Chapter 12: Management and Restoration of Coastal Ecosystems

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SUMMARY

This chapter provides an overview of the management and restoration activities associated with coastal ecosystems within the South Florida Water Management District (SFWMD or District). In addition to this year's consolidated reporting efforts, this chapter's coverage of coastal ecosystems supports the overall objective of the *2007 South Florida Environmental Report – Volume I* (SFER) to provide a comprehensive view of the South Florida environment within the District's boundaries. As an update to previous editions of SFER – Volume I, Chapter 12, the information covered in this chapter focuses on products, events, and scientific insights gained for Water Year 2006 (WY2006) (May 1, 2005 through April 30, 2006). The reader is encouraged to review previous SFERs for background information not provided in this year's document.

Nine major coastal ecosystems in South Florida have been identified as priority coastal water bodies (**Figure 12-1**). While these systems share common problems, each possesses unique hydrologic, biologic, and anthropogenic features. The District conducts scientific research and monitoring for the majority of these ecosystems, and works closely with other local, state, and federal partnering agencies for those areas where the District is not the lead agency. Restoration and management efforts are being implemented for each ecosystem consistent with the availability of resources and the priorities reflected in the District's Strategic Plan.

The District Coastal Watersheds Program goal is to protect and restore coastal watersheds and receiving water bodies through local partnerships and applied scientific research, and to decrease flood damages District-wide through flood management planning. The current coastal ecosystem management objective is to manage freshwater discharge to South Florida's estuaries in a way that provides salinity ranges appropriate for the health of essential estuarine resources.

Coastal ecosystem science and engineering projects undertaken by the District currently focus on developing enhanced knowledge and tools for the management of freshwater resources. Primary investigations continue to focus on analysis of freshwater discharges on seagrasses and oyster beds. Using the resulting information, the District works closely with scientists from other agencies, such as fishery and wildlife experts, to gain a better understanding of the links between water management impacts on estuarine habitats and its utilization by higher trophic levels.

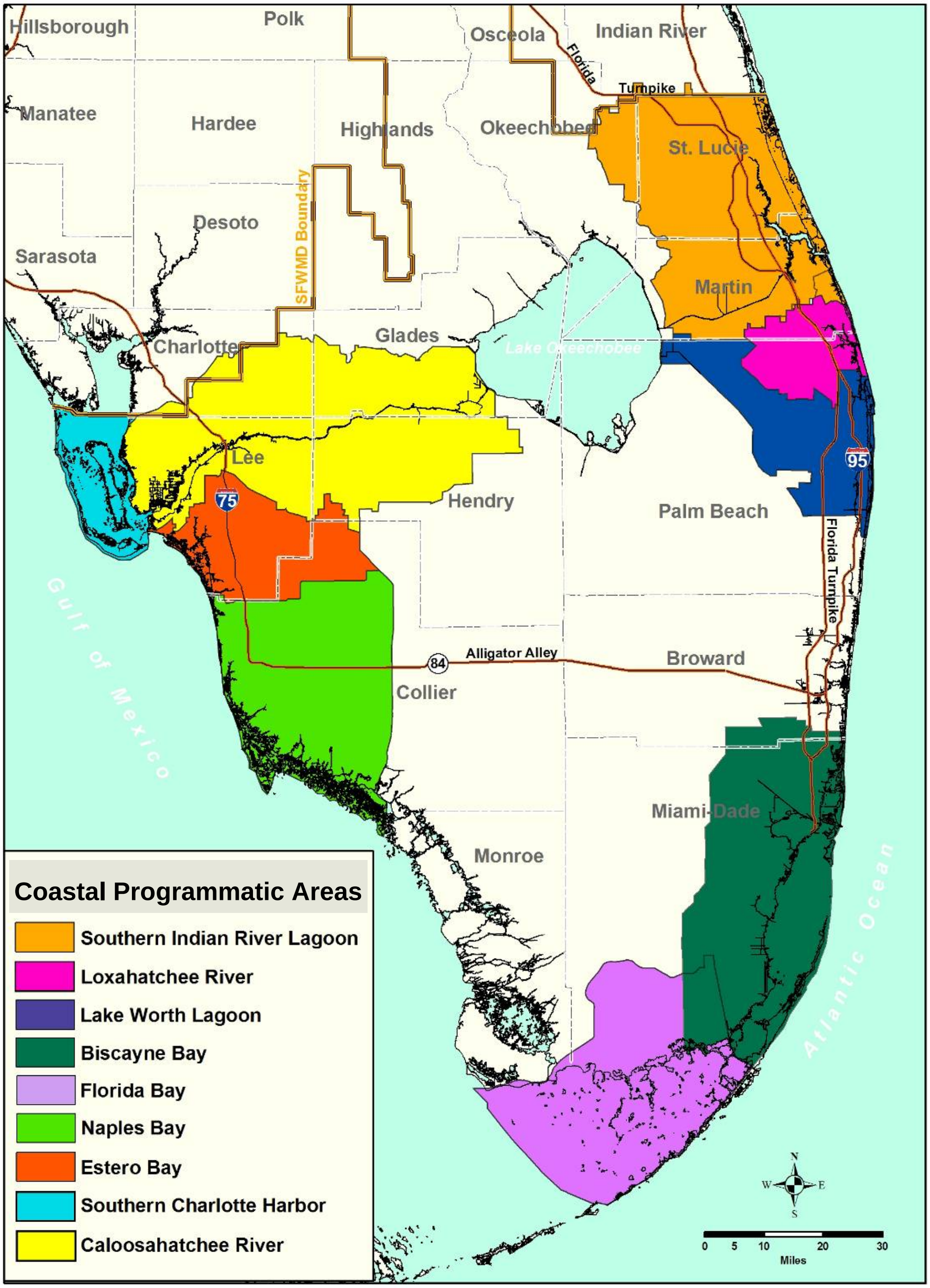

Figure 12-1. Priority coastal ecosystems in the South Florida Water Management District.

The District has organized resources to allow increased focus on coastal science, as part of a continuing effort to support the Comprehensive Everglades Restoration Plan (CERP) activities, as well as other critical needs, such as development of Minimum Flows and Levels (MFLs), water reservations, and Total Maximum Daily Loads. Within the SFWMD Coastal Watersheds Program, the Coastal Ecosystems Division (CED) is responsible for the development and application of science-based information and tools, as well as the design and implementation of projects that reduce scientific uncertainty and provide enhanced predictive capability for management of coastal ecosystems.

The primary objectives of the CED are to characterize and delineate the impact of freshwater discharges on estuaries and to develop models that provide a scientifically valid basis for water management decisions that impact coastal resources. Emphasis has been placed on watershed dynamics and the downstream impacts associated with quantity, quality, timing, and distribution of fresh water. The CED examines these factors to quantify linkages and to provide information to decision makers that will allow them to protect and restore estuarine resources. To accomplish this mission, the CED is committed to partnerships with local, state, and federal agencies, collaboration and peer review with the professional community, and consistent communication with stakeholders.

In WY2006, many areas in the District reflected the continued impact of recent hurricanes. Salinity habitats in the SLE were not favorable for oysters and seagrasses for most of WY2006 due to the high freshwater discharge. Monitoring in late April 2006 indicated some oyster spat settlement on artificial reef material, but no live oysters were found in the middle estuary. Seagrasses near the mouth of the estuary still were under the impact of the two hurricanes in WY2005 and subsequent low salinity and poor light environment in WY2006.

Along the eastern boundary of Florida Bay and southern boundary of Biscayne Bay, an unprecedented phytoplankton bloom that began after the hurricanes of 2005 continued through the remainder of WY2006.

Noteworthy activities undertaken in WY2006 include the following:

- In April 2006, the SFWMD Governing Board accepted the Restoration Plan for the Northwest Fork of the Loxahatchee River. The plan, included in this SFER volume as Appendix 12-2, was developed in partnership with the Florida Department of Environmental Protection (FDEP), the Florida Park Service (FPS), and the Loxahatchee River District. The plan will establish the restoration targets for water reservations and CERP projects in the watershed, and provides the basis for operational protocols for water delivery structures in the watershed.
- A two-year project to examine nutrient limitation of phytoplankton growth in the Caloosahatchee Estuary was initiated. The project is intended to determine which nutrient can become limiting, the concentration at which either nutrient becomes limiting, and the ability of organic nitrogen to support phytoplankton production.
- The District's CH3D hydrodynamic/salinity model was expanded to include Estero Bay. The model can now be used in addition to the C-43 Basin Storage Reservoir Project to support the Southwest Florida Feasibility Study.
- In Lake Worth Lagoon, a multi-year pilot project for sediment removal in the C-51 Canal was initiated. This project is a cooperative effort between the District, Palm Beach County, and the City of West Palm Beach. In addition to the immediate removal of existing sediments, the project will also assist in quantifying the potential for reductions through future restoration actions.

- District staff working with biologists at the National Audubon Society in Tavernier, Florida successfully applied scientific adaptive management to the delivery of water into the southern Everglades by facilitating a slow water level recession during the early winter roseate spoonbill (*Ajaja ajaja*) nesting season. The goal of these deliveries was to keep salinity low in the transition zone ponds through the early dry season, facilitate a slow water level recession in the wetland, and prevent water level reversals. These conditions are thought to maximize prey productivity and forage efficiency. Furthermore, spoonbills are thought to draw their cue to nest, at least in part, from the rate of water level recession. The spoonbill colonies in northeastern Florida Bay had a remarkably successful WY2006 season, evidenced by the results at Tern Key where close to 150 chicks fledged from nearly 100 nests (compared to recent years when the number of chicks was well below 50 at this colony).
- Primary activities of the District's Florida Bay scientists during WY2006 included the completion of analyses using hydrologic and ecological models and the production of an extensive technical report in support of a draft of the District's proposed MFL rule for Florida Bay. Staff also presented this report (included as Appendix 12-3 of this volume) before an independent peer-review panel.
- District staff continued to integrate and streamline coastal watershed monitoring efforts throughout the organization. Staff from CED; the Restoration, Coordination, and Verification (RECOVER) team; CERP Projects, Operations and Maintenance; and District Service Centers are implementing baseline monitoring, adaptive management, and scientific assessments in a variety of projects. CED has integrated ongoing monitoring and assessment requirements and undertaken increased contract management in conjunction with the Northern Estuaries portion of the systemwide RECOVER Monitoring and Assessment Plan (MAP) (see http://www.evergladesplan.org/pm/recover/recover_map.aspx).

SOUTHERN INDIAN RIVER LAGOON AND ST. LUCIE RIVER AND ESTUARY

The Indian River Lagoon (IRL), located on the southeast coast of Florida has been described as one of the most biologically diverse ecosystems in North America (Gilmore, 1985). The Southern Indian River Lagoon (IRL – South), is under the jurisdiction of the SFWMD. (**Figure 12-2**), The St. Lucie Estuary (SLE) is the largest tributary to the IRL – South. The ecological health of these estuaries depends largely on the quantity, quality, timing, and distribution of stormwater runoff from the watersheds, which are drained chiefly through the District's primary canals, including C-44, C-23, C-24, and C-25. The C-44 Canal connects Lake Okeechobee with the SLE and provides a conduit for freshwater releases from the Lake into the estuary. The objective of this section is to evaluate the status of these estuaries during WY2006.

The District uses a Valued Ecosystem Component (VEC) approach to evaluate environmental conditions in the IRL and SLE. Seagrasses are the selected VEC for the IRL and oysters are the selected VEC for the SLE. Salinity is a key factor affecting survival and growth of oysters and seagrasses. Water management practices (freshwater releases from the watershed and Lake Okeechobee) can impact salinity in both of these estuaries. Accordingly, the District uses salinity tolerances reported in published and gray literature to help assess potential impacts to oyster and seagrass resources.

FRESHWATER INFLOWS

Freshwater discharges from the major water management canals to the SLE and IRL during WY2006 are shown in **Figure 12-3**. Significant discharge of freshwater from the C-44 Canal occurred much of the time from June through December 2005. Peak discharges from C-44 of 5,500 cubic feet per second (cfs) and 6,000 cfs occurred in July and October, respectively. The peak in October 2005 occurred in association with Hurricane Wilma.

The freshwater discharges from C-44 during WY2006 are attributable to both watershed runoff and regulatory releases from Lake Okeechobee. **Figure 12-4** shows water discharged from C-44 to the SLE during WY2006 originated primarily as regulatory releases from Lake Okeechobee with considerably smaller amounts attributable to watershed runoff. Lake Okeechobee discharges were necessary to lower the Lake level to protect the integrity of the surrounding dike.

SALINITY

The freshwater releases discussed above had a major effect on salinity in the SLE. **Figures 12-5** and **12-6** show salinity at two locations in the SLE (the U.S. 1 and SR A1A bridges over the estuary). These two continuous salinity stations bracket the most productive oyster beds within the estuary. In addition to top and bottom salinities, the graphs also indicate the upper and lower preferred salinity ranges for oysters. At both sites, salinity was below the desired range much of the time between June and December 2005.

Continuous salinity recorders are not present within the seagrass beds near the mouth of the SLE. However, water quality grab samples collected at nearby locations showed surface salinities as low as 8 parts per thousand (ppt) and bottom salinities as low as 13 ppt, well below the optimal lower salinity limit of 24 ppt for the dominant seagrass species in the area. Lower salinities coupled with low light penetration (Secchi readings as low as 0.3 meters) produced a stressful environment for seagrass growth during WY2006.

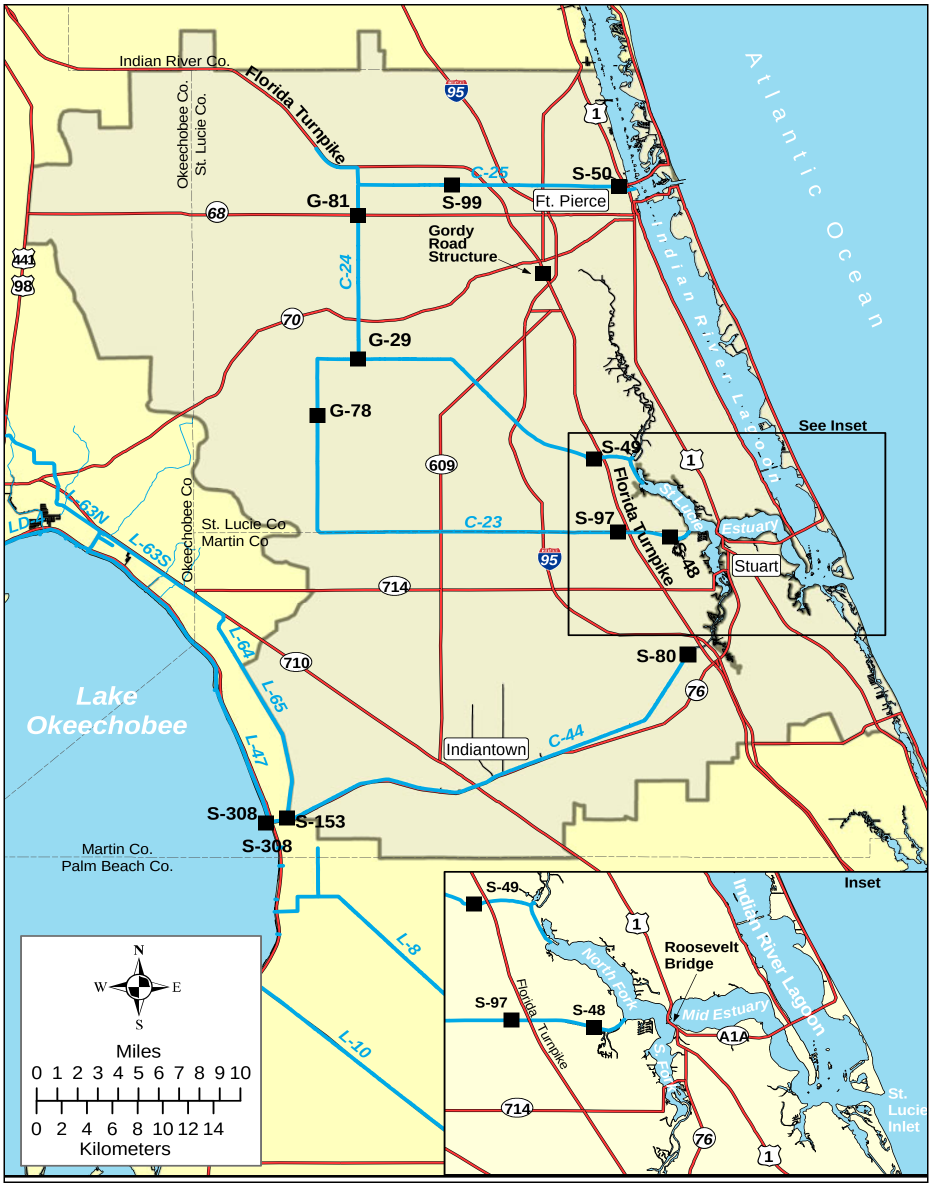

Figure 12-2. Map showing the locations of the Indian River Lagoon – South (IRL – South), St. Lucie Estuary (SLE), and major water management canals that discharge into these estuaries.

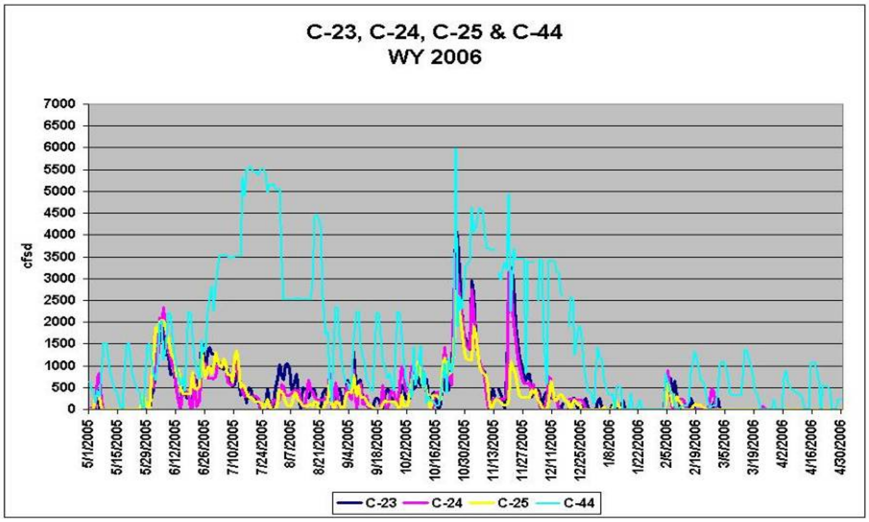

Figure 12-3. Freshwater discharge from the major control structures in the SLE and IRL – South watersheds during WY2006. Note that C-25 discharges directly into IRL – South.

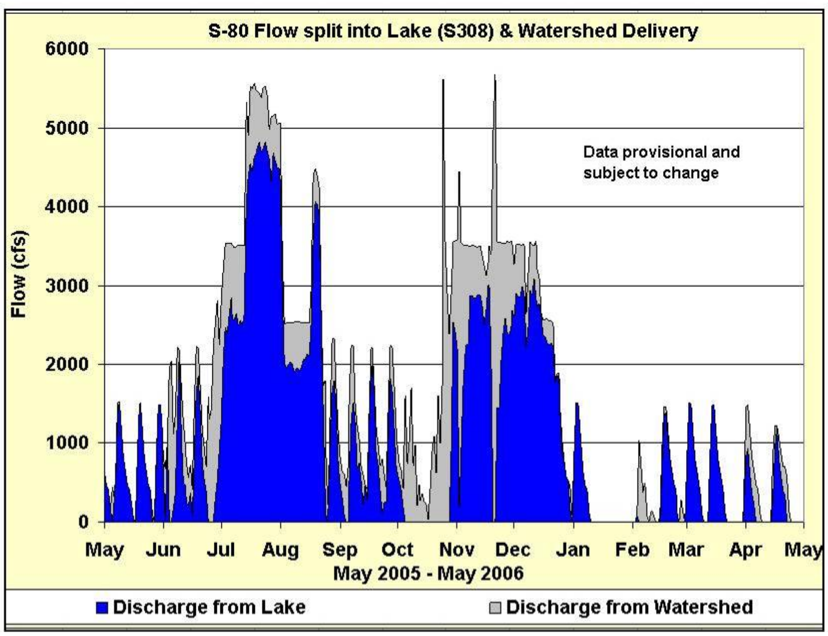

Figure 12-4. Total discharge to the SLE from C-44 during WY2006.

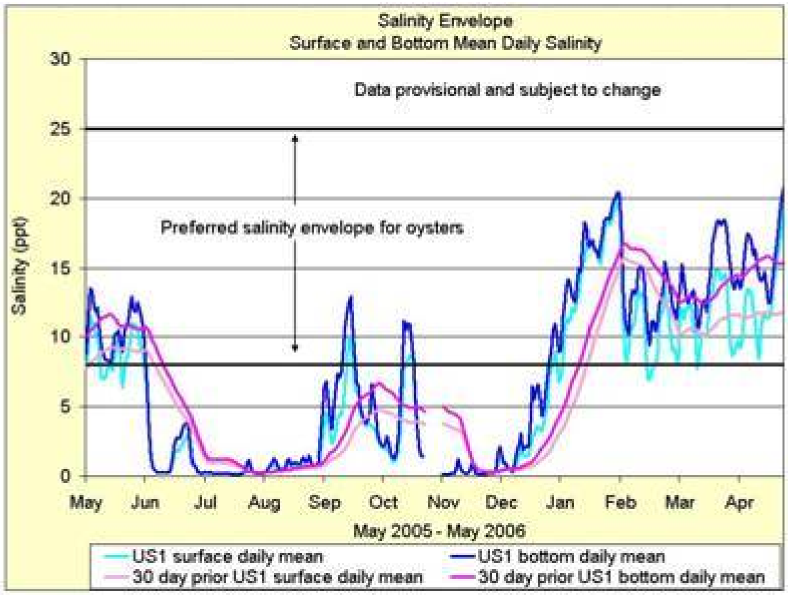

Figure 12-5. Surface and bottom salinities at the U.S. 1 bridge during WY2006.

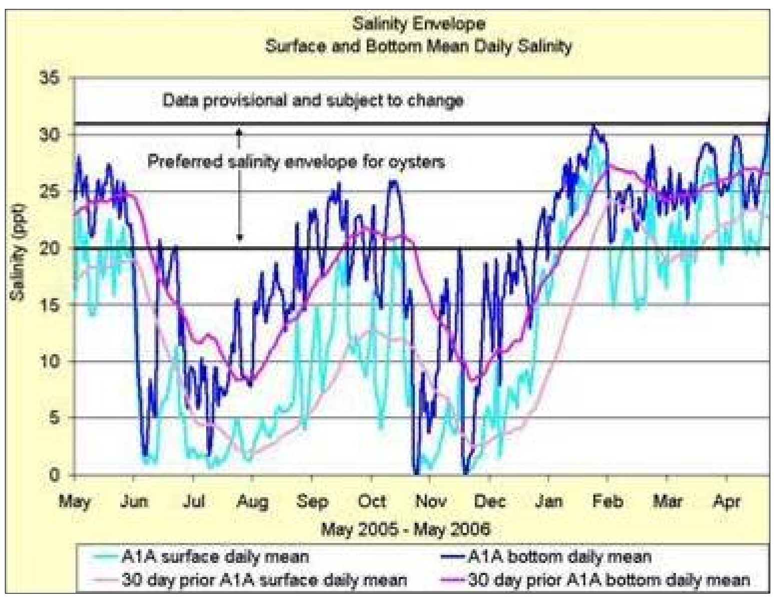

Figure 12-6. Surface and bottom salinities at the SR A1A bridge during WY2006.

OYSTERS

As freshwater flows increased, oyster abundance in the middle estuary of the St. Lucie River (between U.S. 1 and SR A1A) decreased significantly. No live oysters were found at middle estuary monitoring sites between June 2005 and January 2006. By March 2006, as salinities steadily increased, live oysters were found in the middle estuary. Monitoring conducted in late April 2006 indicated that some oyster spat settlements were apparent on artificial reef material placed in the middle estuary during WY2005. No live oysters were found in either the North or South forks of the SLE during WY2006. (Mapping conducted in 1997 indicated small beds of live oysters in these river forks.)

SEAGRASSES

The physical force of two hurricanes and resulting freshwater discharges had impacted the seagrasses in the vicinity of the mouth of the St. Lucie River during WY2005. The low salinity and low light environment for WY2006 further stressed these seagrass resources. Preliminary evaluation of data collected during semi-annual monitoring (**Figure 12-7**) indicates that sites closest to the mouth of the St. Lucie River that were impacted by the 2004 hurricanes had not recovered.

Monthly data collected at two sites (Sites 2 and 3 in **Figure 12-7**) that were influenced by SLE discharges illustrate the degree of impact to seagrass resources near the mouth of the St. Lucie River (**Figures 12-8** and **12-9**). Manatee grass (*Syringodium filiforme*) shoot counts and canopy heights continually declined throughout WY2006, with slight recovery apparent during spring 2006.

Figure 12-7. Location of monthly and semi-annual seagrass monitoring stations influenced by St. Lucie River discharges during WY2006.

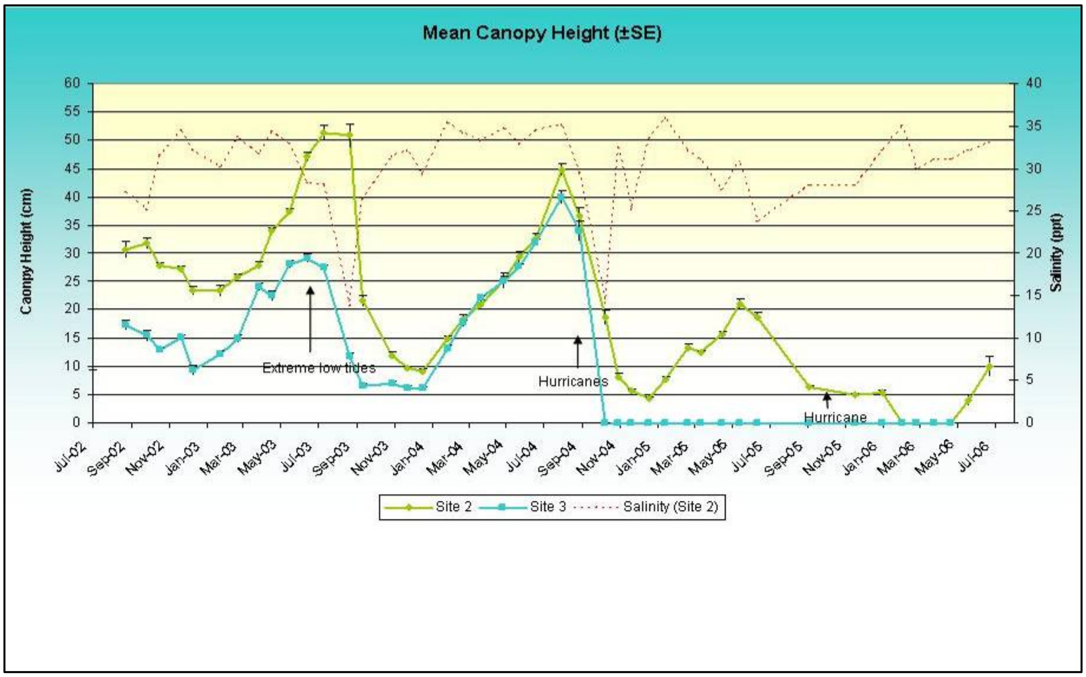

Figure 12-8. Manatee grass (*Syringodium filiforme*) canopy height at Sites 2 and 3 from August 2002 through June 2006.

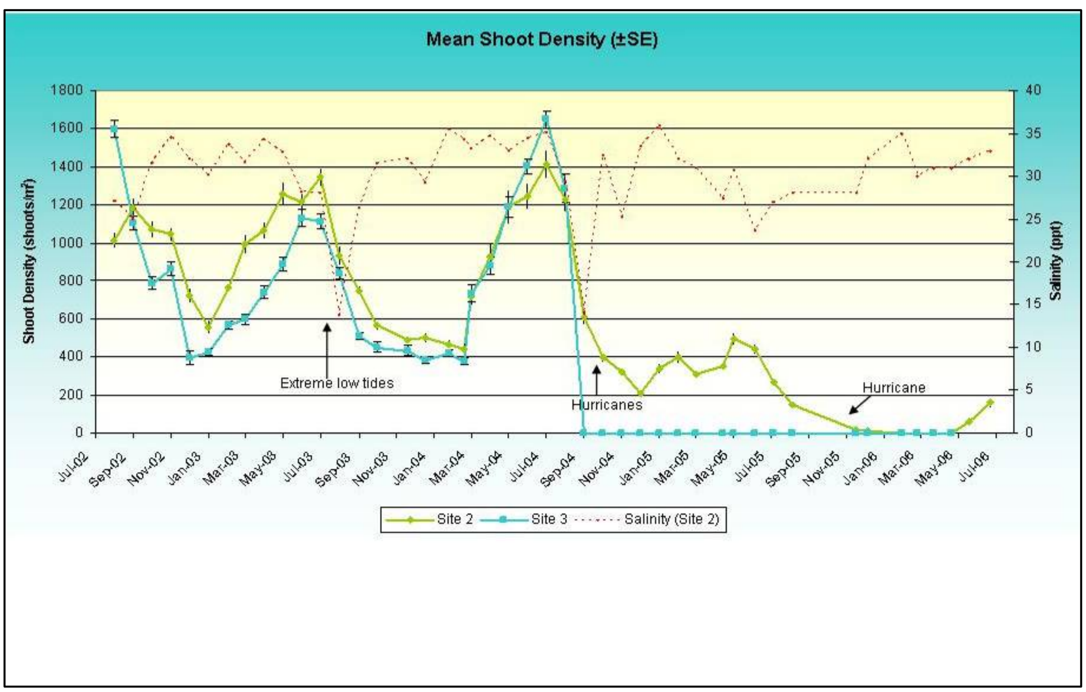

Figure 12-9. Manatee grass shoot counts at Sites 2 and 3 from August 2002 through June 2006.

LOXAHATCHEE RIVER AND ESTUARY

INTRODUCTION

In April 2003, the SFWMD adopted a Minimum Flows and Levels (MFL) Rule, Chapter 40E-8, Florida Administrative Code, with a minimum flow for the Northwest Fork of the Loxahatchee River. As required by legislation, a recovery strategy was incorporated into the MFL Rule, which included a commitment by the District to develop, in partnership with the FDEP, "a practical Restoration Plan and goal" for the Northwest Fork of the Loxahatchee River. In May 2006, the Governing Board of SFWMD voted to adopt the Restoration Plan for the Northwest Fork of the Loxahatchee River. To provide a status report on the District's ecologic and hydrologic data collection and modeling efforts concerning the Loxahatchee River and Estuary, this SFER discussion highlights sections from the restoration plan, included in this volume as Appendix 12-2. The restoration plan was prepared to (1) document the data collection and analysis effort, (2) identify models and other analytical methods used to develop the plan, (3) identify restoration alternatives, and (4) describe the constraints and assumptions of the plan made by staff of the SFWMD, and the FDEP. The plan addresses the environmental stresses facing the Northwest Fork ecosystems, describes the constraints of the existing water management system, and conducts the evaluation of restoration alternatives. It provides the best available technical information to support environmentally sensitive dry and wet-season flows or hydrographs for the ecosystems. A careful balance of the timing and distribution of flows is provided. Protection of the Northwest Fork ecosystem requires reducing or reversing the saltwater intrusion and subsequent environmental impacts on upstream freshwater wetland communities of vegetation and wildlife (e.g., fishes, alligators, turtles, and otters), with minimal impact on the estuarine areas. This major objective will be accomplished with minimum environmental impact on estuarine communities and their functions.

The freshwater and tidal floodplains of the Northwest Fork are unique resources that each contribute to the watershed's great environmental diversity. Besides the rare biological community of coastal sand pine scrub in Jonathan Dickinson State Park, the watershed contains pinelands, xeric oak scrub, hardwood hammocks, freshwater marshes, wet prairies, cypress swamps, mangrove swamps, seagrass beds, tidal flats, oyster beds, and coastal dunes (Treasure Coast Regional Planning Council, 1999). There are also distinct aquatic environments within the Loxahatchee River system: the freshwater zone, the oligohaline (low salinity) zone, the mesohaline zone, and the polyhaline zone. These terrestrial and aquatic habitats support diverse biological communities, including many protected species such as the manatee, an aquatic mammal that is restricted to Florida during the winter, and the four-petal pawpaw, a shrub that is found only in Martin and Palm Beach counties.

Together, the staff of the SFWMD, FDEP, FPS District 5, and the Loxahatchee River District collected and analyzed data used to develop and evaluate restoration flow alternatives for the Northwest Fork of the Loxahatchee River (**Figure 12-10**). After an analysis of historic and current flora and fauna communities, the Northwest Fork ecosystem was partitioned into five VEC categories (Appendix 12-2, Chapter 4):

1. Cypress swamp and hydric hammock in the freshwater riverine floodplain from River Mile (RM) 16 to RM 9.5
2. Cypress swamp in the tidal floodplain from RM 9.5 to RM 5.5
3. Fish larvae in the low salinity zone from RM 9.5 to RM 5.5
4. Oysters in the mesohaline zone from RM 6.0 to RM 4.0
5. Seagrasses in the polyhaline zone downstream from RM 4.0 to RM 0.0

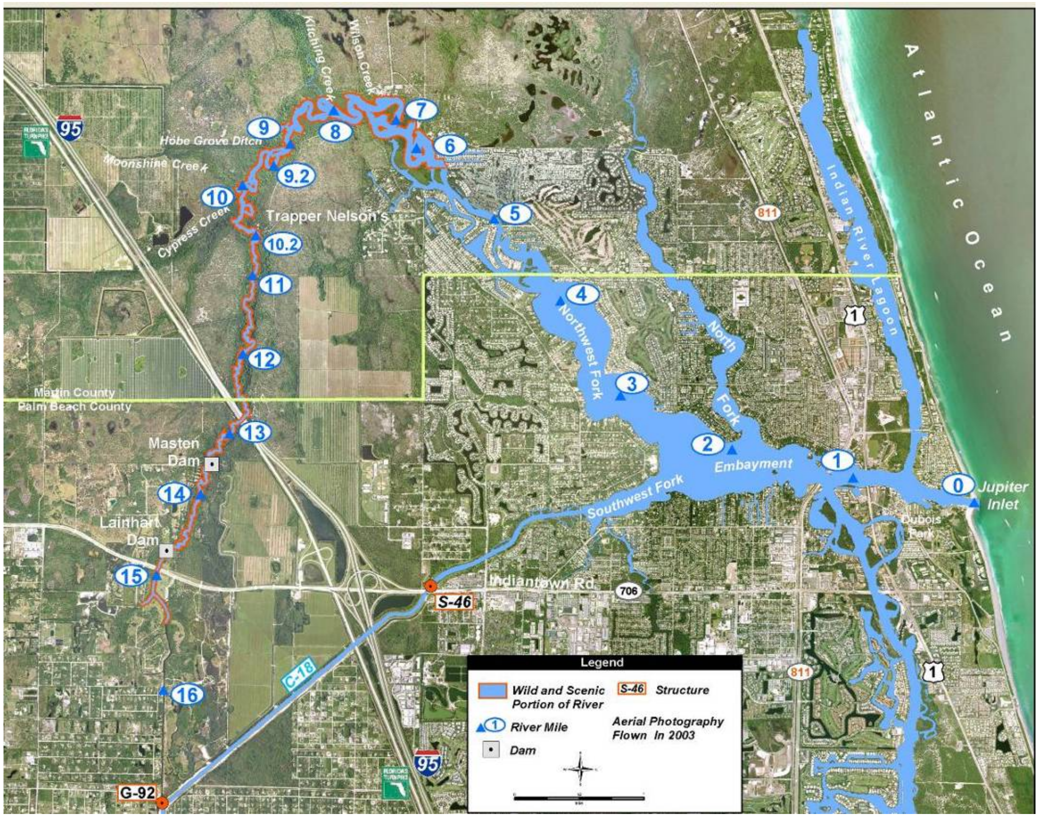

Figure 12-10. The Loxahatchee River and its tributaries. River Miles (RM) 1–16 are based on the 2003 Global Positioning System (GPS) and Geographic Information System (GIS) analyses for the Northwest Fork.

THE FLOODPLAIN ECOSYSTEM

The floodplains of the Northwest Fork of the Loxahatchee River consist of tropical and temperate zone riparian forest. As a riparian forested wetland system, these vegetative communities vary from dry to occasionally flooded as the river and its tributaries react to local rainfall events. Hydric and mesic hammocks commonly signify a higher elevation within the floodplain topography and chiefly consist of cabbage palm (*Sabal palmetto*), live oak (*Quercus virginiana*), wax myrtle (*Myrica cerifera*), and red bay (*Persea borbonia*) on the floodplains of the Loxahatchee River. Riparian forests are referred to in the southeastern United States as bottomland hardwood forests. They contain diverse vegetation that varies along gradients of flooding frequency. These forests are generally considered more productive than the adjacent upland forests because they receive a periodic inflow of nutrients. On the Loxahatchee River, bottomland hardwood communities are dominated by red maple (*Acer rubrum*), water hickory (*Carya aquatica*), buttonbush (*Cephalanthus occidentalis*), and Carolina willow (*Salix caroliniana*). Swamps on the floodplains of the Loxahatchee River consist primarily of bald cypress (*Taxodium distichum*), red and white mangroves (*Rhizophora mangle* and *Laguncularia racemosa*), pond apple (*Annona glabra*), and pop ash (*Fraxinus caroliniana*). The Loxahatchee River contains some of the last pristine subtropical cypress swamps in southeast Florida. For the analysis of canopy data from the 2003 vegetation study (see Appendix 12-2), plant communities of the floodplains of the Northwest Fork of the Loxahatchee River were divided into three distinct groups or reaches (**Figure 12-11**): riverine, upper tidal, and lower tidal.

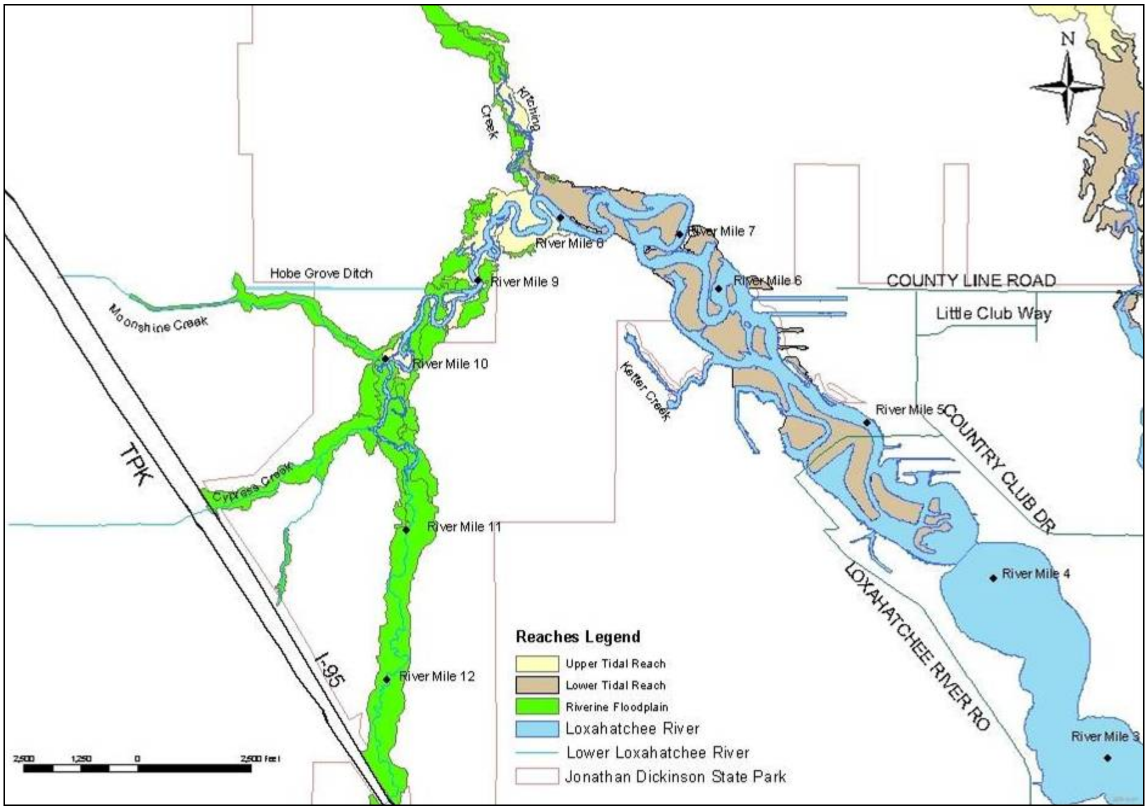

Figure 12-11. Reaches of the Northwest Fork of the Loxahatchee River.

The identification of floodplain forest community type was based on the canopy tree species that generally grow together in recognizable communities (modified from Darst et al., 2003) in the riverine, upper tidal, and lower tidal reaches. Tree canopy data from both the 1995 Ward and Roberts study (76 plots, each 10 square meters, or m^2) and the 2003 transect study (138 plots of 10 m^2 each) were collected; the relative basal area (RBA) of each tree species within a plot was determined using diameter-at-breast-height measurements. RBA is calculated by dividing the total basal area of a species in m^2 by the total basal area of all species within a plot. Guidelines were developed to identify the 16 forest community types by reach (Appendix 12-2, Chapter 3**)**. For each area, the major vegetative community category was identified as swamp, bottomland hardwood (low and high), hydric or mesic hammock, or uplands. The forest community reach and the type were determined based on species composition. These guidelines allowed consistent distinction among forest community types.

Rather than identifying individual species of VECs for the floodplain forest ecosystems, forest community types were used. Cypress swamps and hydric hammocks were chosen as the VEC communities and the restoration plan proposes specific performance measures for each of these plant communities on the Northwest Fork of the Loxahatchee River (Appendix 12-2, Chapter 4). The restoration plan proposes inundation of 4–8 months from about 0 to 1.5 feet below ground elevation for cypress swamp, and 30–60 days from 2 to 6 inches above ground surface elevation for hydric hammocks. Hydroperiod and water levels in the dry season are focused towards keeping root systems moist, providing germination of deciduous trees, and keeping upland and exotic species from invading the floodplains. On the other hand, wet-season hydroperiods and water levels are focused towards providing water and nutrients to the floodplain plant communities. The increase in inundation will also provide greater habitat for aquatic organisms in the floodplains.

THE ESTUARINE ECOSYSTEM

Biological resources of the Loxahatchee River Estuary are greatly affected by freshwater flows, tidal flows, and human activities. Many freshwater and marine organisms are dependent on certain ranges of salinity in relation to habitat at different times of their life cycle. To determine the distribution and abundance of fish and shellfish larvae in the waterway of the Low Salinity Zone (LSZ, 0.5–5.0 ppt, oligohaline), a sampling program was conducted in 2004. This study was undertaken during the dry season to determine the influence the LSZ in the Northwest Fork has on larvae recruitment and abundance as well as species composition. Four regions between RM 6 and RM 10 were chosen for the initial collections in this portion of the Northwest Fork (**Figure 12-12**). SFWMD also conducted zooplankton collections within the Loxahatchee River and Estuary from January 1986 to January 1988. This study allowed a qualitative and quantitative comparison with 2004 zooplankton collections.

The results from the 1986–1988 and 2004 dry-season sampling programs showed the highest densities of fish larvae within the LSZ at salinity levels ranging from 2 ppt to 8 ppt. Based on the SFWMD investigations presented in Appendix 12-2, a dry-season salinity of 2–8 ppt between RM 5.5 and 10.0 was suggested as the performance measure for larval and juvenile fishes of the LSZ area.

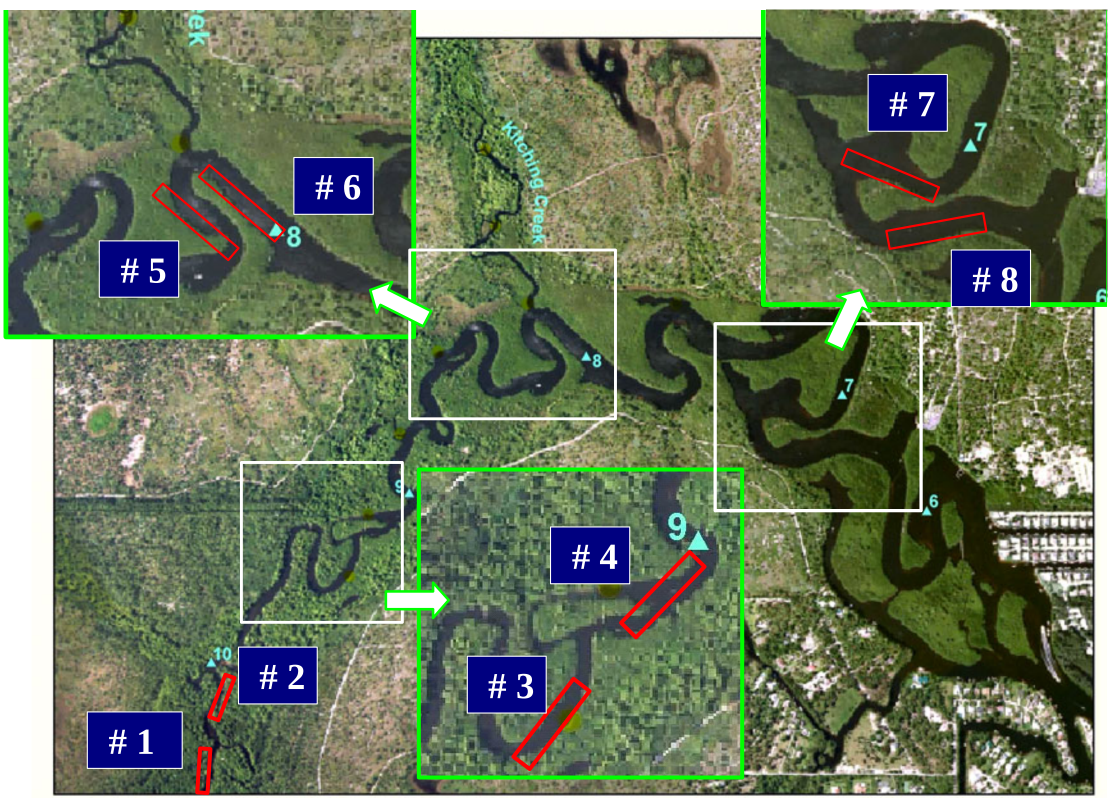

Figure 12-12. Location of 2004 dry-season fish larvae sample stations indicated by red rectangles. White numbers in rectangles are station numbers; smaller blue numbers indicate River Mile (RM).

OYSTERS

In October 2003, under a contract with the SFWMD, the Loxahatchee River District conducted an oyster survey in Loxahatchee River and Estuary (Wild Pine Ecological Laboratory, 2004). The live oyster reefs surveyed were defined as areas having at least five live oysters per square meter. The area of concern, however, was in the Northwest Fork (**Figure 12-13)**, where 9.6 acres of oysters were mapped between RM 4.0 to RM 6.0. The density of live and recently perished oysters as well as their total length (grouped into three classes: < 5 centimeter [cm], 5–10 cm, and > 10 cm) were recorded for four locations in the Northwest Fork. The majority of the oysters (76 percent) were < 5 cm in length, 23 percent were between 5 and 10 cm long, and only 0.2 percent were greater than 10 cm long. The highest density of oysters and largest area of reefs occurred at RM 4.5 (900 oysters/square meter). Density decreased upstream to about 690 oysters/square meter at RM 5.5 and to 410 oysters/square meter at RM 6.0 (Bachman et al., 2004).

In reviewing the literature on oysters and the relationship of salinity to duration of exposure, stress levels were identified for oysters at their various life stages (egg, larvae, spat, and adult). A model of salinity tolerances was developed using daily mean salinity values, alternative flows, and the locations where oysters were known to occur for the base case study. Thus, the salinity tolerance of oysters between RM 4.1 and RM 5.9 was identified as the performance measure for this community (Appendix 12-2, Chapter 4).

Since late 2005, oyster monitoring has been integrated with RECOVER Monitoring and Assessment Plan (MAP) baseline monitoring requirements and principal investigators are now under contract. The data and assessments from these projects will be available in future SFERs, as well as in the initial 2006 RECOVER System Status Report (at http://www.evergladesplan.org/pm/recover).

Figure 12-13. 2003 distribution of oyster reefs (yellow areas) in the Northwest Fork of Loxahatchee River. Red dots indicate oyster monitoring stations (Source: Wild Pine Ecological Laboratory, 2004).

SEAGRASSES

All seven seagrass species that occur in South Florida have been found within the Loxahatchee Estuary. Six species of seagrasses are found in the polyhaline region of the estuary. The seventh species, widgeon grass (*Ruppia maritima*), was observed in 2004 upstream in the oligohaline region near RM 6.5 (Loxahatchee River District, 2004). The six species of seagrass found within the polyhaline region were shoal grass (*Halodule wrightii),* manatee grass *(Syringodium filiforme)*, turtle grass *(Thalassia testudinum),* paddle grass (*Halophila decipiens*), star grass *(Halophila engelmannii),* and Johnson's seagrass *(Halophila johnsonii).* The dominant seagrass species present in the polyhaline region of the estuary was shoal grass. The 2006 SFER includes a map of the 2004 seagrass coverage.

Additional studies were reviewed that identified salinity ranges that may cause stress (reduced growth or increased mortality) to four of the seagrass species found in the Loxahatchee Estuary. The restoration plan considered salinity thresholds documented in the literature or observed in unpublished studies and presented corresponding performance measures for shoal grass, manatee grass, turtle grass, and Johnson's seagrass. Stress level was categorized as no stress, potential stress, or stress. Predicted salinities for nine model runs for a 39-year period

(1965–2003) were compared to the salinity tolerances of the key seagrass species at five locations along a salinity gradient in the Loxahatchee Estuary (see Appendix 12-2, Chapters 4 and 5)

MODELING SCENARIO EVALUATION

The formulation and evaluation of restoration alternatives was based on the successful application of hydrologic and salinity models developed for the Northwest Fork of the Loxahatchee River. These models included the:

- Watershed hydrologic model (WaSh) that simulates long-term freshwater inflows of tributaries to the Northwest Fork
- Two-dimensional estuarine, hydrodynamic, and salinity model called RMA that simulates short-term influences of these inflows and tide on estuarine salinity
- Long-term Salinity Management Model developed from the RMA results, capable of predicting daily salinity in the estuary for the period of record used in the watershed model

The restoration plan document (Appendix 12-2, Chapter 6) provides modeling detail, flow–stage relationships, and field observations of floodplain inundation (Appendix 12-2, Chapter 5). An initial set of alternative flow scenarios represented five constant low flow targets during the 39-year period of record (1965–2003). These scenarios included constant flows of 65 cfs, 90 cfs, or 200 cfs over the Lainhart Dam, coupled with 30 cfs, 65 cfs, 110 cfs, or 200 cfs in flows from the other tributaries of Cypress Creek, Hobe Grove Ditch, and Kitching Creek. The results from these flow scenarios were compared with the base condition. The ecological evaluations of the five constant flow scenarios indicated that while a few of the scenarios achieved some of the restoration goals, the overall ecological goals were not being fully achieved. Furthermore, a constant flow of 200 cfs over the Lainhart Dam during the dry season was considered harmful to the freshwater riverine floodplain and estuarine biota (see Appendix 12-2, Chapter 7 for detail.)

In response to the findings from the constant flow scenarios and public reaction to the results of the first five scenarios gained through a series of public meetings sponsored by the Loxahatchee River Management Coordinating Council, the District developed three variable flow scenarios to simulate a more natural, hydrological variability and to achieve the restoration goal (**Figure 12-14**). Each variable flow scenario represented the Lainhart Dam flows with varying amounts of augmented flows (mostly 65 cfs to 90 cfs during the dry season); added to these were three variable flows from the downstream tributaries: 60 cfs, 90 cfs, and 120 cfs. Evaluation of each variable flow scenario to achieve the restoration goal resulted in the selection of the Preferred Restoration Flow Scenario. The evaluation incorporated both dry- and wet-season hydrologic flow patterns and considered the greatest ecological benefit to freshwater riverine and tidal floodplain VECs, with minimal impact on the estuarine VECs (see Appendix 12-2, Chapter 8).

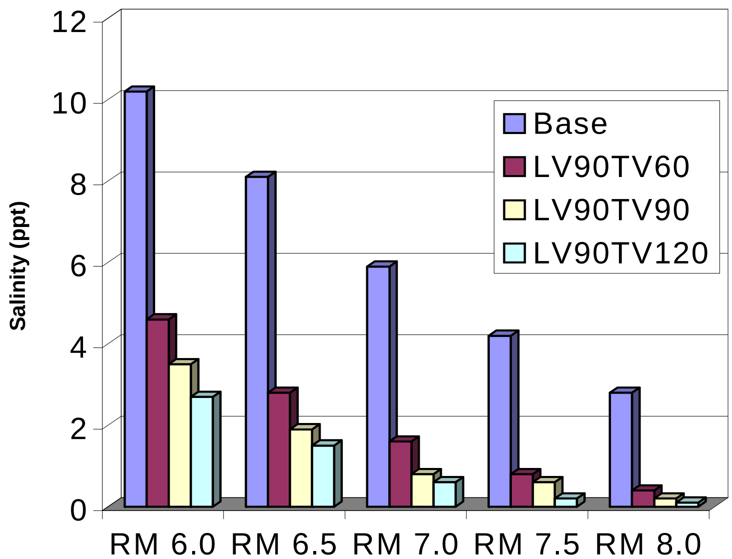

Figure 12-14. Average salinities of the base condition and three variable flow scenarios at RM 6.0, RM 6.5, RM 7.0, RM 7.5, and RM 8.0.

PREFERRED RESTORATION FLOW SCENARIO

Scientific information and modeling analysis indicated that the Preferred Restoration Flow Scenario to be a flow condition simulated by LV90 and TV60 modeling runs, using daily time-steps during a 39-year period of record (1965–2003). Generally, the LV90 model run represents variable flows over the Lainhart Dam providing flow augmentation when the daily flow falls below 70 cfs during the months of February through May, 130 cfs during the months of August through November, and 80 cfs during the transitional months. Adding flow during the wet season achieves 120 days of inundation (> 110 cfs at Lainhart Dam) of the cypress swamp in the riverine floodplain each year. The TV60 model run represents flows from the tributaries downstream of the Lainhart Dam, providing 30 cfs of flow augmentation to the Northwest Fork of the Loxahatchee River, when the total flows are less than 300 cfs. The combination of the LV90 and TV60 provides a Preferred Restoration Flow Scenario of adequate freshwater flows to protect and enhance the riverine floodplain, maintain conditions for the propagation of cypress trees in the tidal floodplain, and promote a healthy estuarine system in the Northwest Fork of the Loxahatchee River. This flow scenario reflects the seasonal variations needed to protect, enhance, and restore the biological values of the Northwest Fork ecosystem. In addition, the scenario includes rainfall-driven monthly and daily flow variability necessary for restoration. The Preferred Restoration Flow Scenario provides a dynamic flow pattern with dry-season mean monthly flows of 69 cfs over Lainhart Dam to maintain total daily flows greater than 150 cfs within the Northwest Fork, to push the saltwater wedge downstream of RM 7.5 more than 70 percent of the time during the 39-year period of record (**Figure 12-14**).

The Preferred Restoration Flow Scenario is expected to reverse saltwater intrusion and restore portions of the tidal floodplain to freshwater swamp, where during dry season the proposed restored flows will push the salinity wedge downstream from its current location near RM 9 to a location near RM 7.5 (**Figure 12-10**). At the new location, the salinity is expected to be below 1 ppt most of the time, increasing to approximately 2–3 ppt during periods of low flow conditions. The analysis of the entire 39-year modeling period indicates that the 2 ppt salinity wedge for the LV90-TV60 flow scenario reaches no further upstream than RM 8.1, which is the river reach immediately downstream of the confluence of Kitching Creek. Limiting saltwater intrusion within this portion of the floodplain will ensure suitable conditions for the propagation of seedlings and healthy growth of bald cypress and other freshwater species.

It is anticipated that with restorative flows, the cypress swamp between RM 16 and RM 9.5 will be inundated for approximately 4–8 months, and the hydric hammocks will be inundated approximately 30–60 days in a year. During the dry season, restoration flows will maintain low water levels in the freshwater riverine floodplain without completely drying it out every year. In the tidal floodplain, between RM 9.5 and RM 5.5, flows will push the saltwater front downstream from RM 9.5 to between RM 8 and RM 7.5. This will allow for recruitment of freshwater species in the upper tidal floodplain. Freshwater species will be expected to expand in number and dominate the canopy to the mouth of Kitching Creek near RM 8.1. There will also be recruitment of pond apple in the tidal floodplain due to the improved freshwater environment near RM 7.5.

The Preferred Restoration Flow Scenario is also designed to minimize the impact on the estuarine ecosystems. The LSZ, located between RM 9.5 and RM 5.5, requires a salinity regime of 2 to 8 ppt during the dry season to function as a nursery for many saltwater fishes. Although restorative flows will move the appropriate salinity range downstream, the low salinity still will remain within an area to provide suitable habitat for juvenile fish development. The optimal salinity range for oysters is from 10 ppt to 20 ppt, which is currently located between RM 6 and RM 4. With increased flows during the dry season, these salinity levels will be moved downstream and the upstream oyster beds at RM 6 will be lost. However, the majority of the oysters are located downstream of RM 5 and will not experience harmful drops in salinity levels. The addition of oyster substrate near RM 4 will mitigate the loss of oysters at RM 6. It will have minimal impact on seagrasses in the Central Embayment area.

The restoration plan also supports existing monitoring activities and proposes new activities and programs necessary to monitor water quantity, water quality, timing, and distribution if increased dry-season flows and improved wet-season flows in the Northwest Fork of the Loxahatchee River (Appendix 12-2, Chapter 10).

LAKE WORTH LAGOON

INTRODUCTION

The Lake Worth Lagoon (LWL) extends for approximately 20 miles in central Palm Beach County, Florida (**Figure 12-15**). The LWL is typically 6–10 feet in depth. The Atlantic Intracoastal Waterway channel runs the entire length of the lagoon. The LWL watershed is highly urbanized and encompasses over 450 square miles (sq mi) that ultimately drain into this water body.

WY2006 SUMMARY

In WY2006, hurricanes — especially Hurricane Wilma — caused considerable physical damage throughout the LWL watershed. Both public and private infrastructure was impacted. Within the lagoon, there were a significant number of vessels that were disabled or sunk, and had to be declared derelict and removed. Despite the impact of these natural disturbances, the SFWMD and Palm Beach County continued to make progress on several significant projects. The SFWMD provided financial support to Palm County for (1) habitat restoration at the Ocean Ridge Natural Area project, and (2) C-51 sediment monitoring. In addition, the SFWMD entered into a multi-year agreement for initiation of a pilot project for sediment removal from the C-51 Canal.

http://www.co.palm-beach.fl.us/erm/enhancement/Images/PDF_Documents/June2006.pdf

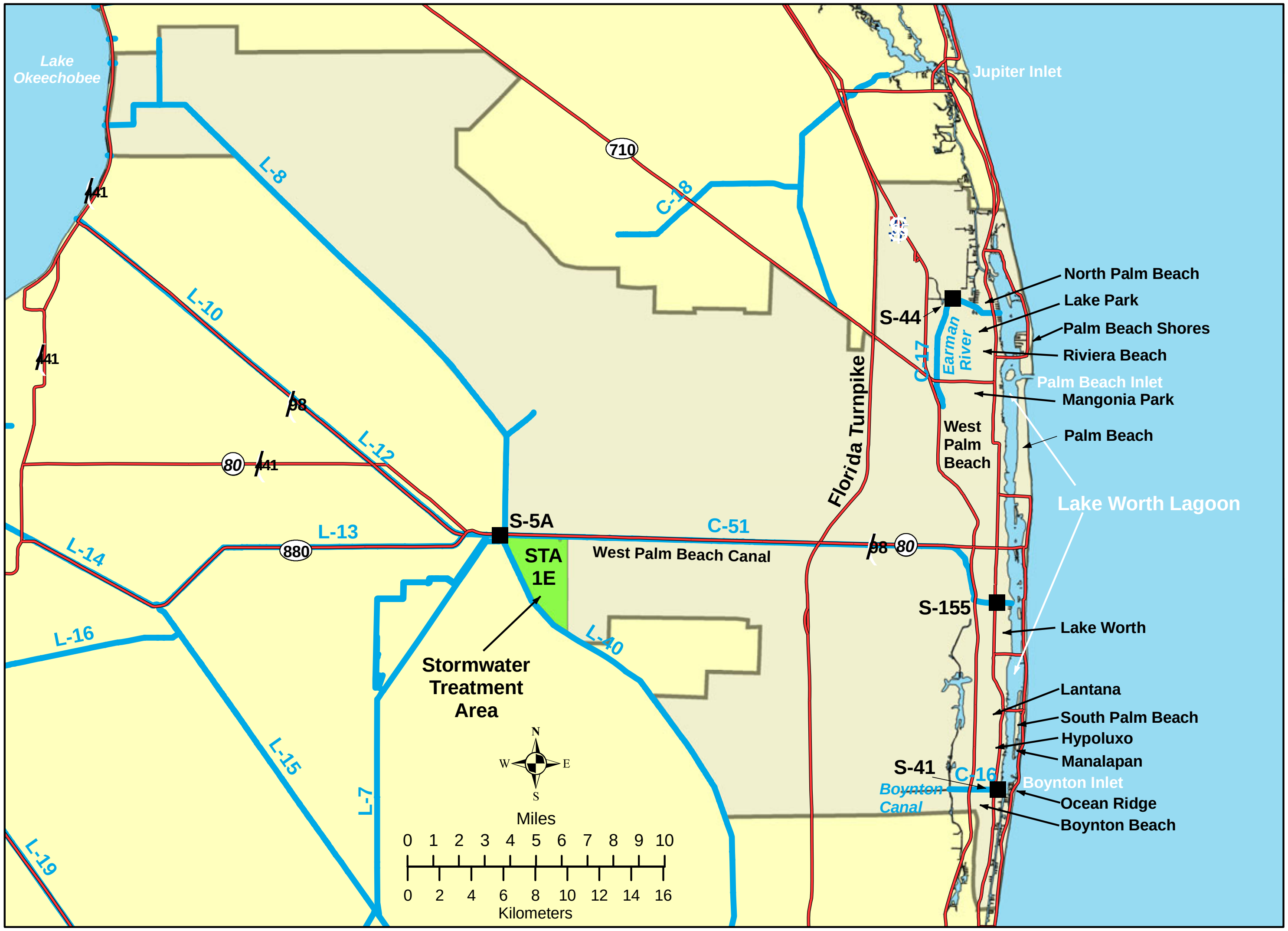

Figure 12-15. Lake Worth Lagoon watershed.

The Restoration, Coordination, and Verification (RECOVER) element of CERP continued existing baseline monitoring to meet long-term assessment needs. Under the requirements of RECOVER, existing water quality data (1990–2004) are being compiled and evaluated. It is anticipated that a full analysis of LWL water quality trends will be included in the RECOVER Systems Status Report, scheduled for production in 2006 (see http://www.evergladesplan.org/pm/recover/recover_map.cfm). Additional information regarding RECOVER is presented in Chapter 7B.

The CERP North Palm Beach County – Part 1 Project is developing performance measures for freshwater discharges to LWL and evaluating redirection of flows and additional retention of storm water from the C-51 Basin and sediment removal and control technologies within the C-51 Canal. Chapter 7A presents further information on CERP, and the CERP website provides project detail (see http://www.evergladesplan.org/pm/projects/proj_17_npbc_1.cfm).

The SFWMD continues to coordinate activities with the Palm Beach County Department of Environmental Resources Management and the FDEP, the lead agencies for LWL habitat management and restoration. The SFWMD participates in the LWL Partnership Grant Program and supports lagoon outreach activities. Further details regarding ongoing cooperation can be found on the following websites.

http://www.co.palm-beach.fl.us/erm/enhancement/lwlagoon.asp

http://www.pbcgov.com/erm/enhancement/Images/PDF_Documents/LWL_Report.pdf

http://www.co.palm-beach.fl.us/erm/enhancement/Images/PDF_Documents/grantposter2.pdf

BISCAYNE BAY

INTRODUCTION

Biscayne Bay is a shallow subtropical estuary located along the southeastern coast of Florida (**Figure 12-16**). The bay comprises a marine ecosystem of about 428 sq mi and a watershed area of about 938 sq mi. Development of the watershed has altered the delivery of freshwater inflows into the bay. Northern and central Biscayne Bay is strongly affected by the urban development associated with the growth of Miami. Southern Biscayne Bay is influenced by drainage from the Everglades, which has been altered by canals and agricultural activities. The opening of inlets and further channelization has contributed to the bay's transition from a freshwater estuary to a marine lagoon.

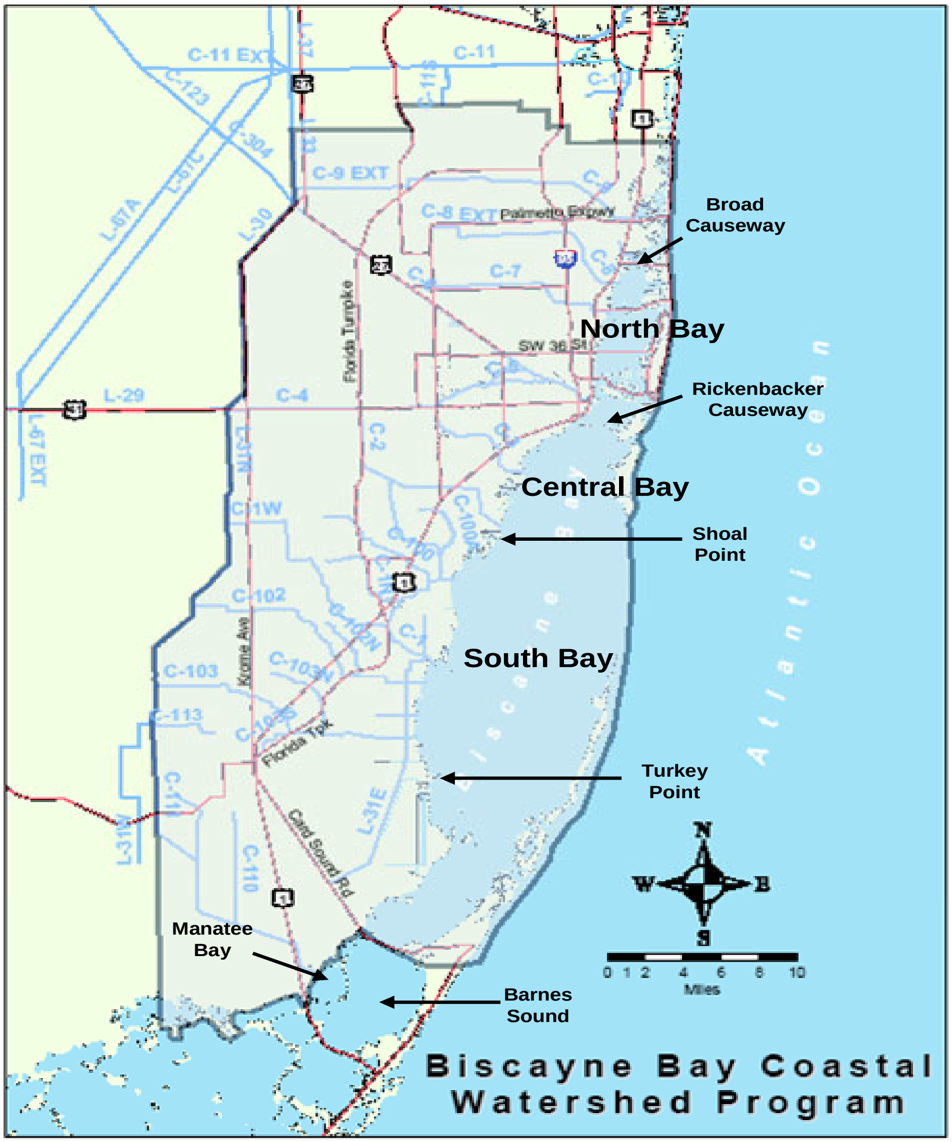

Figure 12-16. Biscayne Bay watershed.

Presently, Biscayne Bay alternates between marine conditions with seasonal hypersalinty, often occuring in the dry season (November–May), and extreme low salinities in nearshore environments, particulary near the mouths of canals during the wet season (June–October). Salinity in the bay is governed by the addition of small volumes, compared to the tidal prism, of fresh water from various sources (primarily canals, rainfall, and groundwater) combined with the influence of tidal exchange with the Florida Straits through various inlets and channels and wind driven circulation.

The following section describes hydrologic and water quality criteria that will be used to assess the status of Biscayne Bay. The performance of the system during WY2006 is evaluated through a comparison of canal flows and bay salinity to restoration targets recommended under CERP RECOVER. Finally, new activities begun during WY2006 are summarized.

ENVIRONMENTAL ASSESSMENT CRITERIA

Freshwater Inflow and Salinity

RECOVER has developed systemwide performance measures that, as indicators of conditions in the natural and human systems, have been determined to be characteristic of a healthy, restored ecosystem. Performance measures have been developed for different regions of the Biscayne Bay based on freshwater canal flows predicted to result in salinity ranges within the Bay that will support healthy ecosystems. Canal flows (based on daily flow rates in the DBHYDRO database), and salinity ranges (based on salinity data collected at 15-minute intervals, at Biscayne National Park) within Biscayne Bay are used here to evaluate flows for four sub-regions of Biscayne Bay: North Bay, Central Bay, South Bay, and Manatee Bay and Barnes Sound (**Table 12-1**).

Table 12-1. Salinity and/or flow targets for sub-regions of Biscayne Bay. Targets based on performance measures adopted by RECOVER (Source: RECOVER website at http//www.evergladesplan.org/pm/recover/eval_team_perf_measures.cfm).

Biscayne Bay Sub-Region	RECOVER Performance Measure	Freshwater Flow Source(s)	Wet-Season Target	Dry-Season Target
North Biscayne Bay	SE-7: Broad Causeway (North) to MacArthur Causeway (South)	C-8 and C-7 Canals through S-28 and S-27 control structures, respectively	107,000 acre-feet (ac-ft) total seasonal flow	49,000 ac-ft total seasonal flow
Central Biscayne Bay	SE-8: Rickenbacker Causeway (North) to Shoal Point (South)	C-2 Canal through the S22 control structure	20–28 practical salinity units (psu) 22,392 – 50,390 ac-ft/month ~600m from shore (DERM Station)	Same as wet season
South Biscayne Bay	SE-6: Shoal Point (North) to Turkey Point (South)	C-100, C-1, C102, Military and C-103 Canals through control structures S-123, S-21, S-21A, S-20G, and S-20F, respectively	Average bottom salinity 20 psu 500 m from shore/321,000 ac-ft total seasonal flow/2,104 ac-ft daily average flow during wet season	Average bottom salinity 20 psu 250 m from shore 146,000 ac-ft total seasonal flow/ 687 ac-ft daily average flow during dry season
Manatee Bay	SE-5: Manatee Bay and the Coastal Embayments of Barnes Sound	C-111 Canal through the S197 control structure, closed most of the time	5–15 psu	10–19 psu < 35 psu 95% of the time
Barnes Sound			15–30 psu 90% of the time	20-35 psu 90% of the time < 35 psu 95% of the time

Biscayne Bay flow and salinity ranges are based on the salinity tolerances of a variety of ecosystem components including seagrasses (North Bay), mullet (Central Bay), oysters, juvenile crocodiles (South Bay), and other estuarine species of fish, invertebrates (spiny lobster, blue crab), mammals (West Indian manatee, bottlenose dolphin), and reptiles including crocodiles, alligators, and green and loggerhead turtles (Manatee Bay and Barnes Sound).

Environmental Condition of Biscayne Bay

Current pre-restoration freshwater canal flows to Biscayne Bay and salinities in the bay were compared to proposed RECOVER targets for post-CERP implementation. Systemwide, current flow and salinity values were below restoration targets, but were closer to the targets in the wet season than in the dry season. This pattern is expected to continue until CERP projects are implemented.

Freshwater Flow

Baywide, canal flows to Biscayne Bay, shown in **Tables 12-2** through **12-4,** were below RECOVER restoration targets, with one exception. Daily flow performances were lowest, meeting restoration targets in a range from none of the time in the dry season in the Central Bay (**Table 12-3**) to 56 percent of the time in the wet season in the South Bay (**Table 12-4**). Monthly and seasonal flow performances were higher, meeting restoration targets in a range from 6 percent of the seasonal flow target in the dry season in the Central Bay (**Table 12-3**) to exceeding the restoration target in the South Bay in the wet season (**Table 12-4**).

Table 12-2. Performance against future targeted volumes – North Biscayne Bay.

	Total Seasonal Canal Flow	Daily Canal Flow
Wet Season	67% of seasonal target volume met	Daily Target volume met 18% of the time
Dry Season (8% data missing)	41% of seasonal target volume met	Daily Target met 7% of the time

Table 12-3. Performance against future targeted volumes – Central Biscayne Bay.

	Daily Salinity	Monthly Canal Flow	Daily Canal Flow
Wet season	Salinity target met 13% of the time (1% data missing)	52% of monthly target range volume met	Daily target volume met 5% of the time
Dry season	Salinity target met 3% of the time (15% data missing)	6% of monthly target range volume met (5% data missing)	Daily target volume met none of the time (5% data missing)

Table 12-4. Performance against future targeted volumes – South Biscayne Bay.

	Daily Salinity	Total Seasonal Canal Flow	Daily Canal Flow
Wet season: 500 m from shore	Salinity target met 66% of the time	>100% seasonal flow target volume met	Daily flow target volume met 56% of the time
Dry season: 250 m from shore	Salinity target met ~48% of the time (71% data missing) *	60% seasonal flow target volume met	Daily flow target volume met 23% of the time

* January–June data subject to quality assurance/quality control (QA/QC) review. Dry-season percentages expected to decrease as late dry-season data become available.

Salinity

Salinity performance was similar in the North and South Biscayne Bay sub-regions, meeting restoration targets 67 percent of the time in the wet season and 41 percent of the time in the dry season (**Tables 12-2 and 12-4**). Manatee Bay and the coastal embayments of Barnes Sound Coastal did not meet restorations targets at any time during WY2006 (**Table 12-5**), however, technical failures and consequent missing data during the highest period of rainfall and canal flow during the WY2006 hurricane season are thought to have affected performance data. Salinities in this sub-region likely met daily salinity restoration targets, however briefly.

Table 12-5. Performance against future targeted volumes Manatee Bay/Barnes Sound.

	Manatee Bay	Barnes Sound Coastal Embayments
Wet season	Salinity target met none of the time (28% data missing)	Salinity Target met 67% of the time (14% data missing)
Dry season	Salinity target met none of the time	No salinity data available

Algal Bloom

The Manatee Bay and Barnes Sound region in WY2006 had an unusual algal bloom event, which has persisted in eastern Florida Bay and southern Biscayne Bay (Manatee Bay, Barnes Sound, and Card Sound) since at least November 2005. The algal bloom was mostly composed of cyanobacteria (blue-green algae) of marine origin. Peak chlorophyll *a* concentrations (an indicator of the amount of algae in the water column) occurred in the fall and early winter. These concentrations greatly exceeded values recorded through the fifteen-year duration of coastal water quality monitoring in this region by the District and Florida International University. By March 2006, chlorophyll concentrations generally decreased, but still were above the highest values observed prior to the bloom. More recent results indicate that bloom increased again in late May 2006. The causes of this algal bloom are currently under investigation.

SCIENCE, ENGINEERING, AND RESTORATION ACTIVITIES

Resource Assessment

The following resource assessment projects were initiated in WY2006. For projects continuing from previous water years, see the 2006 SFER.

Project Title	**Partner**	**Description**
Water Quality Database	--	Initiated the development of a water quality database for Biscayne Bay.
Modeling Hypersalinity in Biscayne Bay	U.S. Geological Survey	Develop an integrated surface water and groundwater model of Biscayne Bay and analysis of the hypersalinity events in southwestern Biscayne Bay.

Project Title	Partner	Description
SAV Mapping	RECOVER/ Florida Fish and Wildlife Conservation Commission	Produce maps from aerial photos of Biscayne Bay taken in 2005, to (1) assess seagrass distribution, (2) provide baseline for future monitoring, and (3) Develop a recommended procedure for fine-scale statistical trend analyses of seagrass habitats.
Relationships of Epifaunal Species in Near-Shore Biscayne Bay	RECOVER/ Florida International University	Increase understanding the physiological state and performance of organisms, especially pink shrimp, at different salinities and temperatures in Biscayne Bay.

Engineering, Restoration, and Improvement Activities

STORMWATER IMPROVEMENT PROJECTS

The following stormwater improvement projects were initiated in WY2006.

Project Title	Partner	Description
Miami River Basin 21 Stormwater Retrofit	Miami-Dade County	Improve stormwater drainage in the Miami River Basin by providing an upgraded drainage and water quality treatment system to the geographic area.
City of Miami Beach Stormwater Drainage System Improvements	City of Miami	Provide for improved flood protection while maximizing water quality treatment of stormwater runoff prior to discharge.

RESTORATION PROJECTS

The following restoration projects were initiated in WY2006.

Project Title	Partner	Description
Chapman Field Restoration and Enhancement	Miami-Dade County	Restore impacted wetlands and reintroduce the native mangrove community at Chapman Field Park.
Virginia Key Restoration	Miami-Dade County	Restore and enhance 50 acres of disturbed wetlands and a network of flushing canals on the site.

PARK IMPROVEMENT PROJECTS

The following park improvement projects were initiated in WY2006.

Project Title	Partner	Description
Chapman Field Park	Safe Neighborhood Parks Bond Program and the FDEP Recreational Trails Program	Increase tidal flow between the East Lake and Biscayne Bay in Chapman Field Park by designing a bridge over the second culvert in the park, and extending the trail. This project will provide access under the bridge for non-motorized boats between East Lake and Biscayne Bay, and access for pedestrians and bicyclists through the bike trail and the bridge to the Lake.
Deering South Addition	Deering Park and Recreation Department and the FDEP Florida Coastal Management Program	Design Phase II, including picnic shelters, environmentally sound restrooms, potable water access to the site for drinking and fire prevention, and a canoe/kayak launch.
Biscayne Bay Blue-Way and Habitat Improvement	City of Miami	Provide shoreline stabilization and installation of canoe/kayak launches with educational materials and navigational signage at two City of Miami parks: Morningside and Margaret Pace.

FLORIDA BAY

INTRODUCTION

Florida Bay covers a triangular area of 2,200 square kilometers (km^2) at the southern tip of the State, between the Everglades and the Florida Keys (**Figure 12-17).** About 80 percent of this estuary is within the ENP. The Bay is shallow, with an average depth of about 1 meter. Most of the Bay's bottom is covered by seagrass, which is habitat for many invertebrate and fish species. The District has sustained a program of monitoring, research, and modeling since the early 1990s to document ecological status and trends within the Bay ecosystem, improve understanding of the ecosystem and its linkage to the Everglades watershed, improve forecasting of the impacts of changing water management, and improve water management for the protection and restoration of the Florida Bay ecosystem. During WY2006, the District's Florida Bay scientific efforts contributed to four major projects or programs: Florida Bay MFLs, Combined Structural and Operational Plan (CSOP) of the Southern C&SF, CERP's Florida Bay and Florida Keys Feasibility Study (FBFKFS), and CERP RECOVER. It is also notable that an unprecedented phytoplankton bloom along the eastern boundary of Florida Bay and southern boundary of Biscayne Bay that began after the hurricanes of 2005 was sustained throughout WY2006. This report provides a synopsis of SFWMD scientific activities supporting the above programs and initial assessment of the 2005–2006 phytoplankton bloom.

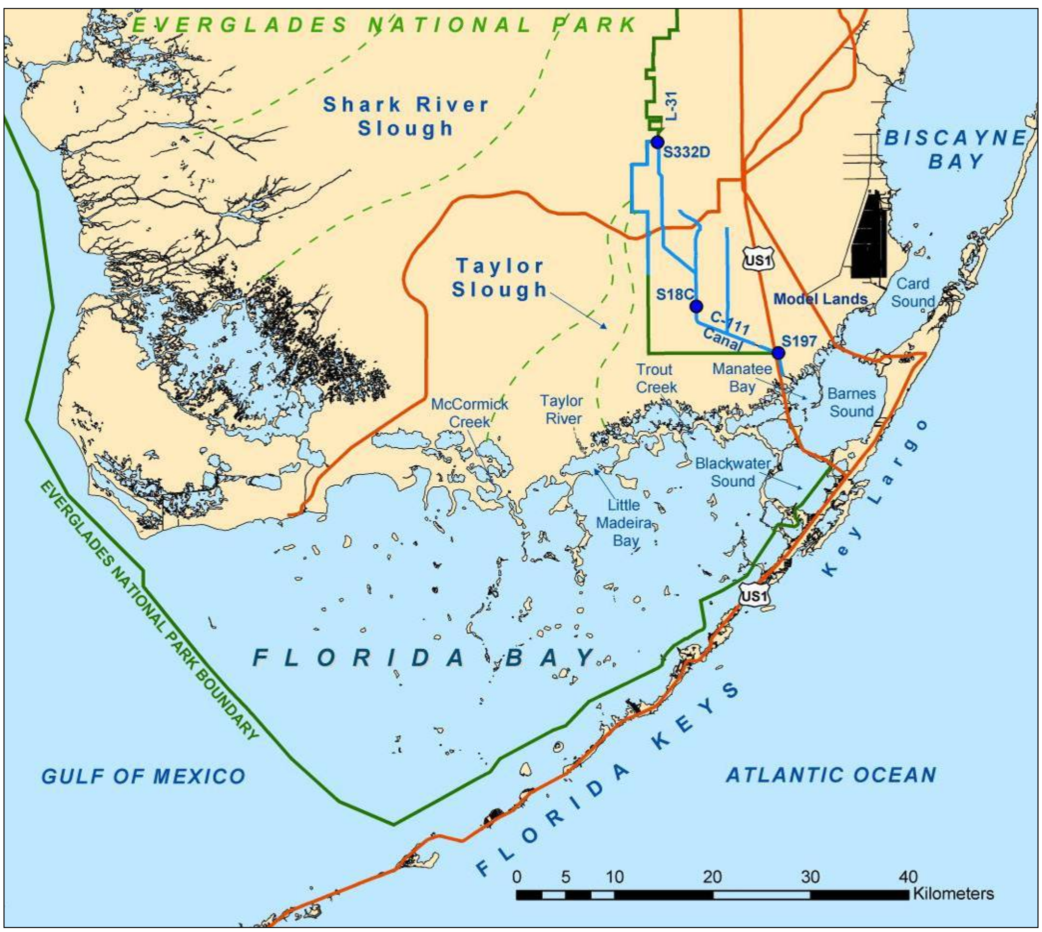

Figure 12-17. Area of Florida Bay and the Florida Keys.

SUMMARY OF SCIENTIFIC ACTIVITIES

Florida Bay Minimum Flows and Levels

Provision of a technical basis for development of an MFL rule for Florida Bay was the primary activity of the District's Florida Bay scientists during WY2006. This included completion of analyses using hydrologic and ecological models, completion of an extensive technical report, presentation of this report before an independent peer review panel, and contributions in the drafting of a proposed MFL rule. Technical analyses have pointed toward a salinity threshold of 30 practical salinity units (psu) in the mangrove-dominated salinity transition zone and 40 psu in northeastern Florida Bay that triggers the loss or degradation of submerged aquatic vegetation (SAV) habitat and can be used for designation of significant harm to the greater Bay ecosystem. A draft MFL rule based on the transition zone salinity threshold has been developed. The project document, *Technical Documentation to Support Development of Minimum Flows and Levels for Florida Bay*, is posted along with all project documents (including the peer review panel report) at http://www.sfwmd.gov/org/wsd/mfl/flbay/.

Interagency Science Program and 2005 Florida Bay Conference

The District's scientific program for Florida Bay is part of a coordinated interagency effort to provide a sound scientific basis for management and restoration of the Bay. The Florida Bay Interagency Program Management Committee (PMC) helps to guide this effort, with the planning, coordination, communication, and review of monitoring, research, and modeling (see http://www.aoml.noaa.gov/flbay/). In December 2005, the PMC (including the District) sponsored the Sixth Florida Bay Science Conference. An independent peer review panel chaired by Dr. John Hobbie attended the conference and has provided a written review of the proceedings and the state of the Florida Bay Science Program. The conference program and abstracts are available at http://conference.ifas.ufl.edu/FloridaBay/ and the peer review report is expected to be posted at http://www.aoml.noaa.gov/flbay/.

Combined Structural and Operational Plan and Current Operations

Scientific support of District operations and operational planning has included (1) analysis of model output to evaluate CSOP alternatives and (2) assessment of current water quality and ecological status downstream of structures and canals of the South Dade Conveyance System (SDCS). (Note that the southeastern Everglades and Florida Bay receive water from the L-31 and C-111 canals).

CSOP Downstream Ecological Monitoring. The District has contracted with Florida International University scientists to collect and analyze environmental data in the southern Everglades wetlands and transition zone of northern Florida Bay. The program has developed a monitoring network of stations in the C-111 Canal Basin, the Model Lands east of U.S. Highway 1, and lower Taylor Slough. The network includes two creeks that are major outlets of water flowing from the southeast Everglades into Florida Bay (Trout Creek and Taylor River) and several stations throughout the wetlands in sensitive areas downstream of canals and structures (L-31, C-111, and S-332S) that are the sites of major operational and restoration projects (CSOP and the C-111 Spreader Canal). This southern Everglades monitoring network gathers baseline ecological data for CSOP improvement and in anticipation of hydrological restoration projects to be completed as part of CERP. The stations in the network monitor surface water quality, including inorganic and total nutrients and salinity; relative water depth; soil nutrients, salinity, and organic matter; rainfall and wet nutrient deposition; wetland plant species composition, productivity, and biomass; and periphyton biomass.

Since the late 1990s, increasing water levels have been associated with reduced *Cladium* at some southern stations and replacement by *Eleocharis*, a desirable native species that is more flood-tolerant. Long-term water quality data has documented that TP concentrations in this region have remained low, at < 10 parts per billion (ppb) TP, equivalent to < 0.3 micromolar (μM) TP. However, following several tropical storms and hurricanes in South Florida in 2005, TP concentrations increased to as much as 25 ppb in surface water of the "Triangle Area" of the Model Lands (between U.S. 1 and Card Sound Road). The southern-most station in the Model Lands also showed an increase in early 2006 in response to an undetermined force. These are the first wetland water quality data collected for the District in this area and will contribute to the establishment of a baseline for the C-111 Spreader Canal.

Operations and Spoonbill Nesting Success. Understanding the relationships between hydrology and the dynamics of biological communities in the Everglades and Florida Bay remains a top priority for SFWMD scientists involved in long-term projects such as CERP and in short-term decision making for weekly operations of the SDCS. WY2006 brought a real-time opportunity to apply scientific adaptive management to the delivery of water into the southern Everglades during the early winter roseate spoonbill (*Ajaja ajaja*) nesting season. As described by Lorenz et al. (2002), nesting spoonbills in northeastern Florida Bay have been negatively impacted when SDCS water deliveries flood their foraging grounds in the southeastern Everglades mangrove transition zone. These events cause prey dispersal, poor nourishment of nesting birds, and nest abandonment at some of the largest colonies in the region (such as Tern Key). District and National Audubon Society scientists have been examining the relationship between spoonbill nesting performance and regional hydrologic conditions, to provide recommendations for SDCS operations that prevent these events and even enhance foraging ground productivity. In January 2006, a team of District engineers, water managers, and biologists collaborated with Audubon staff to examine the effects of slowly decreasing (versus abruptly shutting off) water releases into Taylor Slough (the desired route for water into the area). The goal was to keep salinity low in the transition zone ponds through the early dry season (see section on MFL technical criteria and rule development), facilitate a slow water level recession in the wetland, and prevent water level reversals. The spoonbill colonies in northeastern Florida Bay had a highly successful 2006 season. At Tern Key, for example, nearly 150 chicks fledged from nearly 100 nests, compared to recent years when the number of chicks was well below 50 at this colony. These results may be due in part to this slow drawdown and the enhanced productivity of the oligohaline habitat (in which 30-day mean salinity did not rise above 30 psu).

Florida Bay Water Quality Dynamics – WY2006 Algal Bloom Assessment

The District has made extensive efforts since the early 1990s to quantify water quality status and trends in Florida Bay, understand the role of water management (especially of the SDCS) in water quality dynamics, and build a predictive capability for future management. These efforts include extensive water quality monitoring (since 1991), monitoring of the inflow of freshwater and associated nutrients (since 1995), and research to measure rate processes such as benthic nutrient regeneration and primary productivity that are essential for water quality model development (see CERP RECOVER discussion below). These ongoing efforts were essential in providing documentation and understanding of the unusual water quality conditions of WY2006. The summary of these conditions provided below is drawn from the July 2006 Report on Algae Blooms in Eastern Florida Bay and Southern Biscayne Bay prepared for the District and other agencies (see Appendix 12-3).

A highly unusual algal bloom has persisted in eastern Florida Bay and southern Biscayne Bay (Manatee Bay, Barnes Sound, and Card Sound) since at least November 2005. Similar algal blooms have been observed in central and western Florida Bay, but not in eastern Florida Bay.

Chlorophyll *a* concentrations peaked in the fall and early winter in 2005, decreased in the spring, and increased again in June and July 2006. These concentrations greatly exceeded values recorded during fifteen years of water quality monitoring in this region (SFWMD/Florida International University Coastal Water Quality Monitoring Program) and were highest in the vicinity of U.S. Highway 1 (**Figures 12-18** and **12-19**). A timeline of water quality changes in association with other events (U.S. Highway 1 construction, hurricanes, and canal discharges) is presented in **Table 12-5**.

The algal bloom has been found to be composed chiefly of cyanobacteria, primarily in genus *Synechocystis* and *Synechococcus* (several species, including *elongatus*). These cyanophytes are also the typical dominant taxa in central Florida Bay blooms.

Causes of the bloom are not certain, but may be related to at least two factors: the disturbance associated with road construction activity along U.S. Highway 1 between the Florida mainland and Key Largo (Eighteen Mile Stretch), and impacts in August through October 2005 from hurricanes Katrina, Rita, and Wilma. Highway construction since May 2005 has entailed the cutting and mulching of mangrove trees and soil tilling (mixing fresh mulch into the peat soil) and soil stabilization with injection of cement. Hurricane disturbances included a large discharge of fresh water and phosphorus from the C-111 Canal and the impact of high winds, waves, storm surge, and abrupt salinity change on plants, soils, sediments, and groundwater. The proximity of the blooms to both sides of U.S. Highway 1 — an area where blooms have not been previously recorded — points to the likelihood that the unique disturbance of road construction is involved as a cause of the bloom. A summary of hypotheses regarding the cause of the blooms is presented in **Table 12-6**.

Monitoring results indicate that the bloom was most likely initiated by a large increase in TP; a sharp peak in TP concentrations (to record high values) was measured in a small area (Manatee Bay) in late August immediately following Hurricane Katrina and also in the large region of eastern Florida Bay and southern Biscayne Bay in October (**Figure 12-20**). The highest phosphorus and chlorophyll *a* concentrations were in basins closest to the Eighteen Mile Stretch near Key Largo. However, some lower but elevated TP concentrations were also observed at the same time in areas remote from the road. The timing of the TP peak and subsequent bloom appears to be associated more with hurricane activity (**Table 12-6**), with the regional peak occurring after Hurricane Rita (**Figure 12-20**). Despite major road construction activity during the late spring and through the summer, no blooms or unusually high TP were measured prior to Hurricane Katrina. Thus, while the spatial pattern of the bloom points toward the importance of road disturbance as a cause of the blooms, the timing of these blooms points toward hurricane disturbance as a cause. An interaction of these two factors (disturbance from road construction plus hurricanes) appears to be the likely cause of the blooms.

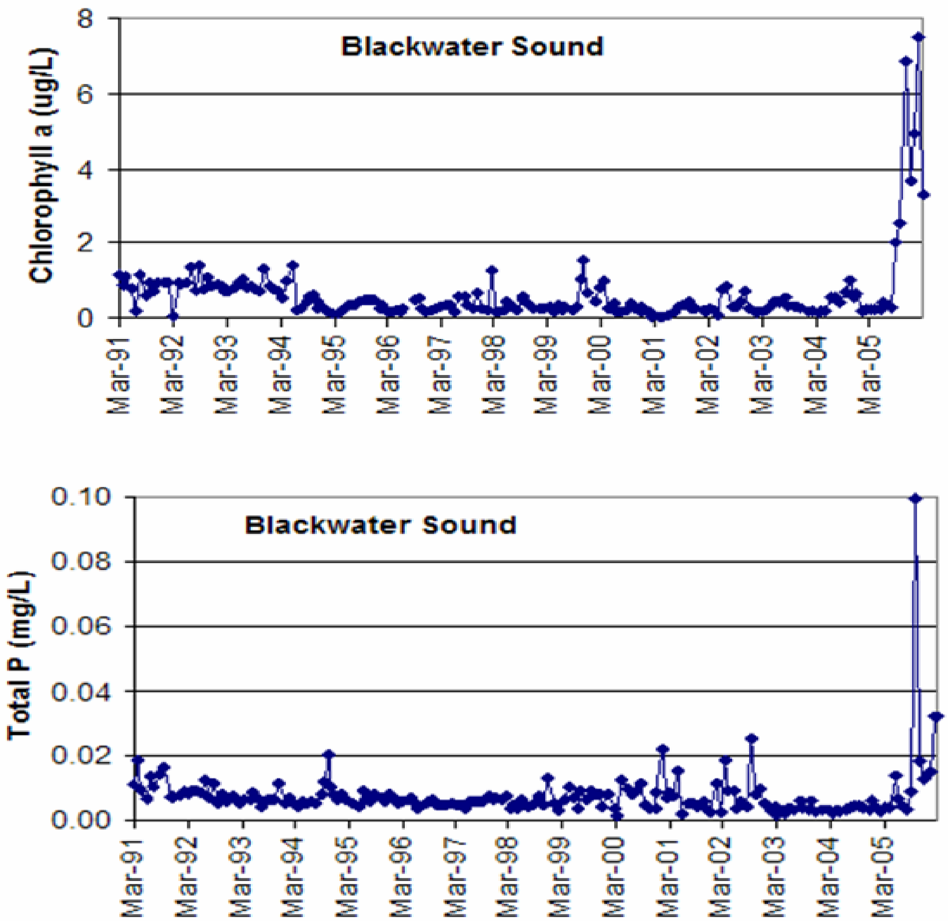

Figure 12-18. Long-term record of chlorophyll *a* and TP in eastern Florida Bay.

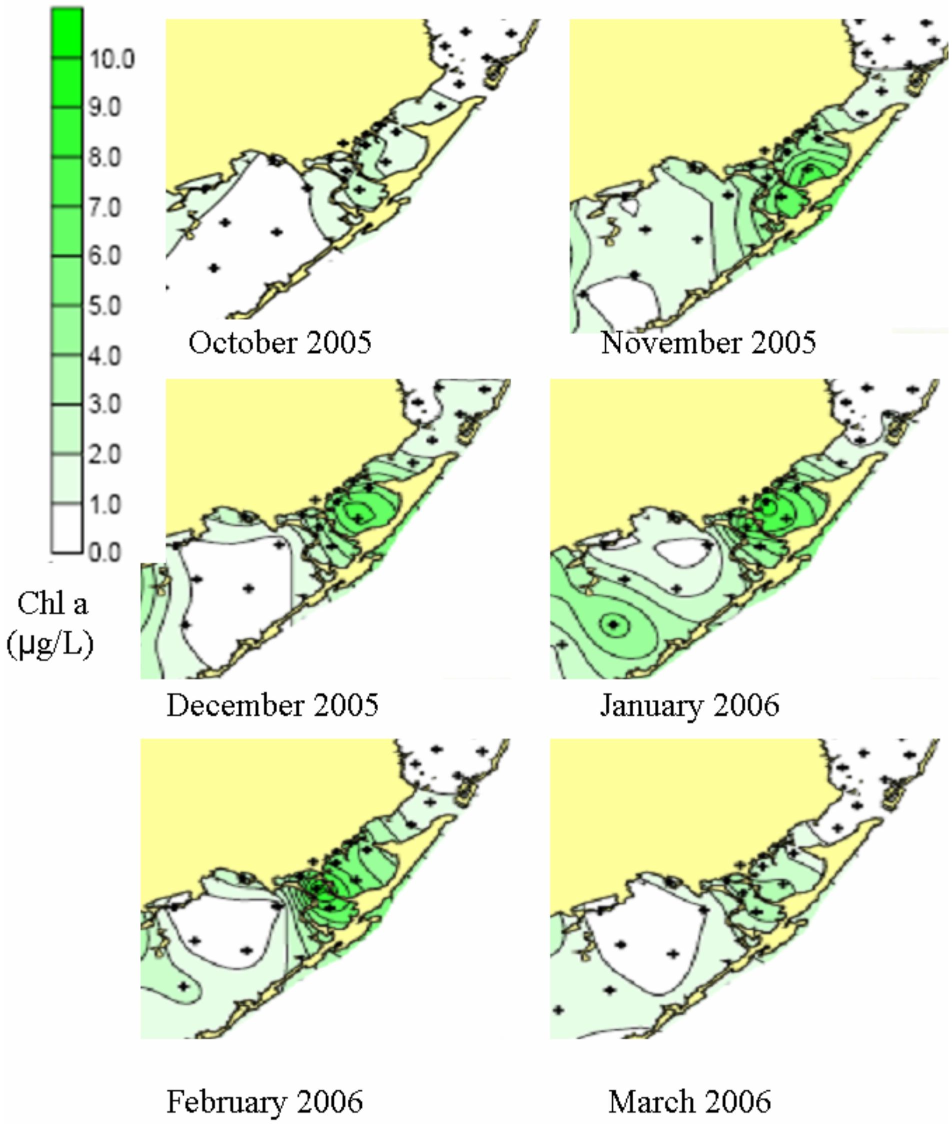

Figure 12-19. WY2006 extent of chlorophyll *a* concentration levels in Eastern Florida Bay.

Table 12-5. WY2006 timeline of Florida Bay and Biscayne Bay algal bloom and potentially associated events.

	Water Quality in Northeast Florida Bay South Biscayne Bay Region	U.S. Highway 1 Activities	Tropical Storm Events	C-111 Canal Discharge
2005				
Apr	No change from historic baseline (low chlorophyll *a* with median 0.4 ppb, and TP with median 6 ppb)	Mangrove clearing begins near Jewfish Creek	--	--
May	No change	0.6 miles cleared north of Jewfish Creek	--	--
Jun	No change	Clearing continues north and south of Lake Surprise	--	S197 open, 7,000 ac-ft discharge
Jul	No change	Clearing to Barnes; mixing of soil, mangrove mulch, and cement begins	--	--
Aug	After Katrina, rapid salinity drop, total phosphorus (TP) increase (84 ppb) in Manatee	Clearing and soil mixing continues north (Barnes Sound area)	Hurricane Katrina (high rainfall, runoff, 47 mph wind, 2 ft. surge)	S197 opens 8/26 (5-day, 27,000 ac-ft, TP load 0.8 metric tons)
Sep	TP near baseline in region, chlorophyll *a* increase in Manatee and Barnes (7 to 16 ppb)	Clearing and soil mixing continues north (Barnes Sound area)	Hurricane Rita (38 mph wind, 2-ft surge)	S197 open for 3 periods (20-days, 21,000 ac-ft)
Oct	High TP in region (60 to 100 ppb) before Wilma; chlorophyll *a* still low except Manatee and Barnes (6 ppb)	Clearing and soil mixing continues north (Barnes Sound area)	Hurricane Wilma (66 mph wind, 2- to 3-ft surge)	S197 opens for 2 periods (10 days, 2,000 ac-ft)
Nov	Regional chlorophyll *a* increase (bloom in Blackwater and Barnes to 15 ppb); TP decrease (slightly > baseline)	Clearing to Manatee Bay marina; soil mixing continues north	--	--
Dec	Bloom continues – highest in Barnes (near 10 ppb)	Soil mixing south of Lake Surprise	--	--
2006				
Jan	Bloom increases – mapping shows highest chlorophyll *a* near U.S. 1 and Key Largo (peak 20 ppb), high turbidity	Mangroves cleared near Manatee Bay	--	--
Feb	Bloom continues – chlorophyll *a* decrease (< 12 ppb in Blackwater, Barnes, Manatee)	Soil mixing near Barnes Sound	--	--
Mar	Bloom continues – chlorophyll *a* decrease (3 to 12 ppb in Blackwater, Barnes, Manatee)	Soil mixing near Barnes Sound	--	--
Apr	Bloom continues - chlorophyll *a* less than 10 ppb in Blackwater, Barnes, Manatee	Soil mixing near Manatee Bay	--	--
May Jun Jul	Bloom decrease in early May (chlorophyll *a* < 6 ppb); increase in June–July/ (> 12 ppb in Blackwater, Barnes, Manatee)	To be determined	--	--

Table 12-6. Hypotheses that may explain the cause of 2005–2006 (calendar year) algal blooms.

Hypothesis	Evidence Supporting	Evidence Refuting
U.S. Highway 1 road construction	• No similar algal bloom known to occur in the region prior to road construction • Bloom spatial pattern brackets highway (especially Blackwater-Barnes) • Bloom sustained 9 months after hurricane events, while construction continued • Mangrove mulch decomposition and soil disturbance likely to yield large nutrient release to adjacent waters	• Five months of construction activity before start of bloom • Bloom started immediately after Hurricanes Katrina and Rita • Bloom spatial pattern within basins adjacent to road do not show increasing chlorophyll *a* near road
Hurricane Katrina related discharge and TP load through S-197 (C-111 Canal)	• High-phosphorus load event occurred and primary production known to be phosphorus-limited • Bloom began in Manatee Bay and Barnes Sound immediately after pulse discharge and measured TP increase in Bay	• Elevated TP observed in areas beyond (west of) influence of S-197 discharge • Regional TP peak occurred one month after TP decreased to near baseline in Manatee Bay • TP load associated with particles – bloom does not follow gradient from canal mouth; chlorophyll *a* concentrations higher near Key Largo than mainland • Similar blooms did not occur after similar C-111 Canal releases and TP loads (even after late 1980s – early 1990s drought)
Hurricane wind, waves, surge eroded sediment and plants, stripped leaves, and pulsed groundwater nutrients	• Phosphorus increase after Katrina and Rita; regional bloom after Wilma • Spatial pattern of highest chlorophyll *a* appears parallel to Key Largo coastline, as could occur with line of storm deposits or groundwater pulse	• Regional TP increase occurred prior to storm with highest surge (Hurricane Wilma) • No similar blooms after previous storms (e.g., Hurricane Georges)
Hurricane disturbance: salinity drop and seagrass	• Salinity drop near coast with Katrina rapid enough to kill plants	• Salinity drop also occurred in areas with little TP increase and no bloom
Combination of road and hurricane disturbance	• Storm energy could move nutrients from road fill – turbidity barriers next to U.S. 1 removed prior to storms • Spatial pattern of bloom follows road for 9 months, while bloom initiation timing follows hurricanes	--

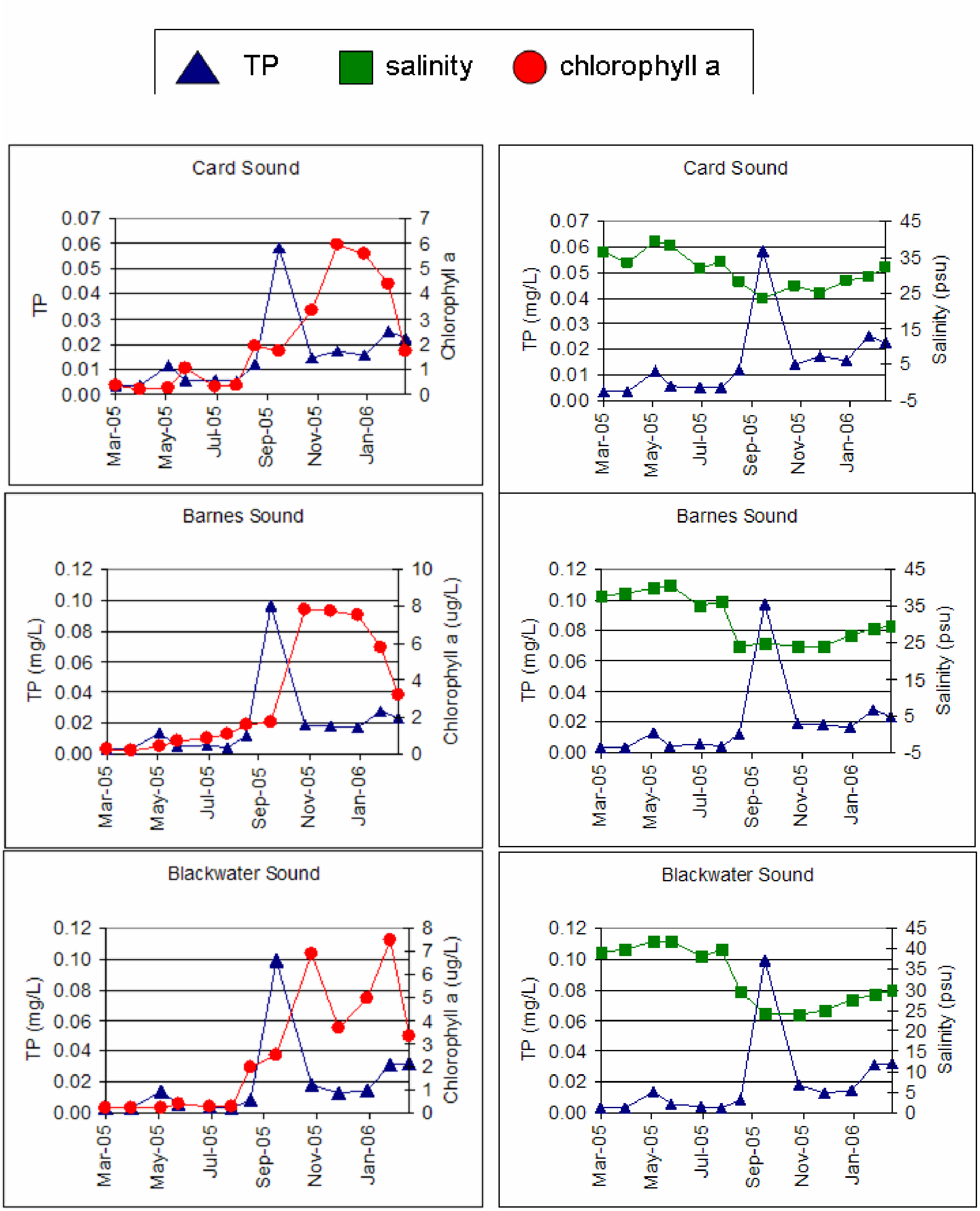

Figure 12-20. Total phosphorus (TP), chlorophyll *a*, and salinity data at three sites in eastern Florida Bay (March 2005–March 2006). Measured in monthly grab samples.

One component of the hurricane effects may have been associated with water management operations. High rainfall from Hurricane Katrina caused a major runoff event in late August 2005. This runoff resulted in a large loading of TP into Manatee Bay from the C-111 Canal along with a lower quantity of TP loading into Florida Bay through the southeastern Everglades. Subsequently, TP concentrations in Manatee Bay sharply increased and then returned to near pre-storm concentrations within one week. TP in Barnes Sound and all Florida Bay waters remained low for more than one month before peaking regionally in October. This one-month lag, along with the absence of a concentration gradient away from Manatee Bay, indicates that the canal inputs did not likely cause the widespread October peak. It is more likely that storm surge transported sediments, seagrasses, organic matter (perhaps including materials from the U.S. 1 worksite) and groundwater nutrients. Furthermore, when the TP peak did occur, areas with low salinity (associated with the most runoff) had lower TP than areas with higher salinity. Similar discharges of water and TP into Manatee Bay in the 1990s did not result in algal blooms similar to those observed between November 2005 and March 2006.

CERP: RECOVER and Florida Bay and Florida Keys Feasibility Study

Several Florida Bay activities during WY2006 supported CERP, especially RECOVER and the FBFKFS. This includes studies of fate of dissolved organic nutrients that flow into Florida Bay from the Everglades, development and review of a Florida Bay seagrass community model, and mesocosm studies of seagrass responses to environmental parameters to help parameterize the seagrass model.

Dissolved Organic Matter Bioavailability. Most of nutrients flowing into the Bay from the Everglades are in the form of dissolved organic matter (DOM). The effect of this form of nutrient input on the Bay, particularly the potential to stimulate phytoplankton blooms, depends on the rate at which this DOM is decomposed by microorganisms — its bioavailability. Research on DOM bioavailability is called for as part of the RECOVER MAP and is also needed as a parameter of the Environmental Fluid Dynamics Computer Code (EFDC) water quality model for the CERP FBFKFS.

Experiments were conducted to determine decomposition rates and bioavailability of Everglades DOM, specifically, dissolved organic nitrogen (DON) and carbon (DOC) in Florida Bay. The experiments tested three factors that may influence decomposition: DOM source (oligotrophic southeast Everglades versus the more nutrient-rich southwestern Everglades), phosphorus limitation, and sediment interactions (the presence or absence of sedimentary particles with associated microbes). Experiments were conducted for two to three months in 2.5-liter bottles in the dark to estimate DOM mineralization rates and the magnitude of labile (bioavailable) and refractory DOM pools. These estimates were derived from oxygen fluxes, DON and DOC measurements, and stoichiometric assumptions. Surface water from Taylor Slough and Shark River Slough served as DOM sources. Replicate bottles were inoculated with microbes contained in filtered Florida Bay water, or this water plus an aliquot of sediment. An artificial seawater sediment control was run to account for sedimentary consumption of oxygen, with consumption in control bottles subtracted from consumption in experimental bottles with sediment. Inorganic phosphorus was also added to half of the bottles to assess the effect of phosphorus limitation. Decay constants and the bioavailable carbon pool were calculated from natural logarithm transformed oxygen uptake rates, using a multiple-pool first-order decay model.

Results from two experiments in Taylor Slough (April–May 2004 and July–August 2005) show that about 15–40 percent of DOM from the southern Slough appears to be bioavailable. A small proportion (3–6 percent) of the DOM is quickly decomposed with a decay constant of 10–40 percent/day. The large remainder of the bioavailable DOM decomposed more slowly with a decay constant of 1–2 percent/day. Both phosphorus enrichment and the presence of sediment particles significantly affected DOM decomposition, increasing the magnitude of cumulative oxygen uptake rates and DOM loss. Loss of DOC and TDKN confirm the trends in the oxygen uptake rates. These results point toward the importance of phosphorus for the decay of less labile DOM by sedimentary microbes. Results also indicate that Everglades DOM decomposition may be more rapid at the sediment-water interface and during resuspension events than in clear Florida Bay waters, especially in central and western parts of the Bay where phosphorus levels are relatively high.

Given the long residence times of central and eastern Florida Bay (roughly 3–6 months based on the FBFKFS hydrodynamic model) it is likely that almost all of the bioavailable DOM entering the Bay through Taylor Slough and the C-111 Basin will be mineralized within the Bay. Effects of changing DOM inputs will be calculated during FBFKFS evaluations using the EFDC water quality model, which is in development.

Florida Bay Seagrass Community Modeling. A simulation model developed for Florida Bay (Madden and McDonald, 2006) was used to examine salinity effects on the seagrass community in support of Florida Bay MFL analyses. This model is being further developed in support of the FBFKFS, the C-111 Spreader Canal Project, and CSOP. Model code has been distributed to CERP managers and several state agencies, model documentation has been developed, and the model itself has been peer reviewed and provisionally approved by the Interagency Modeling Center. The code is currently being integrated into EFDC, the three-dimensional hydrodynamic and water quality model being developed for the FBFKFS.

The Florida Bay seagrass model is a spatially averaged, mechanistic unit model that is based on physiological responses of *Thalassia testudinum* and *Halodule wrightii* to salinity, inorganic nutrients, temperature, light, and sediment sulfide concentrations, incorporating the effects of interspecific competitive interactions. The model tracks units of carbon biomass per unit area, calculates nutrient flows from variable stoichiometric relationships, and considers response variables of percent cover, biomass, and species composition for square-meter sections of Florida Bay bottom with a three-hour time-step. The model is used to predict the effects of salinity variation on seagrass community dynamics by changes in the salinity regime triggered by alternative upstream management strategies. Five-year simulations (1996–2001) for areas influenced by Everglades input (Little Madeira Bay near the mouth of Taylor River and Eagle Key Basin in Florida Bay) have been used for a response-recovery analysis of SAV as part of the Florida Bay MFL evaluation.

Model runs have shown that the *Halodule* community was severely impaired after just two years of hypersaline conditions above 40 psu. Although direct response to high salinity is thought not to be the cause, interaction with secondary biogeochemical factors and competition from *Thalassia* at high salinity are likely responsible for the pattern, as the loss in *Halodule* only occurred in the presence of *Thalassia*. In these situations, *Thalassia* biomass increased by about 20 percent as *Halodule* declined by over 80 percent in three years. Application of recovery scenarios in five-year runs that returned salinity to baseline levels after differing perturbation periods permitted quantification of SAV community recovery after imposition of restoration measures leading to improved environmental conditions. Model runs suggest a period of 3–5 years for recovery of *Halodule* to pre-disturbance levels following a severe hypersalinity event (**Fig 12-21**). These results have been used in setting recommendations for MFLs and in FBFKFS and C-111 performance measures.

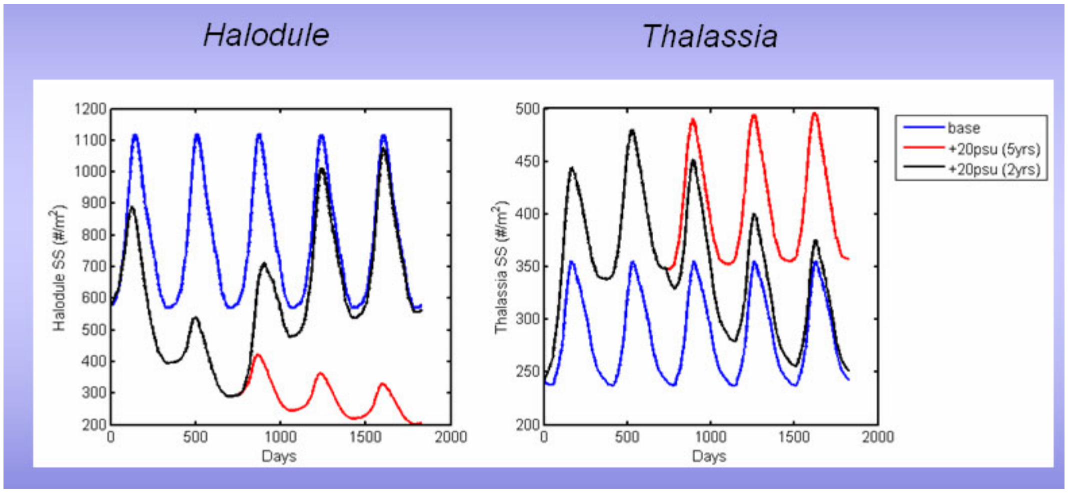

Figure 12-21. Time-course of recovery of the modeled mixed-bed submerged aquatic vegetation (SAV) community's short shoots (SS) after perturbation by hypersalinity.

Mesocosm Studies of Florida Bay SAV Responses to Environmental Parameters. This ongoing project generates data on the physiological tolerances and responses of three species of SAV — *Thalassia testudinum*, *Halodule wrightii,* and *Ruppia maritima* — to environmental variability in Florida Bay. The information generated here (through the District's collaborative experiments with Dr. Marguerite Koch of Florida Atlantic University) is being directly used in the Florida Bay Seagrass Model (above) and in assessing performance targets and recommendations for MFLs, CSOP, and other CERP related projects. Primary stressor variables being examined are salinity changes (as when freshwater is released from upstream sources), hydrogen sulfide (a natural decomposition product potentially toxic to plants), low oxygen, and temperature. The primary response variables being measured are primary productivity, photosynthetic parameters, plant vigor, osmotic parameters, morphometrics, and meristics of the plants. The main goal is determining how the system may best be managed to optimize the seagrass resource and to prevent a reoccurrence of die-off. This information is being developed to create response algorithms in computer models used in the design of water management and restoration strategies.

The experiments are conducted in several large-scale mesocosms (500 liters). Measurements have been recorded of the three dominant Florida Bay seagrasses' physiological responses both to individual stressors and to the interactive effects of stressor combinations. The experiments simulate high temperatures and high salinities of drought conditions, prolonged hypoxia of calm conditions in enriched organic areas, and freshet events after normal and hypersaline conditions. Seed germination and seedling survival are to be examined under the same temperature and salinity treatments in summer 2006. It has been found that seagrasses are generally robust and able to survive adverse conditions for short periods but that combinations of stressors can cause degeneration of the community. Notably, while high salinity is well tolerated by these plants, the resulting energy cost and degradation of efficiency makes plants more susceptible to other stresses such as sulfide **(Figure 12-22)**.

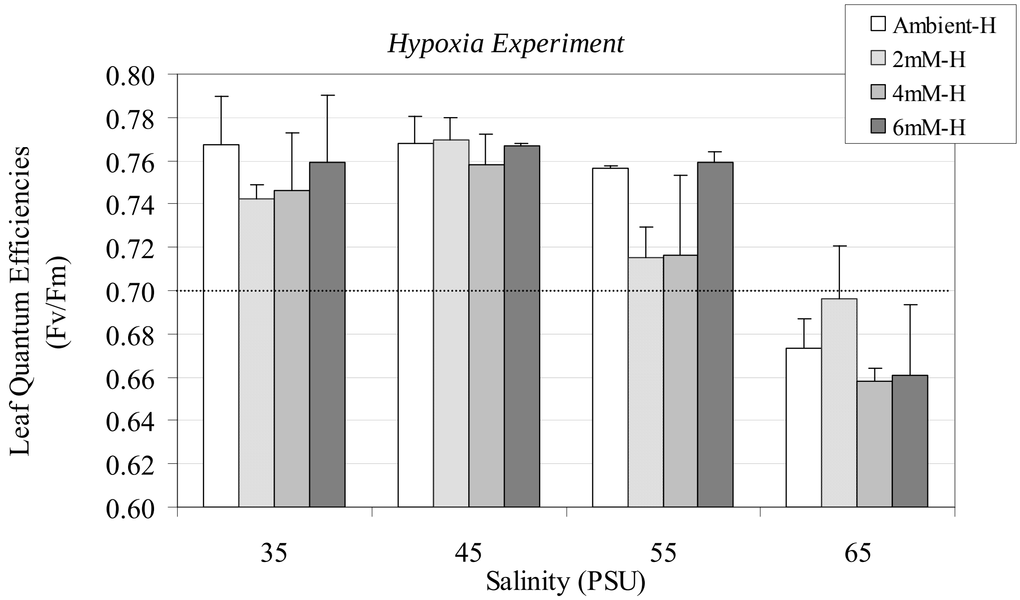

Figure 12-22. Leaf fluorescence (Fv/Fm) for *Thalassia testudinum* in response to salinity and sulfide treatments (n = 4 replicate cores with standard deviations) after a hypoxia treatment for nine days. Plants were measured for quantum yield (the measured fluorescence response divided by the maximum potential fluorescence response), which gives a measure of the photosynthetic efficiency of the plan. Yields below 80 percent are considered to indicate a stressed plant.

CALOOSAHATCHEE RIVER, ESTUARY AND SOUTHERN CHARLOTTE HARBOR REGION

INTRODUCTION

The Caloosahatchee Estuary and Southern Charlotte Harbor are located on the southwest coast of Florida (**Figure 12-23**). The major source of fresh water to the Caloosahatchee Estuary is the Caloosahatchee River, which runs 65 km from Lake Okeechobee, to the head of the estuary at the Franklin Lock and Dam (S-79). Geographically, the estuary extends about 42 km downstream to Shell Point, where it empties into San Carlos Bay at the lower end of Southern Charlotte Harbor (**Figure 12-24**).

Charlotte Harbor is Florida's second largest open-water estuary, and one of the state's major environmental features. The Charlotte Harbor Estuarine System includes Charlotte Harbor, Pine Island Sound, Matlacha Pass, San Carlos Bay, and the Caloosahatchee Estuary. It has a broad barrier island chain and a largely intact mangrove shoreline with significant parts in public ownership and management. Charlotte Harbor is the site of three National Wildlife Refuges and four aquatic preserves.

The Charlotte Harbor estuarine system is dominated by the rivers that flow into the coastal areas. Unlike other estuaries in southwest Florida that are primarily influenced by the Gulf of Mexico, these rivers create Charlotte Harbor's special characteristics. Large fluctuations in river flows between the wet and dry seasons affect its salinity and other water characteristics. This also is true for the Caloosahatchee in Southern Charlotte Harbor. Only this southern portion of the Charlotte Harbor system lies within the District's boundaries, which includes the Caloosahatchee Estuary, San Carlos Bay, and almost all of Pine Island Sound and Matlacha Pass.

Major environmental concerns for the Caloosahatchee Estuary that can extend into Southern Charlotte Harbor are altered freshwater inflows, nutrient enrichment, and habitat loss. For a more complete summary of background information regarding problems and related historical research, please see the *Caloosahatchee River and Estuary* and the *Southern Charlotte Harbor* sections in the 2004 and 2005 SFERs – Volume I, Chapter 12.

The following sections describe the environmental and biological criteria that are used to assess the health and condition of the Caloosahatchee Estuary. The performance of the system during WY2006 is evaluated using these criteria. Descriptions of restoration projects and significant findings of resource assessment projects conducted over WY2006 also are provided.

HURRICANE IMPACTS

In WY2006, three hurricanes impacted the estuary either directly or indirectly. Hurricanes Katrina and Rita passed to the west in the Gulf of Mexico and the tidal surge associated with both caused spikes in water levels and salinity (**Figure 12-25**). During the fourth week in October, Hurricane Wilma made landfall south of the region near Naples, which caused similar water level spikes and brought considerable rainfall to the District, necessitating releases of water from Lake Okeechobee that extended to January 2006 (**Figure 12-26**). These releases drove down salinity at Shell Point (**Figure 12-24** Marker H sensor) and San Carlos Bay. Salinity in the estuary upstream of Shell Point at Cape Coral was near zero ppt (freshwater) for nearly two months.

Figure 12-23. The Caloosahatchee River and Estuary and Southern Charlotte Harbor watershed area.

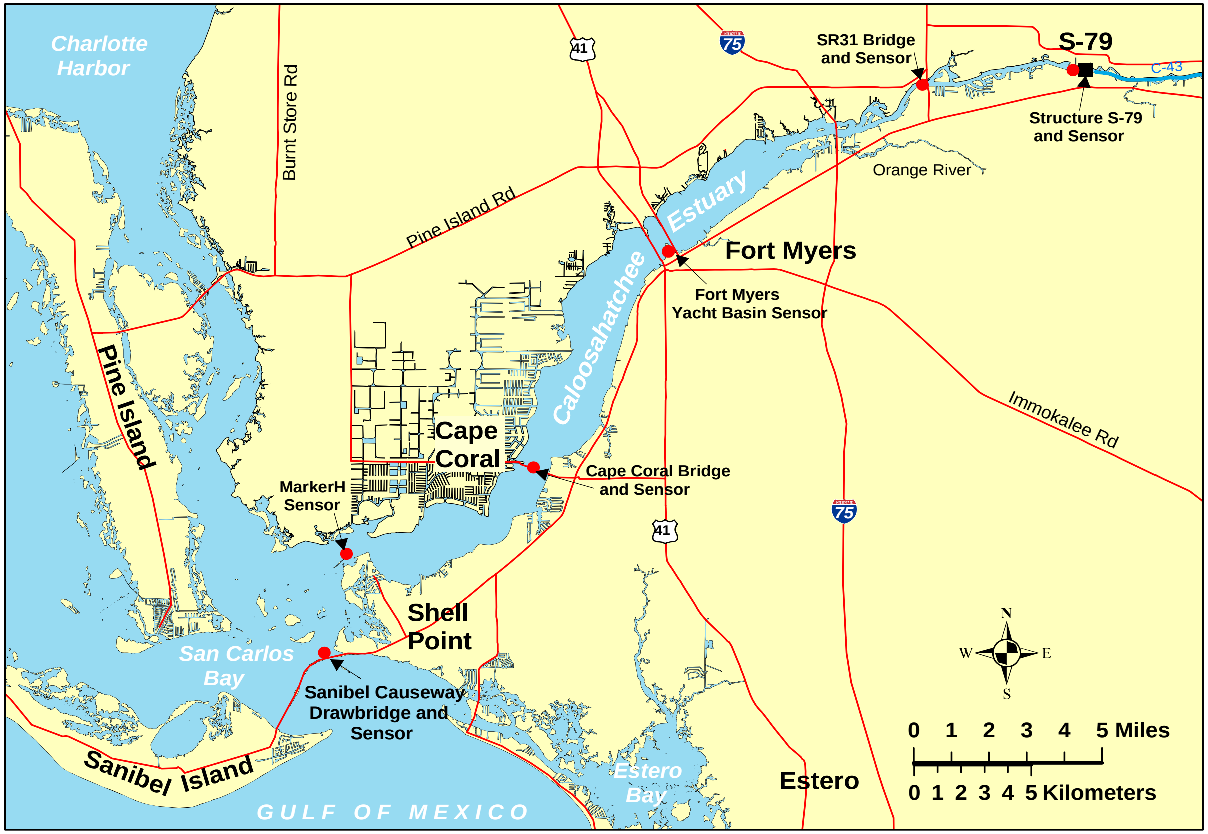

Figure 12-24. Caloosahatchee Estuary salinity sensors and landmarks.

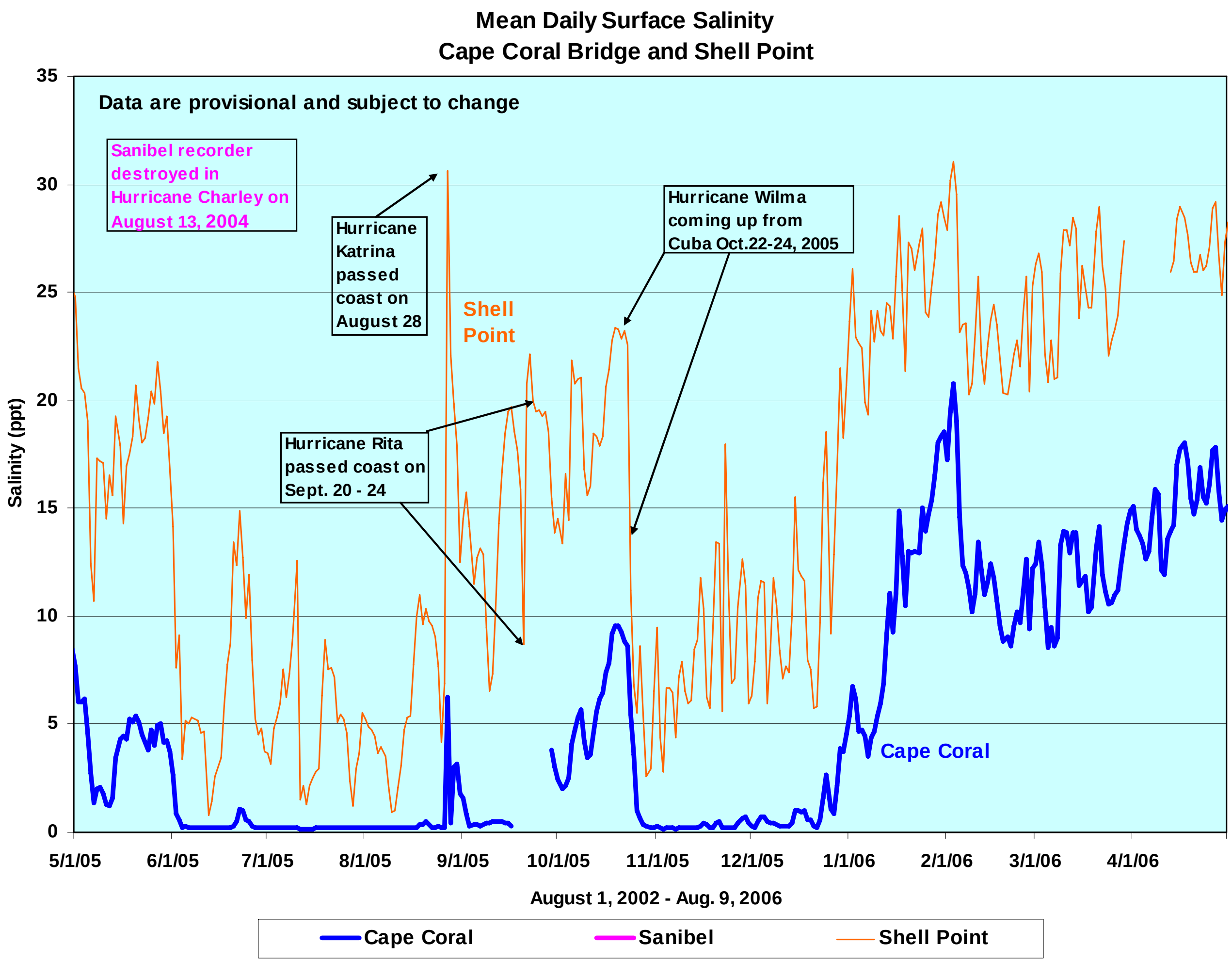

Figure 12-25. Daily average salinity collected by continuous sensors at two downstream locations (Cape Coral Bridge and Shell Point at the river mouth) in the Caloosahatchee Estuary. The timing and influence of three hurricanes is depicted.

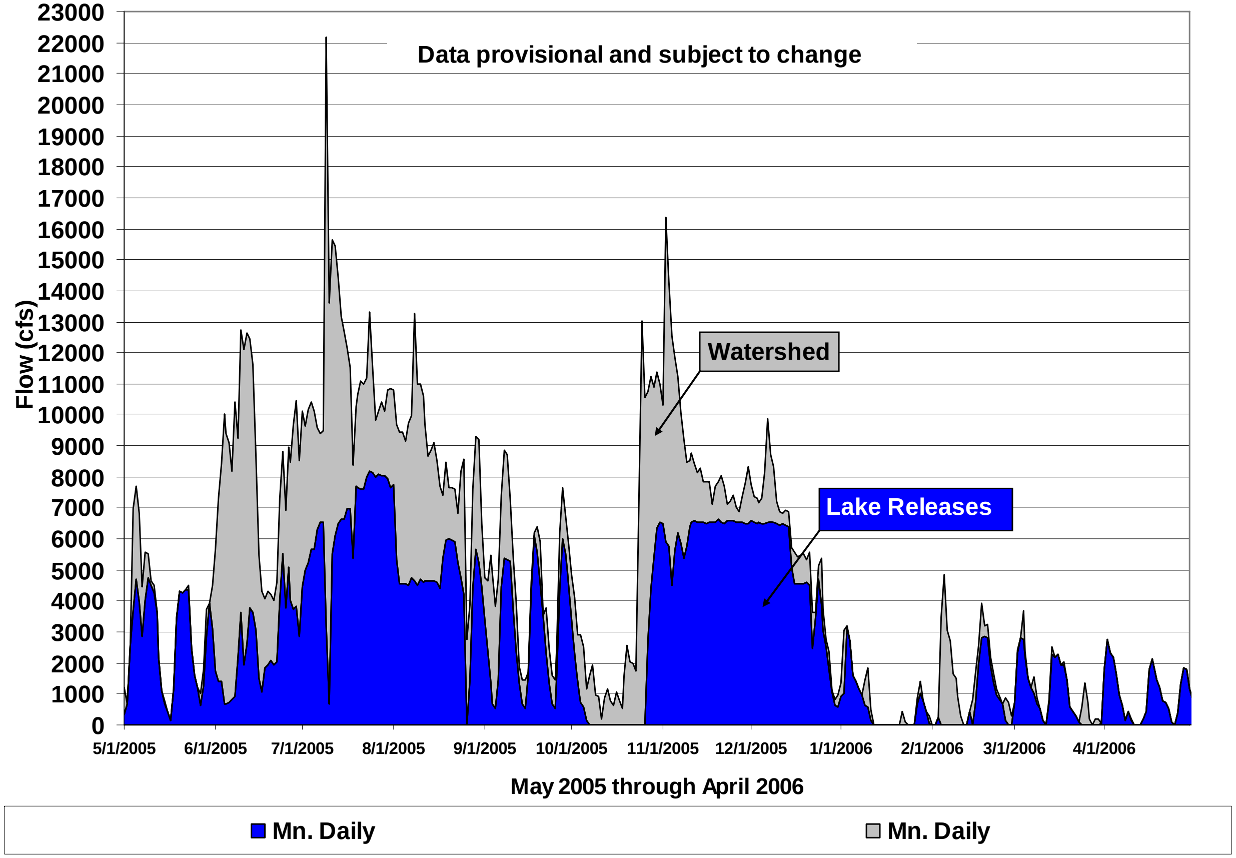

Figure 12-26. Total discharge rate into the Caloosahatchee Estuary (watershed releases) at S-79. The portion of the discharge rate accounted for by Lake Okeechobee releases is shown in blue and the portion from C-43 basin is shown in gray.

ENVIRONMENTAL CONDITION OF THE CALOOSAHATCHEE ESTUARY

Freshwater Inflow at S-79

There were releases from Lake Okeechobee every month of WY2006, in part due to the high Lake level resulting from WY2005 Hurricanes Frances and Jeanne. Level II and III pulses were still being made to the Caloosahatchee through S-79 during the 1.5 months at the beginning of WY2006 (**Figure 12-26**). Notably, a very wet June 2005 throughout the upper District caused a dramatic increase in basin discharges, coupled with regulatory releases from the Lake through mid-August. These discharges were followed by four Level III pulses, lasting into October. As a result, salinity remained very low (zero ppt at Cape Coral Bridge) for four months of WY2006 (**Figure 12-25**). Salinities began to recover during mid-October until Hurricane Wilma struck. During January and the remainder of WY2006, salinities again began to recover as S-79 discharges declined, with only Level I pulse releases being made at the end of WY2006.

The long-term average discharge at S-79 is approximately 1.2 million acre-feet per year (ac-ft/yr). In WY2006, discharge at S-79 was 3.6 million ac-ft, with 2.2 million (60 percent) coming from Lake Okeechobee. Most of the total annual discharge (3.3 million ac-ft = 92.7 percent) entered the estuary through S-79 in the first eight months of WY2006. This marked the second consecutive year that annual discharge to the estuary was well above normal — and surpassed the WY2005 level of 2.0 million ac-ft.

Through research and modeling, the District identified an average monthly flow rate distribution between 450 and 2,800 cfs to protect and promote desirable estuarine biota and resources. This distribution has been adopted as a performance measure target for discharge at S-79 by CERP and SWFFS. In an ordinary year, flow rates less than 450 cfs occur during 4.2 months and are greater than 2,800 cfs for 2.6 months. In WY2006, mean monthly flow rates exceeded only the upper limit, doing so from May through December of 2005. Flows exceeded 4,500 cfs during six of those eight months, which can significantly impact San Carlos Bay seagrass. Half (four) of the exceedances were attributed to average monthly flow rates greater than 8,000 cfs, which can extend freshwater influence well into lower Pine Island Sound.

Salinity at Fort Myers

An MFL for the Caloosahatchee Estuary was established in 2000 (see http://www.sfwmd.gov/org/wsd/mfl/index.html). Surface salinity recorded at the Ft. Myers sensor (**Figure 12-24**) did not exceed either of the two MFL criteria The level set for the moving 30-day average salinity is < 10 ppt at Ft. Myers Yacht Basin and the level set for the daily average is < 20 ppt; the maximum and 30-day and daily averages observed in WY2006 were 6.0 ppt and 11.25 ppt, respectively. The period of record for salinity at Fort Myers extends back to 1991. WY1995, WY2004, and WY2006, are the only 3 of the 15 years on record in which neither criterion was exceeded.

Biotic Resource Monitoring and Assessment

Several prominent species have been identified for long-term monitoring and environmental assessment because they constitute important habitat in the Caloosahatchee, San Carlos Bay, Matlacha Pass, and Pine Island Sound. In addition to tape grass (*Vallisneria americana*), which serves as an indicator of estuarine health in the upper estuary (**Figure 12-27**), these are oysters and marine seagrasses, representing the more seaward portions of the system. See the 2004 and 2005 SFERs –Volume I, Chapter 12 for a background and discussion of monitoring.

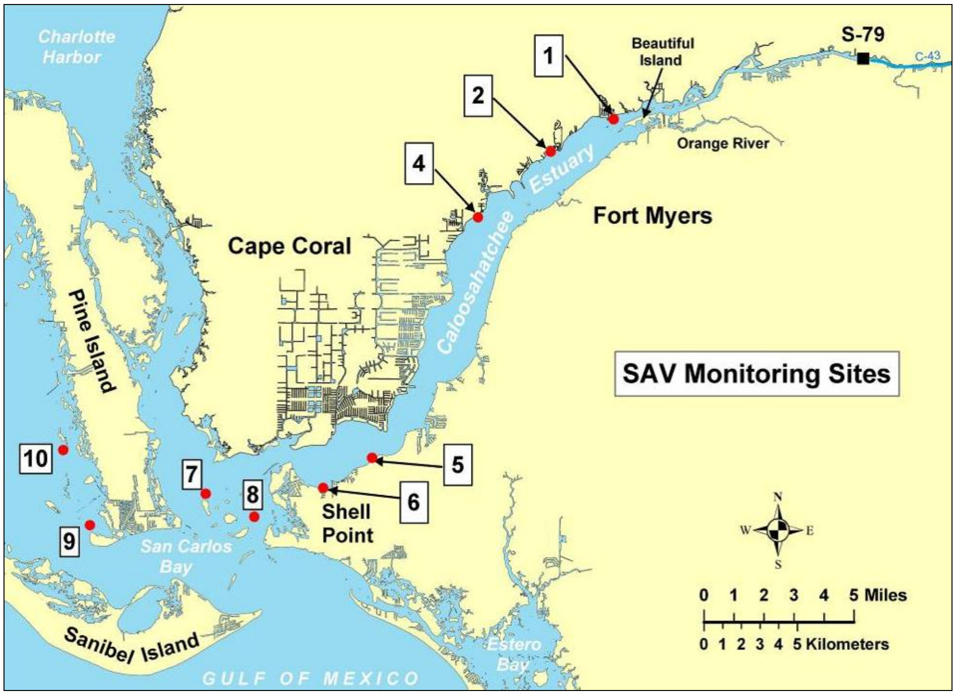

Figure 12-27. Caloosahatchee Estuary SAV monitoring stations and oyster locations. Tape grass (*Vallisneria americana)* is found at stations 1–4, shoal grass (*Halodule wrightii*) at stations 5–10, and turtle grass (*Thalassia testudinum*) at stations 8–10. The area between stations 6 and 7 has the core oyster population, though oysters are located throughout the region downstream of Station 5.

TAPE GRASS IN THE UPPER CALOOSAHATCHEE

Tape grass beds in the upper Caloosahatchee Estuary, which virtually vanished due to high salinity during the 2001 drought, have been in recovery since then (**Figure 12-28**). During WY2004, the beds began to recover in the spring-summer growing season, coinciding with favorable salinity conditions. Similar seasonal growth patterns were evident in the spring-summer growing season of 2005 (WY2006). An increase in plant density has been observed since the growing season of 2003. Before the 2001 drought, plant density was greater at Station 2 than at Station 1. WY2006 marks the first time that this pattern has been observed since 2001. During the high freshwater inflows in June, plant density decreased upstream at Station 1, possibly due to the associated drop in water clarity. Further, more plants persisted at Station 2 during the WY2006 dry season (November–March) than in other years since 2001.

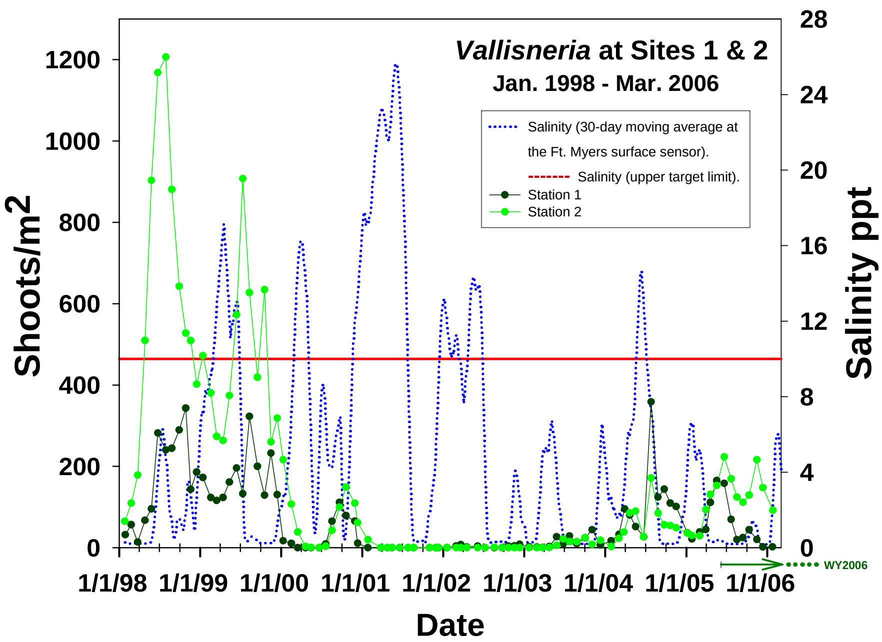

Figure 12-28. Tape grass shoot density in the upper Caloosahatchee Estuary (January 1998–2006). Recent data are from stations monitored by the Sanibel-Captiva Conservation Foundation and Mote Marine Laboratory.

MARINE SEAGRASS

Aerial surveys of seagrass were conducted in 1999, 2002–2003, and 2004. No aerial surveys were conducted during 2005 or 2006. Processing of the 2004 survey was completed during WY2006 (**Figure 12-29**). The results of this survey indicate that there are approximately 38,494 acres in the combined Lower Caloosahatchee, Matlacha, San Carlos Bay, and Pine Island Sound regions. This compares well with the 1999 survey (38,195 acres) but is lower that the 2002–2003 survey (43,486 acres).

Manual (in-water) seagrass monitoring by the Sanibel-Captiva Conservation Foundation Marine Laboratory indicates WY2006 was a very poor year for seagrass at all stations sampled, both upstream of Shell Point and in San Carlos Bay (**Figure 12-330**). This follows a poor WY2005 for *Halodule* upstream of Shell Point when shoot density remained below 200 m^{-2}. During WY2006, *Halodule* remained low upstream, while *Halodule* and especially *Thalassia* fell to a new seasonal low in San Carlos Bay following the large discharges that began in June 2005. These low densities persisted into the winter dry season and recent field trips indicate that *Thalassia's* percent of seagrass species composition has significantly declined.

Hydroacoustic sampling of SAV during the growing season was conducted for the tenth year. Except for Site 4, sampling locations include all sites depicted in **Figure 12-27**.

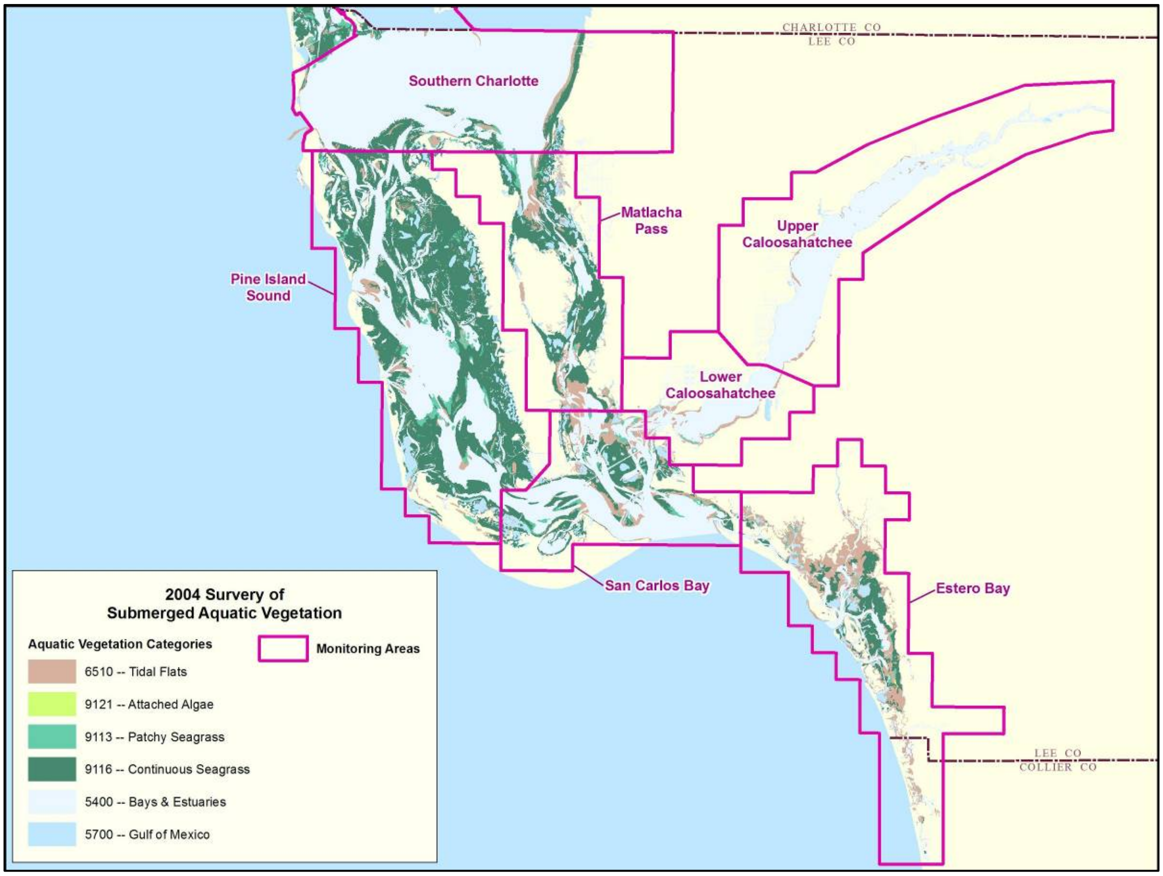

Figure 12-29. Results of seagrass aerial survey conducted in 2004 and processed in WY2006.

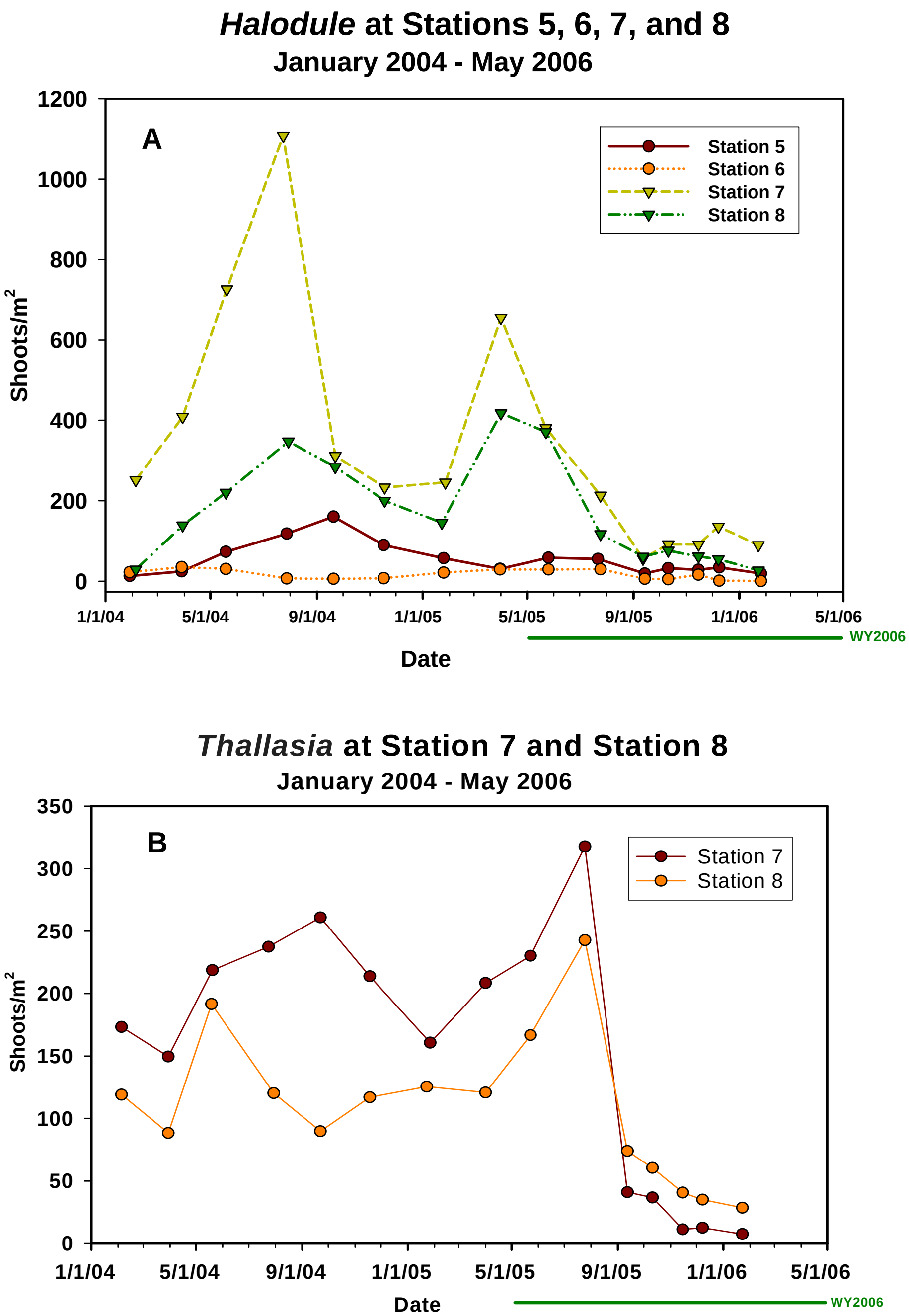

Figure 12-30. Density of seagrass: (A) *Halodule wrightii* and (B) *Thalassia testudinum* in the Caloosahatchee Estuary and San Carlos Bay. Data collected by the Sanibel-Captiva Conservation Foundation.

OYSTERS

Monitoring of oyster health and recruitment began in 2000. Results indicate that oysters in the Caloosahatchee Estuary spawn continuously from April–October, a period that coincides with freshwater releases into the estuary. High freshwater flows flush out oyster larvae and spat from upstream areas with suitable cultch and/or reduce salinities to levels that are unfavorable for spat settlement and survival. Recruitment during WY2005 was among the lowest observed (Volety, personal communication, 2005), which included the 2005 spring start-up (end of WY2005). The high flows of WY2006, which drastically increased during June, resulted in another poor year for oyster survival and recruitment, especially upstream of Shell Point.

Science, Engineering and Restoration Activities

Resource Assessment and Restoration Activities

The District continued to make improvements to the Caloosahatchee Hydrodynamic/Salinity Model during WY2006. An Estero Bay domain was added to support the South West Florida Feasibility Study (http://www.evergladesplan.org). The District employed this model to predict salinity distribution in Caloosahatchee River and Estuary for Acceler8, C-43 (Caloosahatchee River) West Reservoir project.

The District initiated a two-year project to examine nutrient limitation of phytoplankton growth in the Caloosahatchee Estuary. The purpose of the project is to experimentally determine the nutrient (nitrogen or phosphorus) that can become limiting, the concentration at which either nutrient becomes limiting and the ability of organic nitrogen to support phytoplankton production.

The District also funded an oyster reef restoration effort. Eighty-seven volunteers from Florida Gulf Coast University, concerned citizens, SFWMD, and other state, federal, and local agencies placed 200 shell-bags at two locations upstream of Shell Point (Iona Cove and Piney Point) during October and November of WY2006 to provide recruitment substrate for oyster reef development.

The 2004 and 2005 SFERs (Volume I, Chapter 12) provide a historical perspective on resource assessment and restoration activities.

Stormwater Improvement Projects

The following stormwater improvement projects were initiated in WY2006. For continuing projects, see the 2006 SFER.

SOUTHERN CHARLOTTE HARBOR

Project Title	Partner	Description
Sanibel Island Wetland Restoration	City of Sanibel, Lee County, and Sanibel-Captiva Conservation Foundation	Restore wetlands by removing exotic species, removing fill roads, building a weir to re-hydrate wetlands, and replanting native species.
Bowman Beach Park Restoration	City of Sanibel, U.S. Fish and Wildlife Service, and Sanibel-Captiva Conservation Foundation	Restoration of saltwater marshes, tropical hardwoods, dune, and mangrove habitats.

Project Title	Partner	Description
Florida Yards and Neighborhoods Program	City of Cape Coral, Lee County	Pursue greater implementation of the Florida Yards and Neighborhoods Program in the most populous city of southwest Florida, Cape Coral.
Historic Coastal Habitat Map	Charlotte Harbor National Estuary Program, and SFWMD	Prepare a historical habitat map for Charlotte Harbor.

CALOOSAHATCHEE

Project Title	Partner	Description
Fort Myers Stormwater Master Plan	City of Fort Myers	Develop citywide stormwater master plan including prioritization of needed stormwater management system improvements.
Billy Creek Restoration	City of Fort Myers	Restore sections of Billy Creek and provide additional water quality treatment capabilities. Also evaluating water quality improvements for Manual's Branch, Carrell Canal, and Winkler Canal.
Cape Coral Stormwater Improvement	City of Cape Coral	Replace catch basins to include sediment sumps and raise control elevations of the associated swales to improve water quality.
Hendry County Tributary Restoration and Agricultural Best Management Practices (BMPs)	Hendry County Soil and Water Conservation District	Restore Caloosahatchee tributaries and add water quality elements. Implement on farm structural BMPs that will provide water quality benefits.
Glades County Tributary Restoration and Agricultural BMPs	Glades County Soil and Water Conservation District	Restore Caloosahatchee tributaries and add water quality elements. Implement on farm structural BMPs that will provide water quality benefits.
Caloosahatchee River Water Balance and Nutrient Loading Analysis	SFWMD	Assess impact of land use practices on water quality in the C-43 Basin.
ECWCD Water Quality Projects	East County Water Control District	Surface water infrastructure modifications and stormwater retrofits to existing systems to improve water storage capabilities, mitigate flooding, and improve water quality.

NAPLES BAY

INTRODUCTION

Naples Bay is a relatively narrow and shallow estuarine water body ranging in width from 100 to 1,500 feet and in depth from 1 to 23 feet. The watershed is located in western Collier County, Florida (**Figure 12-31**).

The Bay and its major freshwater inputs, Golden Gate Canal, Rock Creek, Haldeman Creek, and the Gordon River, are urbanized and highly altered. The Bay experiences large fluctuations in salinity and water quality associated with rapid storm water runoff.

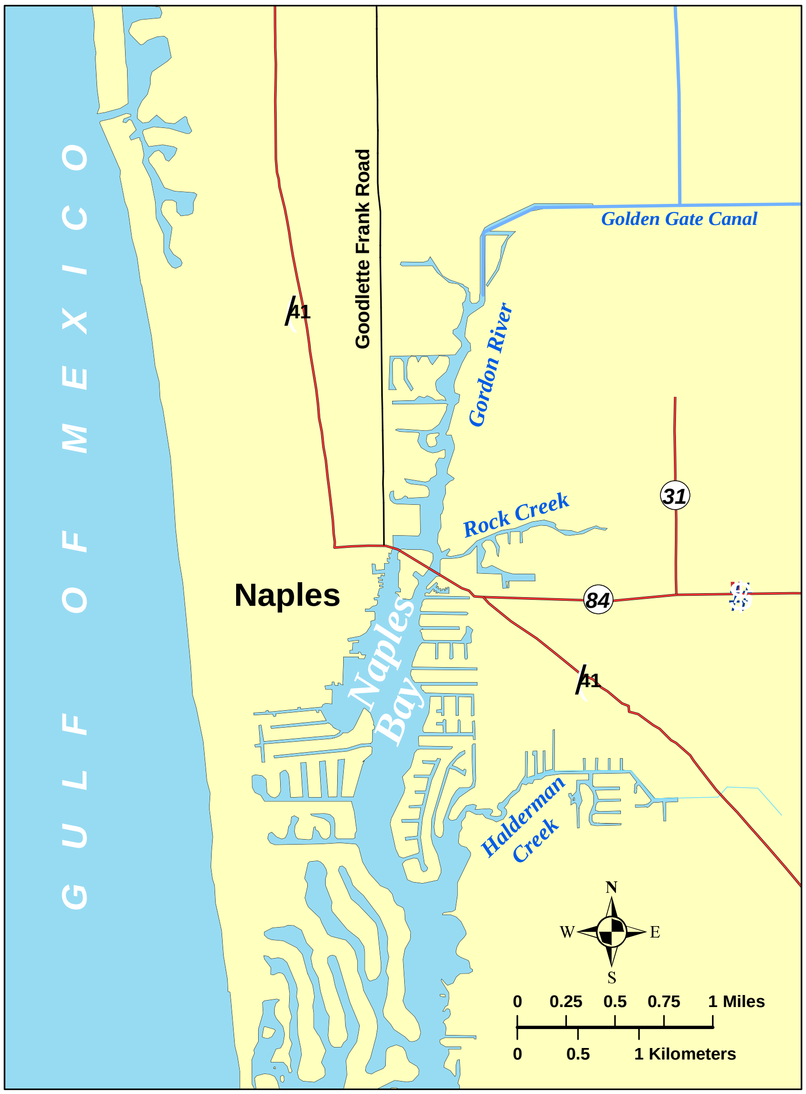

Figure 12-31. Area of Naples Bay.

The discussion below focuses on resource assessment, restoration, and engineering activities conducted in Naples Bay during WY2006.

ENVIRONMENTAL ASSESSMENT CRITERIA

VECs have not been identified for Naples Bay. No hydrologic performance measures have been established for the major freshwater tributaries.

SCIENCE, ENGINEERING AND RESTORATION ACTIVITIES

RESOURCE ASSESSMENT AND RESTORATION

The following resource assessment project was initiated in WY2006. For continuing projects, see the 2006 SFER.

Project Title	Partner	Description
Surface Water Improvement and Management (SWIM) Plan Development	FDEP	Develop the SWIM Plan for Naples Bay.
Naples Bay Water Balance and Nutrient Loading Analysis	U.S. Army Corps of Engineers	Create a spreadsheet model for assessing the relative effectiveness of proposed water quality improvements in the Naples Bay watershed.

STORMWATER IMPROVEMENT PROJECTS

The following restoration and engineering projects were initiated or continued through WY2006.

Project Title	Partner	Description
Lely Area Stormwater Improvement Project	Collier County	Construct Lely Canal flood mitigation and water quality improvement project.
City of Naples Water Quality and Flood Mitigation Projects (Basin III, Basin V, and Royal Harbor)	City of Naples	Design and construct stormwater management system improvements within the City of Naples Basin III, Basin V, and Royal Harbor subdivision.

ESTERO BAY

INTRODUCTION

Estero Bay is a long, narrow, and very shallow lagunal estuarine system. The watershed of the Bay includes central and southern Lee County and parts of northern Collier and western Hendry counties. Estero Bay is Florida's first Aquatic Preserve, designated by the state in 1966.

The Bay (or lagoon) is oriented along a north-south axis with freshwater tributaries distributed along the eastern shore and passes to the Gulf of Mexico along the western shore. From north to south, the barrier islands separating the Bay from the Gulf are Estero Island, Black Island, Long Key, Lover's Key, and Big Hickory Island (**Figure 12-32**).

Figure 12-32. Area of Estero Bay.

The principal freshwater inflows come from Hendry Creek, Mullock Creek, Estero River, Spring Creek, and the Imperial River. Because the tributaries are estuarine in character, salinity gradients in the Bay and those in the tributaries can form a complex temporal and spatial mosaic.

ENVIRONMENTAL ASSESSMENT CRITERIA

Freshwater Inflow

As part of the CERP Southwest Florida Feasibility Study (http://www.evergladesplan.org), acceptable flow ranges are used to evaluate flows for three of the major tributaries to Estero Bay: Ten Mile Canal, the Estero River (South Branch), and the Imperial River. The flow ranges are based on the salinity tolerances of the American oyster (*Crassostrea virginica*) and are used to define flow envelopes that maintain appropriate salinity at creek mouths where oysters are located. The minimum flow results in salinity levels (15–25 ppt) that are optimal for adults. Flows greater than the maximum result in salinities below 5 ppt, which are lethal to juvenile oysters (**Table 12-7**).

Table 12-7. Minimum and maximum flows recommended to maintain salinities between 15 and 25 ppt.

Tributary Control Station	Monitoring Station	Minimum Flow for Salinities of 15–25 ppt	Maximum Flow for Salinities >5 ppt
Ten Mile Canal	Mullock Creek Downstream monitoring station	4–50 cfs	215 cfs
South Branch Estero River	Estero River mouth monitoring station	3–9 cfs	31 cfs
Imperial River	Imperial River mouth monitoring station	8–26 cfs	94 cfs

Valued Ecosystem Components

Both oysters and seagrass are present in Estero Bay, are being monitored, and have been selected as VECs for managing inflows into the bay.

ENVIRONMENTAL CONDITION OF ESTERO BAY

Freshwater Inflow

Freshwater inflows to the three major tributaries were examined regarding their current and historical deviation from the recommended flows (**Table 12-8**).

Seagrasses

Seagrass maps were created in WY2006 using aerial surveys from WY2004. Based on the mapping process, there were 3,431.5 acres of seagrass Estero Bay in WY2004.

Oysters

Information on the aerial extent of oyster reefs in Estero Bay is summarized in the 2004 SFER – Volume I, Chapter 12.

Table 12-8. Hydrologic and salinity ranges for tributary inflow into Estero Bay.*

Tributary Control Station	Historical (Days) 1988–2005	Days in 2006
Imperial River		
4-26 cfs	166.2 ± 15.7	114
>94 cfs	111.7 ± 13.5	194
South Estero		
3-9 cfs	70.4 ± 9.2	55
>32 cfs	40.2 ±6.2	105
Ten Mile Canal		
4-50 cfs	144.9 ± 10.1	166
>215 cfs	35.5 ± 6.5	61

* The number of days in WY2006 when flow was within the minimum flow range is compared to the historical mean ± 95% Confidence Interval (C.I.). The number of days in WY2006 when flow exceeded the recommended maximum is compared to the historical mean ± 95% C.I.

CURRENT SCIENCE, ENGINEERING AND RESTORATION ACTIVITIES

Resource Assessment

The following resource assessment projects were initiated in WY2006. For continuing projects, see the 2006 SFER – Volume I, Chapter 12.

Project Title	Partner	Description
SAV Monitoring Using Hydroacoustic Methodologies	SFWMD	Establish monitoring program. See 2006 SFER – Volume I, Chapter 12 for description of methods.
SAV Mapping Using Aerial Photography	Avineon	Produce maps from 2004 photos.
Shoreline Vegetation Survey	Florida Gulf Coast University	Locate and monitor transition from freshwater to salt tolerant vegetation in major tributaries.
Hydrodynamic Modeling of Estero Bay	University of Florida	Expand existing CH3D hydrodynamic model of Charlotte Harbor to include Estero Bay.

ENGINEERING ACTIVITIES

Stormwater Improvement Projects

The following stormwater improvement projects were initiated in WY2006. For continuing projects, see the 2006 SFER.

Project Title	Partner	Description
Estero Bay Watershed Nutrient Assessment	SFWMD	Creation of a spreadsheet based model for assessing the relative effectiveness of proposed water quality improvements in the Estero Bay watershed.
Imperial Estates Stormwater Retrofit—Phase 3	City of Bonita Springs	Construct stormwater retrofit to reduce flooding and improve water quality before discharge to the Imperial River.
Nevada Street Stormwater Retrofit	City of Bonita Springs	Construct stormwater retrofits to provide water quality treatment prior to discharge to Oak Creek.
Riverside Depot Park Water Quality Improvement	City of Bonita Springs	Construct a stormwater management system to increase storage and improve water quality before discharge in the Imperial River.
Corkscrew Evapotranspiration (ET) Data Analysis	Florida International University	Analyze Corkscrew ET data to provide better estimates of ET in hydrologic modeling.
Six Mile Cypress Hydrologic Restoration	Lee County/SFWMD	Environmental and hydrologic restoration as identified in the Land Stewardship Plan and hydrological report.
Pine Lake Preserve Restoration	Lee County	Environmental restoration, exotic removal at Pine Lake Preserve.

RESTORATION ACTIVITIES

Restoration of Shellfish in Estero Bay

In an ongoing project, Florida Gulf Coast University, through funding from the District, Fish America Foundation, National Fish and Wildlife Foundation, National Ocean and Atmospheric Administration, constructed two oyster reefs (10 m^2 each) in northern Estero Bay in WY2006. Reefs are constructed using recycled oyster shell and stabilizing mesh in order to establish suitable substrate for oyster recruitment. This community-based restoration involved other agencies, the general public, as well as high school and undergraduate students. Since 2003, seven reefs have been constructed within the Bay and tributaries. An ongoing monitoring program is in place to determine restoration success.

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