State of Louisiana

Coastal Protection and Restoration Authority of Louisiana (CPRA)

2018 Operations, Maintenance, and Monitoring Closeout Report

for

Atchafalaya Sediment Delivery (AT-02)

State Project Number AT-02
Priority Project List 2

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Operations, Maintenance, and Monitoring Report
for
Atchafalaya Sediment Delivery
(AT-02)

Table of Contents

Preface

This report includes monitoring data collected through December 2016, and annual Maintenance Inspections through May 2017. The Atchafalaya Sediment Delivery (AT-02) project is federally sponsored by the National Marine Fisheries Service (NMFS) and locally sponsored by the Coastal Protection and Restoration Authority of Louisiana (CPRA) under the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA, Public Law 101-646, Title III). AT-02 is listed on the 2nd CWPPRA Priority Project List (PPL-02).

The 2018 report is the 3rd in a series of OM&M reports since the end of project construction in March 1998 and is the final manuscript written for the AT-02 project. This Operations, Maintenance, and Monitoring Report as well as earlier reports (Rapp et al. 2001; Curole and Babin 2010a) in this series are posted on the Coastal Protection and Restoration Authority (CPRA) website at *http://cims.coastal.louisiana.gov/DocLibrary/DocumentSearch.aspx* and on the official CWPPRA website at http://www.lacoast.gov/new/Projects/Info.aspx?num=AT-02 .

I. Introduction

The Atchafalaya Sediment Delivery (AT-02) project is a sediment diversion and marsh creation restoration project located inside the Atchafalaya Delta. The project lies within the Louisiana Department of Wildlife and Fisheries (LDWF) administered Atchafalaya Delta Wildlife Management Area (WMA) and is positioned approximately 29 km (18 mi) south of Morgan City in St. Mary Parish, Louisiana (Figure 1). The AT-02 project is situated directly across the Atchafalaya River from the Big Island Mining (AT-03) project (Figures 1 and 2) and was placed along East Pass (Figure 3). The project is bounded on the north by Mile Island, the west by East Pass, and to the east and south by the Atchafalaya Bay. The AT-02 project area consists of 833 ha (2,182 acres) of fresh marsh, scrub-shrub, wetland forested, beach/bar/flat, submerged aquatics, and open water habitats (Figure 3).

Atchafalaya Delta growth was originated in 1952 with the deposition of prodelta clay sediments into Atchafalaya Bay. The aggradation of prodelta clay continued until 1962 when distal bar sediments (interlaminated thin sands, silts, and clays) began to accumulate on the bay bottom and form an embryonic subaqueous delta. By the early 1970's, sand rich distributary mouth bar sediments began to aggrade the Atchafalaya River-Atchafalaya Bay interface and establish subaerial mid-channel bar and levee facies (van Heerden and Roberts 1980; van Heerden and Roberts 1988; van Heerden et al. 1991; Roberts and van Heerden 1992; Majersky et al. 1997; Roberts 1998). The substantial floods of 1973, 1974, and 1975 hastened the emergence of the subaerial delta through the frictional deposition of larger grained sediments. These deposits were formed into a bifurcating network of mid-channel bars and secondary and tertiary distributary channels. During this time, seaward channel elongation and bifurcation were the geological mechanisms governing delta growth (van Heerden and Roberts 1980; van Heerden and Roberts 1988; van Heerden et al. 1991; Roberts

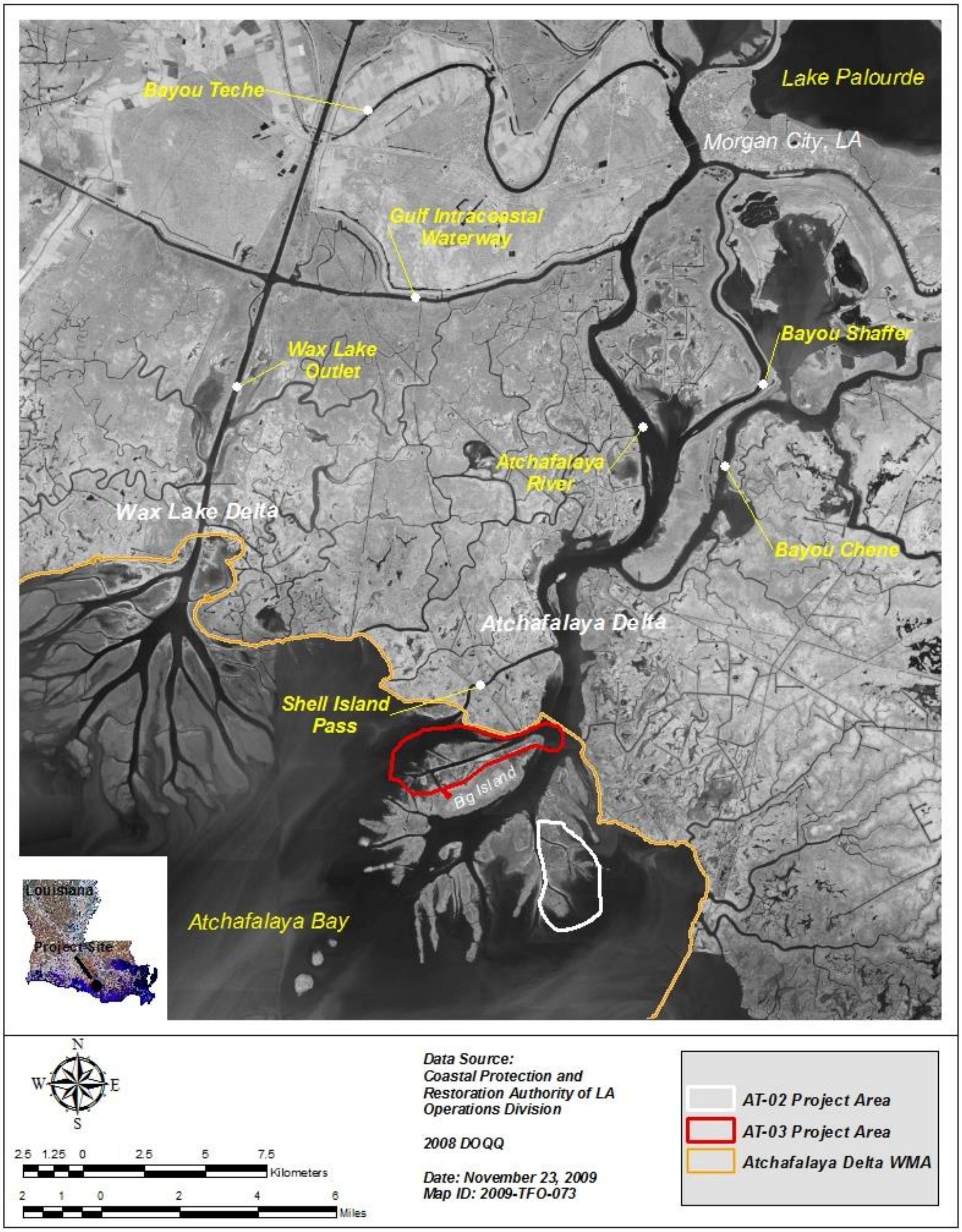

Figure 1. Location and vicinity of the Atchafalaya Sediment Delivery (AT-02) project.

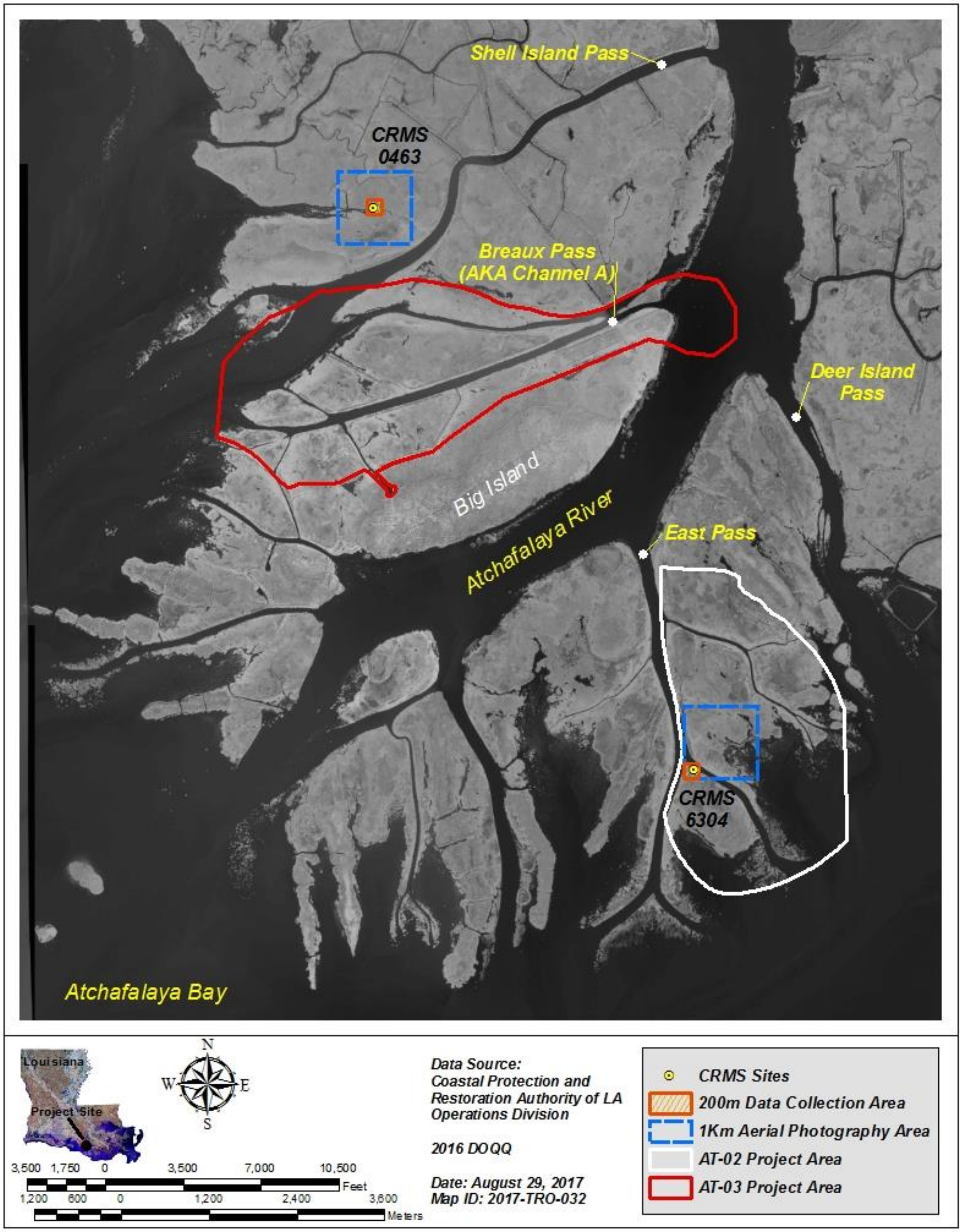

Figure 2. Location of the Big Island Mining (AT-03) project across the Atchafalaya River from the Atchafalaya Sediment Delivery (AT-02) project. The position of two CRMS-*Wetlands* sites are also shown. CRMS6304 is situated within the AT-02 project area.

Figure 3. Location of the Atchafalaya Sediment Delivery (AT-02) project area.

and van Heerden 1992; Roberts 1998). Due to these mechanisms and the large discharge flowing through East Pass, this distributary experienced considerable subaerial expression in the early 1970's. In this period of rapid delta development (1973 to 1976), the land in the Atchafalaya Delta expanded at a rate of 525 ha/yr (1,297 acres/yr) (van Heerden et al. 1991). Moreover, van Heerden et al. (1983) documented that 27% of the Lower Atchafalaya River discharge flowed through East Pass from 1979 to 1981. After 1976, channel abandonment and lobe fusion became the dominant geological processes forcing delta growth. These processes are initiated when subaqueous bars form across tertiary channels leading to deposition of fine grained sediments, channel narrowing, and lobe fusion (van Heerden and Roberts 1980; van Heerden and Roberts 1988; van Heerden et al. 1991; Roberts and van Heerden 1992; Roberts 1998). van Heerden et al. (1991) reported that the rate of land creation in the delta slowed to 193 ha/yr (477 acres/yr) from 1977 to 1991, a period dominated by channel abandonment and lobe fusion. Since this early period of subaerial delta growth, spring floods have arisen along the Atchafalaya River in 1979, 1983, 1984, 1993, 1997 (Trotter et al. 1998), 2001, 2008, and 2011 (DeHaan et al. 2012). Moreover, sediment deposition and subaerial lobe creation in the Atchafalaya Delta generally occur during the late winter and spring when river stages and discharges are highest. The overlying distributary mouth bar facies in the Atchafalaya River Delta consists of approximately 60% sand and have been estimated to be 3.0 m (9.8 ft) thick (Majersky et al. 1997; Roberts 1998).

The construction and maintenance of the Lower Atchafalaya River Bay and Bar navigation channel, which extends the entire length of the Lower Atchafalaya River and Atchafalaya Bay into the Gulf of Mexico, is slowing sediment deposition and subaerial lobe creation in the Lower Atchafalaya River Delta and providing a path for sediment transport into the Gulf of Mexico (van Beek 1979; Roberts 1998). The Lower Atchafalaya River Bay and Bar navigation channel was initially constructed in 1939 to a depth of 3 m (10 ft) and a width of 30 m (100 ft). This navigation channel was expanded to its present dimensions [6 m (20 ft) deep by 122 m (400 ft) wide] in 1974 and has been sustained through annual maintenance dredging (Penland et al. 1996; Penland et al. 1997). Approximately, 12,232,880 m^3/yr (16,000,000 yd^3/yr) of sediments are dredged annually from the Lower Atchafalaya River (the Atchafalaya River south of Morgan City, LA) to maintain the Lower Atchafalaya River Bay and Bar navigation channel (Mashriqui et al. 1997). To dispose of this large volume of sediments, dredged materials have been used to construct islands along the edges of the navigation channel. These artificially built islands have been placed at considerably higher elevations than the naturally created deltaic lobes (van Beek 1979; Sasser and Fuller 1988; Penland et al. 1996; Penland et al. 1997). Creation of dredged material islands in the Atchafalaya River Delta began in 1974 with the expansion of the Lower Atchafalaya River Bay and Bar navigation channel. During the period from 1974 to 1987, the vast majority of dredged materials were placed on the western banks of the Lower Atchafalaya River Delta. However since 1987, large amounts of dredged materials have also been deposited along the eastern banks of the Atchafalaya River Delta (Penland et al. 1996; Penland et al. 1997). As of 1996, 72% of the total area of the Atchafalaya River Delta was created by deposition of dredged materials while only 28% of the total area was created through natural processes (Penland et al. 1997).

The naturally created deltaic lobe islands of the Lower Atchafalaya River are generally composed of fresh marsh and mudflat habitats (Penland et al. 1996; Penland et al. 1997). Johnson et al. (1985) documented the initial colonization and spatial distribution of the naturally created Lower Atchafalaya River deltaic lobe islands as consisting of a *Salix nigra Marsh.* (black willow) association on the higher elevated upstream end of the lobe islands, a *Typha latifloia L.* (broadleaf cattail) association at intermediate elevations, and a *Sagittaria latifloia Willd.* (broadleaf arrowhead) association at intermediate and lower elevations. Later surveys showed increases in species diversity and reductions in vegetative cover in the plant community on these deltaic lobes (Sasser and Fuller 1988; Shaffer et al. 1992). In contrast, the vegetative communities on many of the constructed islands differ from the naturally created islands due to placement of dredged material at higher elevations than the deltaic lobe islands. The vegetative communities on these islands are mainly composed wetland scrub-shrub, wetland forested, and bare ground habitats (Penland et al. 1996; Penland et al. 1997).

The formation of subaerial and subaqueous bars at the upstream end of two tertiary distributaries of East Pass has inhibited river discharge to portions of the eastern Atchafalaya Delta. The establishment of a subaerial bar at the head of Natal Channel in 1989 has obstructed sediment transport and partially fused the channel while the creation of a subaqueous bar on the upstream end of Castille Pass has disrupted sediment transport (Woodward-Clyde 1992). Since the shoaling at the head of Natal Channel and Castille Pass has reduced river discharge and sediment transport, delta growth has been minimized at the mouth of both distributaries (van Heerden et al. 1991). The rate of subaerial land growth inside the AT-02 project area has been estimated to be 4 ha/yr (9 acres/yr) from 1956 to 1978 and 3 ha/yr (8 acres/yr) from 1978 to 1990 (Barras et al. 1994).

The Atchafalaya Sediment Delivery (AT-02) project will attempt to enhance sediment transport and delta growth in the eastern delta by restoring Natal Channel and Castille Pass to functioning tertiary distributaries and constructing dredged material islands with sediments excavated from these channels. The following summary was attained from Mayer 1998. Natal Channel (NC) was reestablished by dredging a 1,829 m (6,000 ft) channel over its former watercourse. At the mouth of NC, this tertiary distributary was bifurcated into two 457 m (1,500 ft) branches (Figure 4). Castille Pass was reestablished by dredging a 610 m (2,000 ft) channel (CPC) at the head of the pass removing the subaqueous bar (Figure 4). The channels were dredged to a depth of -3 m (-10 ft) NGVD 29. The materials dredged from these channels were placed into Disposal Area 1 (DA1) [19 ha (48 acres)], Disposal Area 2 (DA2) [28 ha (70 acres)], Disposal Area 3 (DA3) [17 ha (47 acres)], Disposal Area 4 (DA4) [38 ha (95 acres)], and the Castille Pass Disposal Area (CPDA) [8 ha (21 acres)] (Figure 4). Earthen containment dikes were constructed for DA1, DA2, and DA3 at a 0.9 m (3 ft) NGVD 29 elevation. No containment dikes were constructed for DA4 and CPDA. The DA2 containment dike breached during construction increasing the size of the disposal area by 8 ha (20 acres) (V. Cook, OCPR, pers. comm.). Two 305 m (1000 ft) earthen jetties were installed at the head of NC to alleviate shoaling in this location (Figure 4). Construction of the AT-02 project began on January 25, 1998 and was completed by March 21, 1998. The Big Island Mining (AT-03) project is a similar sediment diversion and marsh creation project in the Atchafalaya Delta that was constructed simultaneously with the AT-02 project in 1998.

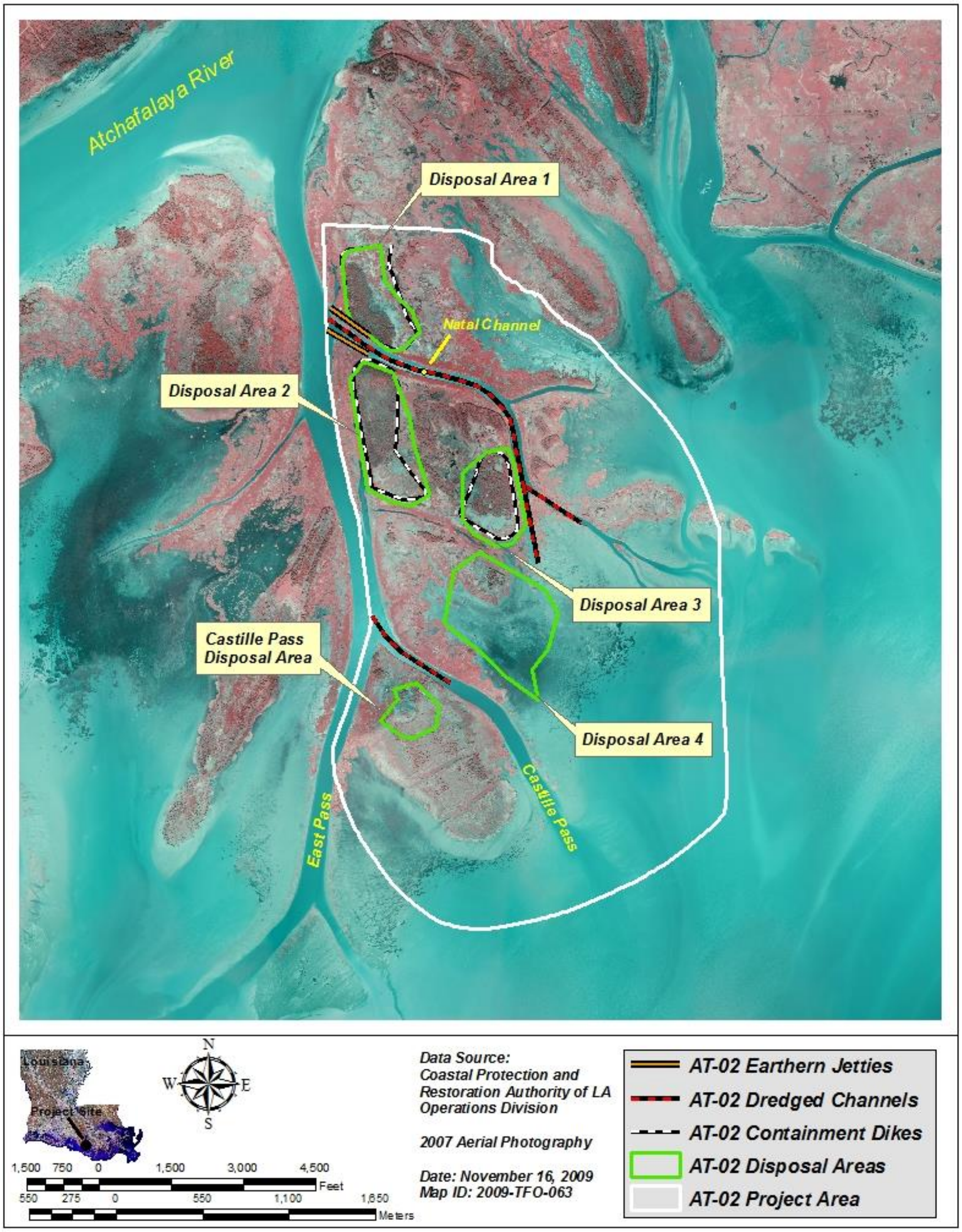

Figure 4. Location of the Atchafalaya Sediment Delivery (AT-02) project features.

II. Maintenance Activity

a. Project Feature Inspection Procedures

The purpose of the project inspections of the Atchafalaya Sediment Delivery Project (AT-02) are to evaluate the constructed project features, identify any deficiencies and prepare a report detailing the condition of such features and to recommend corrective actions needed, if any. Should it be determined that corrective actions are needed, CPRA shall provide, in report form, a detailed cost estimate for engineering, design, supervision, inspection, construction contingencies, and an assessment of the urgency of such repairs. Photographs of the inspection are located in Appendix A (A-1–A-10).

An inspection of the Atchafalaya Sediment Delivery Project (AT-02) was held on May 17th, 2017 under partly cloudy skies and warm temperatures. In attendance were Ben Hartman and Glen Curole of CPRA, Richard Hartman of the National Marine Fisheries Service (NMFS), and David LeBlanc with the Louisiana Department of Wildlife and Fisheries (LDWF). The attendees met at the Berwick Public Boat Launch in St. Mary Parish. The inspection began at approximately 9:00 a.m. and ended at 11:30 a.m.

b. Inspection Results

Inspection of the Atchafalaya Sediment Project (AT-02) began at the head of Natal Channel near East Pass and proceeded downstream to the fork near the Atchafalaya Bay. We did not have problems traveling the length of Natal Channel by boat but the water depths became very shallow along the lower reaches of the west fork. The current bathymetric data (2016 survey) show that the water depths have shifted the channel centerline. The aquatic vegetation in the bay on both sides of the east fork channel had extensive cover and appeared to be healthy. After traveling Natal Channel, we proceeded back upstream to an existing northeast tributary channel extending northeast near Sta. 55+00 of Natal Channel. We call this channel the NE Diversion Channel. The 2016 survey data show that this channel has a centerline depth of approximately 1.8 m (6.0 ft). Without earlier current bathymetric data, it is difficult to determine if substantial changes in channel contours occurred since 2008. However, the 2016 survey data and the 2017 inspection both provide evidence showing that the NE Diversion Channel is capturing a percentage of the Natal Channel flow and currently has a relatively deep centerline.

Inspection of the Castille Pass Channel began at the junction with East Pass and proceeded downstream towards Atchafalaya Bay. The latest survey data available were collected in 2016. This data revealed that the water depths at the junction of East and Castille Passes were around 2.7 m (9.0 ft) deep and became shallower as it proceeded downstream towards the bay. Using the survey data and the 2017 field inspection, it was determined that the channel geometry of Castille Pass Channel has deepened since 2008.

c. Maintenance Recommendations

i. Immediate/ Emergency Repairs
None

ii. Programmatic/ Routine Repairs
None

d. Maintenance History

Since the completion of the Atchafalaya Sediment Delivery (AT-02) Project in March 1998, there were no maintenance dredging or marsh creation efforts proposed or undertaken.

III. Operations Activity

a. Operation Plan
None

b. Actual Operations
None

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 AT-02 Monitoring Plan to merge it with CRMS-*Wetlands* and provide more useful information for modeling efforts and future project planning while maintaining the monitoring mandates of the Breaux Act. There is one CRMS site located in the project area, CRMS6304. This site was added to the project area on July 30, 2009.

a. Monitoring Goals

The Atchafalaya Sediment Delivery (AT-02) project will attempt to enhance sediment transport and delta growth in the eastern delta by restoring Natal Channel and Castille Pass to tertiary distributaries and constructing dredged material islands with sediments excavated from these channels. The objectives of this project are to restore Natal Channel and Castille Pass to functioning tertiary distributary channels thereby enhancing the system's natural delta-building potential and to utilize dredged material from the dredging of Natal Channel and Castille Pass to create delta lobe islands suitable for establishment of emergent marsh.

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The specific measurable goals established to evaluate the effectiveness of the project are:

1. To increase the distributary potential of Natal Channel and Castille Pass by increasing their cross-sectional area and length.

2. Create approximately 92 ha (230 acre) of delta lobe islands through the beneficial use of dredged material at elevations suitable for emergent marsh vegetation.

3. Increase the rate of subaerial delta growth in the project area to that measured from historical photographs since 1956.

b. Monitoring Elements

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

<u>Elevation</u>

Topographic surveys were employed to document elevation and volume changes inside the Atchafalaya Sediment Delivery (AT-02) project disposal areas. Pre-construction (March 1998) and as-built (May 1998) elevation data were collected using cross sectional survey methods (500 ft intervals) with a centerline profile. Five disposal areas (DA) were surveyed during the pre-construction and as-built periods (DA1, DA2, DA3, DA4, and CPDA).

Subsequent post-construction topographic surveys were conducted without a centerline profile and DA2 and DA3 were not surveyed due to budgetary constraints. These post-construction surveys were performed in May 2008 and October 2016. All survey data were established using or adjusted to tie in with the Louisiana Coastal Zone (LCZ) GPS Network, a coastal primary and secondary benchmark network maintained by CPRA (CPRA 2016).

The March 1998, May 1998, May 2008, and October 2016 survey data were re-projected horizontally and vertically to the Universal Transverse Mercator map projection (UTM), the North American Datum of 1983 (NAD83) horizontal datum, and the North American Vertical Datum of 1988 (NAVD 88) vertical datum in meters using Corpscon® software. The re-projected data were imported into ArcView® software for surface interpolation. Triangulated irregular network models (TIN) were produced from the point data sets. Next, the TIN models were converted to grid models (2.0 m^2 cell size), and the spatial distribution of elevations were mapped. The grid models were clipped to the AT-02 disposal area polygons to estimate elevation and volume changes within the fill area.

Elevation changes from March 1998-May 1998, May 1998-May 2008, and May 1998-October 2016 were calculated by subtracting the corresponding grid models using the Light Detection and Ranging (LIDAR) Data Handler extension of ArcView®. After the elevation change grid models were generated, the spatial distribution of elevation changes in the AT-02 disposal areas were mapped in half meter elevation classes. Lastly, volume changes in the disposal areas were calculated in cubic meters (m^3) using the Cut/Fill Calculator function of the LIDAR Data Handler extension of ArcView®. Note, these elevation and volume calculations are valid only for the extent of the survey area.

Bathymetry

Bathymetric surveys were employed to document sedimentation patterns in the Atchafalaya Sediment Delivery (AT-02) dredged tertiary channels. Pre-construction (March 1998) and as-built (May 1998) elevation data were collected using cross sections spaced 100 ft apart and centerline profiles. Natal (NC) and Castille Pass (CPC) channels were surveyed during the pre-construction and as-built periods. Subsequent post-construction bathymetric surveys were conducted using 500 ft intervals and centerline profiles. These post-construction surveys were performed in May 2008 and October 2016. The increase in transect spacing from pre-construction/as-built to post-construction were due to budgetary constraints. All survey data were established using or adjusted to tie in with the Louisiana Coastal Zone (LCZ) GPS Network (CPRA 2016).

The March 1998, May 1998, May 2008, and October 2016 survey data were re-projected horizontally and vertically to the UTM NAD83 coordinate system and the NAVD 88 vertical datum in meters using Corpscon® software. The re-projected data were imported into ArcView® software for surface interpolation. TIN models were produced from the point data sets. Next, the TIN models were converted to grid models (2.0 m^2 cell size), and the spatial distribution of elevations were mapped. The grid models were clipped to the AT-02 dredged channel polygons to estimate elevation and volume changes within each channel.

Elevation changes from March 1998-May 1998, May 1998-May 2008, and May 1998-October 2016 were calculated by subtracting the corresponding grid models using the LIDAR Data Handler extension of ArcView® software. After the elevation change grid models were generated, the spatial distribution of elevation changes in the AT-02 dredged channels were mapped in half meter elevation classes. Lastly, volume changes in the dredged channels were calculated in cubic meters (m^3) using the Cut/Fill Calculator function of the LIDAR Data Handler extension of ArcView®. Note, these elevation and volume calculations are valid only for the extent of the survey area.

Vegetation

Vegetation stations were established in the Atchafalaya Sediment Delivery (AT-02) project area to document species composition and percent cover over time. Random plots were placed in DA1, DA4, and the CPDA (Figure 5). Vegetation data were collected in October 1998 (5 months post-construction), October 2000 (2.5 years post-construction), and October 2007 9.5 years 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 at each station 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. Eighteen (18) stations were sampled in 1998 using a $1m^2$ plot size, 24 stations were sampled in 2000 using $1m^2$ and $4m^2$ plot sizes, and 24 stations were sampled in 2007 using a $4m^2$ plot size.

No reference area was established to compare vegetation communities on the naturally occurring delta islands and the AT-02 disposal areas. However, historical data from Log and Hawk Islands (1979-1998) were obtained from Louisiana State University/Coastal Ecology Institute (LSU/CEI) (Figure 5). This vegetation data were used to establish community colonization and succession trends on a prograding delta island. The LSU/CEI data were also collected with the Braun-Blanquet method (Mueller-Dombois and Ellenberg 1974) and had a $1m^2$ plot size. LSU/CEI sampled 24 vegetation stations in 1979, 34 stations in 1980, 34 stations in 1982, and 55 stations in 1998.

Relative cover and importance value (IV) were calculated to summarize vegetation data. Both these parameters were grouped by disposal area and year in the project area while the reference area was grouped by year. Relative cover represents the cover of each species as a percentage of total cover (Barbour et al. 1999). An IV is calculated using a minimum of two relative measures. The following IV formula was applied to this analysis: IV = (relative cover + relative frequency)/2. IV represents each species relative contribution to the vegetative community (Barbour et al. 1999). Since relative cover and IV are relative measures, each species earns a value ranging from 0 to 100.

Figure 5. Location of the Atchafalaya Sediment Delivery (AT-02) vegetation stations and LSU/CEI's Rodney Island vegetation reference area.

Habitat Mapping

The U.S. Geological Survey's Wetland and Aquatic Research Center (USGS/WARC) obtained 1:12,000 to 1:40,000 scale color infrared (CIR) aerial photography to delineate habitats over time. These aerial images were classified and photo-interpreted to perform habitat analysis of the Atchafalaya Sediment Delivery (AT-02) project area [883 ha (2181 acres)]. Pre-construction aerial photographs were acquired on December 19, 1994 and November 24, 1997 at a 1:12,000 scale while post-construction photographs were acquired on November 3, 1998 (1:40,000 scale), November 15, 2000 (1:12,000 scale), October 29, 2007 (1:12,000 scale) (Figure 6), and November 13, 2016 (1:16,000 scale). The 1998 image was obtained from LDWF at the larger scale. Aerial photographs were scanned at 300 pixels per inch and georectified using ground control data collected with a global positioning system (GPS) and digital ortho quarter quads. These individually georectified frames were assembled to produce a mosaic of the project area.

Using the National Wetlands Inventory (NWI) classification system, the 1994, 1997, 1998, 2000, 2007, and 2016 photography were photointerpreted by USGS/WARC personnel and classified to the subclass level (Cowardin et al. 1979). The habitat delineations were transferred to 1:6,000 scale mylar base maps and digitized. After being checked for quality and accuracy, the resulting digital data were analyzed using geographic information systems (GIS) to determine habitat change over time in the project area. The habitat types were aggregated into seven habitat classes for the purpose of mapping change. Habitat changes inside the project area were calculated for the following intervals 1994-1997, 1994-1998, 1998-2000, 1998-2007, and 1998-2016.

Subaerial and Subaqueous Growth

Subaerial and subaqueous growth in the project area were qualitatively delineated by comparing NWI habitat assessments. These comparisons were undertaken for the 1998 and 2007 interval and repeated for the 1998 and 2016 interval. Areas showing growth were classified as either subaerial growth, subaqueous to subaerial growth, or subaqueous growth. Subaerial growth occurred when the open water-fresh habitat was converted to subaerial land (fresh marsh, upland barren, wetland forested, or wetland scrub-shrub habitats). Subaqueous to subaerial growth arose when beach/bar/flat or submerged aquatics habitats were transformed to subaerial land. Subaqueous growth transpired when the open water-fresh habitat was changed to beach/bar/flat or submerged aquatics habitats. Once classified, these areas were outlined using ESRI shapefiles (polygon) to calculate spatial growth in the project area from 1998 to 2007 and 1998 to 2016.

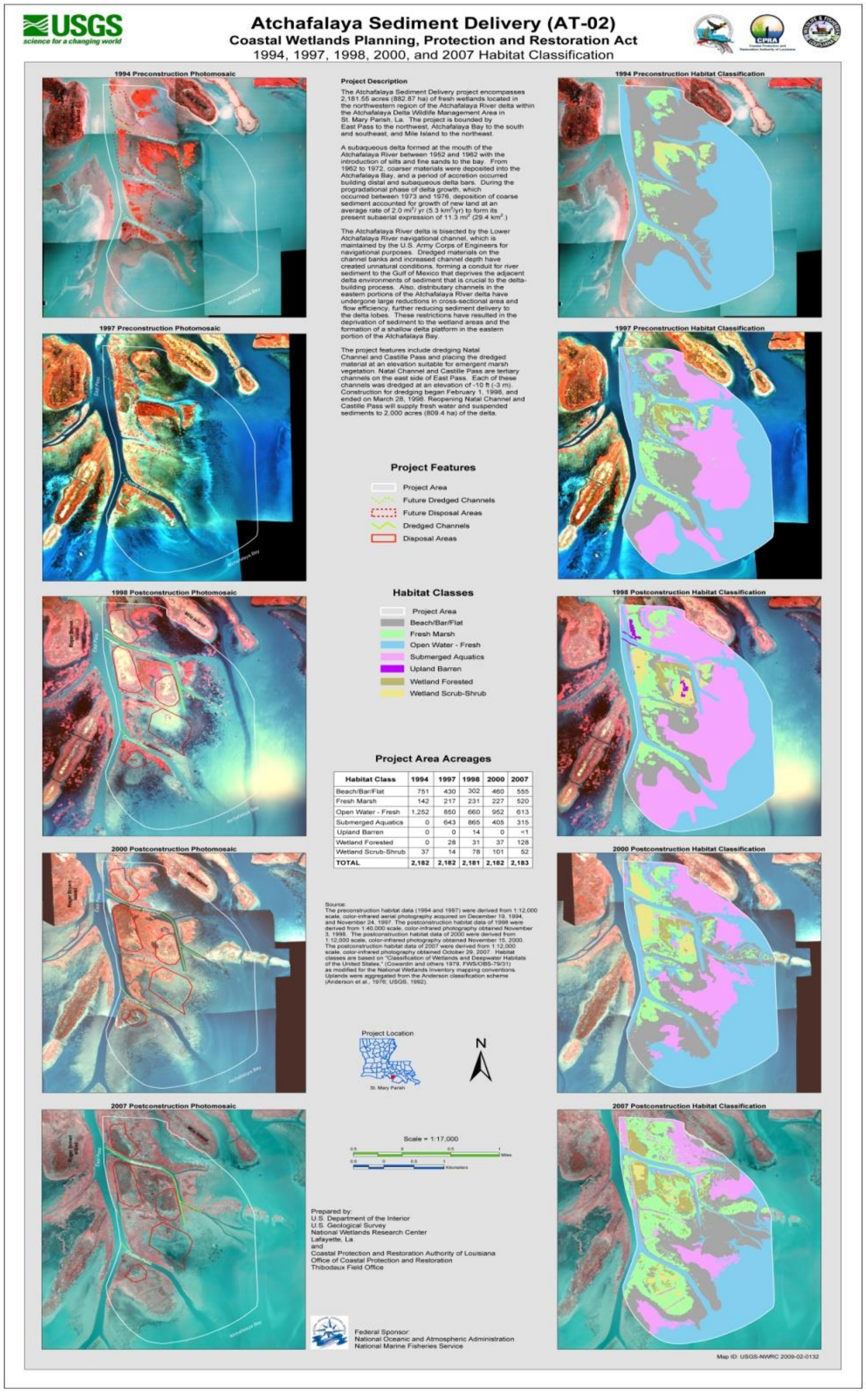


Figure 6. **Pre-construction (1994 and 1997), as-built (1998), and post-construction (2000 and 2007) photomosaics and habitat analysis of the Atchafalaya Sediment Delivery (AT-02) project area.**

Land Area Change

As previously mentioned one CRMS-*Wetlands* site (CRMS6304) is located in the AT-02 project area and was used to characterize the land changes within the site over a 30 year interval. Land area change assessments were performed on a 1.0 km^2 (0.4 mi^2) portion of the project area at the CRMS6304 site (Figure 2) to evaluate land change and to determine annual rates of land change (Folse et al. 2018). The U.S. Geological Survey's Wetland and Aquatic Research Center (USGS/WARC) obtained cloud free 30 m Landsat imagery to delineate land and water habitats over time. Landsat thematic mapper (TM) images were captured from 1984-2010 and Landsat operational land imager (OLI) digital maps were acquired from 2013-2016. These images were normalized, interpreted, processed, and verified for quality and accuracy using protocols established in Couvillion et al. (2017). Specifically, a modified normalized difference water index (mNDWI) and supervised and unsupervised grouping methods were used to classify areas of the imagery as land or water. After the images were interpreted, regression lines were created to show the land area change trends over time for the site.

c. Monitoring Results and Discussion

Elevation

The Atchafalaya Sediment Delivery (AT-02) project disposal areas experienced volume reductions and sediment additions since construction was completed in 1998. Elevation change and volume distributions for the AT-02 disposal areas are shown in Figure 7 (March 1998-May 1998), Figure 8 (May 1998-May 2008) and Figure 9 (May 1998-October 2016). Elevation grid models for the March 1998 (pre-construction), May 1998 (as-built), May 2008 (post-construction) and October 2016 (post-construction) disposal area surveys are also provided in Appendix B (B-1–B-4). Table 1 also lists the volume changes and percentages within the disposal areas over time. Note the low elevations found inside the unconfined disposal areas (DA4 and CPDA) for the as-built period (Figure 7). 85-91% of DA4 and CPDA were filled to elevations below +0.3 m (+1.0 ft) NGVD 29 (Mayer 1998). The confined AT-02 and the Big Island Mining (AT-03) DA1 and DA5 disposal areas were built to higher elevations (Curole and Babin 2010a). Approximately, 385,638 m^3 (504,396 yd^3) of sediment were deposited during construction in DA1, DA2, DA3, DA4, and CPDA (Figure 7 and Table 1). In the post-construction period, sediment volume decreased by 51% in DA1, 58% in DA4 and increased by 405% in CPDA (Figure 8 and Table 1). Sediment volume increased by 43,818 m^3 (57,312 yd^3) or 23% in the disposal areas from 1998 to 2008 (Figure 8 and Table 1). These volumes and percentages are misleading because the large volume gain in the CPDA was the result of an Atchafalaya River navigation channel maintenance event initiated by the U. S. Army CORP of Engineers (USACE), which pumped more than 129,481 m^3 (169,355 yd^3) of sediments into the CPDA (Figure 8 and Table 1). The channel maintenance event occurred during the interval between 2002 and 2004. The total sediment volume loss in DA1 and DA4 from 1998 to 2008 was approximately -85,663 m^3 (-112,043 yd^3), a -55% reduction in volume (Table 1). The volume loss in DA1 and DA4 correlates favorably with the AT-03 disposal area 1 (DA1), which was condensed by -57% from 1998 to 2008 (Curole and Babin 2010b).

By 2016 (project year 18) all three disposal areas studied experienced volume gains when compared to the 2008 volume changes. DA1 (-31%) and DA4 (-51%) displayed reductions in the percentage of volume losses while the CPDA (413%) slightly increased its post-maintenance percentage (Table 1). Volumes expanded by 12,615 m^3 (16,500 yd^3) in DA1, by 6,506 m^3 (8,510 yd^3) in DA4, and by 2,441 m^3 (3,193 yd^3) in the CPDA from 2008 to 2016 (Figure 9 and Table 1). Similar to the 1998-2008 interval, the combined DA1 plus DA4 volume loss percentage for the 1998-2016 interval (-43%) (Table 1) followed a trend that was consistent with AT-03's DA1 (-47%) (Curole and Hartman 2018). A likely catalyst driving these volume increases was the massive flood of 2011. This flood event produced flood stages and discharges that approached the largest Mississippi River flood events recorded (floods of 1927, 1973, and 1993) and required that the Morganza Floodway be opened causing greater discharges to be guided into the Atchafalaya Basin (DeHaan et al. 2012). In the aftermath of the 2011 flood, it was determined that sedimentation increased over a large area of the Atchafalaya Basin (Falcini et al. 2012), the Wax Lake Delta's subaerial extent expanded and elevated (Carle et al. 2015), and nitrate reduction was enhanced through inundation of the basin (Scott et al. 2014) during this flood event. DA1 incurred the highest quantity of volume gains, and the vast majority of this sedimentation transpired in segments of this disposal area that are in close proximity to NC. DA4 gained about half the volume of DA1. This is probably a result of the absence of a direct connection of this area to a secondary or tertiary distributary. Tiger Pass (TP) directly connects DA4 to East Pass was once a tertiary channel but has narrowed and aggraded (Figures 8 and 9). Consequently, TP transports considerably less discharge than NC. The CPDA had not only the lowest volume gains but also had the highest established elevation at the time of the flood. The CPDA was artificially raised to an elevation marginally above 0.61 m (2.0 ft) during the aforementioned maintenance event (Figure 8). Therefore, the lower sedimentation levels in this area were likely derived from the higher elevation of this area. The segments of the CPDA that did vertically accrete were typically of lower elevation and were outside the influence of the earlier maintenance event.

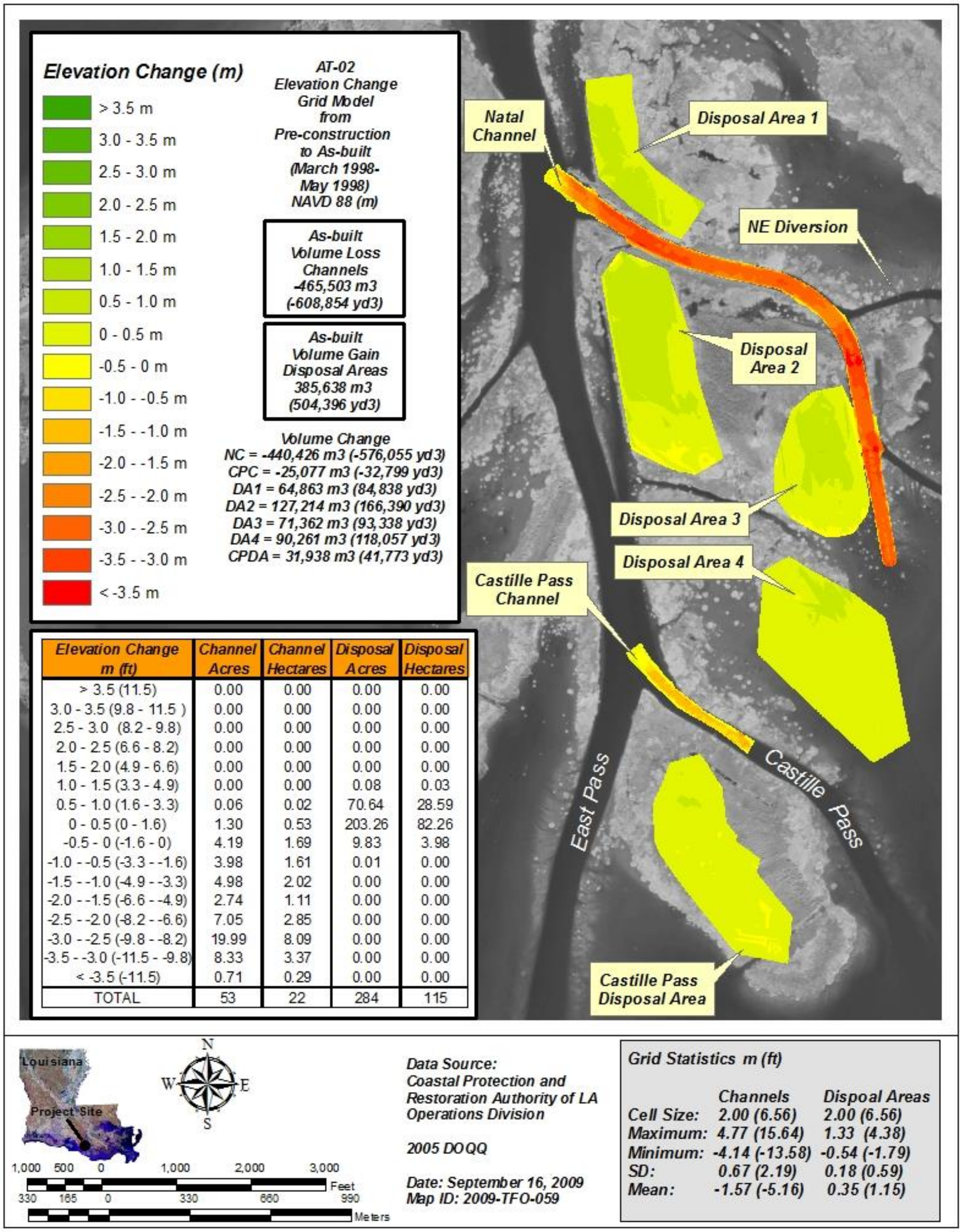
Table 1. Sediment volume changes (m^3) and percentages at the Atchafalaya Sediment Delivery (AT-02) disposal areas (DA1, DA4, and CPDA) over time.

AT-02 Disposal Area	Mar 1998 (Pre) - May 1998 (As-blt) (m3)	May 1998 (As-blt) - May 2008 (10 Yr Post) (m3)	Percent Volume Loss/Gain (%)	May 1998 (As-blt) - Oct 2016 (18 Yr Post) (m3)	Percent Volume Loss/Gain (%)
DA1	64,864	-33,025	-51	-20,410	-31
DA4	90,261	-52,638	-58	-46,132	-51
CPDA	31,938	129,481	405	131,922	413
Total	187,062	43,818	23	65,380	35
DA1+DA4	155,124	-85,663	-55	-66,542	-43

Bathymetry

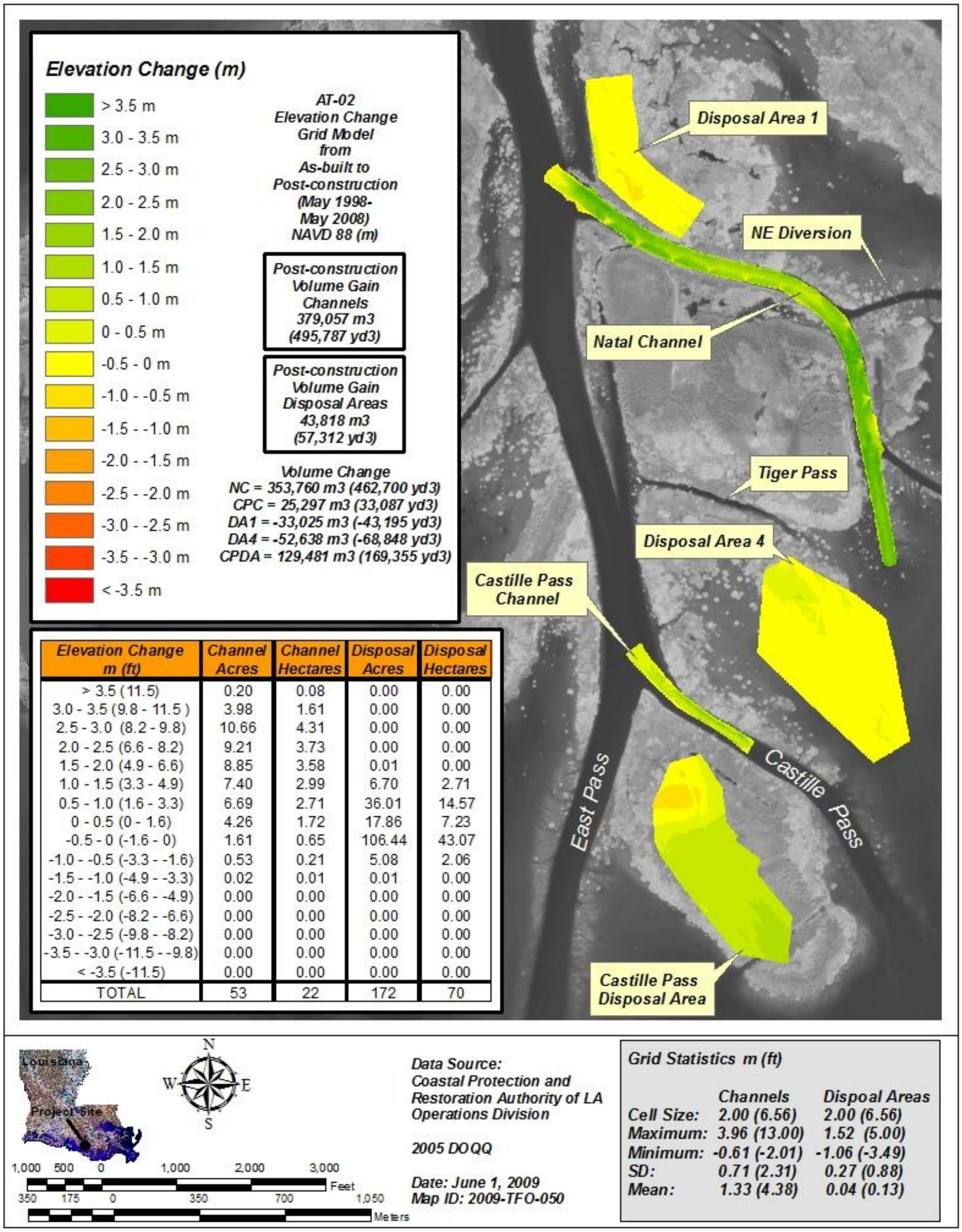
The Atchafalaya Sediment Delivery (AT-02) project's dredged channels experienced differential sedimentation patterns since construction was completed in 1998. Although disproportional shoaling occurred, both channels aggraded from 1998 to 2008 raising channel contours and bedload volumes. Elevation change and volume distributions for the AT-02 channels are shown in Figure 7 (March 1998-May 1998), Figure 8 (May 1998-May 2008) and Figure 9 (May 1998-October 2016). Elevation grid models for the March 1998 (pre-construction), May 1998 (as-built), May 2008 (post-construction) and October 2016 (post-construction) channel surveys are also provided in Appendix B (B-1–B-4). Table 2 also lists the volume changes and percentages within the dredged channels over time. Figure 10 is an elevation grid model that displays NC's distributary centerlines and mid-channel bars. Approximately, 465,503 m^3 (608,854 yd^3) of sediment were removed from the tertiary channels during construction in 1998 (Figure 7 and Table 2).

During the initial post-construction period, sediment volume increased by 80% in NC and 101% in CPC from 1998 to 2008 (Figure 8 and Table 2). The total sediment volume gain in the dredged channels from1998 to 2008 was approximately 379,057 m^3 (495,787 yd^3), an 81% expansion in volume (Figure 8 and Table 2). While it appears that CPC experienced greater shoaling than NC for the 1998-2008 period, these percentages are deceiving because a



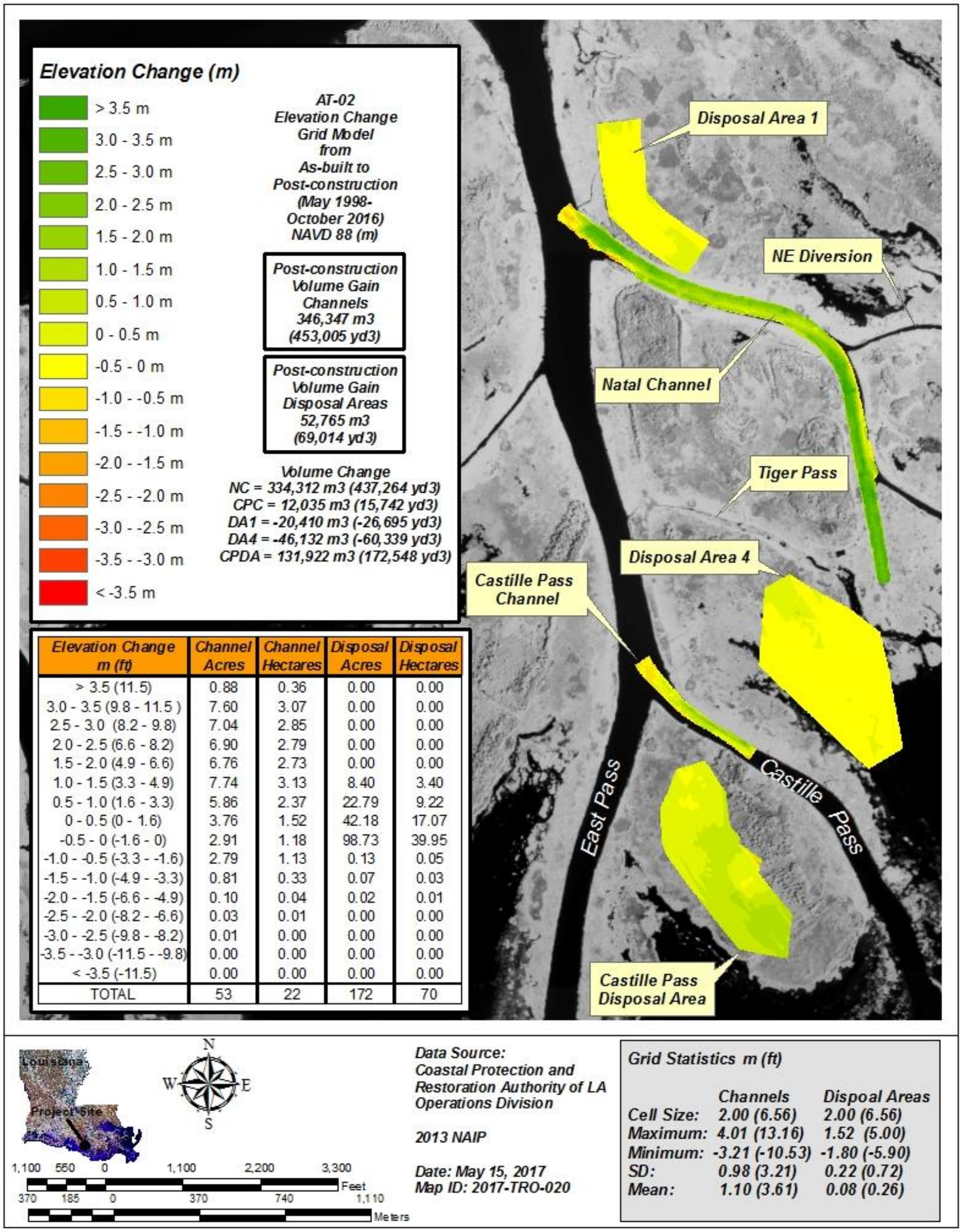
Elevation Change m (ft)	Channel Acres	Channel Hectares	Disposal Acres	Disposal Hectares
> 3.5 (11.5)	0.00	0.00	0.00	0.00
3.0 - 3.5 (9.8 - 11.5)	0.00	0.00	0.00	0.00
2.5 - 3.0 (8.2 - 9.8)	0.00	0.00	0.00	0.00
2.0 - 2.5 (6.6 - 8.2)	0.00	0.00	0.00	0.00
1.5 - 2.0 (4.9 - 6.6)	0.00	0.00	0.00	0.00
1.0 - 1.5 (3.3 - 4.9)	0.00	0.00	0.08	0.03
0.5 - 1.0 (1.6 - 3.3)	0.06	0.02	70.64	28.59
0 - 0.5 (0 - 1.6)	1.30	0.53	203.26	82.26
-0.5 - 0 (-1.6 - 0)	4.19	1.69	9.83	3.98
-1.0 - -0.5 (-3.3 - -1.6)	3.98	1.61	0.01	0.00
-1.5 - -1.0 (-4.9 - -3.3)	4.98	2.02	0.00	0.00
-2.0 - -1.5 (-6.6 - -4.9)	2.74	1.11	0.00	0.00
-2.5 - -2.0 (-8.2 - -6.6)	7.05	2.85	0.00	0.00
-3.0 - -2.5 (-9.8 - -8.2)	19.99	8.09	0.00	0.00
-3.5 - -3.0 (-11.5 - -9.8)	8.33	3.37	0.00	0.00
< -3.5 (-11.5)	0.71	0.29	0.00	0.00
TOTAL	53	22	284	115

Figure 7. **Elevation and volume change grid model from pre-construction (1998) to post-construction (1998) at the Atchafalaya Sediment Delivery (AT-02) project.**



Elevation Change m (ft)	Channel Acres	Channel Hectares	Disposal Acres	Disposal Hectares
> 3.5 (11.5)	0.20	0.08	0.00	0.00
3.0 - 3.5 (9.8 - 11.5)	3.98	1.61	0.00	0.00
2.5 - 3.0 (8.2 - 9.8)	10.66	4.31	0.00	0.00
2.0 - 2.5 (6.6 - 8.2)	9.21	3.73	0.00	0.00
1.5 - 2.0 (4.9 - 6.6)	8.85	3.58	0.01	0.00
1.0 - 1.5 (3.3 - 4.9)	7.40	2.99	6.70	2.71
0.5 - 1.0 (1.6 - 3.3)	6.69	2.71	36.01	14.57
0 - 0.5 (0 - 1.6)	4.26	1.72	17.86	7.23
-0.5 - 0 (-1.6 - 0)	1.61	0.65	106.44	43.07
-1.0 - -0.5 (-3.3 - -1.6)	0.53	0.21	5.08	2.06
-1.5 - -1.0 (-4.9 - -3.3)	0.02	0.01	0.01	0.00
-2.0 - -1.5 (-6.6 - -4.9)	0.00	0.00	0.00	0.00
-2.5 - -2.0 (-8.2 - -6.6)	0.00	0.00	0.00	0.00
-3.0 - -2.5 (-9.8 - -8.2)	0.00	0.00	0.00	0.00
-3.5 - -3.0 (-11.5 - -9.8)	0.00	0.00	0.00	0.00
< -3.5 (-11.5)	0.00	0.00	0.00	0.00
TOTAL	53	22	172	70

Figure 8. **Elevation and volume change grid model from as-built (1998) to post-construction (2008) at the Atchafalaya Sediment Delivery (AT-02) project.**

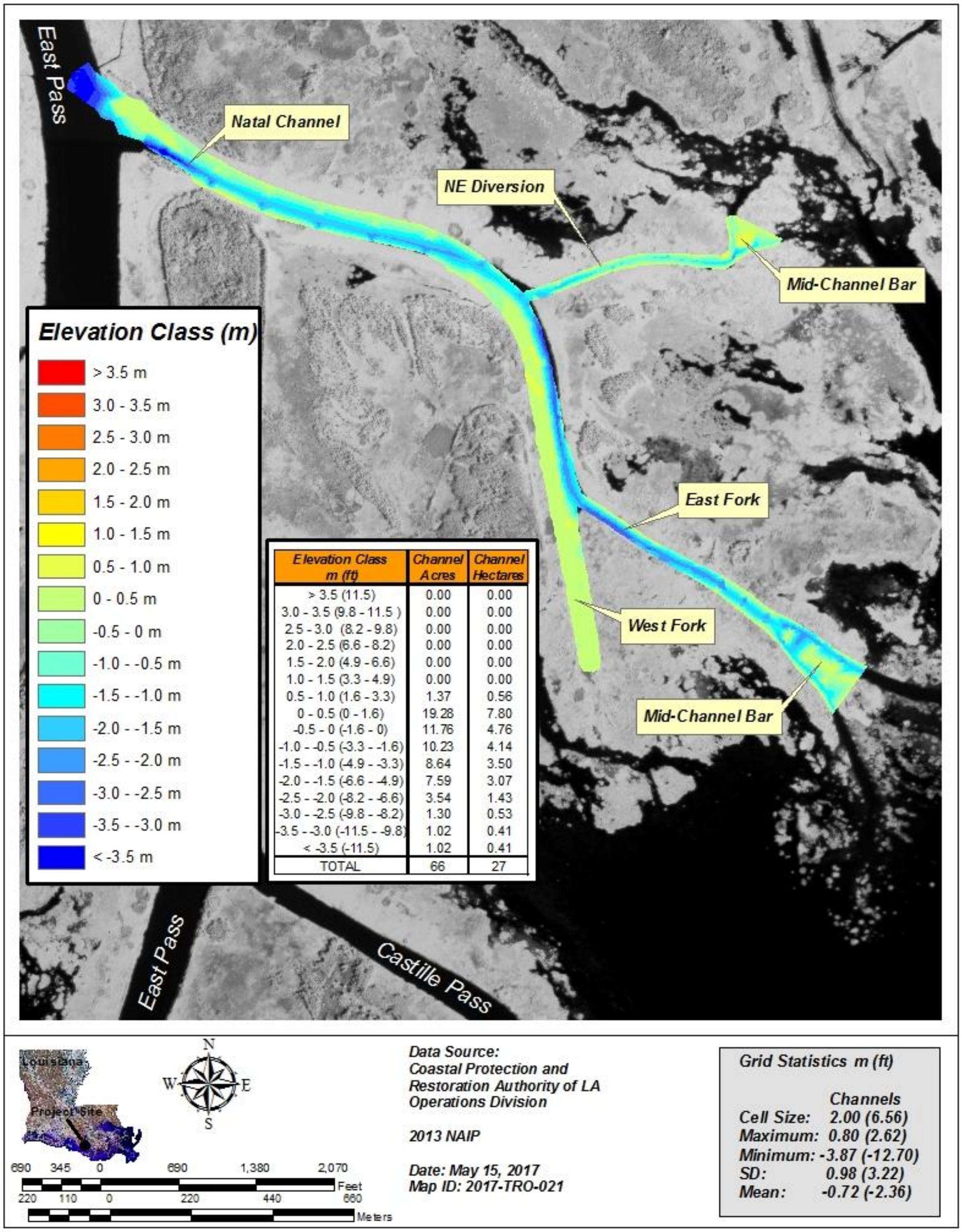


Elevation Change m (ft)	Channel Acres	Channel Hectares	Disposal Acres	Disposal Hectares
> 3.5 (11.5)	0.88	0.36	0.00	0.00
3.0 - 3.5 (9.8 - 11.5)	7.60	3.07	0.00	0.00
2.5 - 3.0 (8.2 - 9.8)	7.04	2.85	0.00	0.00
2.0 - 2.5 (6.6 - 8.2)	6.90	2.79	0.00	0.00
1.5 - 2.0 (4.9 - 6.6)	6.76	2.73	0.00	0.00
1.0 - 1.5 (3.3 - 4.9)	7.74	3.13	8.40	3.40
0.5 - 1.0 (1.6 - 3.3)	5.86	2.37	22.79	9.22
0 - 0.5 (0 - 1.6)	3.76	1.52	42.18	17.07
-0.5 - 0 (-1.6 - 0)	2.91	1.18	98.73	39.95
-1.0 - -0.5 (-3.3 - -1.6)	2.79	1.13	0.13	0.05
-1.5 - -1.0 (-4.9 - -3.3)	0.81	0.33	0.07	0.03
-2.0 - -1.5 (-6.6 - -4.9)	0.10	0.04	0.02	0.01
-2.5 - -2.0 (-8.2 - -6.6)	0.03	0.01	0.00	0.00
-3.0 - -2.5 (-9.8 - -8.2)	0.01	0.00	0.00	0.00
-3.5 - -3.0 (-11.5 - -9.8)	0.00	0.00	0.00	0.00
< -3.5 (-11.5)	0.00	0.00	0.00	0.00
TOTAL	53	22	172	70

Grid Statistics m (ft)

	Channels	Dispoal Areas
Cell Size:	2.00 (6.56)	2.00 (6.56)
Maximum:	4.01 (13.16)	1.52 (5.00)
Minimum:	-3.21 (-10.53)	-1.80 (-5.90)
SD:	0.98 (3.21)	0.22 (0.72)
Mean:	1.10 (3.61)	0.08 (0.26)

Figure 9. Elevation and volume change grid model from as-built (1998) to post-construction (2016) at the Atchafalaya Sediment Delivery (AT-02) project.



Elevation Class m (ft)	Channel Acres	Channel Hectares
> 3.5 (11.5)	0.00	0.00
3.0 - 3.5 (9.8 - 11.5)	0.00	0.00
2.5 - 3.0 (8.2 - 9.8)	0.00	0.00
2.0 - 2.5 (6.6 - 8.2)	0.00	0.00
1.5 - 2.0 (4.9 - 6.6)	0.00	0.00
1.0 - 1.5 (3.3 - 4.9)	0.00	0.00
0.5 - 1.0 (1.6 - 3.3)	1.37	0.56
0 - 0.5 (0 - 1.6)	19.28	7.80
-0.5 - 0 (-1.6 - 0)	11.76	4.76
-1.0 - -0.5 (-3.3 - -1.6)	10.23	4.14
-1.5 - -1.0 (-4.9 - -3.3)	8.64	3.50
-2.0 - -1.5 (-6.6 - -4.9)	7.59	3.07
-2.5 - -2.0 (-8.2 - -6.6)	3.54	1.43
-3.0 - -2.5 (-9.8 - -8.2)	1.30	0.53
-3.5 - -3.0 (-11.5 - -9.8)	1.02	0.41
< -3.5 (-11.5)	1.02	0.41
TOTAL	66	27

Figure 10. Post-construction (2016) elevation grid model at the Atchafalaya Sediment Delivery (AT-02) project showing NC's distributaries and mid-channel bars.

very small volume 25,077 m^3 (32,799 yd^3) was dredged from CPC in 1998 (Figure 7 and Table 2). CPC only aggraded 0.70 m (2.30 ft) and had an average channel contour of -1.79 m (-5.87 ft) while NC aggraded 1.96 m (6.42 ft) and had an average channel contour of -0.59 m (-1.95 ft) (Figures 8 and C-3). None of the Big Island Mining (AT-03) channels aggraded as much as NC for the first ten year post-construction interval (1998-2008). Moreover, CPC and AT-03's secondary channel (CA) experienced the least shoaling, and CPC maintained the deepest channel contour (Curole and Babin 2010b). Interestingly, CPC has aggraded to its pre-construction contours (Figures 8 and C-3) and volumes (Figures 7 and 8) signifying that the CPC discharge rate was in equilibrium with its flow field and sediment load from 1998 to 2008 (DuMars 2002; Mashriqui 2003; Edmonds and Slingerland 2007; Edmonds and Slingerland 2008; Letter et al 2008). Conversely, NC is not capturing enough of the East Pass discharge to prevent large scale shoaling and channel narrowing (Roberts and van Heerden 1992; DuMars 2002; Mashriqui 2003; Letter et al. 2008).

Table 2. Sediment volume changes (m^3) and percentages at the Atchafalaya Sediment Delivery (AT-02) dredged channels (NC and CPC) over time.

AT-02 Channel	*Mar 1998 (Pre) - May 1998 (As-blt) (m3)*	*May 1998 (As-blt) - May 2008 (10 Yr Post) (m3)*	*Percent Volume Gain (%)*	*May 1998 (As-blt) - Oct 2016 (18 Yr Post) (m3)*	*Percent Volume Gain (%)*
NC	-440,426	353,760	80	334,312	76
CPC	-25,077	25,297	101	12,036	48
Total	-465,503	379,057	81	346,348	74

Subsequent bathymetric change models (1998-2016) show that NC and CPC experienced a degree of bedrock erosion from 2008-2016. For this period approximately 19,448 m^3 (25,437 yd^3) of sediments were naturally excavated from NC and 13,262 m^3 (17,346 yd^3) of sediments were removed from CPC (Figure 9 and Table 2). All of the AT-03 dredged channels continued to aggrade and raise their channel contours for the 1998-2016 interval (Curole and Hartman 2018). The AT-02 volume losses translate to 76% (NC) and 48% (CPC) infilling of the dredged channels over the 18 year post-construction period (1998-2016) (Figure 9 and Table 2). Over the entire study period NC [1.86 m (6.10 ft] and CPC [0.34 m (1.12 ft] aggraded resulting in 2016 channel contours of -0.70 m (-2.30 ft) for NC and -2.18 m (-7.15 ft) for CPC. Moreover, CPC is only 0.31 m (1.01 ft) higher than its constructed channel contour (Figures C-2 and C-4). The bedrock erosion in NC and CPC during the 2008-2016 interval was likely initiated by the massive flood of 2011 (DeHaan et al. 2012). This flood transported courser grained sediments than some of the earlier Mississippi River flooding events (Heitmuller et al. 2016), and these sand sized sediments have been implicated in expanding bedrock erosion in the Wax Lake Delta (Shaw et al. 2013). Although the NC sediment volume was lowered by 2016, the channel volume was only reduced by 4% from 2008 to 2016 (Table 2). NC has considerably shoaled and narrowed since construction. Therefore, it seems rather surprising that NC continues to elongate the east fork of its constructed bifurcation and aggrade the mid-channel bar on its distal end while the west fork of the constructed bifurcation is shoaling and appears to be fusing (Figure 10). However, the NC that has emerged from the 2011 flood is narrow but has a well-defined centerline and maintains a minimum centerline channel depth of approximately -2.00 m (-6.56 ft) along its watercourse (Figure 10). The bathymetric record (Figures 8, 9, and 10) also provides evidence showing that NC is diverting flow to a former distributary (NE Diversion) located north of the bifurcation (van Heerden and Roberts 1980; van Heerden and Roberts 1988; van Heerden et al. 1991; Roberts and van Heerden 1992) contributing to the aggradation downstream of the diversion (west fork) (Letter et al 2008). This NE diversion was shaped into an elongated and bifurcated channel and created an embryonic mid-channel bar (Figure 10). Ironically, the original project design included the NE diversion channel. However, the channel was eliminated from the design due to a potential title conflict over property ownership. Hence, NC has two distributaries that have formed mid-channel bars and extend their channels seaward into Atachafalaya Bay. The NC centerline has relocated since construction, and this adjustment seems related to the positioning of the two NC distributaries (Figure 10). Upon further review, it probably is not that surprising that the two NC distributaries are elongating and aggrading mid-channel bars after the 2011 flood because these channels were elongating prior to the flood (Curole and Babin 2010a). However, it is notable that these deltaic features were enhanced while NC underwent considerable shoaling. In conclusion, the cross-sectional area of NC has decreased while the lengths of the east fork and the NE diversion channel have increased since construction. Castille Pass has increased its distributary potential since 2008 and its channel contour and cross-sectional area have been only slightly modified since construction. Therefore, the goal to increase the distributary potential of these channels by increasing their cross-sectional area and length has been realized at this time due to the elongation of the east fork of NC, the elongation of the NE diversion channel, the deepening of CPC, and the formation of the mid-channel bars. However, the extensive shoaling and narrowing of NC may adversely impact the distributary potential of this channel in the future. Though for the present period, the delta is expanding seaward on two fronts at the distal ends of this channel.

Vegetation

The Atchafalaya Sediment Delivery (AT-02) vegetation data show that similar vegetation communities inhabit the disposal areas while the historical reference area community is different. Moreover, the similarities and the disparities in these communities appear to be related to elevation. The results of the relative cover and importance value (IV) analysis are graphically illustrated in Figure 11 and Figure 12 for disposal area habitats. The LSU/CEI vegetation data are delineated in Figures 13 (relative cover) and 14 (IV). Note the differences between relative cover and IV is correlated with the frequency that a species populates vegetation plots. For example if a species is found in only a few plots with a high cover value, the species is likely to have a high relative cover value but probably will not have a high IV. The dominant species found in the CPDA were *Eichhornia crassipes (Mart.) Solms* (common water hyacinth) and *Colocasia esculenta (L.) Schott* (coco yam). By 2007, *Zizaniopsis miliacea (Michx.) Doell & Aschers.* (giant cutgrass) and *Alternanthera philoxeroides (Mart.) Griseb.* (alligatorweed) became the dominant species. The changes in the CPDA community are probably a result of elevation differences incurred between 1998 and 2007 (Figure 8). The dominant species found in DA1 in 1998 were *Eichhornia crassipes (Mart.) Solms* (common water hyacinth) and *Sagittaria latifloia Willd.* (broadleaf arrowhead).

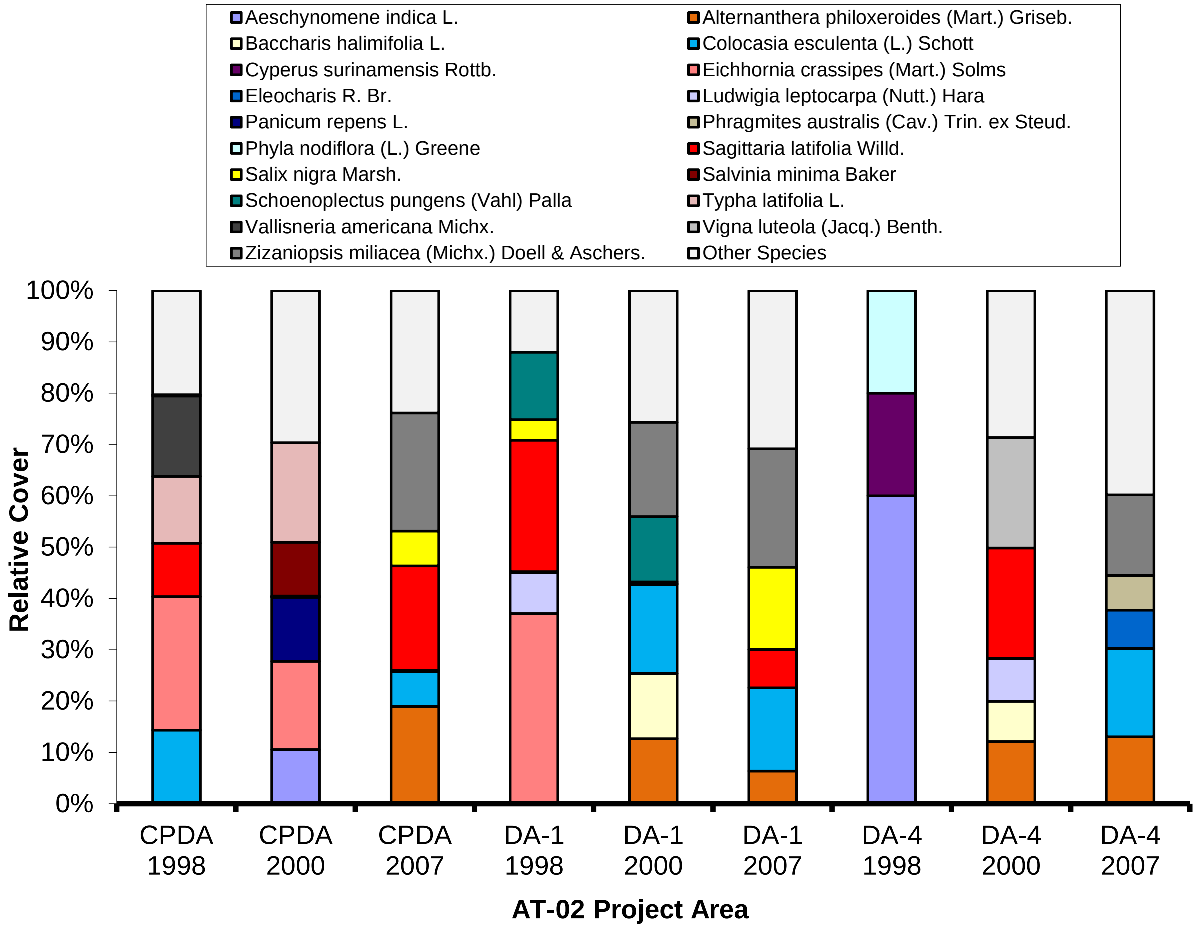


Figure 11. **Relative cover of the top five vegetation species populating the Atchafalaya Sediment Delivery (AT-02) disposal areas from 1998 to 2007. Ocular vegetation data were grouped by disposal area and year.**

By 2007, *Zizaniopsis miliacea (Michx.) Doell & Aschers.* (giant cutgrass) and *Salix nigra Marsh.* (black willow) became the dominant species. Sucession in DA1 (Figure 8) probably was a factor influencing change in this disposal area. No species were dominant in DA4 in 1998 because only 5% of this disposal area was vegetated. By 2007, *Colocasia esculenta (L.) Schott* (coco yam) and *Alternanthera philoxeroides (Mart.) Griseb.* (alligatorweed) became the dominant species. Approximately, 74% of DA4 was vegetated by 2007. Figure 11 and Figure 12 show the similarities and the differences in the CPDA, DA1, and DA4 vegetation communities from 1998 to 2007. Although CPDA and DA1 were inhabited by several matching species before 2007, after 2007 these disposal areas became more parallel suggesting that the disposal of dredge material by the USACE (Figure 8) exerted some influence on the CPDA vegetation community. Conversely, DA4 exhibited many of the same

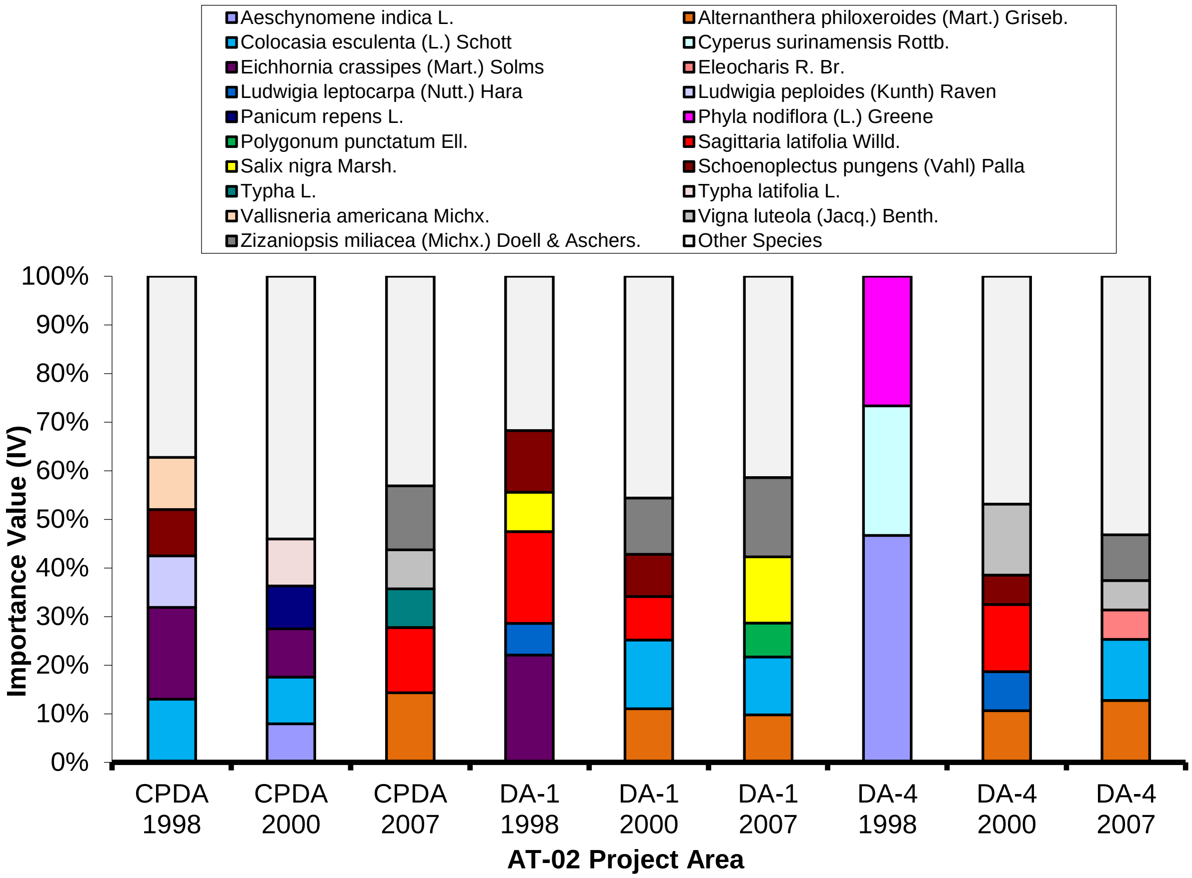


Figure 12. **Importance value (IV) of the top five vegetation species populating the Atchafalaya Sediment Delivery (AT-02) disposal areas from 1998 to 2007. Ocular vegetation data were grouped by disposal area and year.**

species, but this disposal area subsided from 1998 to 2007 (Figure 8). All the disposal areas experienced increases in species diversity and mean cover since 1998. The LSU/CEI historical reference areas have different vegetation community structures than the AT-02 disposal areas. One of the fundamental differences between the project and historical data sets is the naturally created deltaic lobe islands were established at low elevations (Sasser and Fuller 1988; Shaffer et al. 1992; Johnson et al. 1985; Penland et al. 1996; Penland et al. 1997). However, CPDA and DA4 were also established at low elevations (Figure C-2), and their vegetation communities do not resemble the Rodney Island historical data. Therefore, other factors besides elevation are probably influencing these vegetation communities. In conclusion, vegetation data show that similar vegetation communities inhabit the disposal areas while the historical reference area community is different.

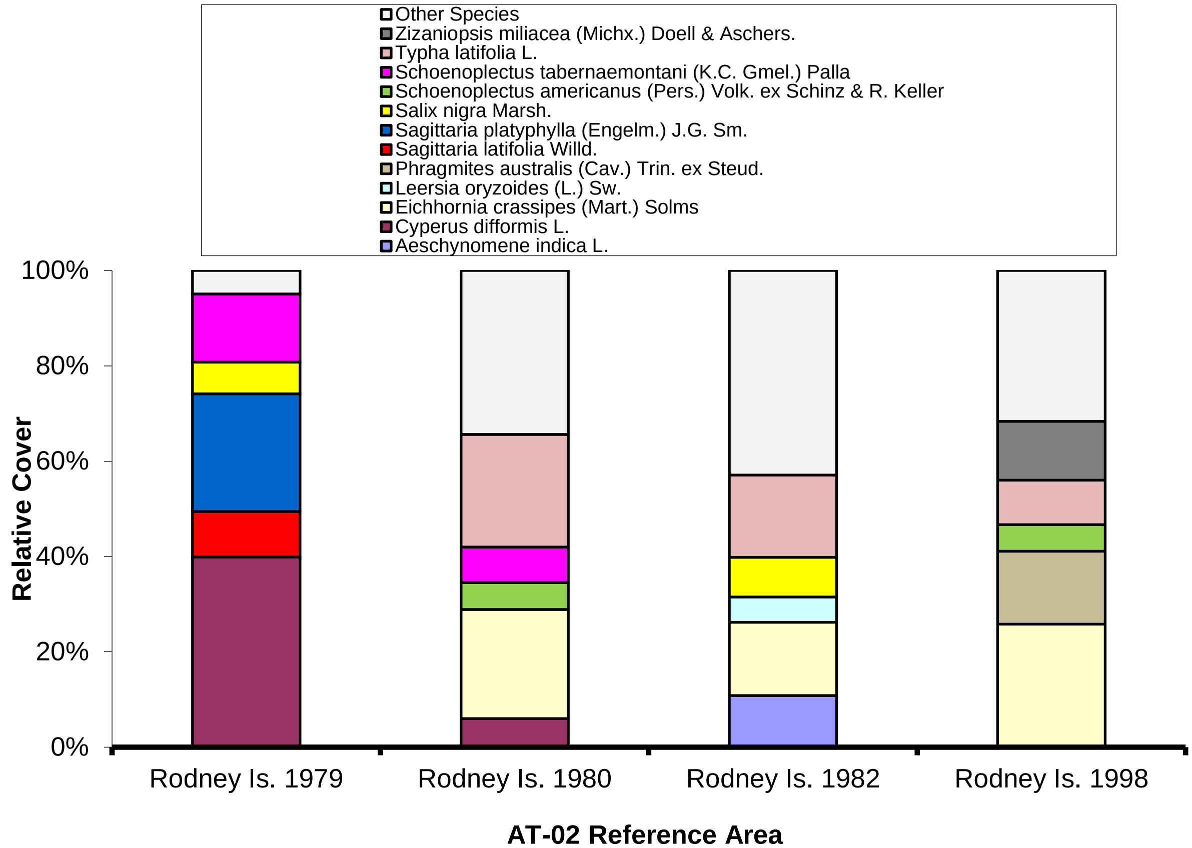


Figure 13. **Relative cover of the top five vegetation species populating the Atchafalaya Sediment Delivery (AT-02) historical reference area from 1979 to 1998. Ocular vegetation data were grouped by year. Vegetation data provided courtesy of Louisiana State University/Coastal Ecology Institute (LSU/CEI).**

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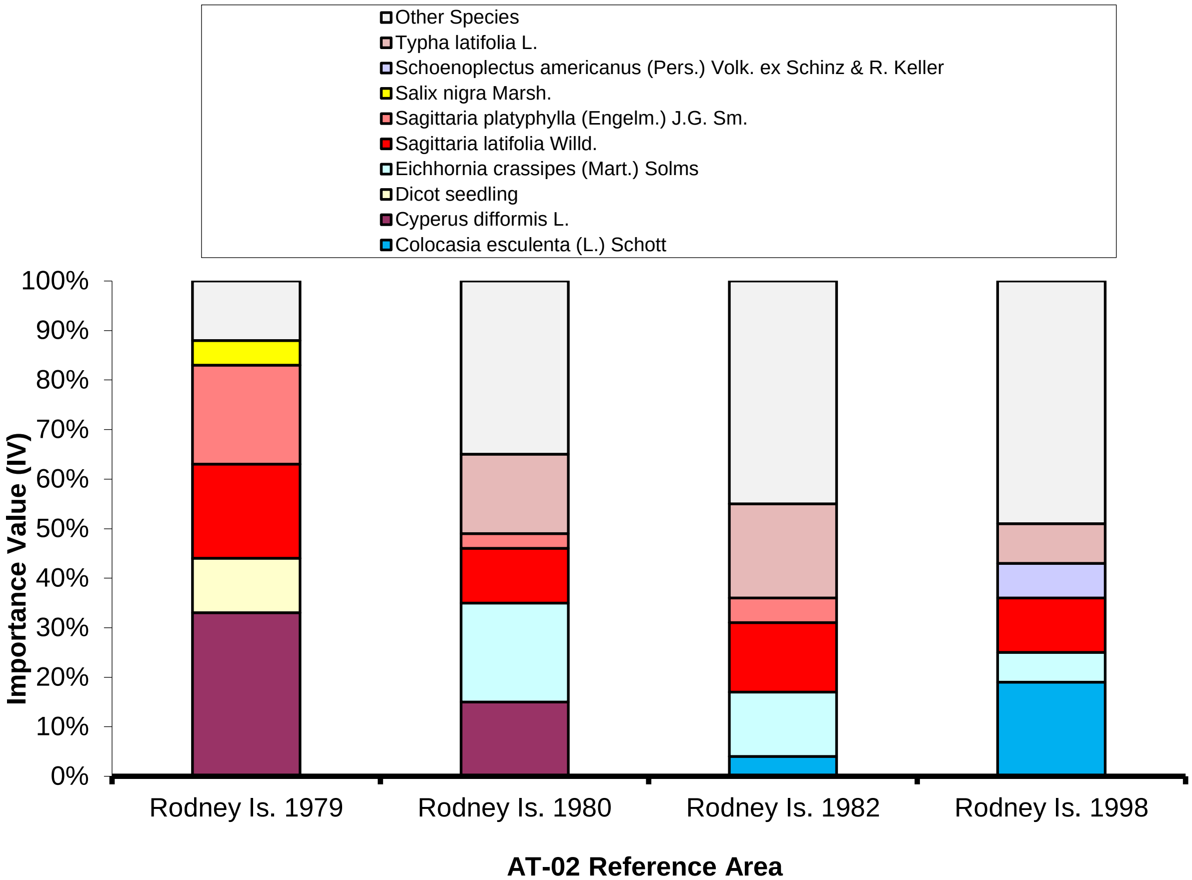

Figure 14. **Importance value (IV) of the top five vegetation species populating the Atchafalaya Sediment Delivery (AT-02) historical reference area from 1979 to 1998. Ocular vegetation data were grouped by year. Vegetation data provided courtesy of Louisiana State University/Coastal Ecology Institute (LSU/CEI).**

Habitat Mapping

The Atchafalaya Sediment Delivery (AT-02) project area experienced habitat colonization, succession, and disturbance since construction was completed in 1998. Combined mosaics and habitat maps for nearly all sampling intervals (1994, 1997, 1998, 2000, and 2007) are chronologically arranged in Figure 6 while the 2016 habitat map is displayed in Figure 15. Additional mosaics and habitat maps are located in appendix C for clarity. By 1998 (as-built), the project area consisted of 40% submerged aquatics, 30% open water-fresh, 14% beach/bar/flat, 11% fresh marsh, 4% wetland scrub-shrub, and 1% wetland forested and upland barren habitats (Figure 6 and Table 3). The initial post-construction (as-built) habitat change analysis of the project area (1994-1998) show increases in wetland scrub-shrub (111%) and fresh marsh (63%) habitats and decreases in beach/bar/flat (-60%) and open water-fresh (-47%) habitats (Table 4). The rapid colonization of DA1 with fresh marsh and DA2 and DA3 with scrub-shrub habitats is primarily due to the elevation and placement of

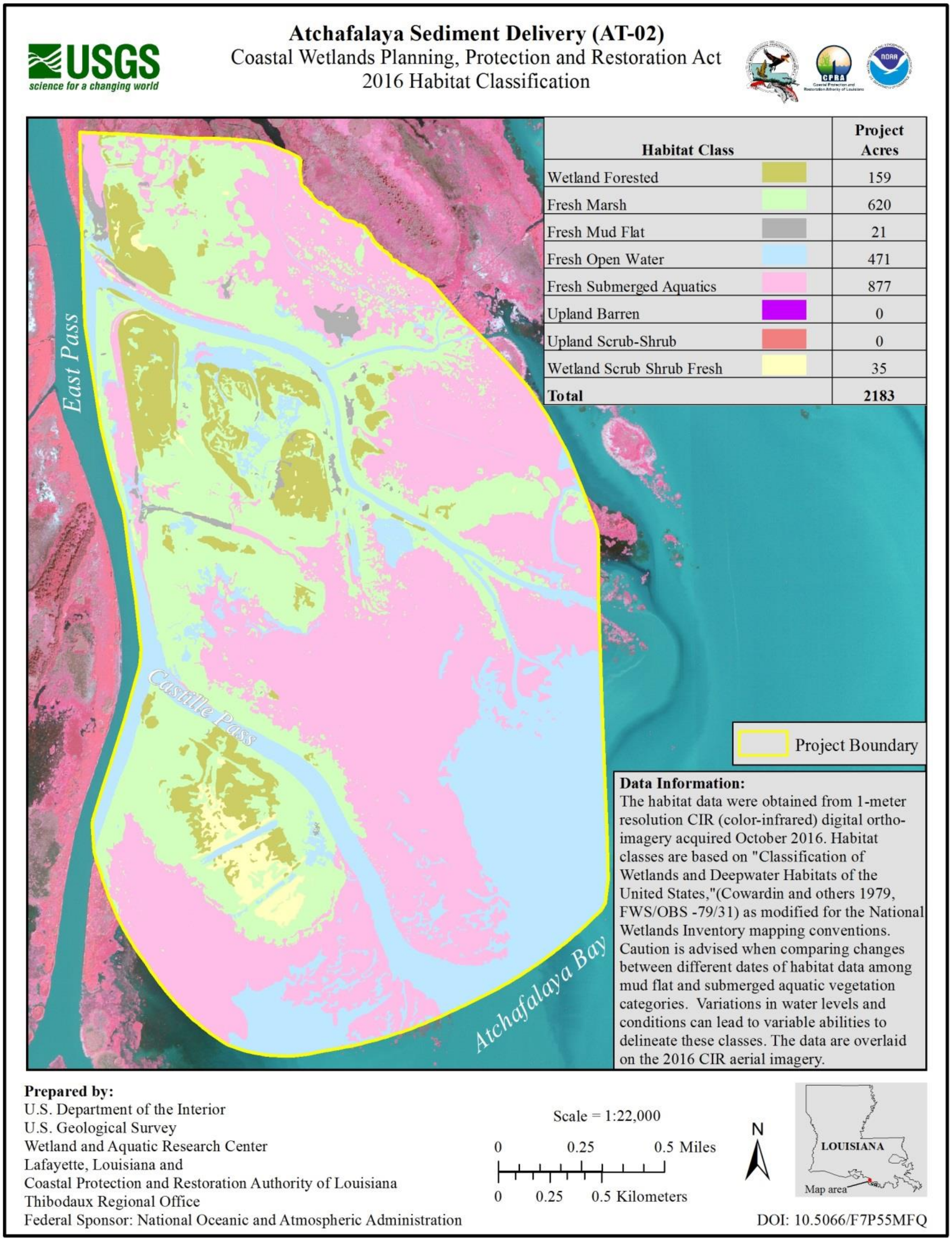

Figure 15. **2016 post-construction habitat analysis of the Atchafalaya Sediment Delivery (AT-02) project area.**

dredged sediments. Moreover, the reason that these habitats are displayed so prominently on the 1998 as-built habitat map (Figure 6) is because construction of the AT-02 project ended in March 1998 but the aerial photographs were not captured until November 1998 allowing the passage one full vegetative growing season before the habitats were delineated. In contrast, the AT-03 as-built (1998) habitats in the disposal areas were at a less advanced stage of development when the aerial photographs were acquired since construction was not completed until October of 1998 (Curole and Hartman 2018). The considerable enlargement of the

Table 3. National Wetlands Inventory (NWI) habitat classes, acreages, and percentages photo-interpreted from 1994, 1997, 1998, 2000, 2007, and 2016 aerial photography for the Atchafalaya Sediment Delivery (AT-02) project.

Habitat Class Project Area	*1994 Acres (%)*	*1997 Acres (%)*	*1998 Acres (%)*	*2000 Acres (%)*	*2007 Acres (%)*	*2016 Acres (%)*
Beach/Bar/Flat	751 (34)	430 (20)	302 (14)	460 (21)	555 (25)	21 (1)
Fresh Marsh	142 (7)	217 (10)	231 (11)	227 (10)	520 (24)	620 (28)
Open Water-Fresh	1,252 (57)	850 (39)	660 (30)	952 (44)	613 (28)	471 (22)
Submerged Aquatics	0	643 (29)	865 (40)	405 (19)	315 (14)	877 (40)
Upland Barren	0	0	14 (1)	0	<1	0
Wetland Forest	0	28 (1)	31 (1)	37 (2)	128 (6)	159 (7)
Wetland Scrub-Shrub	37 (2)	14 (1)	78 (4)	101 (5)	52 (2)	35 (2)
TOTAL	2,182	2,182	2,181	2,182	2,183	2,183

Table 4. Habitat change and percent differences for the intervals listed below for the Atchafalaya Sediment Delivery (AT-02) project. These changes were derived from the NWI habitat classes recorded in Table 3.

Habitat Class Project Area	*94-97 Change (%)*	*94-98 Change (%)*	*98-00 Change (%)*	*98-07 Change (%)*	*98-16 Change (%)*	*94-16 Change (%)*
Beach/Bar/Flat	-321 (-43)	-449 (-60)	158 (52)	253 (84)	-281 (-93)	-730 (-97)
Fresh Marsh	75 (53)	89 (63)	-4 (-2)	289 (125)	389 (168)	478 (337)
Open Water-Fresh	-402 (-32)	-592 (-47)	292 (44)	-47 (-7)	-189 (-29)	-781 (-62)
Submerged Aquatics	643	865	-460 (-53)	-550 (-64)	12 (1)	877
Upland Barren	0	14	-14 (-100)	-14 (-100)	-14 (-100)	0
Wetland Forest	28	31	6 (19)	97 (313)	128 (413)	159
Wetland Scrub-Shrub	-23 (-62)	41 (111)	23 (29)	-26 (-33)	-43 (-55)	-2 (-5)
TOTAL	0	-1	1	2	2	1

wetland scrub-shrub habitat and presence of the upland barren habitat denotes that higher elevated environments were created in DA1, DA2, and DA3 during construction (Figure 6). Subsequent (1998-2000, 1998-2007, and 1998-2016) post-construction habitat change analysis reveals wetland forested gains in 2000, 2007, and 2016; fresh marsh losses in 2000 and gains in 2007 and 2016; and wetland scrub-shrub gains in 2000 and losses in 2007 and 2016 (Figures 6, 15, and Table 4). By 2016, the project area consisted of 28% fresh marsh, 7% wetland forested, 2% wetland scrub-shrub, 40% submerged aquatics, 1% beach/bar/flat, and 22% open water-fresh habitats (Figure 15 and Table 3). Since construction, a large part of the wetland scrub-shrub habitat underwent succession to form wetland forested or fresh marsh habitats. Over time fresh marsh species continued to expand their range through colonization of submerged aquatic, beach/bar/flat, and open water-fresh habitats (Figures 6 and 15). The sizeable reduction in wetland scrub-shrub habitat from 2000 to 2007 (-49%) and from 2000 to 2016 (-65%) is principally attributable to forest maturation in DA1, DA2, and DA3 although this habitat also experienced a smaller degree of conversion to fresh marsh (Figures 6 and 15). In addition, a considerable acreage of submerged aquatic habitats were converted to either beach/bar/flat, open water-fresh, or fresh marsh habitats only to reverberate back to their as-built (1998) acreage in 2016 (Figures 6, 15 and Tables 3-4). Not all the growth inside the AT-02 project area is a result of the project or fluvial processes. During two dredge disposal events, the USACE placed dredged material inside the AT-02 project area significantly impacting habitats (Figure 16). The first disposal event occurred between 1998 and 2000 and altered approximately 29 ha (72 acres) of submerged aquatic and open water-fresh habitats along the east fork of Natal Channel. The second event transpired between 2002 and 2004 and modified approximately 49 ha (120 acres) of beach/bar/flat, submerged aquatic, open water-fresh, and fresh marsh habitats along Castille Pass (Figures 6, 15, and 16). These two USACE disposal events contributed to the enlargement of fresh marsh, beach/bar/flat, wetland forested, and wetland scrub-shrub habitats. In closing, the project area has been altered since construction through colonization, succession, and disturbance (USACE dredge disposal events).

The Atchafalaya Sediment Delivery (AT-02) project did not reach its beneficial use of dredge material acreage goal. Approximately, 178 ha (441 acres) of emergent wetland habitats were created in the project area for the ten year period from 1997 (pre-construction) to 2007 (post-construction), and by 2016, a nineteen year period (1997-2016), the wetland acreage expanded to 225 ha (555 acres). Moreover, 186 ha (460 acres) of the land habitats were established after construction from 1998 (as-built) to 2016 (post-construction) (Figures 6, 15, and Tables 3-4). On the surface it appears that the creation of 225 ha (555 acres) of emergent wetland habitats exceeds the projected goal to create 92 ha (230 acres) of delta lobe islands in the project area. However, a considerable acreage of these habitats were created outside of the disposal areas and 78 ha (192 acres) of the project area were impacted by the USACE dredge disposal events (Figure 16). The beneficial use emergent marsh acreage in the five AT-02 disposal areas resulted in only 74 ha (182 acres) being formed. Therefore, the goal was not surpassed largely due to the low acreage of wetlands created in DA4. Wetland land habitats were created in only 21% of the DA4 area. Moreover, the failure of DA4 to elevate and construct emergent marshes is a direct result of not using containment dikes to shape this disposal area. The contained disposal areas [D1 (93% land), D2 (93% land), and D3 (92% land)] were all successful in creating and sustaining marsh and forested habitats while the CPDA was partially impacted [5 ha (11 acres)] by USACE dredge disposal events.

The Atchafalaya Sediment Delivery (AT-02) project area experienced considerable subaqueous growth and moderately high subaerial growth before construction. Pre-

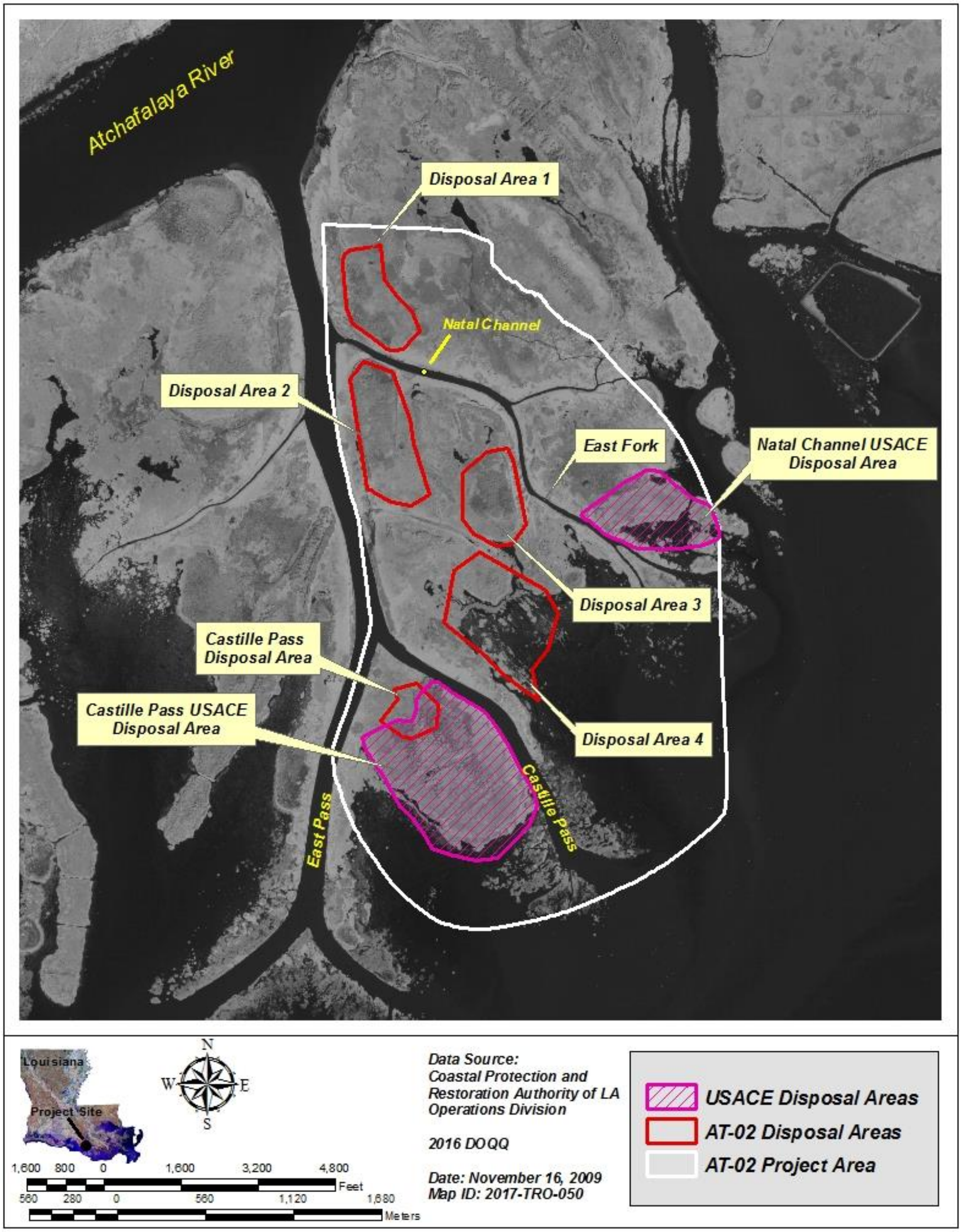

Figure 16. Location of USACE dredge disposal areas inside the Atchafalaya Sediment Delivery (AT-02) project.

construction habitat change analysis of the project area (1994-1997) show increases in fresh marsh (53%) habitats and decreases in and wetland scrub-shrub (-62%), beach/bar/flat (-43%), open water-fresh (-32%) habitats while submerged aquatics 260 ha (643 acres) and wetland forested 11 ha (28 acres) habitats were created (Table 4 and Figure 6). During this 3 year pre-construction interval, extensive conversion of open water-fresh and beach/bar/flat habitats to submerged aquatics habitat transpired, fairly small acreages of the large beach/bar/flat habitat were colonized by fresh marsh vegetation, and a sizeable part of the wetland scrub-shrub habitat underwent succession to form wetland forested habitats. The distribution and abundance submerged aquatic habitats can be ephemeral because these environments are very susceptible to changes in light penetration. Increases or decreases in light penetration alternatively regulate the growth or declines in this habitat (Koch 2001; Cho and Poirrier 2005). Furthermore, submerged aquatic and beach/bar/flat habitats are challenging to delineate and variations in water level and the population of floating vegetation can alter the classification between these habitats (Figure 15-Data Information Box). The sizeable reduction in wetland scrub-shrub habitat in the pre-construction period (-62%) is attributable to forest maturation. Although submerged aquatics environments are very dynamic, habitat expansion at a rate of 89 ha/yr (219 acres/yr) is noteworthy (Tables 3, 4, and Figure 6). Fresh marsh and wetland forested habitats enlarged their areal extent by 11 ha/yr (26 acres/yr) and 4 ha/yr (10 acres/yr) in the pre-construction period (Table 3 and Figure 6). The substantial spring flood of 1997 probably induced these increases in submerged aquatics and fresh marsh habitats (Trotter et al. 1998; DeHaan et al. 2012). While the rate of fresh marsh development was appreciably higher following construction, the pre-construction data illustrates that subaerial growth was occurring in the project area before construction.

<u>Subaerial and Subaqueous Growth</u>

The Atchafalaya Sediment Delivery (AT-02) project area experienced subaerial growth, subaqueous to subaerial conversion, and subaqueous growth since construction. Figures 17 and 18 delineate the growth in the project area from 1998 to 2007 and from 1998 to 2016. Small acreages of subaqueous habitats were converted to subaerial habitats (subaqueous to subaerial) inside the AT-02 disposal areas over the project life (1998-2007 and 1998-2016) (Figures 17, 18, and Table 5). This occurred primarily through the colonization of beach/bar/flat and submerged aquatics habitats by fresh marsh and wetland forested vegetation. A large part of this subaqueous to subaerial growth arose along the perimeter margins of the disposal areas. However, the unconfined disposal areas (DA4 and CPDA) displayed increased subaqueous to subaerial growth inside their enclosures (Figures 16, 17, and 18) because these two disposal areas had larger populations of beach/bar/flat habitats in 1998 that were colonized later in the project life (Figures 6 and 15). Very little subaerial (open water-fresh to subaerial habitat) or subaqueous (open water-fresh to beach/bar/flat or submerged aquatics habitat) growth developed in the disposal areas in the intervals from 1998-2007 and 1998-2016 (Figures 16, 17, 18, and Table 5). The largest part of this subaerial and subaqueous growth occurred along the edges of DA2 and DA3 (Figures 16, 17, and 18).

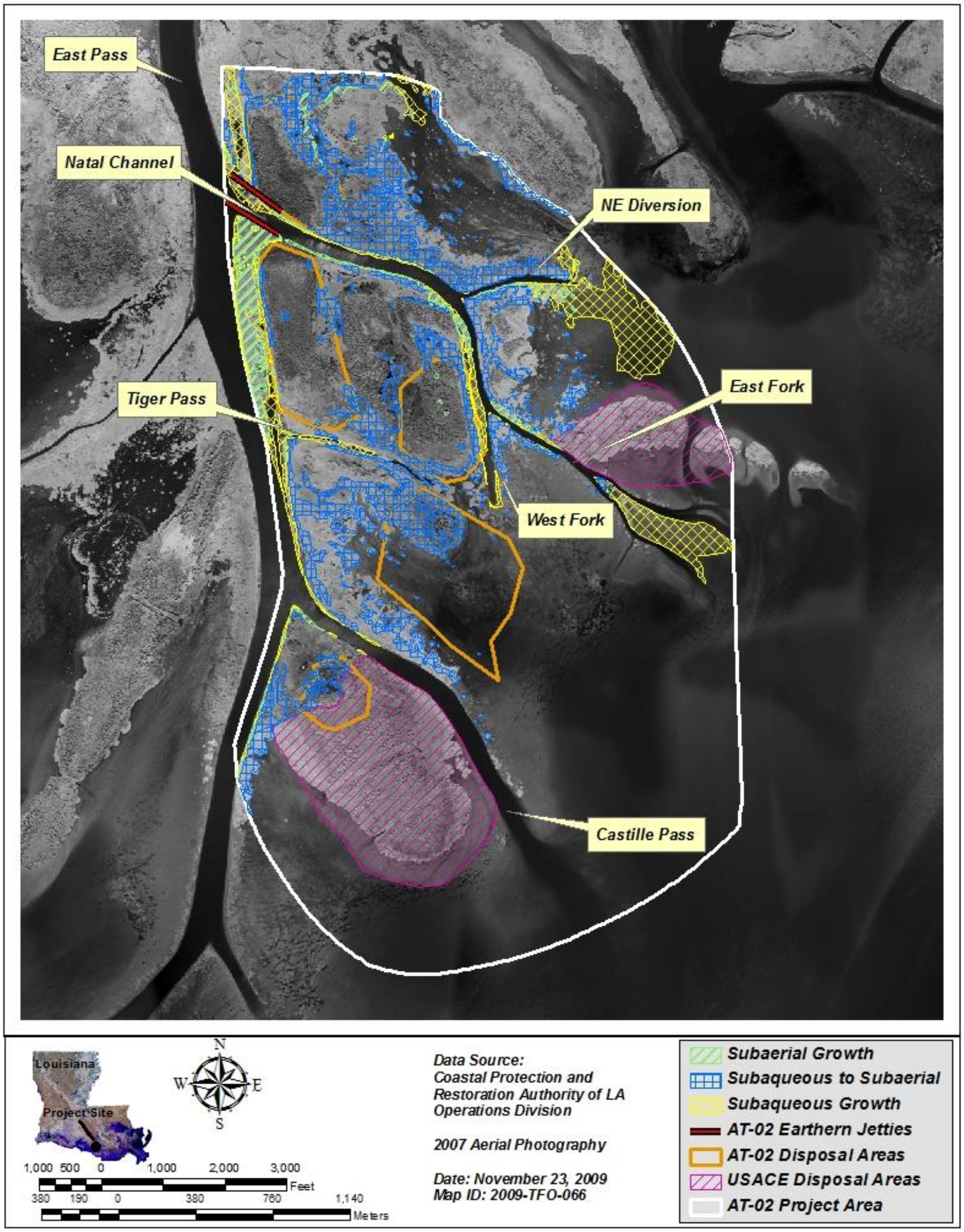

Figure 17. Location of areas experiencing subaerial growth, subaqueous to subaerial conversion, and subaqueous growth inside the Atchafalaya Sediment Delivery (AT-02) project area from 1998 to 2007.

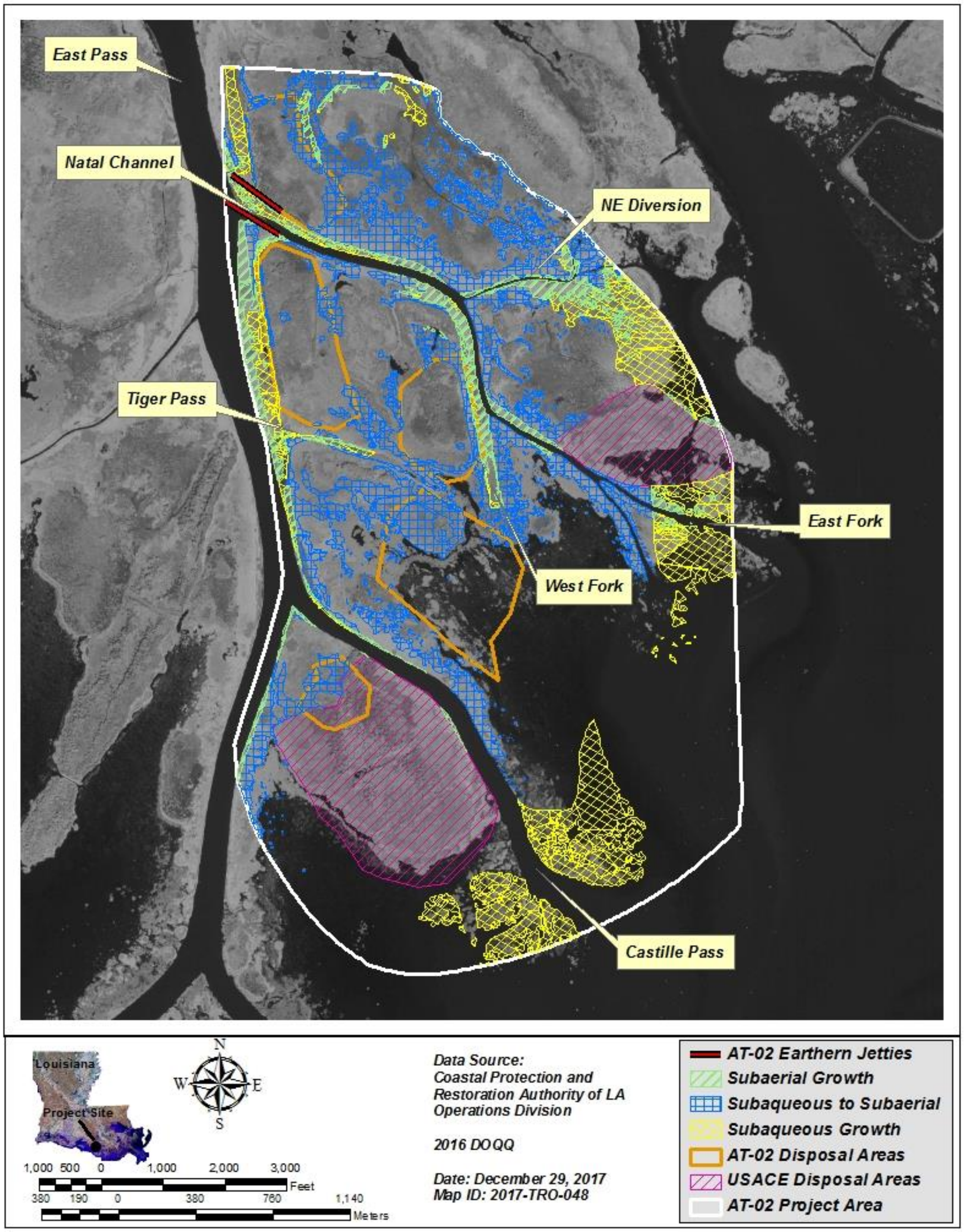

Figure 18. Location of areas experiencing subaerial growth, subaqueous to subaerial conversion, and subaqueous growth inside the Atchafalaya Sediment Delivery (AT-02) project area from 1998 to 2016.

Table 5. **Subaerial growth, subaqueous to subaerial conversion, and subaqueous growth occurring inside and outside the disposal areas at the Atchafalaya Sediment Delivery (AT-02) project from 1998 to 2007 and 1998 to 2016. Data reported in acres, acres/yr, and percentage (%).**

AT-02 Area	1998-2007 Acres	1998-2007 Acres/yr	1998-2007 %	1998-2016 Acres	1998-2016 Acres/yr	1998-2016 %	Classes
Outside DA	34.5	3.8	98.6	58.8	3.3	97.1	*Subaerial*
Inside DA	0.5	0.1	1.4	1.8	0.1	2.9	*Subaerial*
Total	35.0	3.9		60.5	3.4		*Subaerial*
Outside DA	147.1	16.4	77.8	211.0	11.7	81.7	*Subaqueous to Subaerial*
Inside DA	41.9	4.7	22.2	47.4	2.6	18.3	*Subaqueous to Subaerial*
Total	189.0	21.0		258.4	14.3		*Subaqueous to Subaerial*
Outside DA	103.4	11.5	99.4	203.5	11.3	99.3	*Subaqueous*
Inside DA	0.6	0.5	0.6	1.4	0.1	0.7	*Subaqueous*
Total	104.0	12.0		204.9	11.4		*Subaqueous*

Outside the disposal areas subaerial growth emerged (Table 5) primarily along East Pass and Natal Channel. The largest subaerial geomorphic feature to develop in the project area is a predominantly subaerial bar that formed in the lee of the southern jetty at the head of NC (Figures 17 and18). This subaerial feature extends from the earthen structure to CPC. The presence of this emergent feature indicates that sediment is depositing on the downdrift end of the jetty. Furthermore, the subaerial feature seems to be a discontinuous part (separated by NC) of a bar that formed in the Atchafalaya River and has been narrowing the eastern bank of East Pass since 1997 (Figures 6 and 15). Other interesting subaerial formations are found along the northern and southern banks of NC, the NE diversion channel, the east fork of NC, and the west fork of NC (Figures 17 and 18).

A sizeable portion of the project area outside the disposal areas underwent subaqueous to subaerial conversion for the 1998-2007 and 1998-2016 intervals (Table 5). The areas experiencing this conversion are found throughout the project area but are concentrated in settings located adjacent to channel banks (Figures 17 and 18). Of particular note, a large continuous acreage that extends from DA1 to the NE diversion has incurred subaqueous to subaerial conversion. By 2016, a considerable acreage along the east and west forks of NC displayed subaqueous to subaerial habitat conversion, and the northern bank of Castille Pass (CP) extended the coverage of this habitat southward (Figures 17 and 18).

Several noteworthy subaqueous features were created in the project area from 1998 to 2007 and 1998 to 2016 (Figures 17 and 18). The first of these features is the aforementioned predominantly subaqueous bar that extends down East Pass and occupies a small portion of the project area north of the earthen jetties (Figures 17 and 18). The formation of this bar is important because NC has undergone channel abandonment and lobe fusion in the recent past (van Heerden et al. 1991). Secondly, the period from 1998-2016 shows growth in subaqueous habitats at the mouths of the NE diversion, NC, and CP signifying that sediments are being deposited and aggrading these regions (Figure 18). Lastly, the most prominent features created in the AT-02 project area are the formation by 2007 of two subaqueous mid-channel bars and seaward levee extensions at the mouth of NC and the NE diversion (Figure 17). These predominantly subaqueous deltaic features were vegetated to create higher elevated subaerial landscapes (subaqueous to subaerial and subaerial) and their channels were reshaped and elongated for better efficiency between 2007 and 2016 (Figure 18). The enlargement of these features indicate that the delta is growing at these locations through sediment additions and raising subaqueous geomorphic features to shape emerging subaerial landscapes (van Heerden and Roberts 1980; van Heerden and Roberts 1988; van Heerden et al. 1991; Roberts and van Heerden 1992; Roberts 1998; DuMars 2002; Mashriqui 2003; Edmonds and Slingerland 2007; Edmonds and Slingerland 2008; Letter et al. 2008). Moreover, the river mouth bar model of delta growth is the dominant mechanism forcing delta expansion, and the creation of these mid-channel bars infers that some bedload transport is occurring within the project area (Edmonds and Slingerland 2007). However, the NE diversion is rerouting discharge away from the east fork mid-channel bar causing shoaling north of the constructed bifurcation and in the west fork (Letter et al 2008). Indeed, the west fork of the bifurcation seems to be undergoing channel abandonment and lobe fusion (Figure 18), but asymmetrical bifurcations are common in fluvial deltas (Edmonds and Slingerland 2008). In the future, NC may abandon the constructed bifurcated channels and occupy the NE diversion or NC may be abandoned if the bar that is drifting down East Pass migrates across NC and impedes discharge through NC. Presently, the NC deltas are expanding seaward at the distal ends of this channel, and the hydrodynamics point towards a near term sustainability (Figures 10 and 18). The enlargement of these deltaic features was greatly enhanced by the substantial Mississippi River flood of 2011 (Figures 17 and 18) (DeHaan et al. 2012; Falcini et al. 2012; Carle et al. 2015). However, earlier Mississippi River floods (i.e., 2001 and 2008) also aided in the formation and early development of these emerging micro-deltas (very small subdeltas) of the Atchafalaya River (Figures 6 and 18) (DeHaan et al. 2012). While the growth of these deltaic features at the distal ends of NC is impressive, the absence of an emerging mid-channel bar at the mouth of CP is equivalently notable. Although discharge through CP is large enough to keep the channel stable, no subaerial mid-channel bar is forming at the mouth of CP. Mashriqui (2003) corroborates this by providing evidence showing that very little sand is being deposited at the mouth of CP. Furthermore, the East and Castille Pass (EP/CP) bifurcation seems to also be asymmetrical (Edmonds and Slingerland 2008) discharging larger volumes of water and sediment through East Pass because mid-channel bars and natural levees are extending East Pass seaward south of the EP/CP bifurcation. The channel widths of both forks of the southern East Pass bifurcation are visibility widening (Figures 17 and 18). Nevertheless, the formation of a large acreage of subaqueous habitats at the mouth of CP in 2016 (Figure 18) is an encouraging sign that might lead to CP extension and mid-channel bar establishment during the next great Mississippi River flooding cycle.

Table 6 illustrates the growth of the three subaerial and subaqueous growth classes for the 1998-2007 and 1998-2016 intervals. Percent differences reveal that the later interval has a slightly slower subaerial and subaqueous growth rates while the subaqueous to subaerial class had a greater reduction in growth. Although the growth rate slowed over time, approximately 40 ha (100 acres) of both subaqueous and subaerial (subaerial + subaqueous to subaerial) habitats were created in the project area from 2007 to 2016 (Table 6). In conclusion, the goal to increase the rate of subaerial delta growth in the project area was attained due to the formation of mid-channel bars, the elongation of NC on two fronts, and the large acreage of emergent subaerial growth from 1998 to 2007 [8 ha/yr (20 acres/yr)] and from 1998 to 2016 [6 ha/yr (15 acres/yr)] (subaerial + subaqueous to subaerial) occurring in the project area since construction. Moreover, these rates exceed the Barras et al. 2004 estimates of subaerial land growth inside the AT-02 project area from 1956 to 1978 [4 ha/yr (9 acres/yr)] and from 1978 to 1990 [3 ha/yr (8 acres/yr)].

Table 6. Subaerial growth, subaqueous to subaerial conversion, subaqueous growth, and subaerial + subaqueous to subaerial conversion acreage changes and percent differences for the intervals listed below for the Atchafalaya Sediment Delivery (AT-02) project. These changes were derived from the classes recorded in Table 5.

1998-2007 Acres	*1998-2016 Acres*	*Change Acres*	*2007-2016 % Diff*	*Classes*
35.0	60.5	25.5	73.0	*Subaerial*
189.0	258.4	69.4	36.7	*Subaqueous to Subaerial*
104.0	204.9	100.9	97.0	*Subaqueous*
224.0	319.0	95.0	42.4	*Subaerial + Subaqueous to Subaerial*

Land Area Change

The land area change assessment of CRMS6304 showed that a 1.0 km^2 (0.4 mi^2) square portion of the AT-02 project increased in land area over the 30 year interval. Figure 19 displays the trend in the regression line for the 1984 to 2016 interval and estimates the acreage gain at 1.7 ha/yr (4.3 acres/yr) inside the CRMS site. The acreage increases seen in the regression line generally support the trends seen in the AT-02 assessment and point toward continued growth in the project area. The trend seen in the AT-03 CRMS site (CRMS-0463) also reinforces growth but at a slower rate than the CRMS6304 site (Curole and Hartman 2018). These comparisons are similar to the AT-02/AT-03 subaerial growth relationship.

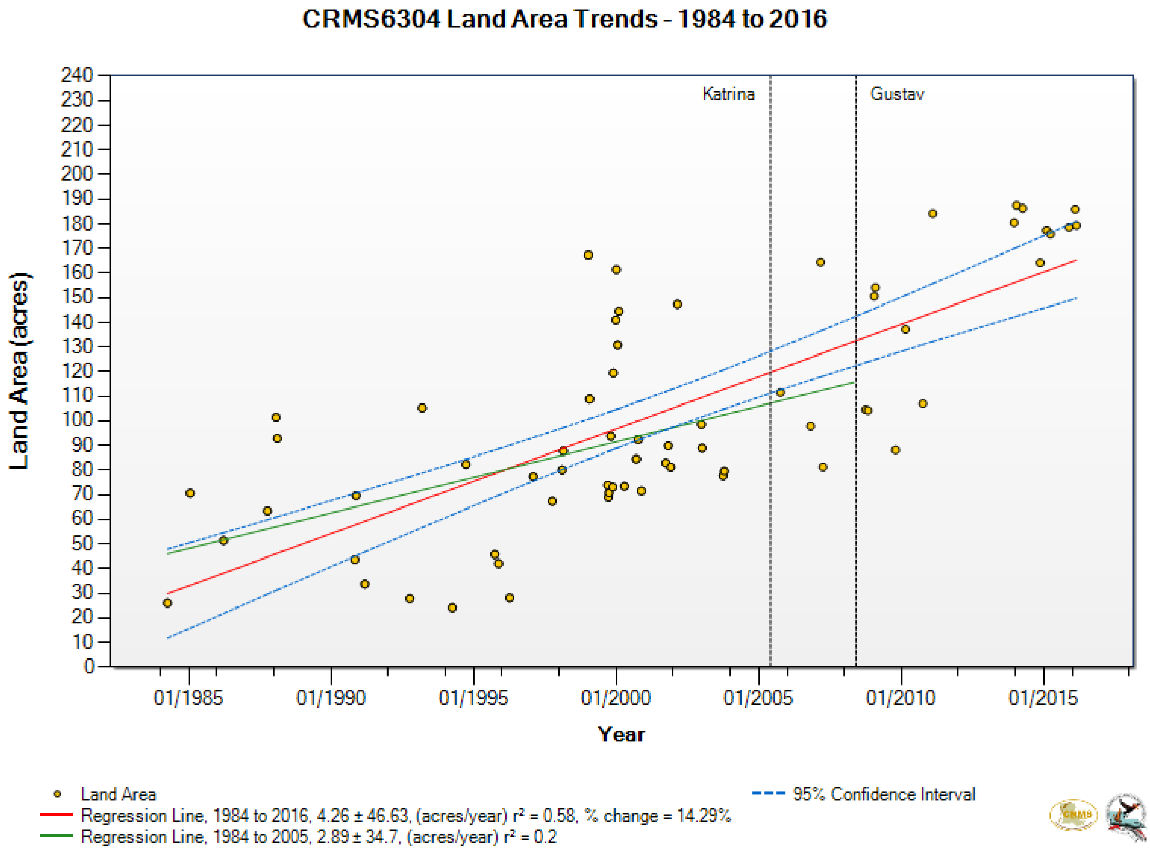

Figure 19. Site scale land area change for CRMS6304. Land area values are displayed for all cloud free Landsat images available for 1984-2016. The red line depicts the land change trend for the entire period of record.

V. Conclusions

a. Project Effectiveness

The results of the Atchafalaya Sediment Delivery (AT-02) project reveal that two of the project goals were attained while one was not eighteen years after project construction. The first goal to increase the distributary potential of Natal Channel and Castille Pass by increasing their cross-sectional area and length has been achieved at this time due to the elongation of the east fork of NC, the elongation of the NE diversion channel, the deepening of CPC, and the formation of two mid-channel bars. The creation and enlargement of these features indicate that the delta is growing at this location through sediment additions and raising subaqueous geomorphic features to shape emerging subaerial landscapes (van Heerden and Roberts 1980; van Heerden and Roberts 1988; van Heerden et al. 1991; Roberts and van Heerden 1992; Roberts 1998; DuMars 2002; Mashriqui 2003; Edmonds and Slingerland 2007; Edmonds and Slingerland 2008; Letter et al. 2008). Moreover, the river mouth bar model of delta growth is the dominant mechanism forcing delta expansion, and the creation of two mid-channel bars and the elongation of two channels (east fork and NE diversion) infers that some bedload transport is occurring within the project area (Edmonds and Slingerland 2007). However, NC is also experiencing channel narrowing and modifications to its channel morphology due to infilling along its watercourse and the reoccupation of a former distributary, the NE diversion channel. Currently, NC is narrow but has a well-defined centerline that has relocated over time to distribute flow to the two NC distributaries, the east fork and the NE diversion. As for CPC, it has deepened since 2008 and can distribute larger discharge volumes. Many of these features were formed, shaped, or enhanced by the great Mississippi River flood of 2011.

The second goal to create approximately 92 ha (230 acres) of delta lobe islands through the beneficial use of dredged material at elevations suitable for emergent marsh vegetation was not realized because only 76 ha (188 acres) of beneficial use subaerial land habitats were created. The primary reason for the under achievement of the beneficial use goal is the minimal subaerial land acreage created in DA4. Moreover, the failure of DA4 to elevate and shape emergent marshes is a direct result of not using containment dikes to construct this disposal area. The contained disposal areas (D1, D2, and D3) were considerably more effective in creating subaerial land.

The third goal to increase the rate of subaerial growth in the project area was achieved because of the formation of two mid-channel bars and the large acreage of emergent subaerial growth occurring in the project area since construction. The subaerial growth rate outside of the disposal areas was 6 ha/yr (15 acres/yr) from 1998-2016, which exceeded pre-construction Barras et al. (1994) growth rate estimates. Of particular note, a large continuous acreage of subaerial habitat was created north of NC (DA1 to the NE diversion), and the NC mid-channel bar and channel elongation developments are building subaerial land habitats at the distal ends this tertiary distributary. Furthermore, the emergence and shaping of these deltaic features indicates that the NC micro-deltas are growing seaward at these locations. In conclusion, the AT-02 project has been successful in increasing the distributary potential of the dredged channels (NC and CPC) and increasing the subaerial growth rate within the project area, but the project was not effective in creating 92 ha (230 acres) of delta lobe islands during the 18 year post-construction period.

b. Recommended Improvements

The monitoring regime of the Atchafalaya Sediment Delivery (AT-02) project should have been expanded to estimate the geomorphic processes affecting the project area. The current data collection scheme is very reactionary (passive). The data collected from these methods only confirm what already happened. The data show where the channel has shoaled or where new landforms are visible. This data leads to speculation as to why the channel shoaled or why the new landforms were created. A more dynamic sampling protocol is needed to determine the mechanisms forcing geomorphic change in the project area. This protocol should include quantitative estimates of discharge (Q) during flood and non-flood conditions. The discharge measurements should consist of water velocity and volume, suspended sediment concentrations, and channel stratigraphy. The suspended sediment and channel stratigraphy data should be qualitative and quantitative to estimate the probability of geomorphic change in the project area. In addition, the habitat mapping, bathymetry, and topography procedures still need to be collected to locate change within the project area over time. Moreover, the data collected from this type of sampling regime could be used to not only foresee changes in the project area but also could be used to design more sustainable sediment diversion projects.

A small dredging event should be considered in the future if the bar that is drifting down East Pass migrates across NC and obstructs discharge through this tertiary channel. Presently, the NC deltas are expanding seaward at the distal ends of this channel. However, if discharge through NC becomes severely restricted due to shoaling at the East Pass and NC junction, the emerging deltas along the east fork and the NE diversion would be abandoned and NC would likely shoal extensively and possibly fuse. NC has fused in the past and can fuse again in the future.

c. Lessons Learned

One channel morphology and sediment transport lesson was learned from the Atchafalaya Sediment Delivery (AT-02) project. This lesson is that creating the NC bifurcation and bypassing the NE diversion channel during construction led to extensive aggradation in NC. Ironically, the original project design included the NE diversion channel. However, the channel was eliminated from the design due to a potential title conflict over property ownership. The area directly south of the NE diversion has incurred large scale shoaling and channel narrowing. In the future, this section of NC could fuse eliminating discharge to an expanding part of the delta. Moreover, the NE diversion channel is a historical distributary of NC, and has been persistently discharging part of NC's flow since 1976. Since the diversion channel has a shorter course to Atchafalaya Bay, the hydraulic efficiency of this channel is greater than the constructed bifurcation. Therefore, it seems that NC would have sustained less shoaling and higher discharges if the project design would have been rerouted to reoccupy the diversion channel bypassing the constructed bifurcation.

One disposal area lesson was learned from the Atchafalaya Sediment Delivery (AT-02) project. Containment dikes should be installed on the outer perimeter of all disposal areas to retain dredged sediments and allow consolidation. After construction and primary consolidation, these dikes can be removed or gapped to allow drainage and tidal activity. DA4 and the CPDA were built to lower elevations because they were unconfined. As a result, containment dikes should be installed in all disposal areas to retain sediments and to elevate the wetlands created.

One habitat mapping lesson was learned from the Atchafalaya Sediment Delivery (AT-02) project. The Atchafalaya Sediment Delivery (AT-02) and Big Island Mining (AT-03) projects are excellent examples of why temporal consistency is important when creating as-built habitat maps for marsh creation projects. The AT-02 project had one full growing season before the habitat maps were created while the AT-03 maps were created soon after construction was complete. The results of these maps reflected this. All the confined AT-02 disposal areas (DA1, DA2, and DA3) were colonized with vegetation for the as-built habitat map. As for AT-03, only DA1 had large percentages of vegetative cover for the as-built habitat map. The fact that the as-built habitat maps were collected at different temporal points of vegetation colonization construed the results a little. AT-03 showed greater conversion of beach/bar/flat habitats to fresh marsh and wetland scrub-shrub within the disposal areas over time while AT-02 did not because the AT-02 confined disposal areas were already colonized when the as-built map was delineated. In conclusion, temporal timing of as-built habitat maps is necessary when comparisons between projects are to be undertaken. Moreover, if the baseline mapping events of paired projects have similar timings, the early vegetation colonization assessments should likewise follow the same trajectory.

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Appendix A
(Inspection Photographs)

Figure A-1. **View of the mid-channel bar at the distal end of the Natal Channel's East Fork looking southeast toward Atchafalaya Bay.**

Figure A-2. **View of the Natal Channel looking east.**

Figure A-3. **View of fresh marsh habitat north of Natal Canal's constructed bifurcation.**

Figure A-4. **View of fresh marsh and Atchafalaya Bay south of Natal Channel Southern Fork.**

Figure A-5. **View of fresh marsh and Atchafalaya Bay south of Natal Canal's Southern Fork.**

Figure A-6. **View of fresh marsh and forested habitats at the head of Castille Pass looking southwest. Photo shows the CRMS6304 site located directly north of the CPDA.**

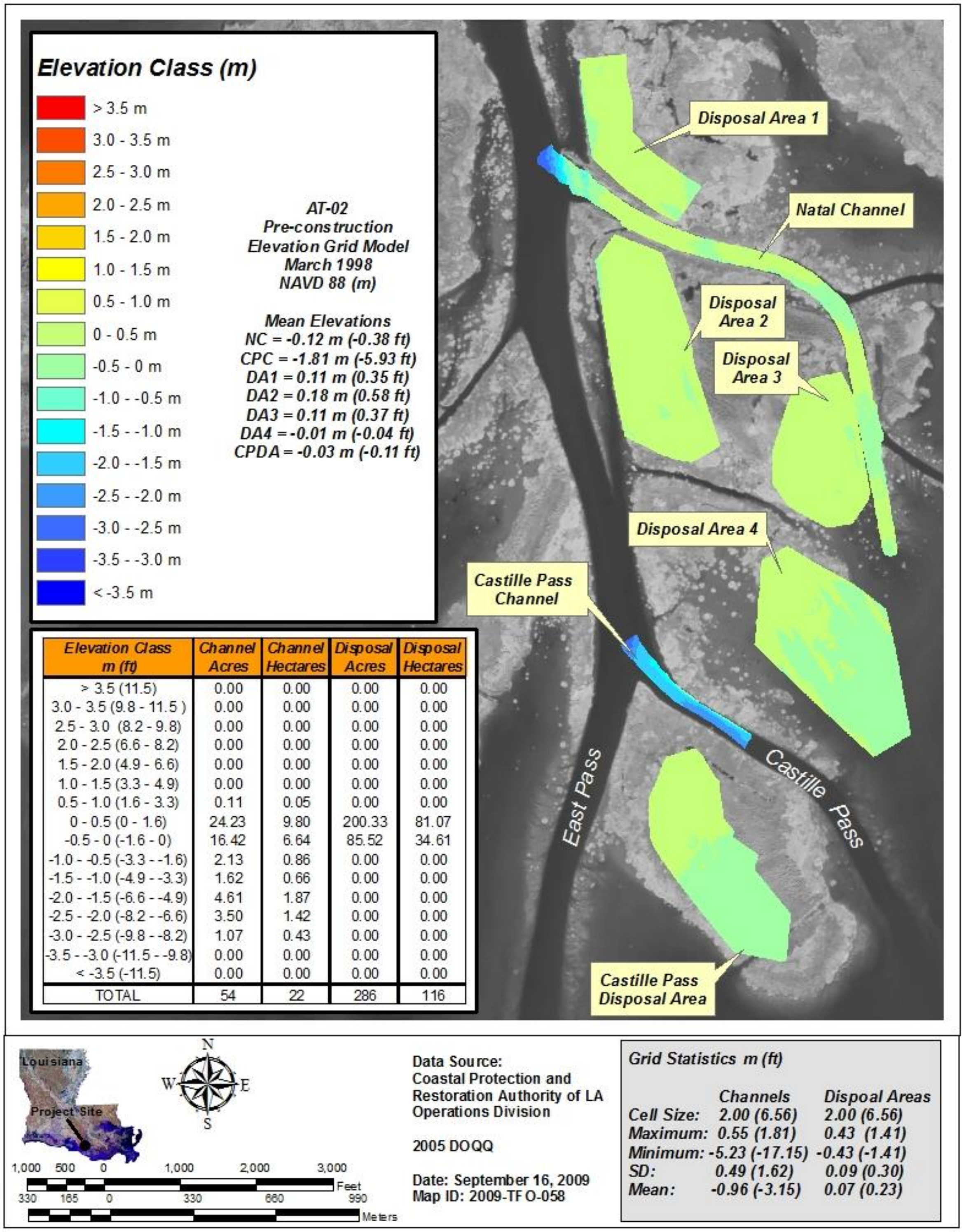
Figure A-7. **View of the Atchafalaya Bay from the end of Castille Pass looking southeast.**

Figure A-8. **View of the mid-channel bar at the distal end of NE Diversion Channel looking east.**

Figure A-9. **View of the northern fork at the distal end of NE Diversion Channel looking north.**

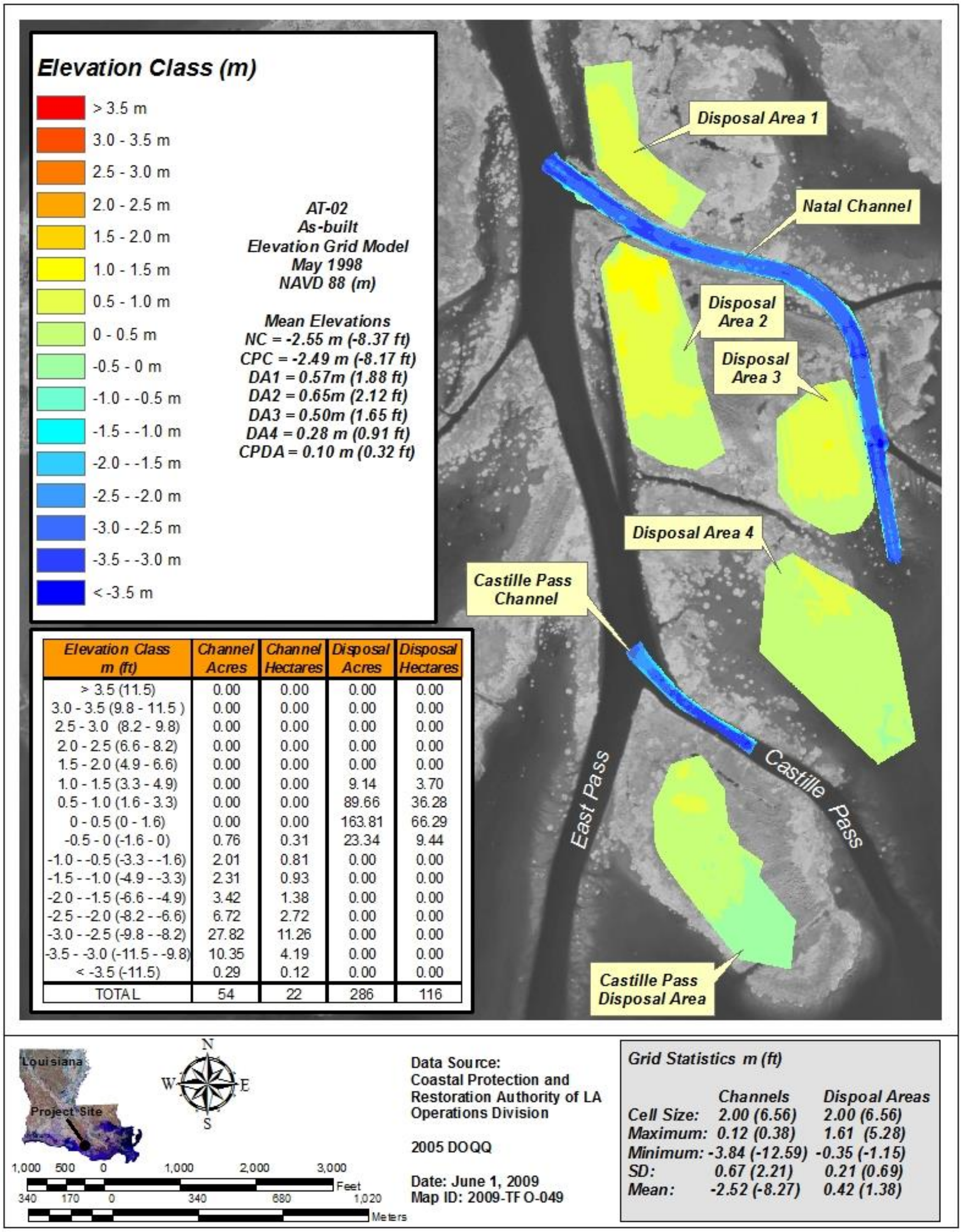
Figure A-10. **View of the southern fork at the distal end of the NE Diversion Channel looking east.**

Appendix B
(Elevation Grid Models)



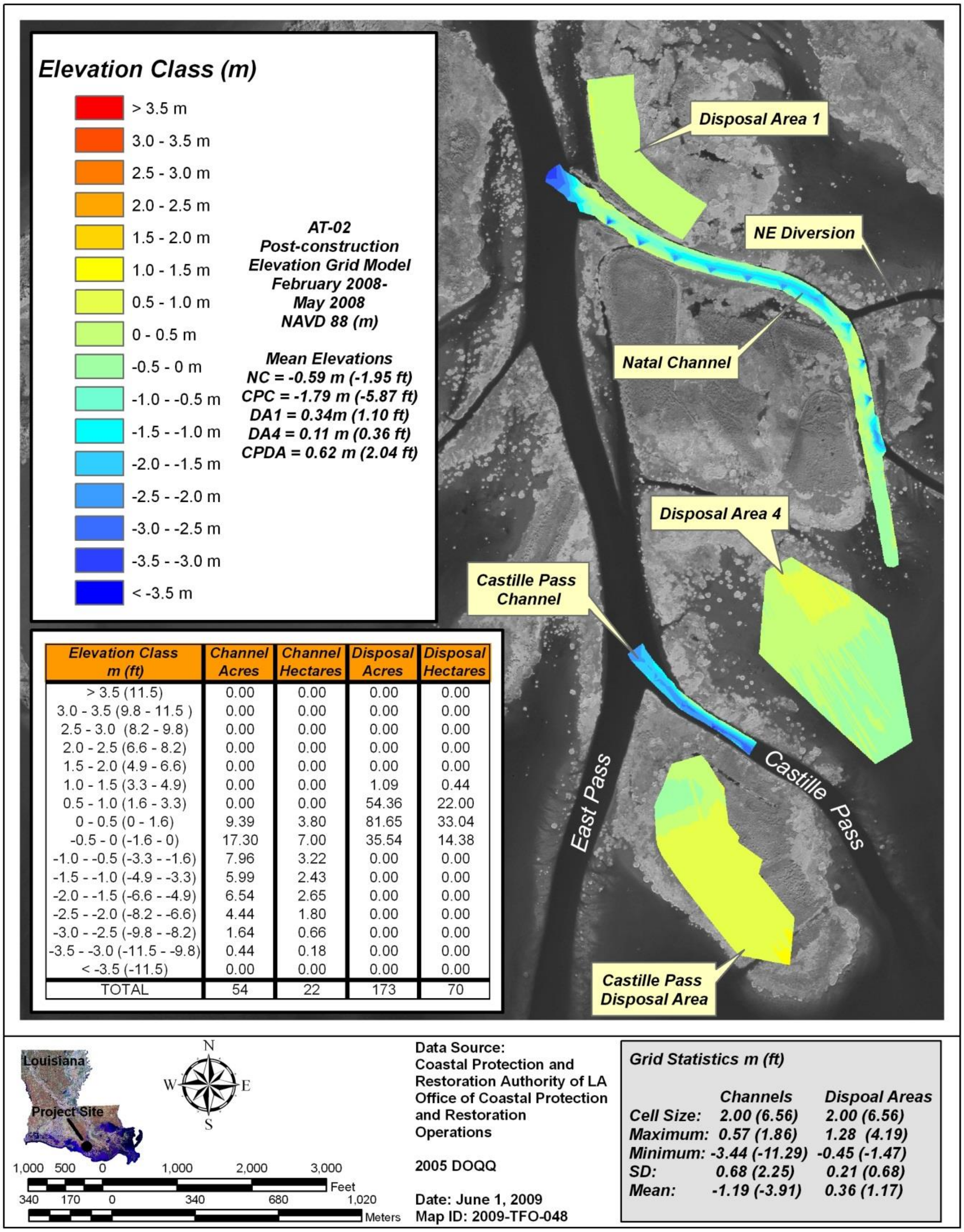
Elevation Class m (ft)	Channel Acres	Channel Hectares	Disposal Acres	Disposal Hectares
> 3.5 (11.5)	0.00	0.00	0.00	0.00
3.0 - 3.5 (9.8 - 11.5)	0.00	0.00	0.00	0.00
2.5 - 3.0 (8.2 - 9.8)	0.00	0.00	0.00	0.00
2.0 - 2.5 (6.6 - 8.2)	0.00	0.00	0.00	0.00
1.5 - 2.0 (4.9 - 6.6)	0.00	0.00	0.00	0.00
1.0 - 1.5 (3.3 - 4.9)	0.00	0.00	0.00	0.00
0.5 - 1.0 (1.6 - 3.3)	0.11	0.05	0.00	0.00
0 - 0.5 (0 - 1.6)	24.23	9.80	200.33	81.07
-0.5 - 0 (-1.6 - 0)	16.42	6.64	85.52	34.61
-1.0 - -0.5 (-3.3 - -1.6)	2.13	0.86	0.00	0.00
-1.5 - -1.0 (-4.9 - -3.3)	1.62	0.66	0.00	0.00
-2.0 - -1.5 (-6.6 - -4.9)	4.61	1.87	0.00	0.00
-2.5 - -2.0 (-8.2 - -6.6)	3.50	1.42	0.00	0.00
-3.0 - -2.5 (-9.8 - -8.2)	1.07	0.43	0.00	0.00
-3.5 - -3.0 (-11.5 - -9.8)	0.00	0.00	0.00	0.00
< -3.5 (-11.5)	0.00	0.00	0.00	0.00
TOTAL	54	22	286	116

Figure B-1. **Pre-construction (Mar 1998) elevation grid model of the dredged channels and disposal areas at the Atchafalaya Sediment Delivery (AT-02) project.**



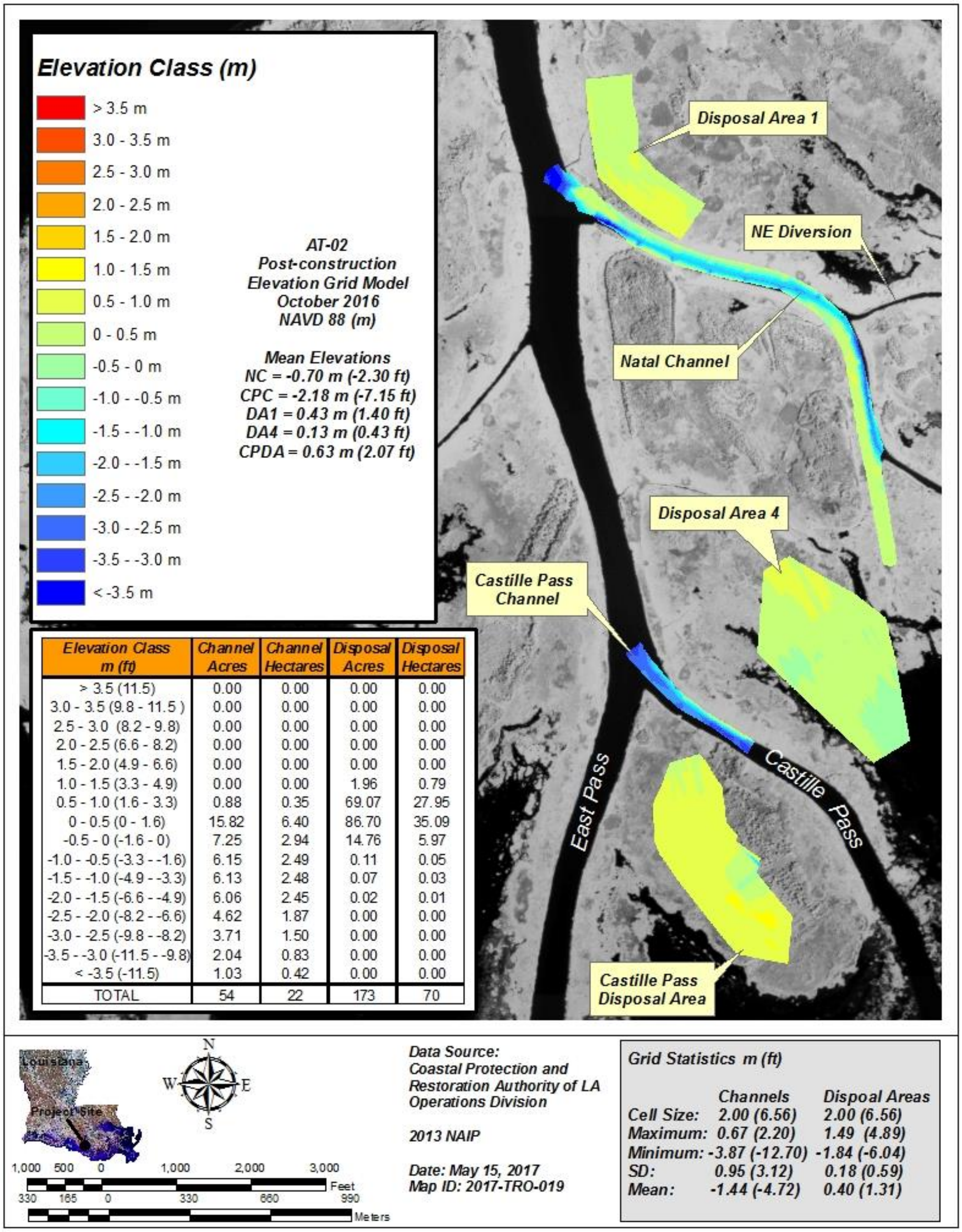
Elevation Class m (ft)	Channel Acres	Channel Hectares	Disposal Acres	Disposal Hectares
> 3.5 (11.5)	0.00	0.00	0.00	0.00
3.0 - 3.5 (9.8 - 11.5)	0.00	0.00	0.00	0.00
2.5 - 3.0 (8.2 - 9.8)	0.00	0.00	0.00	0.00
2.0 - 2.5 (6.6 - 8.2)	0.00	0.00	0.00	0.00
1.5 - 2.0 (4.9 - 6.6)	0.00	0.00	0.00	0.00
1.0 - 1.5 (3.3 - 4.9)	0.00	0.00	9.14	3.70
0.5 - 1.0 (1.6 - 3.3)	0.00	0.00	89.66	36.28
0 - 0.5 (0 - 1.6)	0.00	0.00	163.81	66.29
-0.5 - 0 (-1.6 - 0)	0.76	0.31	23.34	9.44
-1.0 - -0.5 (-3.3 - -1.6)	2.01	0.81	0.00	0.00
-1.5 - -1.0 (-4.9 - -3.3)	2.31	0.93	0.00	0.00
-2.0 - -1.5 (-6.6 - -4.9)	3.42	1.38	0.00	0.00
-2.5 - -2.0 (-8.2 - -6.6)	6.72	2.72	0.00	0.00
-3.0 - -2.5 (-9.8 - -8.2)	27.82	11.26	0.00	0.00
-3.5 - -3.0 (-11.5 - -9.8)	10.35	4.19	0.00	0.00
< -3.5 (-11.5)	0.29	0.12	0.00	0.00
TOTAL	54	22	286	116

Figure B-2. As-built (May 1998) elevation grid model of the dredged channels and disposal areas at the Atchafalaya Sediment Delivery (AT-02) project.



Elevation Class m (ft)	Channel Acres	Channel Hectares	Disposal Acres	Disposal Hectares
> 3.5 (11.5)	0.00	0.00	0.00	0.00
3.0 - 3.5 (9.8 - 11.5)	0.00	0.00	0.00	0.00
2.5 - 3.0 (8.2 - 9.8)	0.00	0.00	0.00	0.00
2.0 - 2.5 (6.6 - 8.2)	0.00	0.00	0.00	0.00
1.5 - 2.0 (4.9 - 6.6)	0.00	0.00	0.00	0.00
1.0 - 1.5 (3.3 - 4.9)	0.00	0.00	1.09	0.44
0.5 - 1.0 (1.6 - 3.3)	0.00	0.00	54.36	22.00
0 - 0.5 (0 - 1.6)	9.39	3.80	81.65	33.04
-0.5 - 0 (-1.6 - 0)	17.30	7.00	35.54	14.38
-1.0 - -0.5 (-3.3 - -1.6)	7.96	3.22	0.00	0.00
-1.5 - -1.0 (-4.9 - -3.3)	5.99	2.43	0.00	0.00
-2.0 - -1.5 (-6.6 - -4.9)	6.54	2.65	0.00	0.00
-2.5 - -2.0 (-8.2 - -6.6)	4.44	1.80	0.00	0.00
-3.0 - -2.5 (-9.8 - -8.2)	1.64	0.66	0.00	0.00
-3.5 - -3.0 (-11.5 - -9.8)	0.44	0.18	0.00	0.00
< -3.5 (-11.5)	0.00	0.00	0.00	0.00
TOTAL	54	22	173	70

Figure B-3. Post-construction (May 2008) elevation grid model of the dredged channels and disposal areas at the Atchafalaya Sediment Delivery (AT-02) project.



Elevation Class m (ft)	Channel Acres	Channel Hectares	Disposal Acres	Disposal Hectares
> 3.5 (11.5)	0.00	0.00	0.00	0.00
3.0 - 3.5 (9.8 - 11.5)	0.00	0.00	0.00	0.00
2.5 - 3.0 (8.2 - 9.8)	0.00	0.00	0.00	0.00
2.0 - 2.5 (6.6 - 8.2)	0.00	0.00	0.00	0.00
1.5 - 2.0 (4.9 - 6.6)	0.00	0.00	0.00	0.00
1.0 - 1.5 (3.3 - 4.9)	0.00	0.00	1.96	0.79
0.5 - 1.0 (1.6 - 3.3)	0.88	0.35	69.07	27.95
0 - 0.5 (0 - 1.6)	15.82	6.40	86.70	35.09
-0.5 - 0 (-1.6 - 0)	7.25	2.94	14.76	5.97
-1.0 - -0.5 (-3.3 - -1.6)	6.15	2.49	0.11	0.05
-1.5 - -1.0 (-4.9 - -3.3)	6.13	2.48	0.07	0.03
-2.0 - -1.5 (-6.6 - -4.9)	6.06	2.45	0.02	0.01
-2.5 - -2.0 (-8.2 - -6.6)	4.62	1.87	0.00	0.00
-3.0 - -2.5 (-9.8 - -8.2)	3.71	1.50	0.00	0.00
-3.5 - -3.0 (-11.5 - -9.8)	2.04	0.83	0.00	0.00
< -3.5 (-11.5)	1.03	0.42	0.00	0.00
TOTAL	54	22	173	70

Figure B-4. Post-construction (Oct 2016) elevation grid model of the dredged channels and disposal areas at the Atchafalaya Sediment Delivery (AT-02) project.

Appendix C
(Habitat Maps)

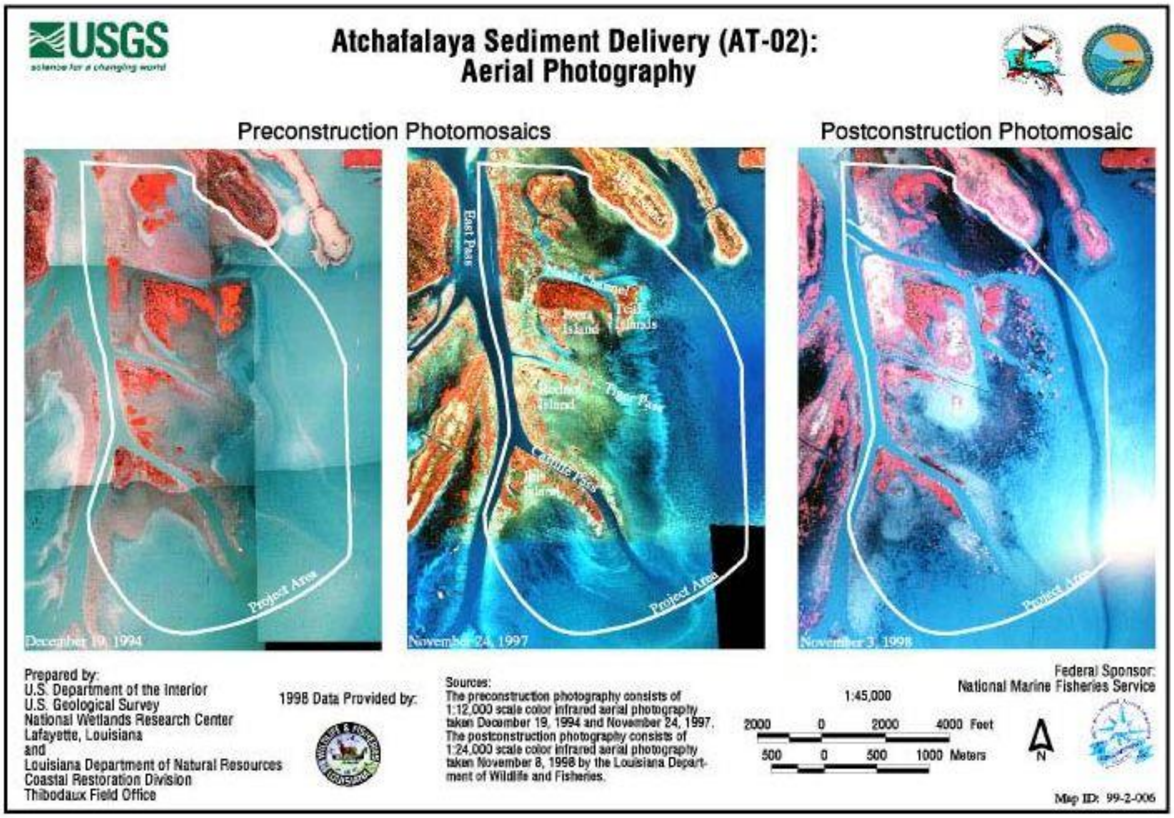


Figure C-1. **Pre-construction (1994 and 1997) and as-built (1998) photomosaics of the Atchafalaya Sediment Delivery (AT-02) project area.**

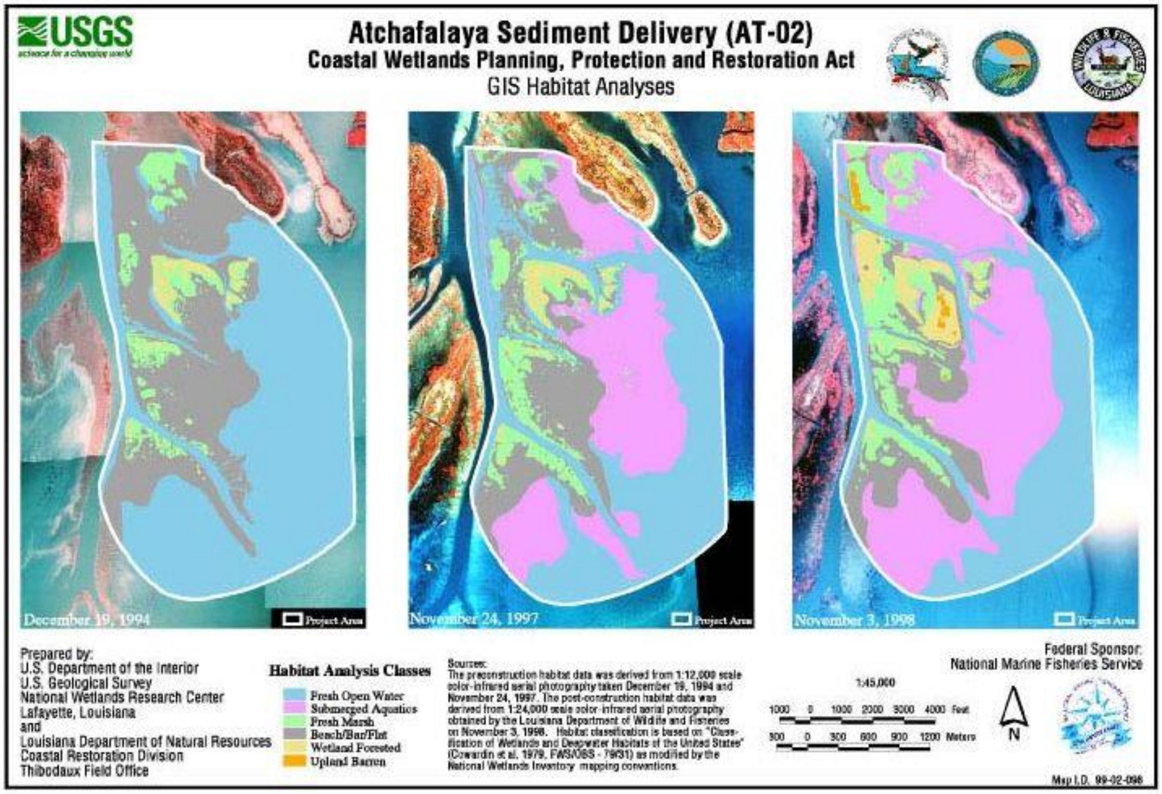


Figure C-2. **Pre-construction (1994 and 1997) and as-built (1998) habitat analysis of the Atchafalaya Sediment Delivery (AT-02) project area.**

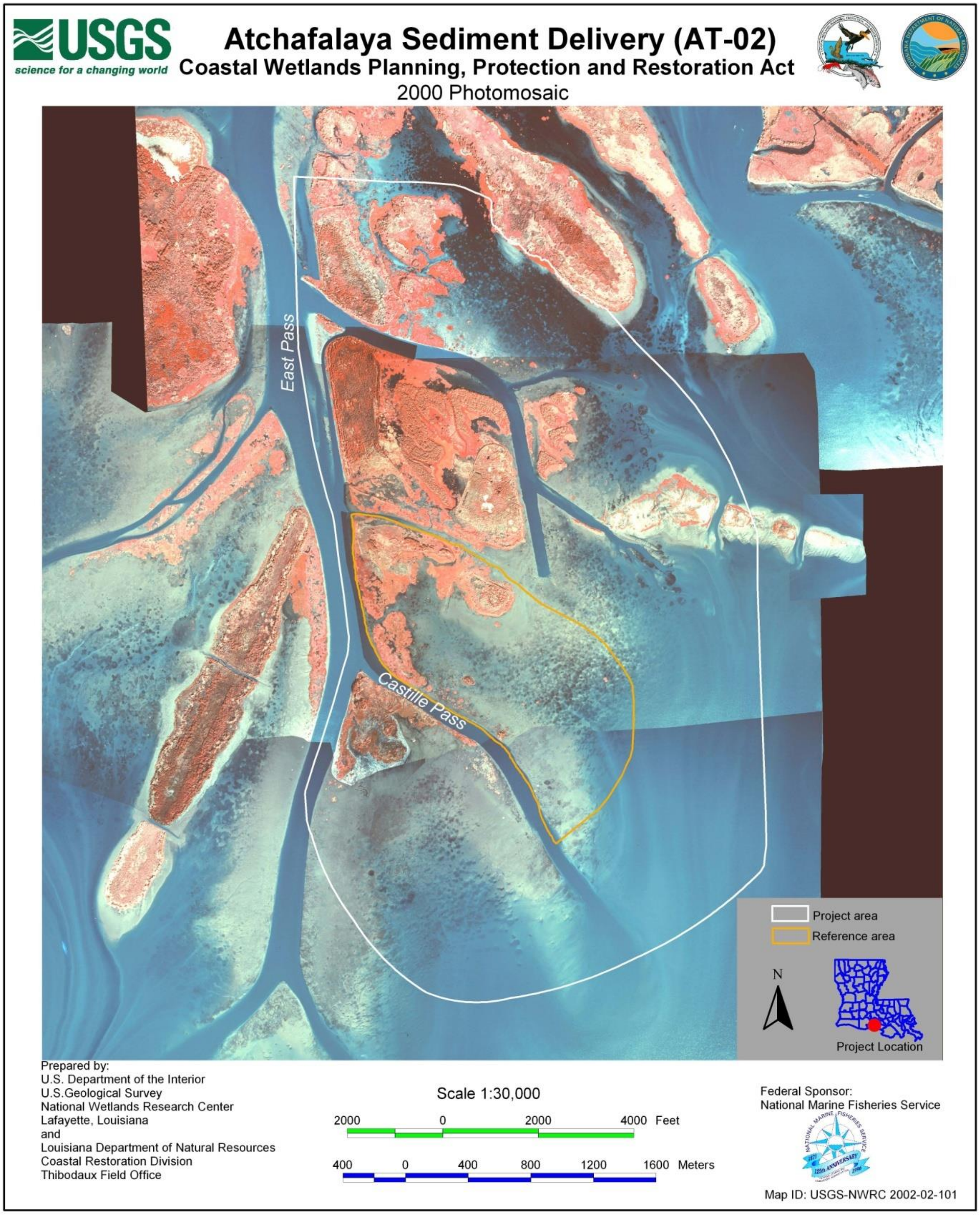


Figure C-3. **Post-construction (2000) photomosaic of the Atchafalaya Sediment Delivery (AT-02) project area.**

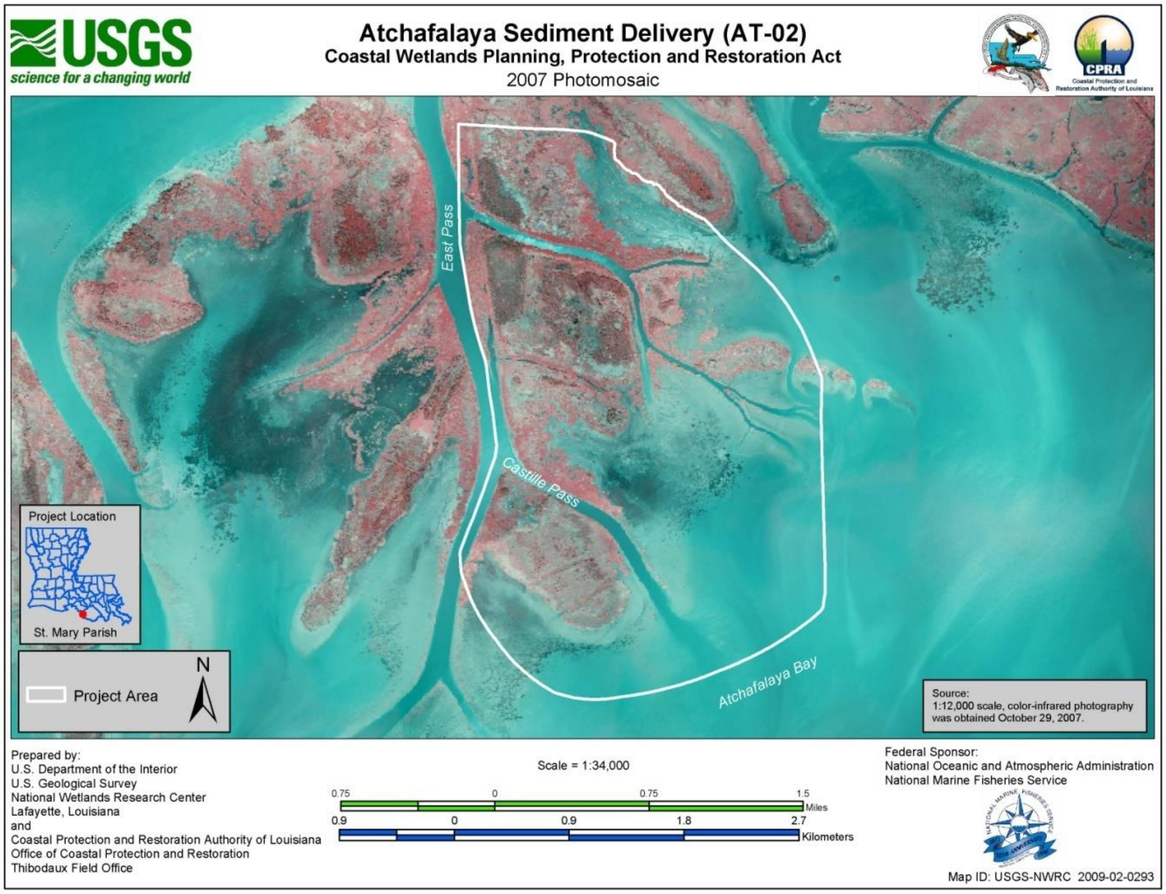


Figure C-4. Post-construction (2007) photomosaic of the Atchafalaya Sediment Delivery (AT-02) project area.

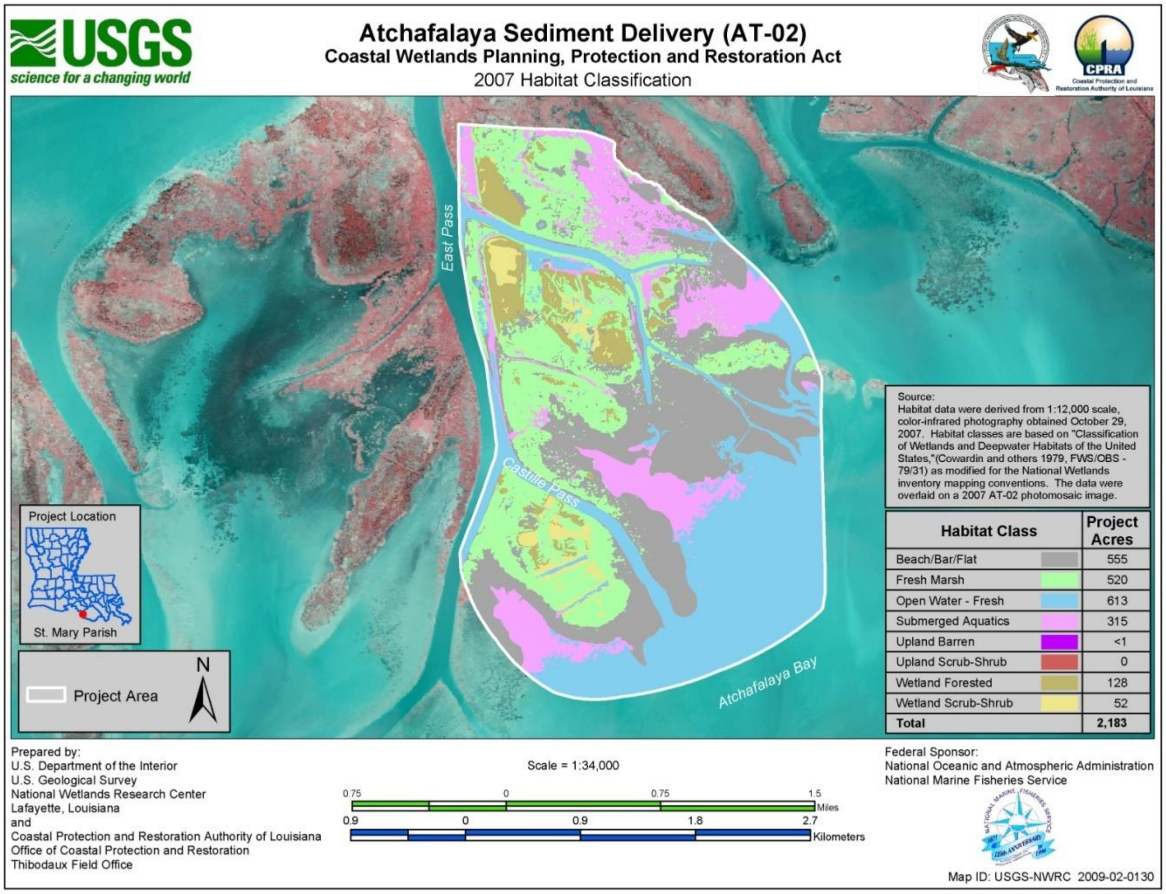


Figure C-5. Post-construction (2007) habitat analysis of the Atchafalaya Sediment Delivery (AT-02) project area.