 and CTU 3 were found to have statistically insignificant differences in the mean water level range, and CTU 3 shared a similar water level range with both its reference recorder CRMS0398 and CTU 1 (Table 9).

Table 9. Average Weekly Range of Water Level observations for TE-28 Project and Reference recorders from 2010 through 2017.

Mean Weekly Water Level Range (2010-2017)					
Station					**Range**
CRMS4045	A				1.17
TE28-03	A	B			1.13
CRMS0398		B			1.08
TE28-01		B			1.08
CRMS0294			C		0.64
TE28-02				D	0.51

Marsh Mat Movement

Marsh mat movement was evaluated in CTU 2 using continuous hourly data collected at marsh mat stations TE28-218, located inside the Project area, and CRMS0294, located in the CTU 2 Reference area. Mean daily marsh mat elevations were determined and compared between the Project and Reference areas for the 2010-2017 period (Figure 14). Similar analyses in the earliest reports used data from project-specific Reference area recorder TE28-219R, which was deactivated in 2002 in anticipation of CRMS-Wetlands implementation. CRMS0294 was constructed in late 2005 and its first full year of data was collected in 2006. Initial analysis of Project and Reference data revealed a mean marsh mat elevation of 0.94 ft (SD=0.46) at CRMS0294 and a mean marsh mat elevation of 1.36 ft (SD=0.40) at TE28-218. These mean and standard deviation values approximate to coefficients of variation (CV) in the Reference and Project areas of ~0.49 and ~0.29, respectively, and suggest fairly low variance in the dataset. Statistical comparison of the weekly means from these stations for the same period were found to differ significantly ($p<0.0001$) with CRMS0294 exhibiting an average marsh mat elevation of 0.92 ft and TE28-218 an average marsh mat elevation of 1.36 ft.

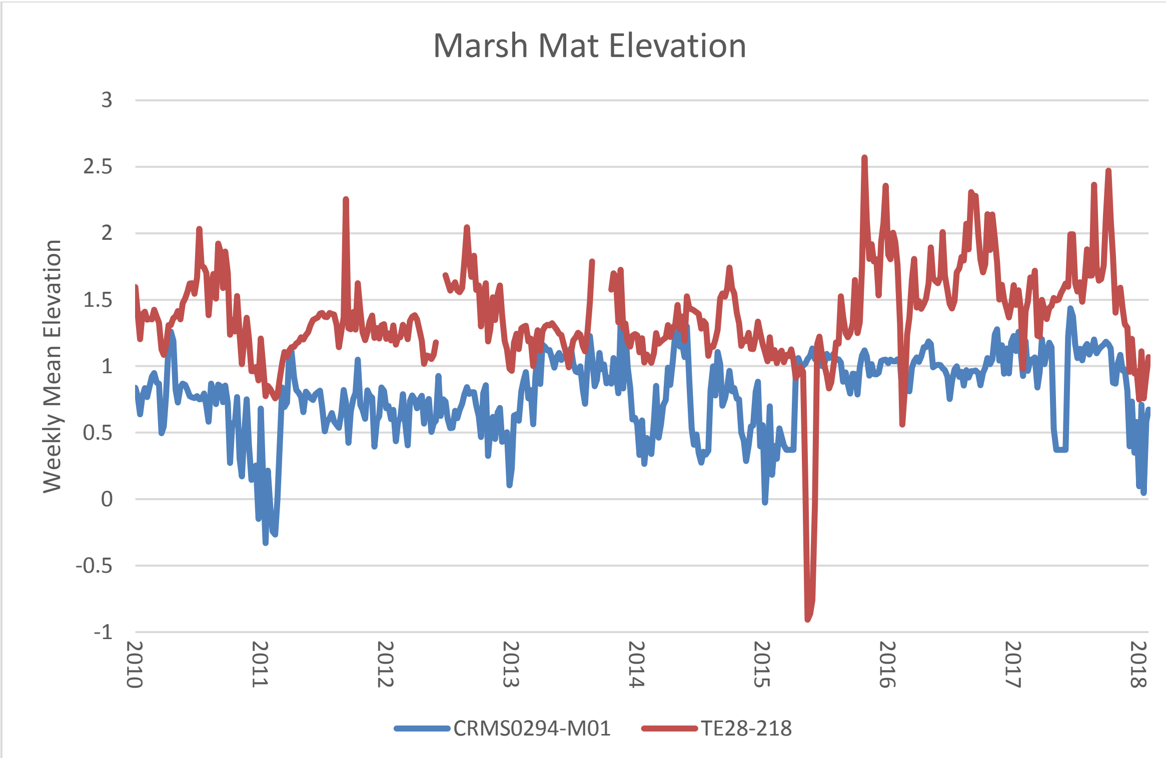

Figure 14. Weekly Mean Marsh Mat Elevation in CTU 2 and Reference Area 2 of the Brady Canal Hydrologic Restoration (TE-28) Project from 2010 through January of 2018.

Habitat Mapping

Habitat types within the Brady Canal Hydrologic Restoration (TE-28) project area were assessed via color-infrared photography and digital imagery in 1998, 2002, 2008 and 2016. The U.S. Fish and Wildlife Service's (USFWS) National Wetland Inventory (NWI) wetland classification system was used to define habitat categories within Project and Reference boundaries. Change analyses are based on increases or decreases of a given habitat category within the Project or Reference boundary and between the most recent as well as preliminary and final data collection events (Table 10).

Table 10. National Wetland Inventory habitat classes and changes in Project versus Reference area since most recent data acquisition (2008) and over the life (1998-2016) of the Brady Canal Hydrologic Restoration (TE-28) Project, reported in acres.

	Project (ac)		Reference (ac)	
Habitat Classification	08-'16 Change	98-'16 Change	08-'16 Change	98-'16 Change
Marsh - Fresh	294	294	50	-185
Marsh - Intermediate	-78	37	23	215
Upland Barren	-3.5	-0.25	0	-0.75
Upland Forested	0	-56	0	1
Upland Range	-3	0	0	0
Upland Scrub-Shrub	0	5	0	0
Upland Urban	-0.25	-1.5	-0.5	-0.5
Wetland Forested	19	29	9	12
Wetland Scrub-Shrub	-35	4	35	32
Mudflat	-120.5	51.75	-24.5	12
Open Water - Fresh	-917	-1374	226	48
Open Water - Intermediate	846	1013	-320	-136

The Project area has experienced a net gain of 331 total marsh acres over the life of the Project, Fresh Marsh constituting the bulk of this gain at ~294 acres, while Intermediate marsh has gained a more modest ~37 acres. The net gain in the Reference area for these same two categories and over the same time period is ~30 acres, ~215 of which are additional Intermediate Marsh acres offsetting a ~185 acre loss in Fresh Marsh. Fresh, open water habitat within the Project area has decreased by ~1374 acres while intermediate open water acreage has increased by ~1013 acres. Changes to open water habitats in the Reference area were much more modest, with an increase of ~48 freshwater acres and a net loss of ~136 intermediate open water acres. Forested Wetland acreage increased in both Project and Reference areas over the life of the Project at ~29 and ~12 acres, respectively. Mudflat acreage showed similar trends and trajectories in both Project and Reference areas, exhibiting increases of ~52 and ~12 acres respectively. Interim changes in remaining habitat classes from 2008 to 2016 as well as over the life of the Project are far more moderate or even negligible, especially in upland categories, which are not substantially represented in either Project or Reference areas.

Submerged Aquatic Vegetation (SAV)

The frequency of occurrence of submerged aquatic vegetation within the project area had decreased from the pre-construction sampling periods in the fall of 1996 and 1999, to the sole post-construction sampling event which occurred in 2002. The significant decrease observed during the post-construction period can be explained by the passing of Hurricane Lili just prior to the sampling event in the fall of 2002. This hurricane passed just weeks before the scheduled sampling effort and affected the SAV as well as emergent vegetation. During the pre-construction sampling period, the dominant species included *Ceratophyllum demersum*, *Najas guadalupensis*, *Nuphar lutea*, and *Nymphaea mexicana*. During the post-construction sampling period, the dominant species included *Ceratophyllum demersum* and *Nymphaea mexicana*. Decreases in SAV presumed to be a result of the hurricane are corroborated by the fact that relative frequency decreased equally both in project and reference areas.

Accretion

The most recent analysis of accretion data was presented in Folse and Babin (2007) just after the last data collection event in 2006. At that time, the rate of vertical accretion within the project area had decreased from the pre-construction to post-construction sampling periods. This decrease was attributed to environmental conditions brought on primarily by the drought that occurred from mid-1999 to mid-2001. Decreased water levels and increased salinity concentrations did not allow marsh flooding and mineral sediment deposition and likely reduced the productivity of aboveground biomass, all of which are important components to vertical accretion in fresh marsh.

V. Conclusions

a. Project Effectiveness

The stated goals of this project were to decrease marsh loss in the project area, maintain or increase plant species typical of fresh or intermediate marsh, decrease water level variability in the project area, and to decrease variability in salinity in the southern portion of the project. The overall project objectives were to maintain and enhance marsh by reducing tidal exchange and to improve freshwater and sediment retention. The combination of results presented in this report and discussed here suggest that these objectives have been achieved.

The goal of decreasing marsh loss has been achieved as both fresh and intermediate marsh acreages have increased inside the project area by ~294 and ~37 acres, respectively. These increases equate to a project-wide average marsh gain of ~16 acres per year, nearly completely reversing historical loss rates from 1932–1958. Intermediate marsh experienced no change in CTUs 2 and 3 from 1998 to 2016, but increased by ~37 acres in CTU 1. Fresh marsh and fresh open water acreages in CTU 2 fluctuated very modestly over the life of the project and, in 2016, had only experienced a loss of ~1 acre in each of these habitat classes. Interim changes of this habitat class in CTU 2 were all small and incremental, suggesting a stable environment that may be due in part to its more northward, interior location within the project area. Its reference area is similarly situated and experienced overall changes in habitat class of similar negligibility. Fresh marsh in CTU 1 increased by ~60 acres while CTU 3 experienced an increase of ~235 fresh marsh acres over the life of the project. Conversely, CTU 1 and 3 reference areas exhibited losses in fresh marsh habitat of ~120 and ~74 acres, respectively. The net gain in marsh acres inside the project area was substantial and heartily supports the project's success in achieving decreased rates of marsh loss. This is especially true when compared to the much poorer performance in the reference areas.

The goal to increase or maintain fresh and intermediate marsh vegetation has likewise been successfully achieved over the course of the project. Obligate Wetland and Facultative Wetland species dominate the wetland status of species throughout the project area. Positive trends in important fresh and intermediate marsh indicator species such as *Sagittaria lancifolia*, *Panicum hemitomon*, *Paspalum vaginatum* and *Schoenoplectus americanus* are evident within the project area where they are out-performing their influence in reference areas. Indicator species are typically used as such because they are not tolerant of disturbance and/or are sensitive to small environmental changes indicative of the health of the overall system.

Mean water level was found to be slightly higher in CTU 2 and 3, and slightly lower in CTU 1, when compared to respective reference areas. However, the goal of decreasing variability in water level within the project area has been achieved, as an examination of water level range revealed statistically different, lower water level variability in CTU 1 and 2 when compared to respective reference areas. The range analysis also revealed lower variability within CTU 3 compared to its reference area, although the difference was not statistically significant. Additionally, statistical analyses of marsh mat data in CTU 2 and its reference area revealed this metric to exhibit lower variability inside the project area. An analysis of range comparing all six stations supports a latitudinal or geographic proximity effect in water level variability.

Mean weekly project area salinity was higher than corresponding reference areas in CTU 1 and 2 but lower in CTU 3. Using the range in salinity readings to measure variability revealed statistically significant results in which variability was higher in CTU 1 and 3. While CTU 2 exhibited less variability than its reference area, those results were not statistically significant. These results indicate that the monitoring goal of reducing salinity variability inside the project area was not achieved. Analyses indicated close relationships between project recorders in CTU 1 and 3 and CRMS4045 for both water level and salinity, and the geographical proximity or latitudinal effect that this highlights has been apparent throughout the data collection and reporting duration of the project. The freshwater and sediment retention success of the project may also be related to salinity concentrations. Reduced tidal exchange has the potential to ensure a less variable salinity regime, but in the event of a tropical storm or drought, it can also have a moderating effect on the ability of the area to freshen so that it eventually experiences higher highs and lower lows than surrounding, less impounded areas. Salinity frequency distributions in CTU 3 did not reveal appreciable differences in the proportion of time that either CTU 3 or its reference area experienced salinity spikes, however, and combined with the analytical and anecdotal support from other project metrics, particularly emergent vegetation trends, it is not likely that statistical significance of salinity concentrations translates to biological significance.

c. **Lessons Learned**

Restoration and marsh creation projects such as the Brady Canal Hydrologic Restoration (TE-28) project, which either encompass large enough areas or are near or within transition zones such that different marsh types, hydrology and salinity regimes are included within the project footprint, present challenges to monitoring overall project effectiveness. Unforeseen programmatic changes that may occur over the course of a 20-year project and which either facilitate or necessitate changes in monitoring strategies or abilities also have the potential to complicate the monitoring process. The forethought of monitoring managers at the inception of this Project, which did indeed face challenges of this nature, allowed successful circumnavigation of these challenges. The Project area was subdivided into CTUs based on hydrology and marsh type and each of these were paired with a comparable reference area. These smaller units allowed flexibility in assessment strategies and were able to effectively guide developing shifts in project-specific and programmatic data collection. As changes continue to evolve in Louisiana's coastal zone, future projects in this area would benefit from similar strategies that offer built-in flexibility in measuring and evaluating project performance standards.

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Appendix A
(Inspection Photos)

Photo No.1 – View of northeast side of rock plug (Breach Closure No.7) on north bank of location canal along Superior Canal.

Photo No.2 – View of rock plug (Breach Closure No. 7) on north bank of location canal along Superior Canal.

Photo No.3 – View of southwest side of rock plug (Breach Closure No.7) on north bank of location canal along Superior Canal

Photo No.4 – recent earthen embankment repairs made by landowner along southwest bank of Superior Canal.

Photo No.5 – recent earthen embankment repairs adjacent to existing dock made by landowner along southwest bank of Superior Canal.

Photo No.6 – east end of existing rock revetment (Breach Closure 1-4) along north bank of Bayou Decade near Turtle Bayou.

Photo No.7 –existing rock revetment (Breach Closure 1-4) along north bank of Bayou Decade between Turtle Bayou and Jug Lake.

Photo No.8 –existing rock revetment (Breach Closure 1-4) along north bank of Bayou Decade between Turtle Bayou and Jug Lake.

Photo No.9 – existing rock revetment (Breach Closure 1-4) along north bank of Bayou Decade between Turtle Bayou and Jug Lake.

Photo No.10 – existing earthen embankment along south bank of Jug Lake near Bayou Decade.

Photo No.11 – existing earthen embankment along south bank of Jug Lake between Bayou Decade and Structure No.24.

Photo No.12 – rock revetment tie-in to the bank line of Jug Lake on the south side of Structure No.24.

Photo No.13 – Fixed crest weir (Structure No.24) along the south bank of Jug Lake.

Photo No.14 – south side of the rock revetment tie-in of the Variable crest weir (Structure No.23) along the east bank of Jug Lake.

Photo No.15 – north side of the rock revetment tie-in of the Variable crest weir (Structure No.23) along the east bank of Jug Lake.

Photo No.16 – Variable crest weir (Structure No.23) along the east bank of Jug Lake.

Photo No.17 – existing earthen bank line on the northeast side of Jug Lake just north of Structure No.23.

Photo No.18 – existing earthen bank line on the northeast side of Jug Lake north of Structure No.23.

Photo No.19 – breach in the earthen bank line on the northeast side of Jug Lake north of Structure No.23.

Photo No.20 – existing earthen bank line on the north side of Jug Lake northeast of Structure No.21.

Photo No.21 – existing earthen bank line on the north side of Jug Lake northeast of Structure No.21.

Photo No.22 – rock revetment tie-in on the south side of Structure No.21 along the north bank of Jug Lake.

Photo No.23 – variable crest weir (Structure No.21) located along the north bank of Jug Lake.

Photo No.24 – existing bank line on the northwest side of Jug Lake south of Structure No.21.

Photo No.25 – breach in the existing bank line on the northwest side of Jug Lake between Structure No.21 and Structure No.20.

Photo No.26 –existing bank line on the northwest side of Jug Lake between Structure No.21 and Structure No.20.

Photo No.27 –existing bank line on the northwest side of Jug Lake between Structure No.21 and Structure No.20.

Photo No.28 – rock lined channel (Structure No.20) located along the northwest bank of Jug Lake.

Photo No.29 – rock lined channel (Structure No.20) located along the northwest bank of Jug Lake.

Photo No.30 – south side rock lined channel (Structure No.20) located along the northwest bank of Jug Lake.

Photo No.31 – earthen bank along northwest side of Jug Lake south of Structure No.20.

Photo No.32 – earthen bank along northwest side of Jug Lake near Bayou Decade.

Photo No.33 – rock revetment bank tie-in on east side of Structure No.6 along Bayou Decade.

Photo No.34 – Navigational Aids at the entrance to the barge bay of Structure No.6.

Photo No.35 – northeast steel sheetpile tie-in at Structure No.6 along Bayou Decade.

Photo No.36 – damaged timber bollard and warning sign on the southwest side of the barge bay at Structure No.6.

Photo No.37 – staff gauge in channel on the north side of Structure No.6 (Elev: 1.7' @ 10:00 a.m.)

Photo No.38 – rock dike along north bank of Bayou Decade just west of Structure No.6.

Photo No.39 – rock dike along north bank of Bayou Decade just east of rock plug (Structure No.7)

Photo No.40 – rock plug (Structure No.7) across pipeline canal along the north bank of Bayou Decade.

Photo No.41 – rock plug (Structure No.7) across pipeline canal along the north bank of Bayou Decade.

Photo No.42 – beginning of a rock dike section west of Structure No.7 along Bayou Decade.

Photo No.43 – earthen embankment along north bank of Bayou Decade between Structure No.7 and Voss Canal.

Photo No.44 – rock revetment along north bank of Bayou Decade at Voss Canal.

Photo No.45 – rock channel liner (Structure No.10) at the southern end of Voss Canal along the east bank.

Photo No.46 – earthen embankment along the east bank of Voss Canal.

Photo No.47 – earthen embankment along the east bank of Voss Canal.

Photo No.48 – existing bank line along the northern reach of Voss Canal along the east bank.

Photo No.49 – existing bank line along the northern reach of Voss Canal along the east bank.

Photo No.50 – steel sheetpile wing wall on the south side of the Variable Crest Weir (Structure No.14).

Photo No.51 – Variable Crest Weir (Structure No.14) along the east bank of Carencro Bayou.

Photo No.52 – steel sheetpile wing wall on the north side of the Variable Crest Weir (Structure No.14).

Photo No.53 – breach in the overflow bank along Bayou Carencro north of Structure No.14

Photo No.54 – breach in the overflow bank along Bayou Carencro north of Structure No.14

Photo No.55 – existing rock closure between bankline and timber bulkhead at intersection of Brady Canal and Carencro Bayou. The rock closure is below the water line and is not visible in photo.

Appendix B
(Habitat Maps)

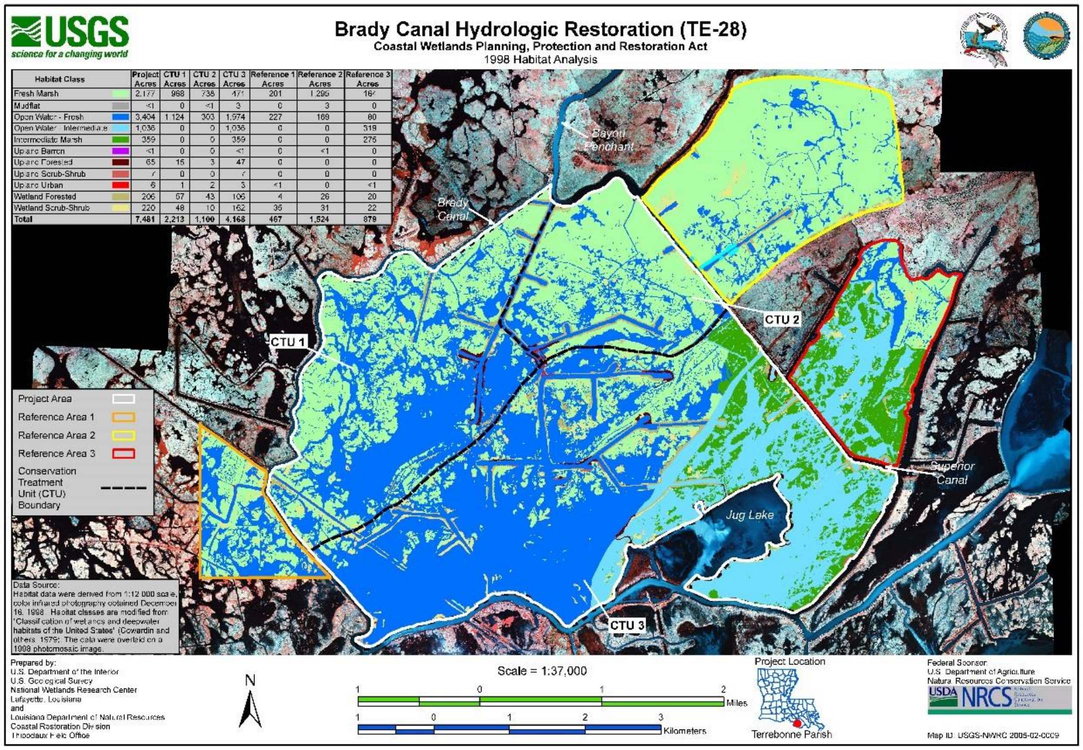


Figure. Pre-construction (1998) habitat analysis of the Brady Canal Hydrologic Restoration (TE-28) project and reference areas.

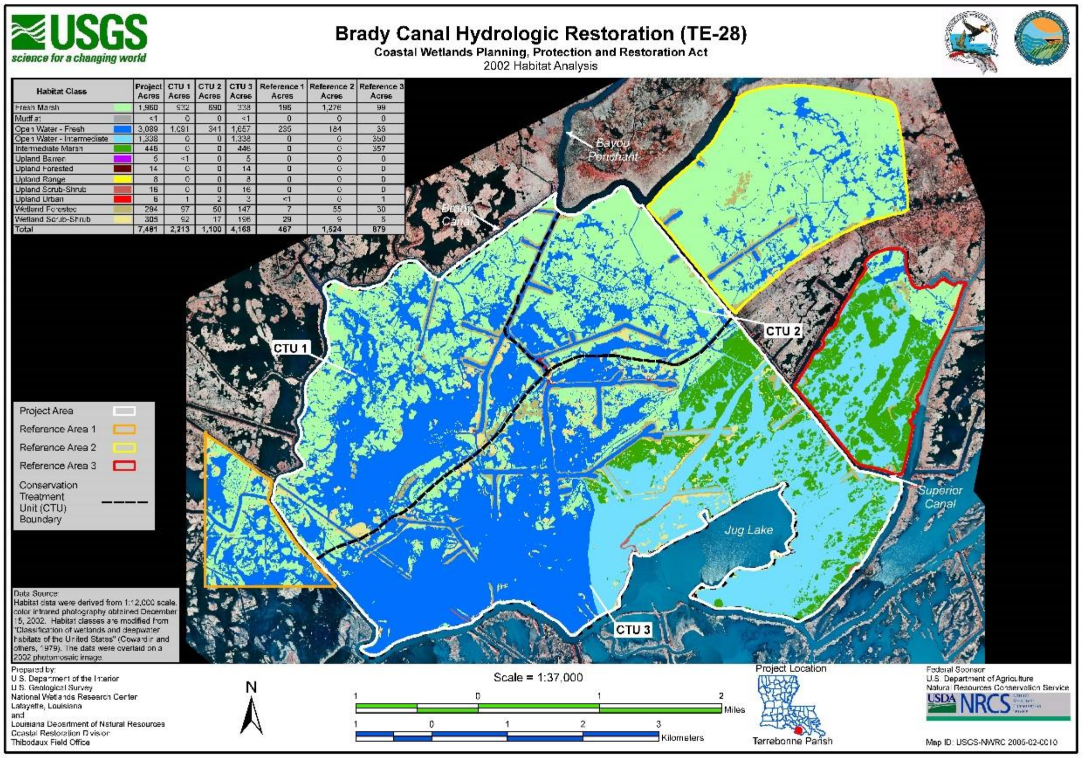
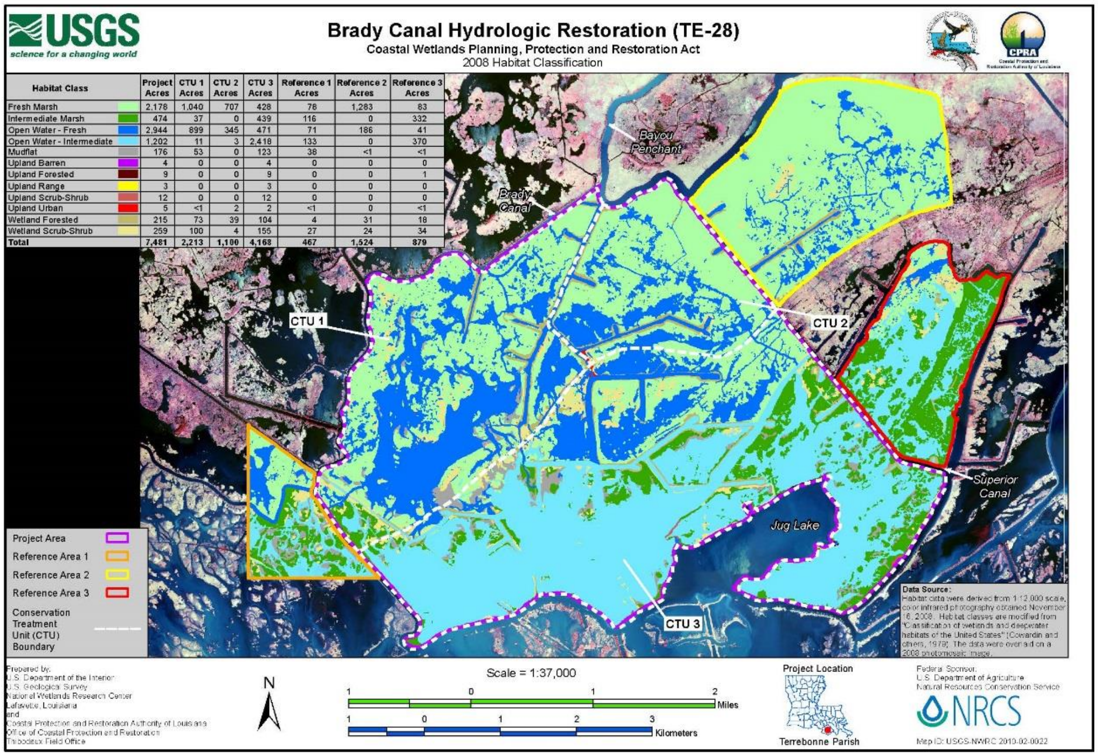
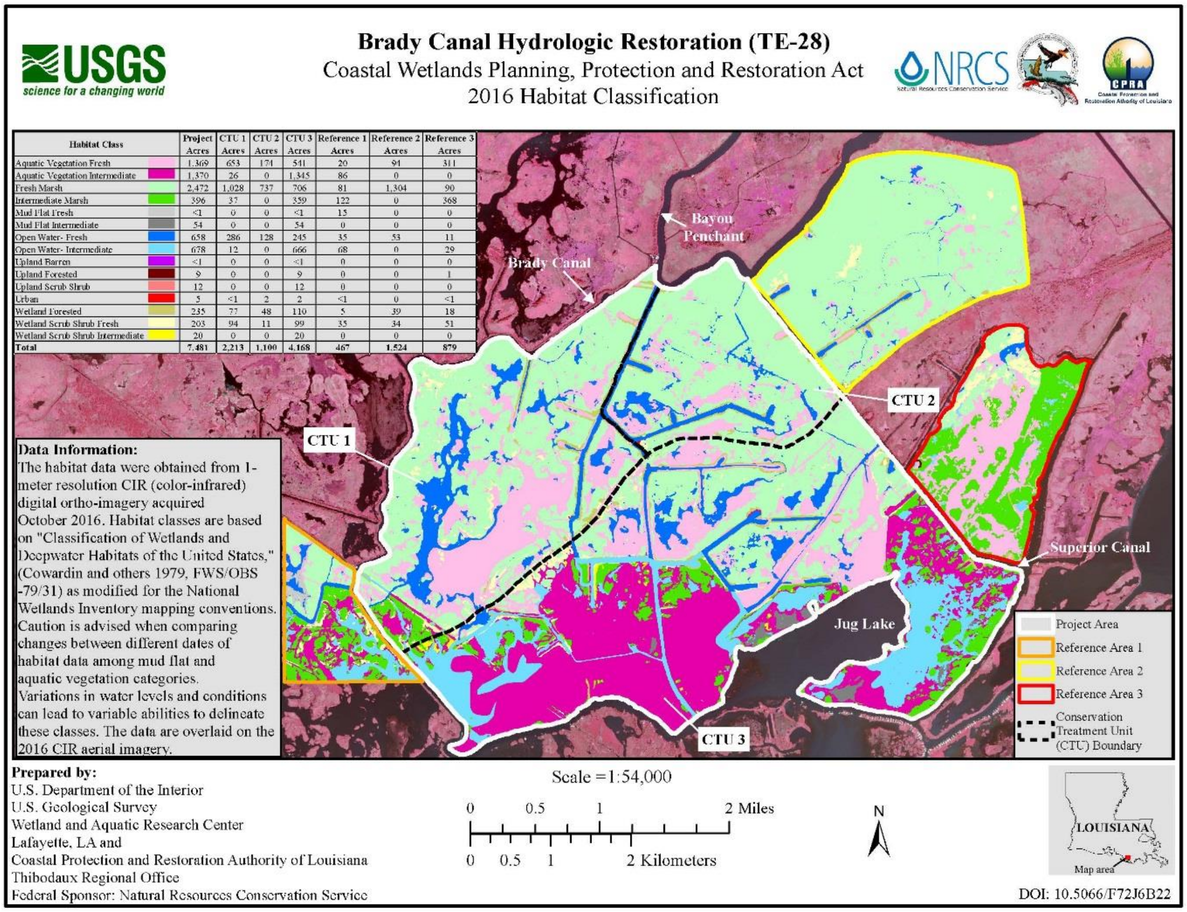


Figure. **Post-construction (2002) habitat analysis of the Brady Canal Hydrologic Restoration (TE-28) project and reference areas.**



Habitat Class	Project Acres	CTU 1 Acres	CTU 2 Acres	CTU 3 Acres	Reference 1 Acres	Reference 2 Acres	Reference 3 Acres
Fresh Marsh	2,178	1,040	707	428	78	1,283	83
Intermediate Marsh	474	37	0	439	116	0	332
Open Water - Fresh	2,944	899	345	471	71	186	41
Open Water - Intermediate	1,202	11	3	2,418	133	0	370
Mudflat	176	53	0	123	38	<1	<1
Upland Barren	4	0	0	4	0	0	0
Upland Forested	9	0	0	9	0	0	1
Upland Range	3	0	0	3	0	0	0
Upland Scrub-Shrub	12	0	0	12	0	0	0
Upland Urban	5	<1	2	2	<1	0	<1
Wetland Forested	215	73	39	104	4	31	18
Wetland Scrub-Shrub	259	100	4	155	27	24	34
Total	**7,481**	**2,213**	**1,100**	**4,168**	**467**	**1,524**	**879**

Figure. **Post-construction (2008) habitat analysis of the Brady Canal Hydrologic Restoration (TE-28) project and reference areas.**



Habitat Class	Project Acres	CTU 1 Acres	CTU 2 Acres	CTU 3 Acres	Reference 1 Acres	Reference 2 Acres	Reference 3 Acres
Aquatic Vegetation Fresh	1,369	653	174	541	20	91	311
Aquatic Vegetation Intermediate	1,370	26	0	1,345	86	0	0
Fresh Marsh	2,472	1,028	737	706	81	1,304	90
Intermediate Marsh	396	37	0	359	122	0	368
Mud Flat Fresh	<1	0	0	<1	15	0	0
Mud Flat Intermediate	54	0	0	54	0	0	0
Open Water- Fresh	658	286	128	245	35	53	11
Open Water- Intermediate	678	12	0	666	68	0	29
Upland Barren	<1	0	0	<1	0	0	0
Upland Forested	9	0	0	9	0	0	1
Upland Scrub Shrub	12	0	0	12	0	0	0
Urban	5	<1	2	2	<1	0	<1
Wetland Forested	235	77	48	110	5	39	18
Wetland Scrub Shrub Fresh	203	94	11	99	35	34	51
Wetland Scrub Shrub Intermediate	20	0	0	20	0	0	0
Total	**7,481**	**2,213**	**1,100**	**4,168**	**467**	**1,524**	**879**

Figure. Post-construction (2016) habitat analysis of the Brady Canal Hydrologic Restoration (TE-28) project and reference areas.