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 (District or SFWMD). In addition to this year's consolidated reporting efforts, this chapter's coverage of coastal ecosystems supports the overall objective of the *2005 South Florida Environmental Report* to provide a more comprehensive view of the South Florida environment within the District's boundaries. The information covered in this chapter focuses on Water Year 2004 (WY2004) (May 1, 2003 through April 30, 2004), but also includes historical trends for some ecosystems.

Overall, one of the District's primary goals is to manage freshwater discharge to South Florida's estuaries in a way that preserves, protects and, where possible, restores essential estuarine resources. The District seeks to ensure that estuaries receive not only the right amount of water at the right time, but also clean high quality water. Presently, the District and the scientific community are conducting interdisciplinary research to produce a broad range of data, information, and tools that will assist in achieving this goal.

Coastal ecosystem science and engineering projects undertaken by the District 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. These have been chosen as key variables for several reasons: (1) both are stationary features with some historical data available, (2) they represent consistent features of the estuarine landscapes in South Florida, and (3) much of the subtidal structure in South Florida's estuaries is biological (e.g., coral reefs, seagrass beds, oyster beds). The information developed through these investigations allows the District to work closely with scientists from other agencies, such as fisheries and wildlife experts, to better understand the links between water management impacts on estuarine habitats and utilization by higher trophic levels.

In a continuing effort to support the Comprehensive Everglades Restoration Plan (CERP) activities, as well as other critical needs, the District has organized resources and developed a focal point for coastal science. Within the Coastal Watersheds Program (http://www.sfwmd.gov/images/pdfs/stratplan_final51304_40.pdf), 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 which will 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. These factors are being examined 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.

South Florida's coastal ecosystems are comprised of several major ecosystems within the District. Each ecosystem, informally named by the coastal water body in which it resides, possesses unique hydrologic, biologic, and anthropogenic features. These ecosystems are the Southern Indian River Lagoon, including St. Lucie River and Estuary; Loxahatchee River and Estuary; Lake Worth Lagoon; Biscayne Bay; Florida Bay and Florida Keys; Naples Bay; Estero Bay; Caloosahatchee River and Estuary; and Southern Charlotte Harbor (**Figure 12-1**). Presently, the District conducts scientific research and monitoring for the majority of these ecosystems, which have been identified as priority coastal water bodies. The District also 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 at varying levels of activity for each ecosystem due to the availability of resources and the need to address priorities reflected in the District's Strategic Plan.

Currently, there are many assumptions and uncertainties regarding the physical, chemical, and biological dynamics necessary for the long-term sustainability of coastal ecosystems. However, it is clear that South Florida's coastal ecosystems are impacted by three major issues: (1) disruption of the natural magnitude and timing of freshwater discharges, (2) increasing input of nutrients and other materials of concern, and (3) continued loss of critical ecosystem habitats and their biological communities. Together, the cumulative impact of these changes has resulted in altered ecosystem structure and impaired function.

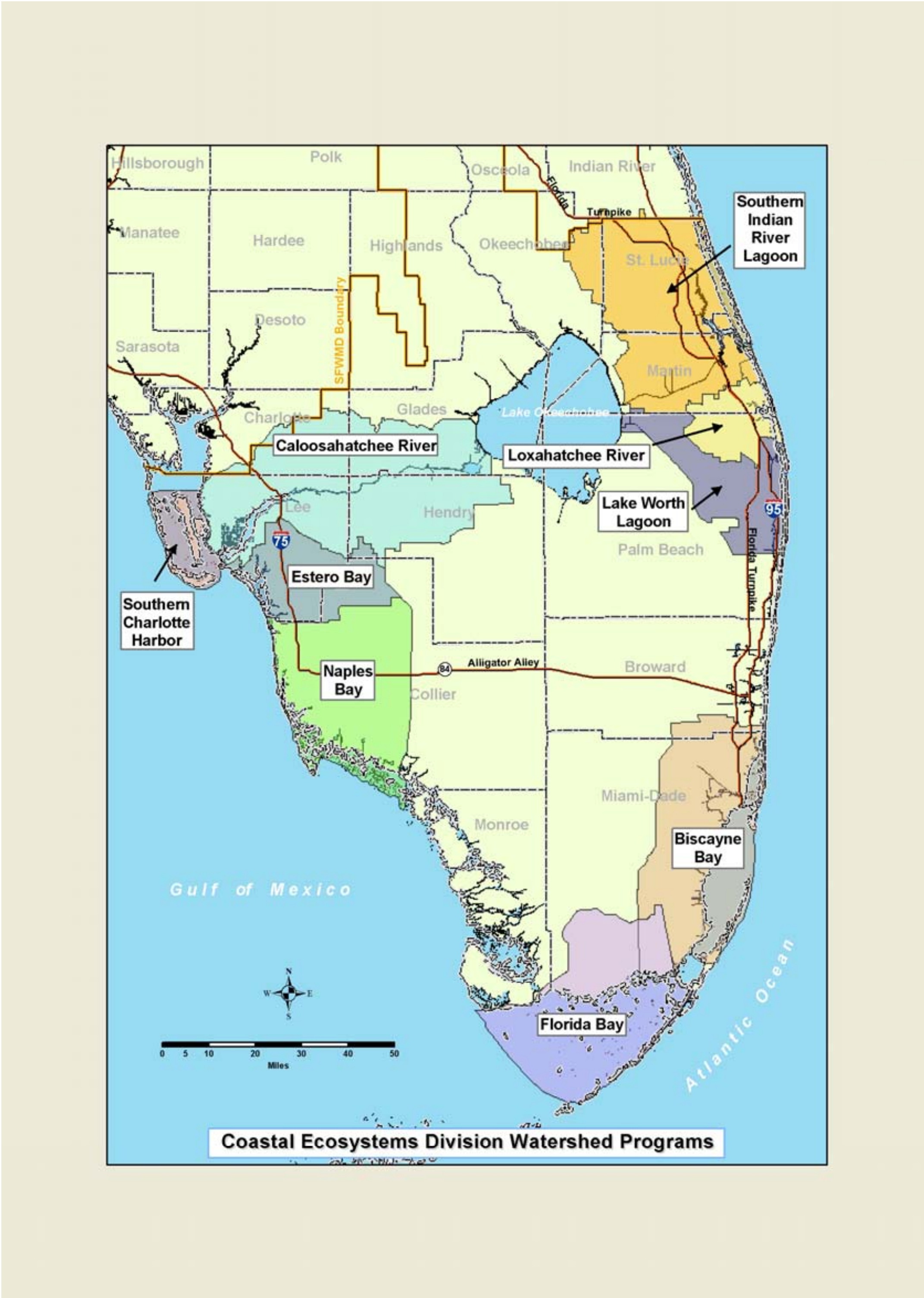


Figure 12-1. Geographic location of the coastal ecosystems in South Florida.

The key highlights related to the District's management and restoration efforts for each coastal ecosystem during WY2004 are summarized below. More detailed information is presented in the following sections of this chapter.

SOUTHERN INDIAN RIVER LAGOON AND ST. LUCIE RIVER AND ESTUARY

- The construction on the Ten Mile Creek Critical Project was initiated in October 2003. This project is the first regional stormwater reservoir and treatment cell in the upper east coast service area, and is part of the greater CERP.
- The Citrus Best Management Practice (BMP) Rule was adopted in June 2002 by the Florida Department of Agriculture and Consumer Services, and provides incentives for growers to voluntarily implement BMPs on Indian River groves. Through June 2003, over 82 percent of the citrus acreage in the Indian River Lagoon production area had provided notice of intent to comply.
- Funding was secured from the St. Lucie River Issues Team for implementing a modified water quality and quantity monitoring network on tributaries to the St. Lucie Estuary. This cooperative monitoring network will cover about 30 percent of the watershed that is not captured by District monitoring at major discharge structures in the watershed.
- The District is continuing to monitor seagrass health and distribution in the estuary. Seagrasses have been identified as Valued Ecosystem Components, whereby their state or condition is considered an indicator of the health of the lagoon system.
- Oyster survival studies were conducted in the St. Lucie Estuary. Similar to seagrasses, oysters are considered as indicators of lagoon health condition. Periodic monitoring provides a check on the state of achievement of lagoon restoration objectives.
- Development of water quality models for the watershed and estuary is near completion. These models will serve as essential tools for the District to establish Pollutant Loading Reduction Goals (PLRGs) and Total Maximum Daily Loads (TMDLs) for the South Indian River Lagoon and St. Lucie Estuary.
- The Indian River Lagoon License Plate Program continues to fund six "turn dirt" habitat restoration projects in the lagoon.

LOXAHATCHEE RIVER AND ESTUARY

- In 2004, the Restoration Plan for the Northwest Fork of the Loxahatchee River was initiated. This plan will provide an assessment of the ecological health of the Northwest Fork, establish current conditions, and identify restoration scenarios for this unique and important riverine system.
- Project Implementation Report for the North Palm Beach County CERP Project – Part 1 is in development. This project is expected to increase water supplies to the Grassy Waters Preserve and Loxahatchee slough; provide flows to enhance hydroperiods in the Loxahatchee slough; increase base flows to the Northwest

Fork of the Loxahatchee River; and reduce high discharges to the Lake Worth Lagoon and Loxahatchee River.

- Development of an Initial Water Reservation for the Northwest Fork has been initiated. This work has been incorporated into the MFL Rule for the protection of the remaining floodplain swamp community and downstream estuarine resources against significant harm
- Data collection in the riverine/freshwater segment of the Northwest Fork of the Loxahatchee River in continuing to establish vegetation and dry season inundation relationships.
- Seagrass and oyster bed data collection in the tidal segment of the Northwest Fork and River Embayment areas of the Loxahatchee River is ongoing.
- The collection of salinity and flow data in the Northwest Fork of the Loxahatchee River is continuing to monitor the extent or abatement of saltwater intrusion in the freshwater segment of the River.
- Construction of projects to increase dry season flows to the Northwest Fork is continuing.
- Support of state appropriations for the Loxahatchee River Preservation Initiative sponsored projects is ongoing.
- The District is currently working with the Florida Department of Environmental Protection (FDEP) and the University of South Florida to develop a surface water/groundwater model for the Northwest Fork (Loxahatchee River Integrated Surface/Groundwater Model). Expanding on an existing model, this new model is expected to predict salinity levels in the river and floodplain, as well as helping to determine the floodplain hydroperiod.

LAKE WORTH LAGOON

- The Lake Worth Lagoon was recently included in the Restoration Coordination and Verification (RECOVER) Monitoring and Assessment Plan as part of CERP's overall objective to define monitoring and assessment performance measures and to identify long-term goals for ecosystem restoration.
- Development of the Project Implementation Report for the North Palm Beach County CERP Project – Part 1. The primary goal of this project is to evaluate flow redirection, additional stormwater retention, and sediment control technologies for the C-51 basin.
- Canal backpumping and conveyance facilities at the C-51 canal were completed in 2004.
- Data collection and water quality monitoring activities in the Lake Worth Lagoon are ongoing by the District, FDEP, and Palm Beach County.
- The District is continuing participation in the Lake Worth Lagoon Partnership Grant Program.

BISCAYNE BAY

- The District is currently developing a water budget, a hydrodynamic model, and Minimum Flows and Levels (MFL) technical criteria for south-central Biscayne Bay.
- A total of 23 projects for the protection, restoration, and enhancement of Biscayne Bay are being implemented though funding by the state of Florida legislative special appropriations for the bay.
- Collaboration and coordination efforts are ongoing with local municipalities in the Biscayne Bay watershed to improve stormwater management systems through the development and implementation of stormwater master plans and stormwater system upgrades in an effort to improve water quality in and reduce stormwater runoff to the bay.
- During 1991–2003, total phosphorus (TP) concentrations have decreased in the canal that discharges to Biscayne Bay, although some of this trend may be explained by improved analytical methods.
- During 1991–2003, nitrogen concentrations, especially nitrate, have generally increased in the canal water that discharges to Biscayne Bay.
- Overall, downstream surface water quality data indicates that Snake Creek (C-9), Biscayne Canal (C-8), Snapper Creek (C-2), and Aerojet Canal (C-111) have the least contaminated major canals in Miami-Dade County.
- The annual "dry season" for south central Biscayne Bay, when both rainfall is low and salinity is elevated, typically occurs from December through May.

FLORIDA BAY AND FLORIDA KEYS

- During WY2004, Florida Bay hydrologic conditions were near long-term averages with regard to rainfall, freshwater flow into the bay, and salinity. From 1992–2002, water quality conditions in Florida Bay showed a decade-long period of improvement with decreasing concentrations of total nitrogen, total phosphorus, chlorophyll *a*, and decreasing turbidity, although this trend reversed in 2003. In 2004, each of these parameters had values well below the long-term average. A similar trend of decreasing nutrient concentrations in water flowing into the bay also has occurred since 1996. During this period, nutrient and chlorophyll concentrations generally have been highest in the central bay.
- Several models needed to provide technical criteria for Florida Bay MFLs are presently under development. These models will also help to support CERP's Florida Bay and Florida Keys Feasibility Study (FBFKFS), which is evaluating the role of water management as a driver of ecological change in the bay, and evaluating the restoration needs of the bay. The models include (1) a mass balance salinity model of the bay; (2) a dynamic model of the seagrass community; and (3) statistical models of shrimp, fish, and wading bird species.
- Studies of the fate and effect of Everglades dissolved organic nutrients in Florida Bay (as part of RECOVER) are assessing the relationship between changing flow and bay algal blooms. A water quality model (as part of the FBFKFS) will be used to evaluate this issue, but this model will require data on the fate and effects

of Everglades dissolved organic nutrients in the bay. Preliminary experiments indicate that about 15–30 percent of the dissolved organic matter flowing into bay is readily decomposed (at a rate of about 2 percent per day) and that rates are sensitive to phosphorus concentrations and sediment particles. Nutrients from the Everglades inputs may be most "available" at the sediment-water interface, and during sediment resuspension in central and western Florida Bay, where phosphorus levels are relatively high

NAPLES BAY

- Resource assessment and restoration activities for Naples Bay are currently in the planning stages and will begin next year.

ESTERO BAY

- Several new studies were instituted to support the development of the Estero Bay MFL.
- Oyster beds were mapped for the first time, and three new beds were constructed as part of a restoration effort in the bay.
- Collaboration with local communities on projects to improve stormwater management continued this year through development of management plans, system upgrades, and restoration of flow-ways.
- As part of the cooperative effort between the District and the U.S. Geological Survey (USGS), continuous salinity and other water quality information was collected at semi-permanent sensor stations, primarily to provide necessary information for supporting the development of MFLs and a hydrodynamic/salinity model.
- Through collaborative efforts between the District and other resource agencies, a preliminary estimate of desirable freshwater inflow volumes for selected tributaries was estimated as part of the Southwest Florida Feasibility Study's (SWFFS) goal to identify hydrologic targets. This effort is dependent upon data collected from the above-referenced USGS salinity sensors.

CALOOSAHATCHEE RIVER AND ESTUARY

- The MFL salinity criteria (monthly average salinity of > 10 parts per thousand (ppt), at Ft. Myers Yacht Basin; daily average of > 20 ppt for the Caloosahatchee River and Estuary) were achieved in WY2004. The resulting favorable salinities allowed continued recovery of valuable tape grass beds in the upper estuary.
- Water quality is becoming a concern in the Caloosahatchee River and Estuary. The District has been working on the development of a water quality target for chlorophyll *a* and on the initial phases of a water quality model.
- Similar to Estero Bay, the District is continuing to collaborate with local communities on projects to improve stormwater management through development of management plans, system upgrades, and restoration of flow-ways.

- Monitoring of submerged aquatic vegetation, oysters, water quality, and habitat utilization continues to be part of the research and protection efforts by the District in collaboration with other agencies.
- An important component of the above-noted collaboration efforts is the development of hydrologic targets to be used as part of the SWFFS and C-43 Basin Reservoir Storage (BRS) assessment requirements under CERP. Additional cooperative efforts have been focused on the development of regional and basin hydrology models and ecological models for estimating habitat units associated with various water resource management alternatives.

SOUTHERN CHARLOTTE HARBOR

- In early 2004, the District funded the expansion of the Florida Fish and Wildlife Conservation Commission's Fisheries Independent Monitoring Program to Southern Charlotte Harbor. This program will provide much needed information on economically important species.
- To date, restoration activities included removal of exotic vegetation from the Buffer Preserve, mangrove plantings on Sanibel Island, and the construction of five new oyster reefs.
- Due to the Caloosahatchee River and Estuary's connection to Southern Charlotte Harbor, much of the efforts regarding monitoring, identification of flow and water quality targets, and development of a hydrodynamic/salinity model have been extended to incorporate the harbor. This will help achieve the goals of the SWFFS, C-43 BRS Project, Charlotte Harbor National Estuarine Program, and Surface Water Improvement and Management Program.

INTRODUCTION

Maintaining the health and biodiversity of coastal ecosystems is essential to the sustainable development of both coastal and economic resources. Coastal ecosystems are complex, and the challenges and threats associated with these systems occur on many levels. There are continuing widespread concerns over several key issues related to coastal ecosystems including (1) the impact of continued habitat loss; (2) accelerating population growth; (3) management of water quantity and quality; (4) providing infrastructure critical to economic and ecosystem sustainability; (5) the impact of sea level rise; (6) the impact of exotic species; and (7) the cumulative impact of multiple watershed stressors.

The widespread challenge of effectively implementing management and restoration strategies for coastal ecosystems was addressed in the 2000 U.S. Commission of Ocean Policy's Preliminary Report, which is available online at http://www.oceancommission.gov/documents/prelimreport/chapter14.pdf. According to this report, "Coastal waters are subject to cumulative impacts from a variety of pollutants – from near and far, and from point, non-point, and airborne sources. For this reason, any solution must be founded on an ecosystem-based and watershed management approach involving a broad range of agencies, program, and individuals. Solutions will also require a substantial financial investment and will take time."

Today the majority of South Florida's coastal ecosystems have been substantially altered by drainage and development, resulting in hydrology changes, nutrient inputs, and the spread of exotics, caused directly or indirectly from a century of water management. Much of South Florida's shoreline and adjacent coastal ridges have been developed for urban use. The hammock and dune communities along the beaches are unique subtropical ecosystems that have very little protection, and are rapidly disappearing. The remaining natural areas are threatened by continuing development and rising sea levels. Problems are especially apparent in areas where fresh water historically flowed from rivers, streams, and wetlands into estuarine systems. Reduced freshwater flows have caused saltwater intrusion of some river systems, while coastal lagoons have experienced prolonged hypersaline conditions affecting water quality and estuarine biota. In addition to direct impacts from within their watersheds, South Florida coastal ecosystems can be impacted by hydrological and meteorological conditions that occur in other areas of the greater Everglades system, due to a network of water conveyance facilities. Additional details are presented in the Draft Consolidated Water Supply Plan Support Document, which can be found on the District's Website at http://www.sfwmd.gov/org/wsd/wsp/pdfs/cwssd_v2-1.pdf.

Examination of the resource and policy issues that impact coastal ecosystems in South Florida reveal many similarities with other coastal regions. For instance, coastal ecosystems are especially vulnerable because they attract intense human development, making these areas highly prone to habitat loss and alteration. In South Florida, the population growth statistics are quite dramatic. Based on 2000–2003 U.S. Census Bureau data, two of the top ten fastest growing cities in the country, Port St. Lucie and Cape Coral, are located in South Florida. South Florida coastal counties have been and continue to be high-growth areas (**Figure 12-2**). According to the U.S. Office of Management and Budget, the primary counties in Southeast Florida (Miami-Dade, Broward and Palm Beach) comprise the sixth largest Metropolitan Statistical Area in the United States, with a population of more than 5.1 million, and they are projected to have over 7.4 million residents by 2030 (http://www.broward.org/urbanplanning/bbtn20.pdf).

To a large extent, freshwater and marine habitats in South Florida lay the foundation for a thriving, impressive economy, where the ability to participate in various recreational activities through the state's coastal waters is one of its greatest tourist attractions. In addition to local resident impacts, the non-resident, tourist population also has significant effects on the utilization of coastal resources. Again, the statistics in South Florida are impressive. For example, according to the 2000 U.S. Commission of Ocean Policy's Preliminary Report, it is noted that in only four southeastern Florida coastal counties, recreational diving, fishing, and ocean watching generate about $4.4 billion in local sales, and almost $2 billion in local income annually, while more than 2.9 million tourists annually visit the Florida Keys.

In South Florida, recreational boating also significantly contributes to coastal resource utilization while bolstering the economy. Notably, more than 150,000 boats are currently registered in Miami-Dade, Broward, and Palm Beach counties, and there are over 300,000 registered vessels in the coastal counties of South Florida. In Palm Beach and Martin counties alone, more than 1,000 marine-related businesses generate over $1 billion dollars annually. Miami is known as the "Cruise Ship Capital of the World," with operation of about 3.6 million passengers in 2002. Remarkably, the Port of Miami ranks first among Florida's containerized ports, and ninth among all U.S. ports, while annually contributing $8 billion and 45,000 jobs to the economy (http://www.beaconcouncil.com).

The following sections of this chapter consist of a brief introduction, followed by descriptions of District-related activities that are under way in each coastal ecosystem. Key areas of the District's coastal ecosystem management and restoration efforts include the following:

- Environmental monitoring and assessment of status and trends focused largely on salinity, seagrass, and other biological indicators
- High-quality applied science and tool development for analysis and prediction of habitat response to the Comprehensive Everglades Restoration Plan (CERP), Pollutant Loading Reduction Goals (PLRGs), Minimum Flows and Levels (MFLs), Total Maximum Daily Loads (TMDLs), and other technical criteria
- Implementation of restoration projects for coastal watersheds and estuaries through collaborative partnerships and local initiatives

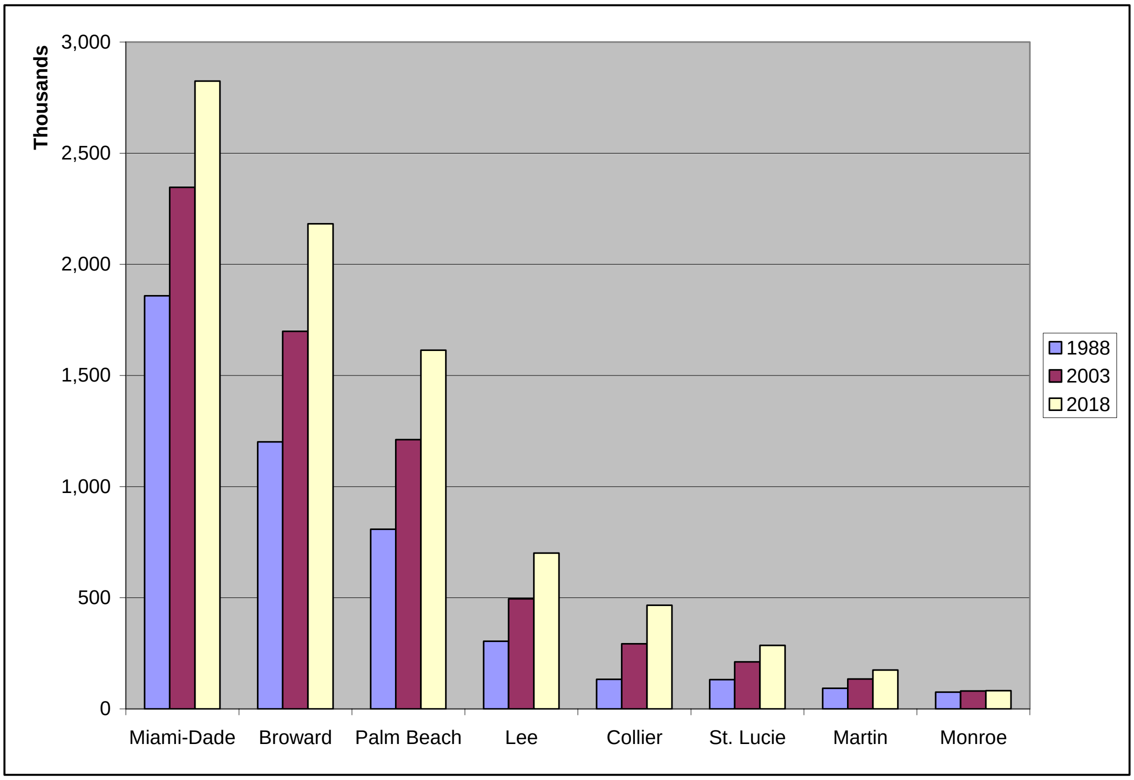


Figure 12-2. Population growth for South Florida coastal counties. Data is from the Office of Economic and Demographic Research, February 2004 (http://www.state.fl.us/edr/population/web10.xls).

SOUTHERN INDIAN RIVER LAGOON AND ST. LUCIE RIVER AND ESTUARY

INTRODUCTION

The Indian River Lagoon (IRL), located on the southeast coast of Florida (**Figure 12-3**), has been considered one of the most biologically diverse ecosystems in North America (Swain et al., 1995). The St. Lucie Estuary (SLE) is the largest tributary to the Southern Indian River Lagoon (SIRL). The ecological health of these estuaries depends largely on the quantity, quality, timing, and distribution of stormwater runoff from the watersheds. Historically, SIRL watersheds supported extensive areas of ridges, sloughs, pine flatwoods, upland scrub, wetland flats, cypress ponds, and savannas. Over the last 100 years, land use and drainage patterns in the watersheds have undergone substantial changes as a result of the construction of a network of primary, secondary, and tertiary canals. The large primary South Florida Water Management District (SFWMD or District) canals C-44 (completed in 1924 and enlarged to its current size in 1949), and the C-23, C-24, and C-25 canals (completed circa 1961), were constructed by the U.S. Army Corps of Engineers (USACE) under the auspices of the original Central and Southern Florida Flood Control (C&SF) Project (**Figure 12-3**). In particular, the C-44 canal connects Lake Okeechobee with the SLE, and provides a conduit of freshwater release from the lake into the estuary.

An unanticipated result of land development was an approximately eight-fold increase in the quantity of storm water delivered to the coast with a corresponding increase in loads of nutrients and other pollutants (USACE and SFWMD, 2001). Major stresses to the ecosystem include excess amount of fresh water during the wet season, and frequent low dissolved oxygen (DO) events and light limitation due to turbidity from resuspension of fine-grain sediments (Haunert et al., 1985; Chamberlain and Hayward, 1996; Doering, 1996). Sediments in the SLE have been shown to contain heavy metals at levels potentially harmful to fish and benthic macroinvertebrate communities (Haunert, 1988). The unfavorable salinity regimes during high freshwater discharge and increased accumulation of unconsolidated sediments have nearly eliminated seagrass beds, and have negatively influenced oyster growth in SLE (Chamberlain and Hayward, 1996; Doering, 1996).

Environmental preservation and restoration activities in the SIRL are driven and, to some extent, shaped by the 1987 Surface Water Improvement and Management Act (SWIM) [Chapters 373.451–373.4595, Florida Statutes (F.S.)], the Indian River Lagoon South Feasibility Study (USACE and SFWMD, 2001), and the 1999 Watershed Restoration Act (Chapter 403.067, F.S.). The Indian River Lagoon SWIM planning process resulted in the creation of the Indian River Lagoon SWIM Plan, which was first adopted in 1994, and has been most recently updated and revised in 2002. The SWIM Plan identifies the overreaching environmental restoration and preservation goals for the Indian River Lagoon system. The Indian River Lagoon South Feasibility Study and the Watershed Restoration Act provide mechanisms that support achieving the SWIM goals. The SWIM Plan can be found at the District's Website at http://www.sfwmd.gov/org/wrp/wrp_ce/projects/irl_swim.html, and additional information on the Indian River Lagoon South Feasibility Study is presented on the CERP Website at http://www.evergladesplan.org/pm/studies/irl_south.cfm.

Figure 12-3. Geographic location of the Southern Indian River Lagoon (SIRL) and St. Lucie Estuary (SLE).

The objective of this section is to (1) evaluate the status of the SLE/SIRL estuarine ecosystem during Water Year 2004 (WY2004) (May 1, 2003 through April 30, 2004); (2) document water quality monitoring and modeling efforts for the establishment of the PLRGs of the SIRL and SLE; and (3) provide a description of the District's environmental management programs and projects over the subject period in support of the lagoon restoration and preservation efforts.

ECOLOGICAL MONITORING AND ASSESSMENT

Freshwater Input and Salinity in the St. Lucie Estuary

Using the U.S. Environmental Protection Agency's (USEPA's) Valued Ecosystem Component (VEC) approach, a favorable range of freshwater inflow and salinity, referred to as a "salinity envelope," has been established for juvenile marine, fish, shellfish, oysters, and submerged aquatic vegetation (SAV). In the SLE, a salinity envelope from 350–2,000 cubic ft per second (cfs) was determined based on research and data acquired during discharge events. The SFWMD's Operations and Maintenance Department employs a pulse release strategy for discharging excess water from Lake Okeechobee through the C-44 canal, in order to reduce the potential for ecological harm to the estuary. These discharges, in conjunction with inputs from the C-23 and C-24 canals, Ten Mile Creek, and other tributaries which discharge into the North and South Forks of the St. Lucie River, all contribute to meeting or exceeding salinity targets set at the Roosevelt Bridge (US1 station) in the SLE.

Figure 12-4 depicts freshwater discharge measured during WY2004 at major flow structures including S-80 (C-44 basin), S-48 (C-23 basin), and S-49 (C-24 basin). Together these structures provide flood control for approximately 70 percent of the SLE watershed. Discharge from part of the watershed in the North Fork and South Fork basins is not included in the measurement. Note that during high discharge in the wet season, in particular when the lake is releasing, the salinity envelope is exceeded. Also note that fresh water from the watershed peaked during July and August 2003 (for S-48 and S-49), while the lake release (S-80) seemed to be highest in September and October 2003. The pulse release from the lake is obvious in the latter part of the water year.

The high discharge events are consistent with low salinity monitored at the US1 station by the SFWMD in **Figure 12-5,** indicating that mean daily salinity drops below 10 to 8 parts per thousand (ppt) at the onset of the wet season. The salinity becomes lowest (about 1 ppt) during the period of August–September, when the combined lake release and watershed runoff reach the maximum. This salinity condition in relationship to oyster health in the SLE is further discussed in the next section.

Oyster Monitoring and Habitat Assessment

The American oyster (*Crassostrea virginica*) has been selected as a VEC, or a key biological indicator, for developing appropriate salinity ranges and inflow ranges for the SLE. The District is conducting field and lab studies to determine oyster response to salinity changes to help evaluate freshwater inflow management strategies. Laboratory experiments are currently being conducted by Florida Atlantic University under contract to the District to better understand the response of St. Lucie oysters to differences and changes in environmental salinity, with temperature and disease as modifying factors. This work is expected to be completed by September 2005.

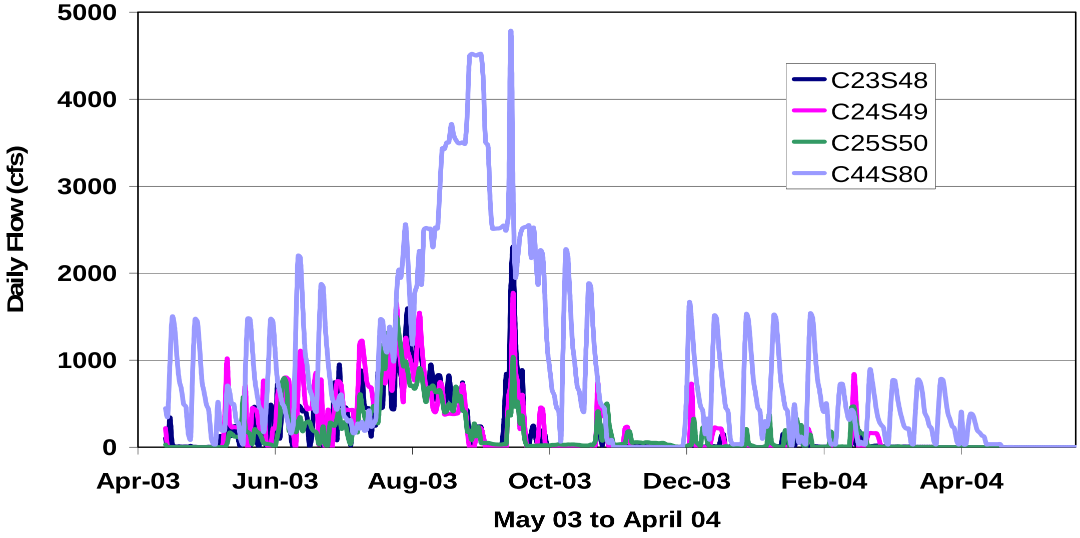


Figure 12-4. Freshwater discharge from the major control structures in the SIRL and SLE watersheds during Water Year 2004 (WY2004). Note that C-25 S-50 discharges directly into the SIRL.

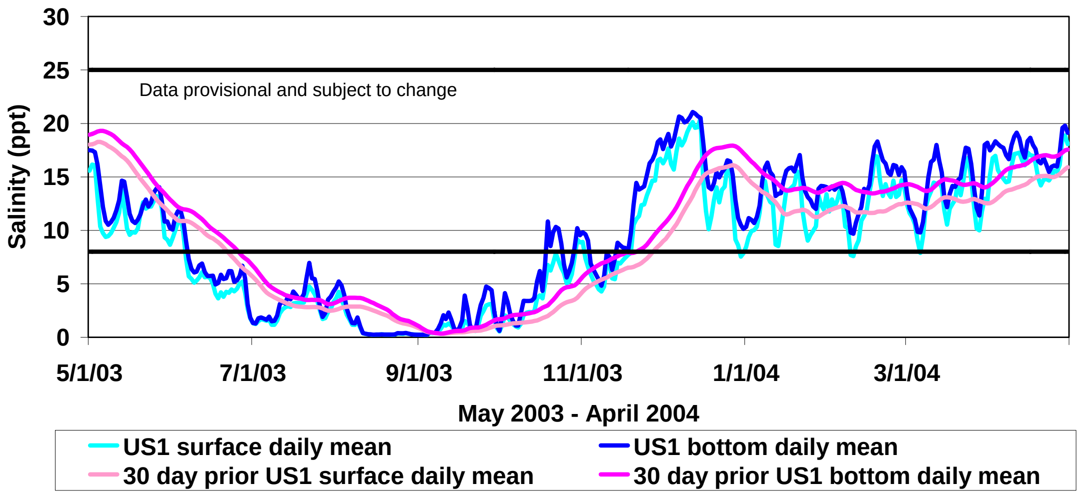


Figure 12-5. Salinity measurements at the US1 station during WY2004. The solid straight lines represent the salinity target range that is favored for oysters in the SLE.

Additionally, the District conducted a field study to evaluate oyster survival in response to salinity changes from watershed runoff and Lake Okeechobee regulatory releases. Oyster survival was monitored monthly at six sites (**Figure 12-6**) located along a salinity gradient in the SLE from September 2002 through February 2004. Salinity declined rapidly from April 2003 through August 2003 (from 23 to 1 ppt at US1, as shown in **Figure 12-5**) and stayed below oyster salinity targets until October 2004 as a result of freshwater inflows from the watershed and Lake Okeechobee. Survivorship declined dramatically at upstream and mid estuary sites from August 2003 through September 2003 (**Figure 12-7**). This research supports the findings in the Indian River Lagoon South Feasibility Study that restoration of coastal ecologic health in SLE relies primarily on the increase in flow storage via large storage reservoirs in the watershed.

A study to map oysters in the St. Lucie was conducted in fall 2003. Approximately 116.9 acres of live oyster beds were mapped (**Figure 12-8**). This indicates a 90.6-acre decline compared with the 207.5 acres mapped in 1997 (URS Greiner Woodward Clyde, 1999). No live oysters were found in the North or South Forks during the 2003 mapping study. The 2003 mapping effort revealed that oyster survivorship throughout the estuary was low.

Indian River Lagoon Seagrass Monitoring

Seagrasses provide important habitat and are indicators of a healthy estuarine system. Consequently, it is important to obtain current and accurate maps to document existing conditions and to monitor changes in seagrass coverage over time. The SFWMD, in cooperation with the St. John's River Water Management District (SJRWMD), has mapped seagrasses in the IRL every 2–3 years since 1986. The maps are prepared through photointerpretation of aerial photographs with limited ground-truthing. This data allows evaluation of trends and variability over time. A 2003 map is currently being finalized.

In addition to seagrass mapping, the SFWMD conducts monthly seagrass monitoring in the SIRL. This monitoring was conducted at four sites from August 2002 through September 2003, and it is continuing at two of the four sites, Sites 2 and 3 (**Figure 12-9**). The purpose of this monitoring is to document seasonal changes in seagrass and associated macro-algae (epiphytes, attached algae, and drift algae) near the mouth of the St. Lucie River. Data collected is used to better understand the natural seasonal variability of seagrass and macro-algae in the study area, and the response of the seagrass community to freshwater discharge.

Shoot count and canopy height data from the two sites currently being monitored are presented in **Figure 12-10**. Rapid declines in shoot counts and canopy height occurred from July 2003 through September 2003. Possible causes for the declines include low salinity (a low of 14 ppt from an average of 30 ppt), and extreme low tides, which exposed seagrasses. Shoot counts and canopy height have increased steadily at both sites since February 2004. This project is expected to continue for a minimum of three years.

Figure 12-6. Locations of oyster experimental cages in the SLE.

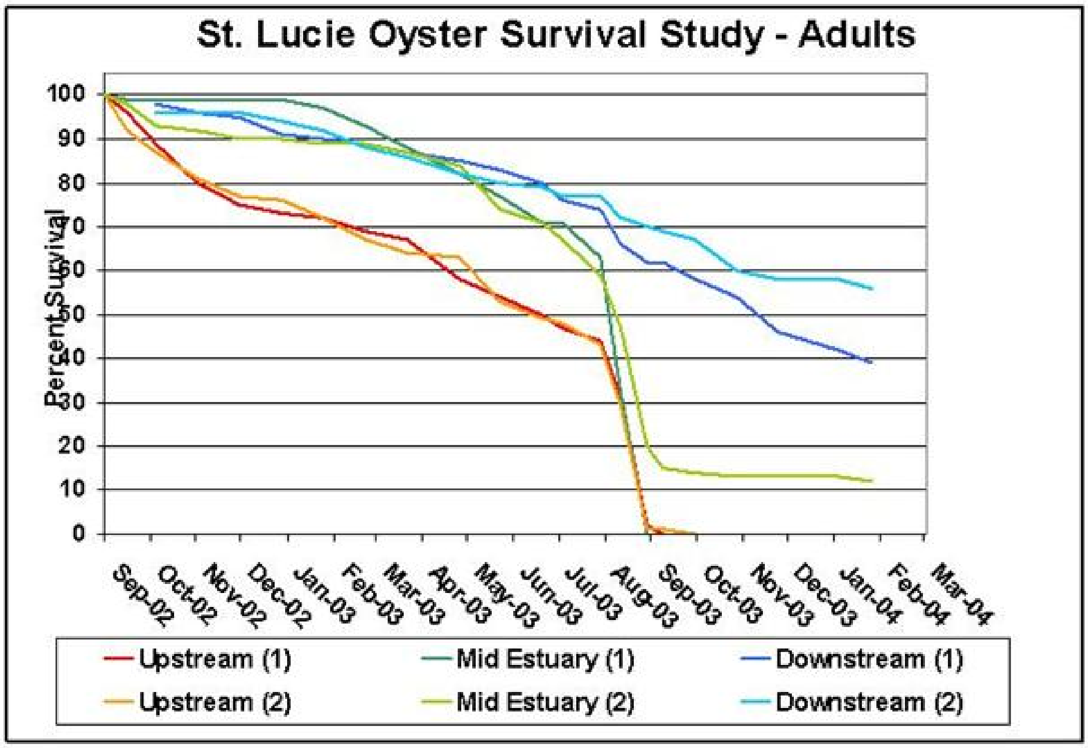


Figure 12-7. Oyster survival data from six experimental cages in the SLE.

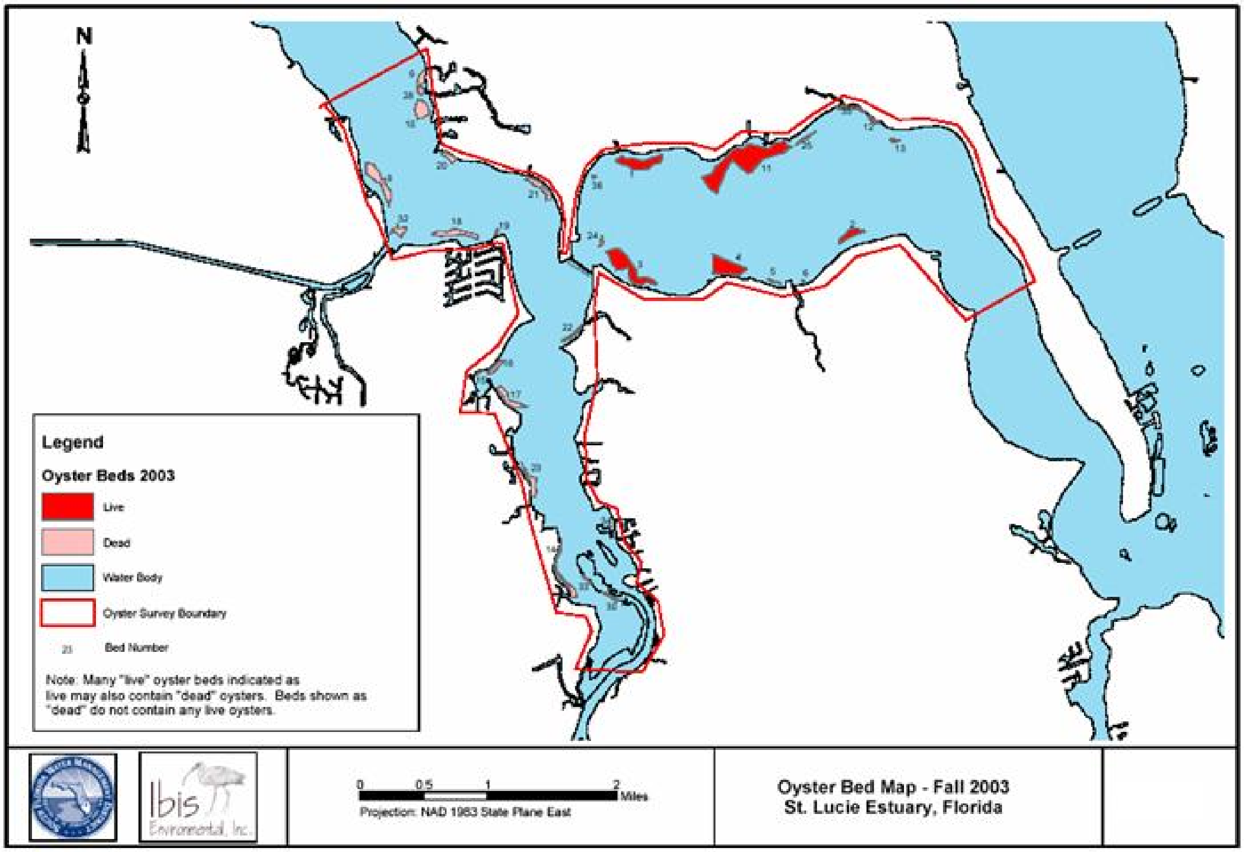
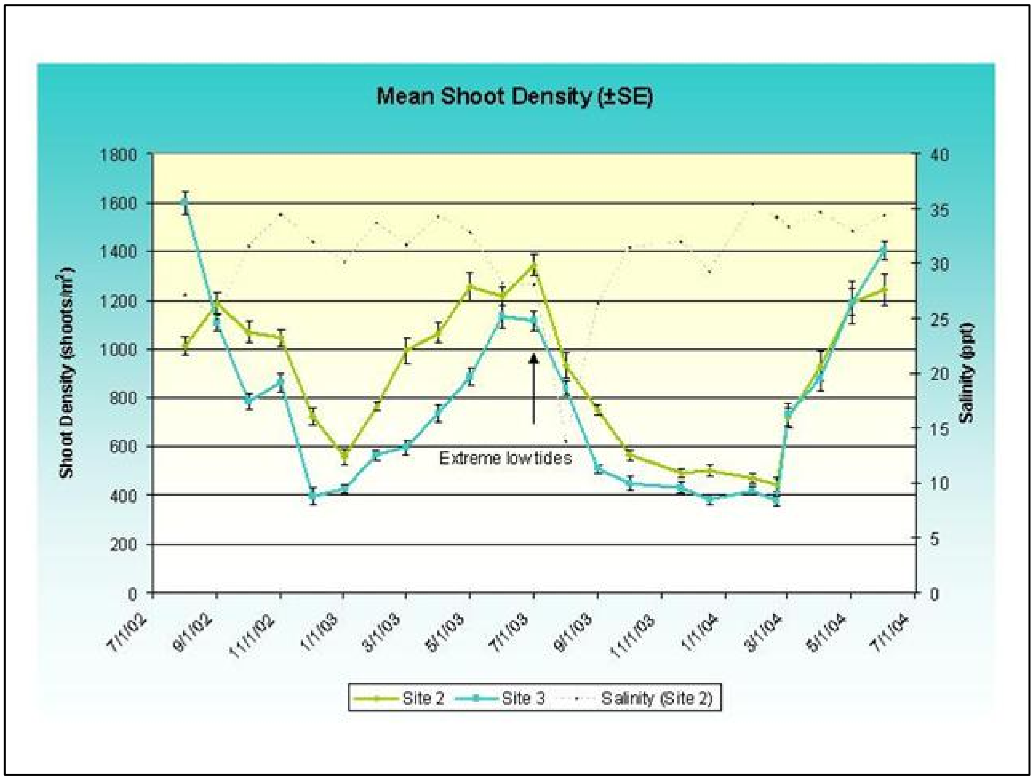


Figure 12-8. Oyster mapping conducted in 2003 in the SLE.

Figure 12-9. Seagrass monitoring stations in the SIRL and SLE.



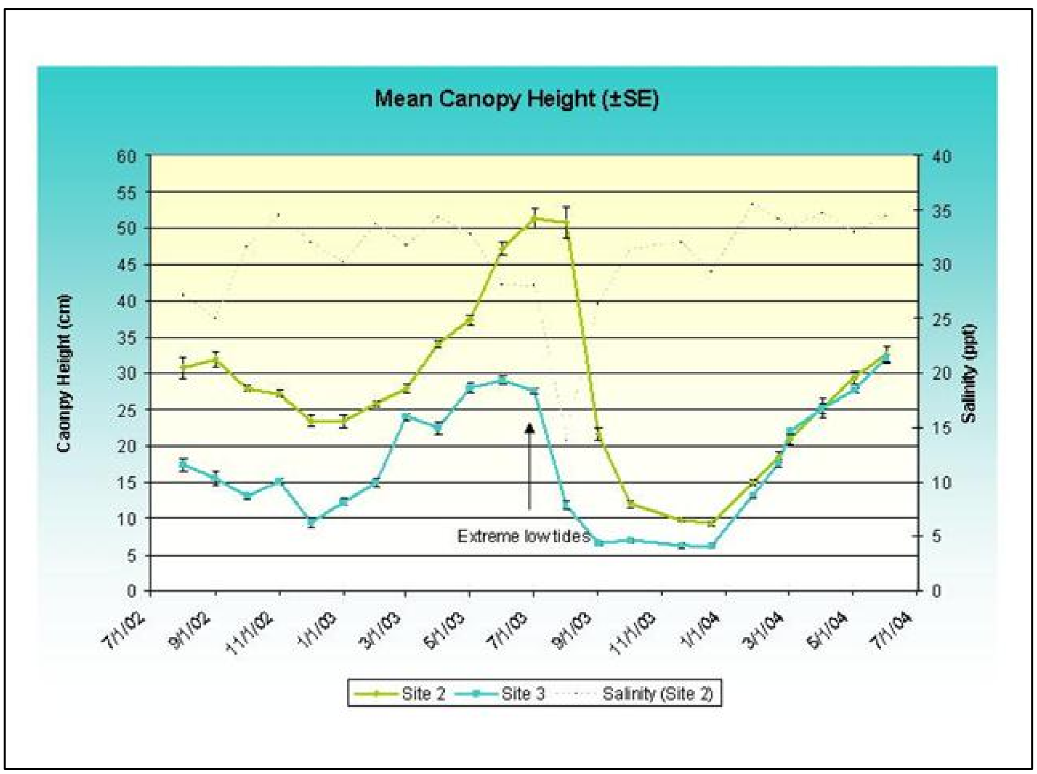


Figure 12-10. Mean shoot densities and mean canopy heights observed at Sites 2 and 3.

MONITORING AND MODELING OF WATER QUALITY FOR THE ESTABLISHMENT OF POLLUTION LOADING REDUCTION GOALS

To address the water quality issues of the SLE, the Florida legislature designated the SLE as a SWIM priority water body. The SFWMD's technical efforts are intended to be responsive to water quality monitoring and modeling needs to establish the Pollutant Loading Reduction Goals (PLRGs) in the area watersheds. The District focuses its technical resources on two major areas.

1. Support water quality monitoring in tributaries and estuary/lagoon receiving waters to provide real time water quality information to all the stakeholder parties.

2. Development of watershed, estuary hydrodynamic, and water quality models as tools for information processing and management option evaluations.

In addition, the District also provides support for research and development of new Best Management Practices (BMPs) and evaluates effectiveness of BMPs. The BMP program is discussed later in this section.

Water Quality Monitoring and Assessment

Water quality monitoring efforts in the SLE and SIRL watersheds have two distinct components. The first is the District's long-term monitoring network at four coastal structures: S-80, S-48, S-49, and S-50. Nutrient and sediment data are collected on a monthly basis at these major control structures. Total flow discharge and associated total nitrogen (TN) and total phosphorus (TP) loads are calculated for WY20004, and the data is summarized in **Table 12-1**. Note that the highest nutrient loads among these structures are consistent with the high flow discharge from S-80.

Table 12-1. Total nitrogen (TN) and total phosphorus (TP) loads monitored at major flow control structures during WY2004.

Structure	Flow (ac-ft)	TP (mt)	TN (mt)
C23/S48	139,988	82.1	272.6
C24/S49	155,816	60.1	284.7
C25/S50	119,284	36.6	214.9
C44/S80	690,194	153.6	1214.8

The second monitoring component is a more recent, finite time period evaluation of the remaining natural and man-made drainage features that discharge directly into the SLE and SIRL. These tributaries provide drainage for the remaining 30 percent of the contributing watershed. This area is also immediately adjacent to the North and South Forks of the St. Lucie River.

The monitored sites are the most dynamic in terms of land use and growth, as they are either already urbanized or are being converted from citrus/agricultural uses into urban use. Stormwater attenuation and water quality mitigation for this area is not being addressed by the Comprehensive Everglades Restoration Plan (CERP), and must be provided for by other means. Water quality monitoring for this area is anticipated to be a three- to five-year effort in which data will be collected to:

1. Establish a baseline characterization of water quality constituents contributed from these areas and get some indication of their behavior.

2. Aid in problem source identification.

3. Support the development of the watershed water quality model.

4. Establish a baseline for evaluating the effectiveness of watershed water quality management programs (voluntary BMPs) on reducing pollutant loads from these areas.

5. Provide information to help in determining PLRGs.

This program began in 2001 with biweekly monitoring at 38 tributary locations. Since this initial start-up period, some of the sites have been dropped. The remaining network consists of 19 locations, where flows and water quality will be monitored for the next two to three years. Data collected by this program can be used to calculate pollutant loads coming from these areas. **Table 12-2** exemplifies how the data collected during the first two years are used to identify the most problematic areas. The SFWMD is currently in the process of identifying causes and possible solutions through performing watershed water quality assessments. The first type of this effort was conducted during this past year on the Manatee Creek basin, south of Stuart in Martin County. The Manatee Creek basin watershed covers roughly 800 acres of predominantly urban single family and business land use. A synoptic water quality evaluation, with the intent of characterizing typical values of some water quality parameters in the basin, was performed to identify problem areas and potential sources.

Water Quality Modeling Tool Development

Formulation of the SLE/SIRL ecosystem restoration plan in the Indian River Lagoon South Feasibility Study is based on integration of seven models for simulating watershed hydrology, reservoir optimization, irrigation demands and supplies, estuary salinity, and oyster stress (Wan et al., 2002). Water quality model development for the estuary and watershed is a continuing effort that the SFWMD has undertaken. These models shall serve as essential management tools for the establishment of PLRGs.

The watershed water quality model (WaSh) has been calibrated using hydrologic and water quality data in four basins: C-23, C-24, C44, and C-25. The watershed hydrology and water quality model has a cell-based representation of watershed where hydrology and water quality is modeled with the Hydrological Simulation Program – Fortran, or HSPF (Wan et al., 2003). The infiltrated water is routed to a groundwater model that represents the surficial aquifer of the SLE watershed. The overland flow and drainage water is routed to a drainage system model that is governed by the continuity equation and a full dynamic depth- and width-averaged shallow water wave equation. The drainage network model has the capacity to simulate bio-directional flow, branches, and common flow structures. HSPF nutrient and sediment simulation modules are used for water quality modeling. Key watershed restoration elements such as land use change,

Table 12-2. Stations with median value larger than 75th percentile of the data collected. This data provides useful information for identifying "hot spot/opportunity areas" with corresponding parameters of concern within SLE tributary basins as part of management efforts for load reduction.

Station	Total Copper	Total Phosphorus	Soluble Reactive Phosphorus	Total Nitrogen	Inorganic Nitrogen	Total Number of Parameters
SLT-36	•	•	•	•	•	5
SLT-3		•	•	•	•	4
SLT-6		•	•	•	•	4
SLT-2	•	•	•			3
SLT-24	•	•	•			3
SLT-5		•	•			2
SLT-9		•	•			2
SLT-22		•	•			2
SLT-14				•	•	2
SLT-37	•				•	2
SLT-8	•					1
SLT-28	•					1
SLT-30	•					1
SLT-31	•					1
SLT-35	•					1
SLT-12					•	1
SLT-34					•	1
SLT-13				•		1
SLT-15		•				1
SLT-33			•			1

irrigation demand and supplies, storage reservoir and stormwater treatment systems, interbasin transfer, and BMP implementation are embedded in the model. An Arcview Graphic User Interface is designed to support the implementation of these watershed restoration practices.

The model calibration process consisted of two consecutive efforts. First, a compact version of the WaSh model (MicroWaSh) was used to calibrate the model for single land uses such as citrus, pasture, or wetland. MicroWaSh simulates a single land use hydrologic cycle and water quality, and allows for rapid model execution and calibration. MicroWaSh was applied to numerous sites of differing land use to reproduce site-specific water quality event total suspended solids (TSS), TN, and TP mean concentrations collected at sites throughout the watershed over a two-year period. **Figure 12-11** exemplifies how total suspended sediment concentration was calibrated in accordance with the measured data. The calibrated model parameters obtained with MicroWaSh were implemented in the WaSh model, which was subsequently calibrated to 30-year basin structure daily flow records, and 15-year monthly or bimonthly water quality data records, as well as various groundwater elevation data sets. The successful WaSh calibration and proper physical representation of the basins provide a useful management tool to evaluate future impacts of watershed management options on the systems.

The estuary water quality model is built on the 3-Dimensional (3-D) Environmental Fluid Dynamics Code (EFDC). This model uses curvilinear orthogonal grid to represent the estuary and consists of 1,161 horizontal grid cells (**Figure 12-12**). Three vertical layers are used for hydrodynamic model calibration and verification. As the first step of model development, the hydrodynamic and salinity models for the SLE and SIRL were calibrated. The hydrodynamic model was calibrated using the observed data in 1999, and verified using the data in 2000. Site variables used for model-data comparisons include tidal elevation, current, temperature, and salinity. The WaSh modeling results for 1999 and 2000 for tidal influenced-basins, such as the North Fork and South Fork, were used as the input data for the estuary model. The lateral inflow from these basins, which contributed about 23 percent of total freshwater inflow in 1999 and 37 percent in 2000, was found to be critical for the simulations of water elevation and salinity in the estuary. The lateral inflows can change surface elevation up to 5 cm inside the SLE, and 10 cm in narrow channels. Without lateral inflow, salinity could be over predicted for over 4 practical salinity units (psu).

The next phase of model development for the estuary model is calibrating the model to properly simulate sediment transport and water quality in the SLE. The water quality model is a sub-model of the EFDC model that simulates dynamics of phytoplankton, DO, nitrogen, phosphorus, and carbon in the water column. In the EFDC model, the eutrophication model is coupled to the hydrodynamic model, so that the transport fields simulated by the hydrodynamic model drive the eutrophication model directly. The water temperature from the hydrodynamic model is also used in calculating kinetic processes of the eutrophication model. The eutrophication model is also coupled to the sediment model, in that suspended sediment concentrations from the sediment model are used to simulate sorption and desorption of phosphorus in the eutrophication model. The model grid of the eutrophication model is identical to the hydrodynamic model, with 1,161 horizontal grid cells and three vertical layers. The water quality model was calibrated using the 1999 data, and validated using data collected in 2000. **Table 12-3** is a summary of mean errors of model calibration.

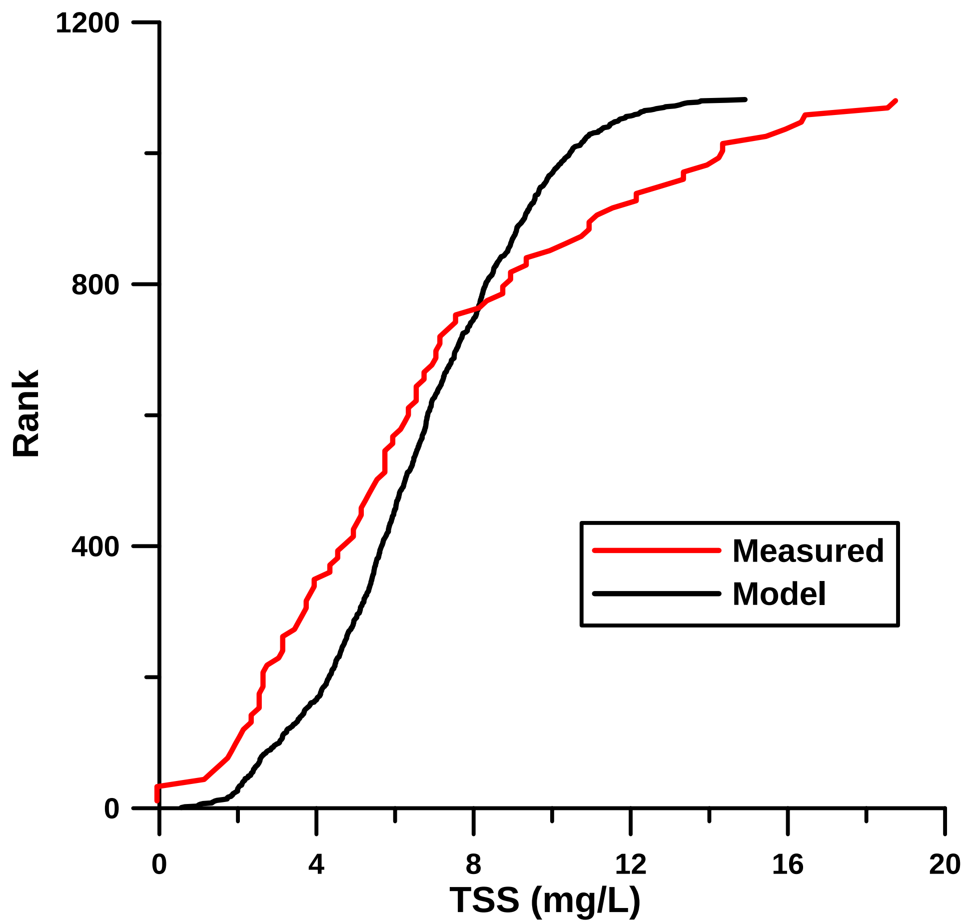


Figure 12-11. Sediment concentration calibration using citrus as an example of a land-use specific calibration of the watershed water quality model (WaSh).

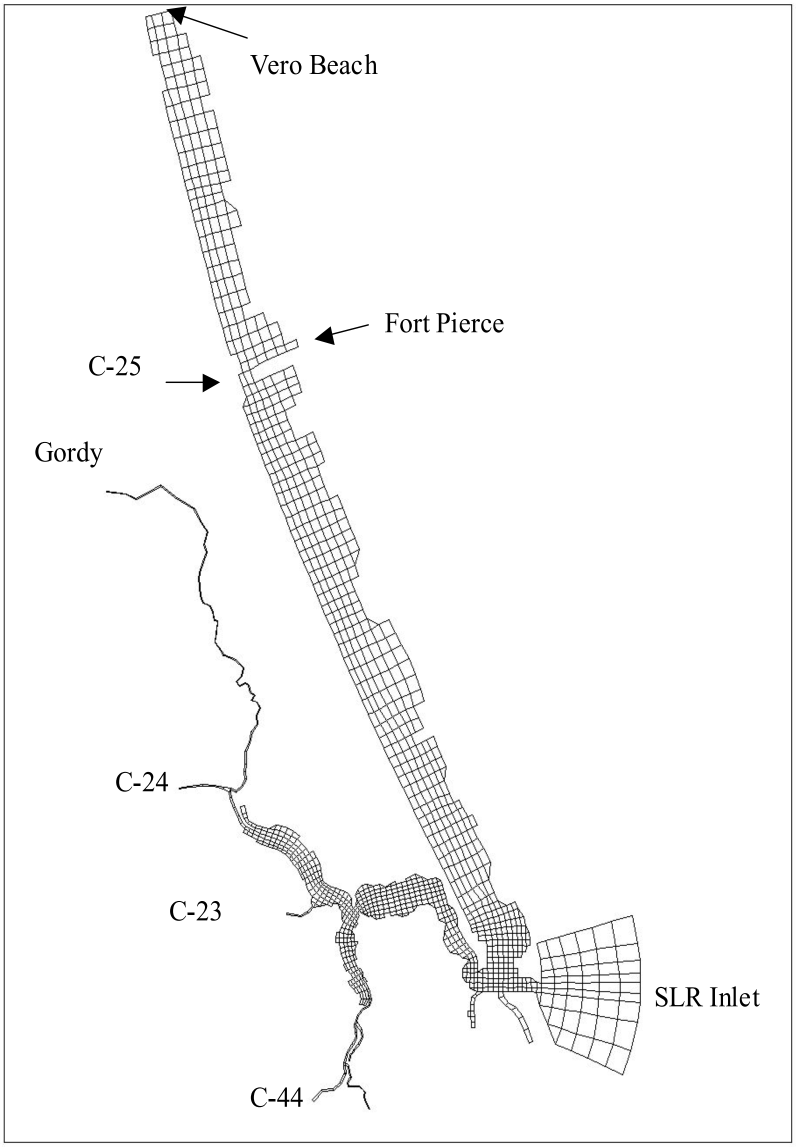


Figure 12-12. The SLE Environmental Fluid Dynamics Code (EFDC) model grid (1,161 horizontal grid cells with three vertical layers).

Table 12-3. Summary of mean errors of EFDC water quality model calibration.

Parameters	Inside SLE				Upstream of SLE			
	RER (%)	**RMS**	**Obs. Mean**	**Model mean**	**RER (%)**	**RMS**	**Obs. Mean**	**Model mean**
Algae (µg/L)	0.334.3	6.35	7.79	12.27	31.1	5.66	8.17	12.09
TP (mg/L)	23.7	0.09	0.20	0.15	22.6	0.11	0.25	0.27
PO_4 (mg/L)	31.6	0.04	0.06	0.07	29.9	0.06	0.09	0.09
TKN (mg/L)	27.9	0.32	0.69	0.54	26.8	0.40	0.89	0.84
NH_4 (mg/L)	32.3	0.06	0.06	0.04	28.2	0.06	0.08	0.08
DO (mg/L)	21.5	1.57	5.88	7.01	27.1	2.51	5.74	6.19
Mean RER	28.6	---	---	---	27.6	---	---	---

Note: RER = relative error.

COASTAL ECOSYSTEMS RESTORATION PROGRAMS AND ACTIVITIES

The restoration of the SIRL/SLE ecosystem is centered on the implementation of the current Indian River Lagoon South Feasibility Study through CERP (USACE and SFWMD, 2001) [refer to Chapter 7 of the *2005 South Florida Environmental Report – Volume I* (2005 SFER) for additional information on CERP]. This restoration plan aims to reestablish an appropriate salinity regime and improve water quality conditions in the estuary through construction of large regional reservoirs and Stormwater Treatment Areas (STAs), as well as rehydration of large tracts of former wetlands. The ecological improvements afforded by these large-scale efforts will be complemented by an effective agricultural and urban BMP program that is currently implemented in the watershed.

Management of Watershed Storage

Regional reservoirs are being planned and created through the CERP. Activities are underway to address the Indian River Lagoon South Feasibility Study recommendations related to land acquisition, engineering and design, and construction activities. These activities include the Ten Mile Creek Project in Ft. Pierce, purchase and restoration activities on the Allapattah Ranch property in Martin County, and identification of sites and partnerships for large reservoir/treatment areas elsewhere in the watershed. To date, there has been significant progress made on the implementation of the larger regional reservoir/STA strategy in the Indian River Lagoon South Feasibility Study through land acquisition on the C23-C24 project (approximately 70 percent of the STA site, and 40 percent of the reservoir site). Recently, the District has entered into an agreement exploring the feasibility of using a public/private partnership to locate, build, and operate a 12,000-acre reservoir/STA project in the C-44 basin, east of Indiantown.

Construction on the Ten Mile Creek project began in October 2003. The project is a 550-acre reservoir/110-acre STA located at the headwaters of the North Fork of the St. Lucie River. Project completion is scheduled in November 2005. It is identified as a “critical project” in the 1996 Water Resources Development Act (WRDA), and is funded by a state and federal partnership. It is intended to capture about 37 percent of the basin runoff and achieve a 70-percent reduction in TP concentrations, and a 27-percent reduction in TN concentrations.

Allapattah Ranch is a 42,000-acre parcel identified in the Indian River Lagoon South Feasibility Study for restoration to more closely mimic predevelopment hydrography reflecting small steady stormwater runoff releases rather than brief bursts of high volume discharge. Approximately 20,000 acres were acquired prior to 2003. Since 2003, an additional 960 acres have been acquired. All of the acquired property has been treated for exotic vegetation. Functional wetland assessments have been conducted on nearly 11,000 acres of wetlands, topographic and wildlife surveys have been conducted, and 275 acres have been planted with native slash pines.

Best Management Practices Program

BMPs are being actively incorporated into daily activities of citrus growers in the watershed. In late 1998, the Indian River Citrus League, in conjunction with the Florida Department of Agriculture and Consumer Services (FDACS) and the University of Florida Institute of Food and Agricultural Sciences (UF-IFAS), began a program to develop and implement BMPs on area citrus groves. The practices are intended to help growers find economically feasible ways to improve water quality and to reduce the quantity of runoff water leaving the farms. The resulting BMP development process was a voluntary effort in partnership with other state, federal, and local agencies. Five areas of concern were identified: water volume, pesticides, nutrients, sediments, and aquatic weeds. The growers and their partners developed an Indian River Area Citrus BMP manual, which was adopted by the industry in 2000. The group subsequently received funding support from the Federal 319 Grant Program to develop and staff an implementation team that provides technical assistance to growers in producing and implementing appropriate BMPs on their individual farms. In June 2002, the BMP manual was adopted by the FDACS (Rule 5M-2) as the industry's standard for compliance with the Florida Watershed Restoration Act. Through cost-sharing efforts, the SFWMD and FDACS provide funding to support growers in altering their farm systems or purchase equipment to use in implementing BMPs. According to the Treasure Coast Resource Conservation and Development Council, the cost-share matched funds provided to the growers from May 2003 through April 2004 are in excess of $320,000.

In addition to implementation activities, there is ongoing research and development focused on evaluating effectiveness of existing and proposed BMPs. One of the key issues identified during manual development was the realization that most of the identified BMPs, although thought to be of value, were not scientifically validated as to their degree of effectiveness. Scientific validation is a requirement for rule-adopted BMPs. That effort is supported by the FDACS, FDEP, SFWMD, and SJRWMD and by funding provided from state appropriations prioritized and allocated through recommendations of the St. Lucie River Issues Team (SLRIT). The SLRIT is a public/private stakeholder advisory group that provides state legislative delegation input as to the SLE and SIRL funding needs.

Research efforts that are under way include (1) water table management as a means of reducing stormwater runoff surges from citrus groves; (2) a variety of fertilizer application and management practices; (3) evaluation of soil amendments for nutrient controls; (4) quantification and comparison of runoff quality from citrus, pastures, golf courses, and urban areas; (5) pesticide spraying practices for reducing application amounts and drift; and (6) herbicide application practices. Detailed information on the status of each of these research efforts is contained in the Indian River Citrus BMP Implementation Committee Activity Report: 2001–2003 (prepared for the growers of the Indian River Citrus League by the Florida Center for Environmental Studies, and received in 2004), and Upper East Coast BMPs: Report and Summary of Ongoing Research Efforts Related to Indian River Area Citrus BMPs and Water Quality (Wilson, 2003).

Greater onsite retention is being pursued through BMP programs and municipal stormwater treatment retrofit projects. Agricultural industry BMPs is discussed in greater detail in the next section. Municipal retrofit projects continue to be constructed in the largely urbanized watersheds in St. Lucie and Martin counties. These projects are funded through local, regional, and state government partnerships, with funding derived from local tax initiates and state appropriations. The SLRIT serves as the mechanism for prioritizing and allocating annual state appropriations that are provided to the area for lagoon and estuary projects. The Federal Working Group established the SLRIT in summer 1998. This group has been tasked with creating a report on the current condition of the estuary and developing a list of local watershed projects that would provide immediate and tangible benefits to the SLE. Annually, the group evaluates and ranks projects, and then submits a list to the FDEP for cost-sharing assistance. Since 1998, the SLRIT, with the co-sponsorship from state and local partners, has funded projects for over $53 million.

Indian River Lagoon License Plates Program

On February 15, 1995, the Florida legislature enacted the Indian River Lagoon (IRL) License Plate Legislation to help restore and protect the lagoon system. Since that time, these license plates have been sold throughout the state of Florida and over $3 million of revenue has been generated to support IRL projects that provide habitat restoration, water quality improvement, and environmental education. The SFWMD administers the funding allocation for the SIRL region including St. Lucie, Martin, and Palm Beach counties. Funding is limited to governmental and non-profit organizations. From 1996–2003, 89 projects have been funded through the IRL License Plate Program. A total of nine projects have been completed during WY2004 (**Table 12-4**).

Table 12-4. IRL License Plate Program projects completed in WY2004.

Organization	Project Title	County	Funding
Loxahatchee River District	North Center Street Wastewater Improvements	Palm Beach	$70,000
The Nature Conservancy/ Blowing Rocks Preserve	The restoration of Units 4 and 5 on the Blowing Rocks Preserve along the IRL	Martin	$29,760
Martin County Board of County Commission/ Public Services Department	Martin County Conservation Area Restoration	Martin	$29,760
River Pines Home Owners Association	Swamp Restoration and Brazilian Pepper Eradication	Martin	$18,765
Martin County Audubon Society	Habitat Enhancement of Spoil Island MC2 in the Indian River Lagoon (IRL)	Martin	$17,000
Florida Department of Environmental Protection (FDEP) Division of Parks and Recreation	Restoration of disturbed exotic overgrown tropical hardwood hammock in St. Lucie Inlet State Park	Martin	$ 7,204
Environmental Learning Center	Establishment of fringing mangrove habitat along the Southern IRL (SIRL)	Martin	$ 1,850
Environmental Learning Center	Establishment of fringing mangrove habitat along the SIRL	St. Lucie	$ 1,850
St. Lucie County Board of County Commission/ Mosquito Control District	Mosquito Impoundment Restoration	St. Lucie	$56,816
		Total	**$233,005**

LOXAHATCHEE RIVER AND ESTUARY

INTRODUCTION

The Loxahatchee River and Estuary are located along the lower east coast of Florida (**Figure 12-13**). This watershed drains an area of approximately 210 square miles within northern Palm Beach and southern Martin counties, and connects to the Atlantic Ocean through the Jupiter Inlet. Just west of the inlet, the river opens into a central embayment area at the confluence of three major tributaries: the Northwest Fork, North Fork, and the Southwest Fork. The Loxahatchee River is generally referred to as the "last free flowing river in southeast Florida" (SFWMD, 2002). In May 1985, 7.5 miles of the Northwest Fork of the Loxahatchee River, between River Miles 6 and 13.5 (RM 6 and RM 13.5), were federally designated as Florida's first National Wild and Scenic River. Other unique resources of the river and estuary include state designations as an Aquatic Preserve, an Outstanding Florida Water, and a state park.

Originally, the Loxahatchee River was a freshwater system, with headwaters which originated in the Loxahatchee and Hungryland sloughs. Most of the watershed was drained by the Northwest Fork of the Loxahatchee River. During the past 100 years, the natural hydrologic regime of the Loxahatchee watershed has been altered by the permanent opening of the Jupiter Inlet in 1947, the construction of the C-18 canal, and drainage activities associated with urban and agricultural development. In recognition of the impacts of past activities many plans, projects, and studies have been conducted and continue to take place in support of the restoration of the Northwest Fork of the Loxahatchee River. Environmental and hydrologic studies continue to be conducted in order to document hydrological, chemical, and biological factors associated with the health of the Loxahatchee River watershed. Hydrologic changes which have occurred in the Loxahatchee River and Estuary due to navigation, drainage, and flood control activities have significantly altered the volume, timing, and distribution of freshwater flow. In response to flooding, drainage ditches and canals have been built to drain and provide flood protection to developed areas. Canals divert water and affect the historical flow patterns to and within natural wetland systems. Barriers have been built that interfere with the historical movement of water in this region. This network of canals and barriers has reduced water storage in natural areas, reduced dry season flows to natural systems, and increased wet season discharges to the Loxahatchee Central Embayment and Estuary areas of the Loxahatchee River.

The Northwest Fork contains one of the last examples of a pristine subtropical riverine cypress swamp in South Florida. Protection of this resource requires reducing or reversing the current trend of saltwater intrusion and the subsequent transition from cypress to mangrove within the upstream freshwater portion of the Northwest Fork. Maintenance of freshwater habitats in the upper reaches of the river is also desirable to protect existing populations and distribution of wildlife (e.g. fishes, alligators, turtle, and otters) that require freshwater habitat. Reduction of sediment loading from tributaries is required to protect benthic communities in the Central Embayment and Estuary areas of the Loxahatchee River.

The combination of the permanent opening of Jupiter Inlet and the construction of the C-18 canal, which reduced dry season flows in the Northwest Fork of the Loxahatchee River, has allowed salt water to migrate upriver. This has caused increasing levels of salinity in the Northwest Fork of the Loxahatchee River. In this segment of the river, there appears to be a strong relationship between elevated salinity levels and cypress tree die-off.

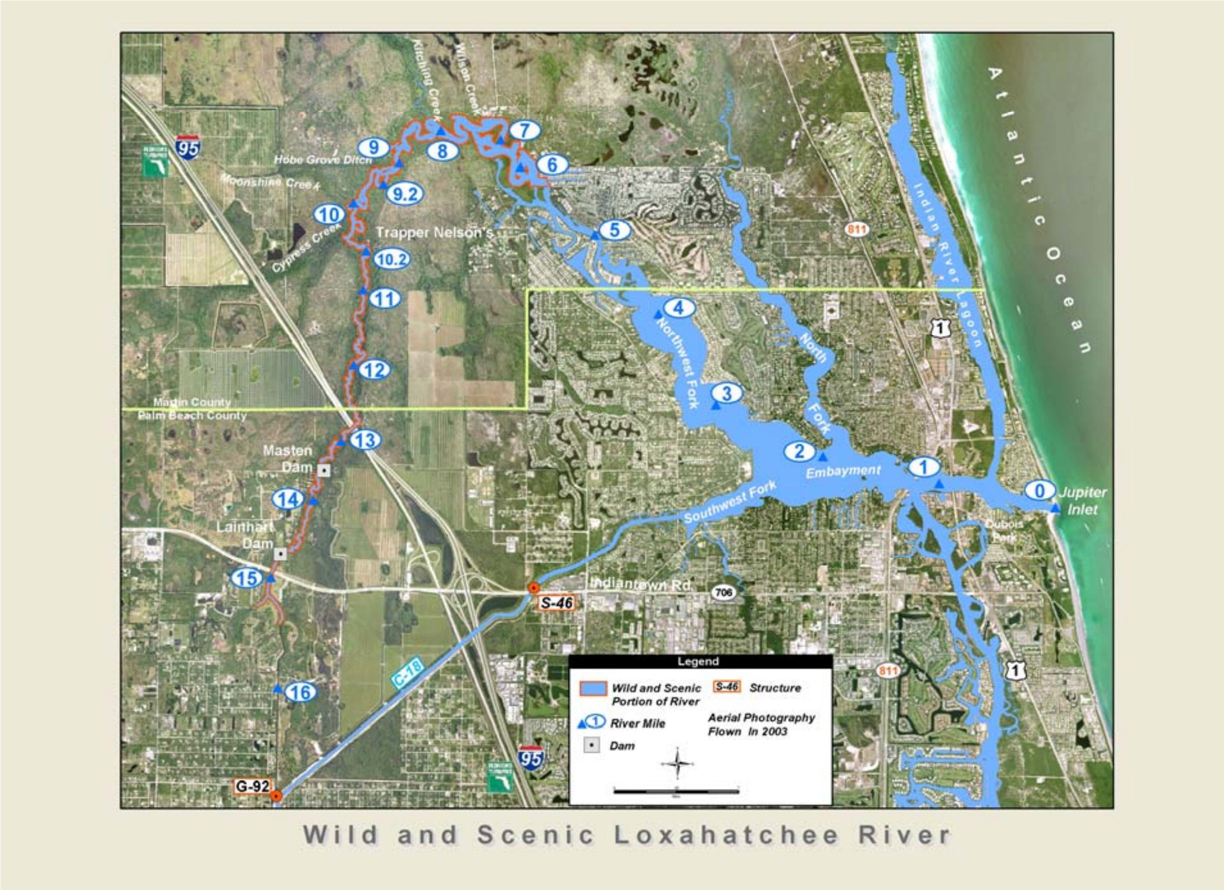


Figure 12-13. Geographic location of the Loxahatchee River and Estuary.

The objective of this section is to provide a status report on the District's hydrologic and ecologic data collection and modeling efforts and restoration programs for the Loxahatchee River and Estuary.

DATA COLLECTION, ANALYSIS AND MODELING ACTIVITIES

2003 Vegetation and Groundwater in the Floodplains of the Loxahatchee River Watershed Study

Changes in the balance of fresh and salt water appear to have resulted in significant changes in the distribution of freshwater and saltwater vegetation along the floodplain of the Northwest Fork of the Loxahatchee River (Ward et al., 1996). While cypress and other freshwater communities can still be found in the upper reaches of the Northwest Fork of the Loxahatchee River, the lower portions of the floodplain are now dominated by mangrove forest and subject to daily tidal fluctuations. These anthropogenic alterations within the Loxahatchee River watershed have been well documented throughout the 1900s.

The 2003 Vegetative Transect Study established a long-term monitoring program for plant community composition, structure, and groundwater, in order to document current conditions and future plant community health along the floodplains of the North and Northwest Forks of the Loxahatchee River, Kitching, and Cypress creeks. The vegetation and groundwater studies are being conducted jointly by the SFWMD and FDEP Florida Park Service (FDEP-FPS). The objectives of this joint monitoring program are to (1) determine the composition and structure of floodplain plant communities and their associated surface and groundwater hydrological and chemical characteristics; (2) identify short-term indicator plant species for salinity; (3) identify key chemical parameters in the soils that are indicative of the various forest types; (4) examine the influence of exotic plants on this system; and (5) determine if additional dry season freshwater flows sent down the river system are improving or changing the structure of the vegetative communities and/or groundwater, which would verify the success or failure of established restoration performance measures.

A total of 10 belt transects were examined during the 2003 study (**Figure 12-14**). These locations were representative of riverine (predominantly non-impacted fresh water), and upper and lower tidal (salt water intruded with fresh and brackish water) communities. Seven transects were established at designated locations along the middle and upper segments of the Northwest Fork of the Loxahatchee River. Additional transects were established in the lower segments of Kitching and Cypress creeks (tributaries of the Northwest Fork), and in the upper North Fork of the Loxahatchee River. Transects NW01, NW02, NW03, NW04, CC05, and NW06 are the historical transects utilized by Dewey Worth in 1983–1986, and by Ward and Roberts in 1993–1994. Transect NW09 was surveyed by Dr. Taylor Alexander in 1967, while transect NF10 established a completely new study area on the North Fork of the Loxahatchee River.

Within each 10 m x 10 m segment, all trees with greater than 10-cm diameter at breast height (dbh) were identified by species, and dbh and tree height were measured. Tree heights were measured using a Haglöf Vertex III Hypsometer and T3 Transponder. Cover, by species, of all woody plant species with a height greater than 1 m and dbh less than 10 cm were measured within a 10 m x 1 m subplot nested within each 10 m x 10 m plot. Cover and stem counts of all herbaceous plants and woody plant species less than 1 m were measured within three 1-m subplots nested within each 10 m x 10 m plot. Additional information collected at each segment included the presence of hummocks and the presence of cypress stumps, as well as estimates of

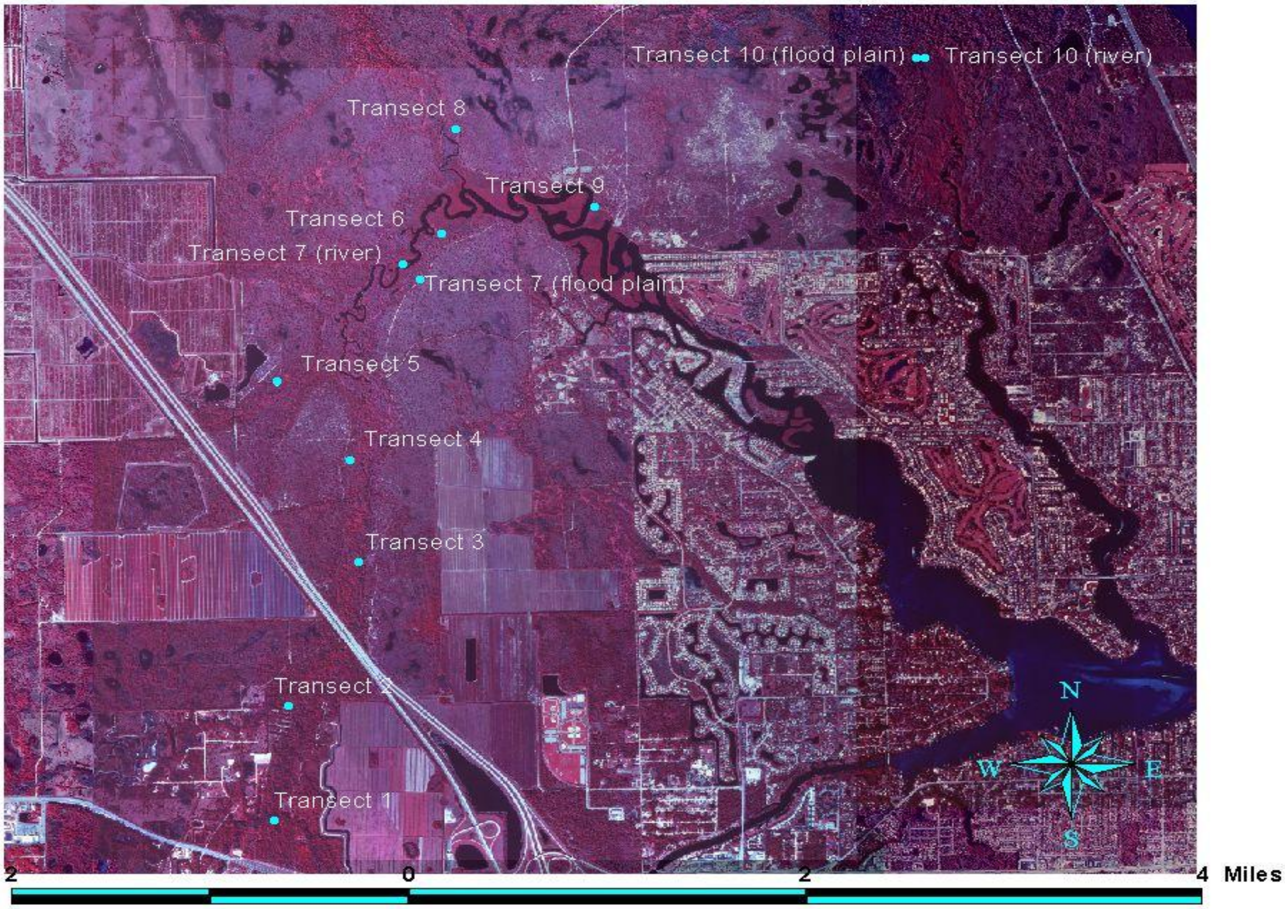


Figure 12-14. Vegetation transects in the freshwater and tidal segments of the Northwest Fork of the Loxahatchee River.

percent open ground, percent exposed roots, percent leaf litter, and percent fallen logs. Also, corresponding elevation and soil characteristics were examined within each transect.

In support of the 2003 vegetation study, 12 groundwater wells were installed along vegetation transects 1, 3, 7, 8, and 9. The objective of this monitoring project is to measure long term water level, salinity, and DO of groundwater in the floodplains. This monitoring program provides data critical for estimation of hydroperiods, model calibration and interpretation of vegetation health in the floodplains.

Loxahatchee River Water Quality Monitoring

The Loxahatchee River District (LRD) has established a comprehensive water quality monitoring network in the freshwater and tidal segments of the Loxahatchee River. Nutrients and other parameters are monitored. The District is currently in the process of working together with the LRD to determine the long-term trend of water quality in the Loxahatchee River and Estuary.

Loxahatchee Estuary Seagrass Monitoring

The LRD and SFWMD are working cooperatively to evaluate potential impacts of proposed upstream restoration efforts on the seagrass resources in the Loxahatchee Estuary. Beginning in June 2003, the LRD began a project to monitor seasonal trends in seagrass at three sites in the Central Embayment of the Loxahatchee Estuary (**Figure 12-15**) to better understand the natural seasonal variability of seagrass in the study area, and the response of the seagrass community to freshwater discharge. The monitoring is conducted monthly, and includes shoot counts, canopy height, percent cover, species diversity, species shifts, and species depth distribution. This project is expected to continue for a minimum of three years.

General seagrass maps of the Loxahatchee Central Embayment have been prepared by various agencies using numerous mapping methodologies. Because seagrasses provide important habitat and are indicators of a healthy estuarine system, it is important to obtain current and accurate maps to document existing conditions, and to monitor changes in seagrass coverage over time.

In July 2003, the SFWMD began mapping seagrasses in the Central Embayment (see project boundary in **Figure 12-15**) of the Loxahatchee Estuary. The mapping will be conducted annually through 2005, and then every two to three years thereafter, using the same mapping techniques (i.e., mapping from aerial photography using an analytical stereoplotter) that are being used in the SIRL. The 2003 seagrass coverage is shown in **Figure 12-16**.

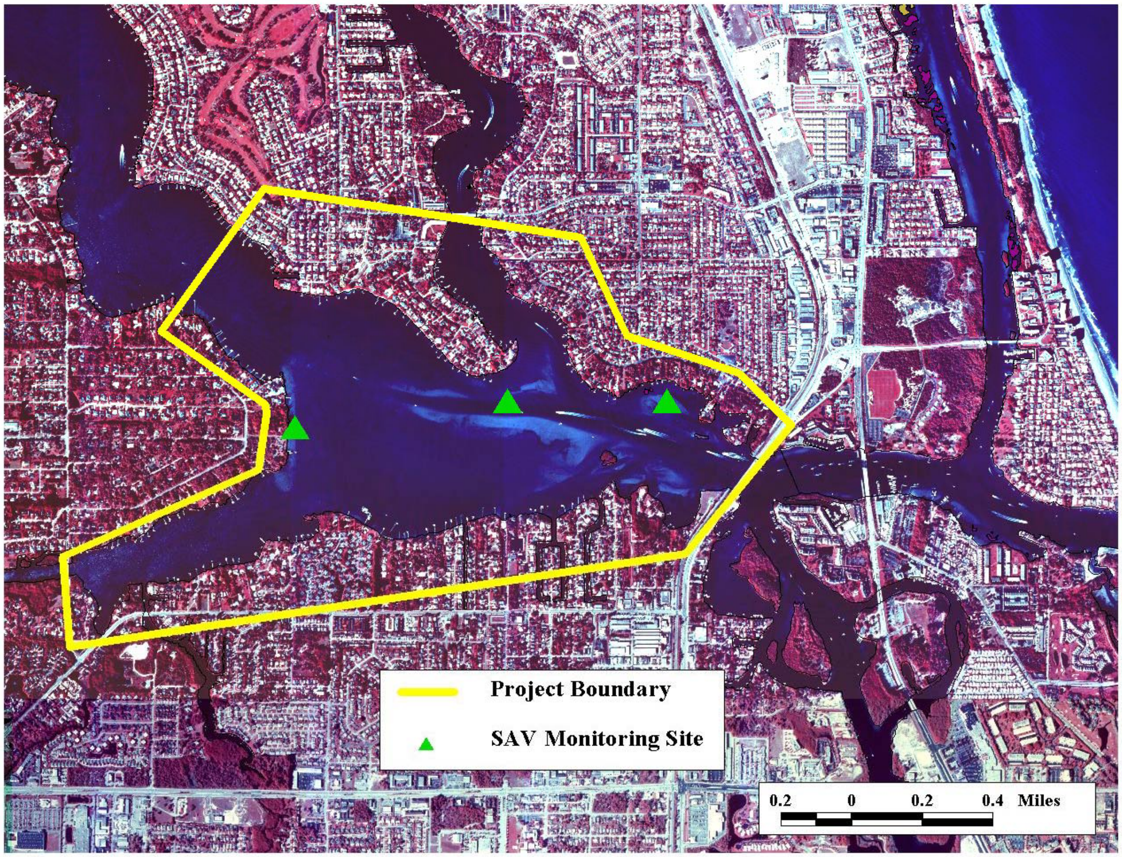


Figure 12-15. Aerial photograph indicating location of seagrass monitoring stations in the Loxahatchee Estuary.

Figure 12-16. Map of 2003 seagrass coverage in the Loxahatchee Estuary prepared through photointerpretation of aerial photography.

Loxahatchee Estuary Oyster Monitoring

The LRD and SFWMD are working cooperatively to assess the oyster resources in the Loxahatchee Estuary to help evaluate potential impacts of proposed upstream restoration efforts on estuarine communities. As a first step in this effort, the LRD mapped live oysters during 2003. Live oyster bars were found in the Northwest Fork (9.5 acres) and Southwest Fork (0.74 acres), but not in the North Fork or Central Embayment. The maps resulting from the 2003 oyster mapping project are provided in **Figures 12-17** through **12-19**.

Salinity Monitoring

Through an agreement with the USGS, the SFWMD is able to monitor salinities at RM 8.2 and RM 9.1 to measure compliance with the Minimum Flow Rule, and to assess the benefits of additional dry season flows in terms of salinities in the Northwest Fork.

The Minimum Flow Rule establishes a minimum flow of 35 cfs over the Lainhart Dam to the Northwest Fork of the Loxahatchee River during the dry season. It is anticipated that salinity will be lower than 2 ppt at RM 9.1, if all the projects (G-160 and G-161) that will allow the District to deliver the minimum flow are constructed. Currently, G-160 has been constructed and G-161 is being detailed as part of the design stage.

Preliminary 2003 data, which is provisional and subject to revision, indicates that the peak average daily flow at the Lainhart Dam was 264 cfs on November 6, 2003. The daily average flow at the Lainhart Dam fell below 35 cfs for six days from May 16–21, 2003; for 29 days from July 8, 2003–August 5, 2003; for eight days from March 9–16, 2004; and for 44 days between March 18, 2004–April 30, 2004. Salinities at Kitching Creek (RM 8.2) generally exceeded 1 ppt during WY2004, except for a decrease in late February 2004.

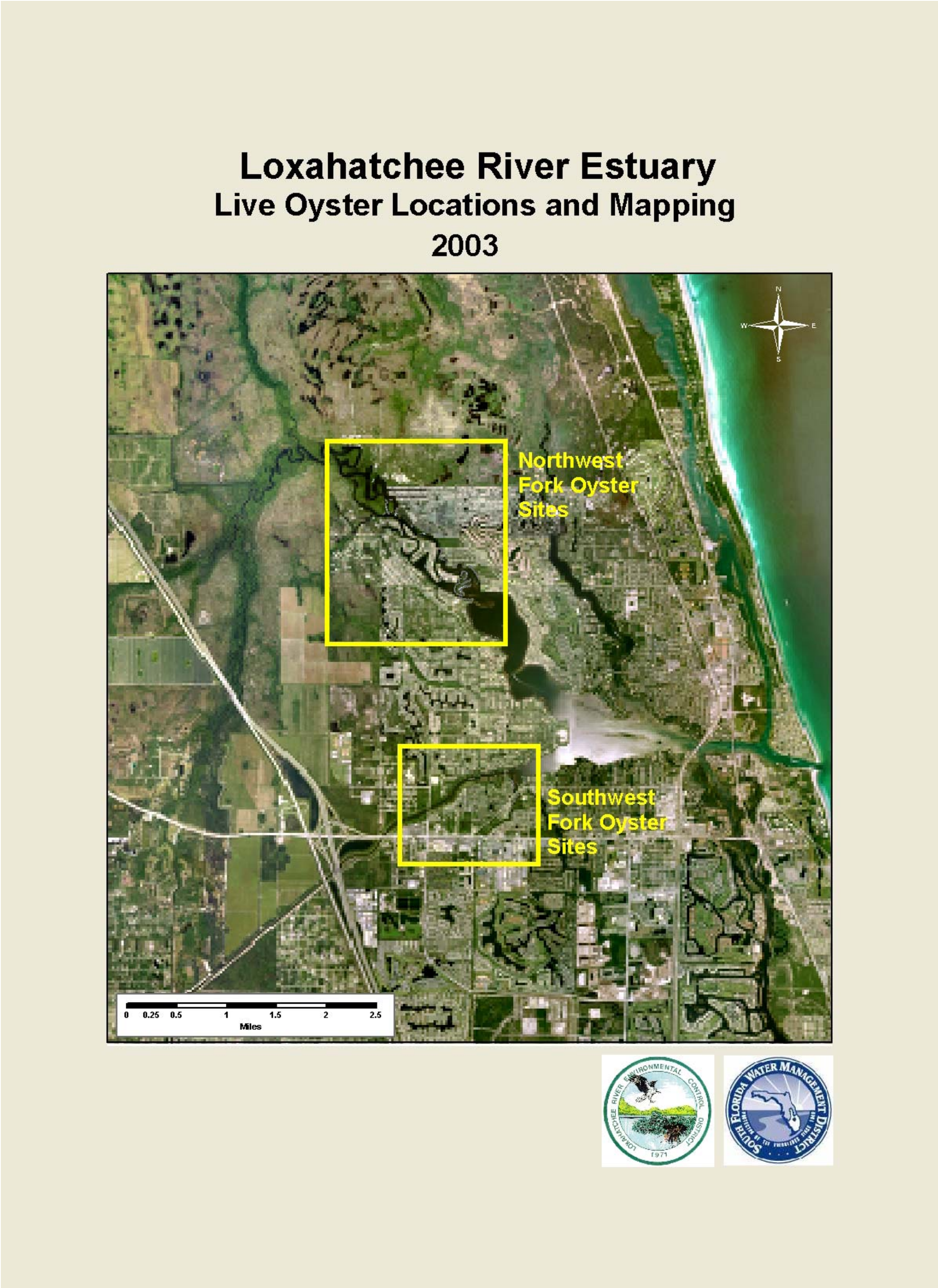


Figure 12-17. Loxahatchee Estuary live oyster locations.

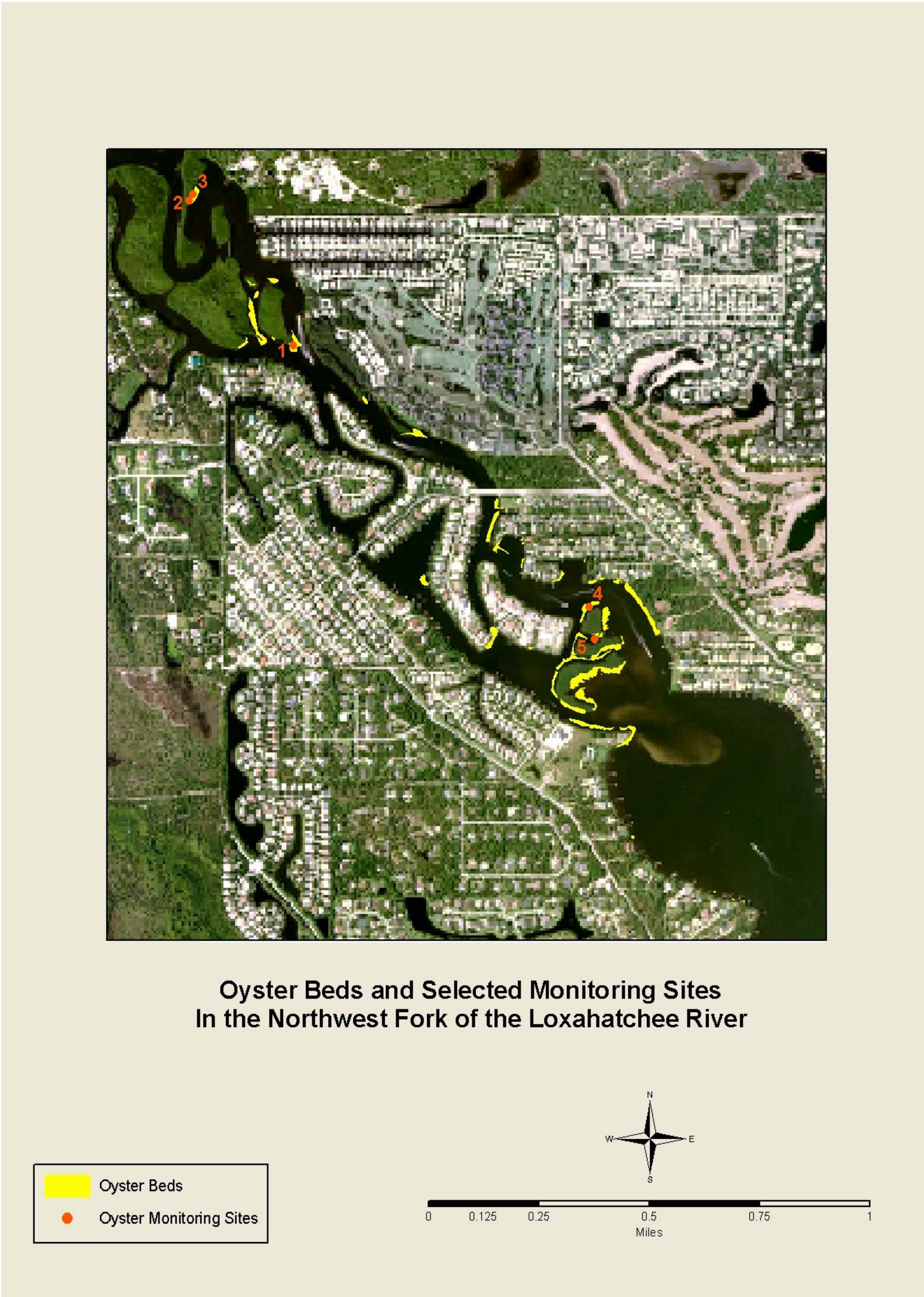


Figure 12-18. Live oyster beds in the Northwest Fork of the Loxahatchee Estuary.

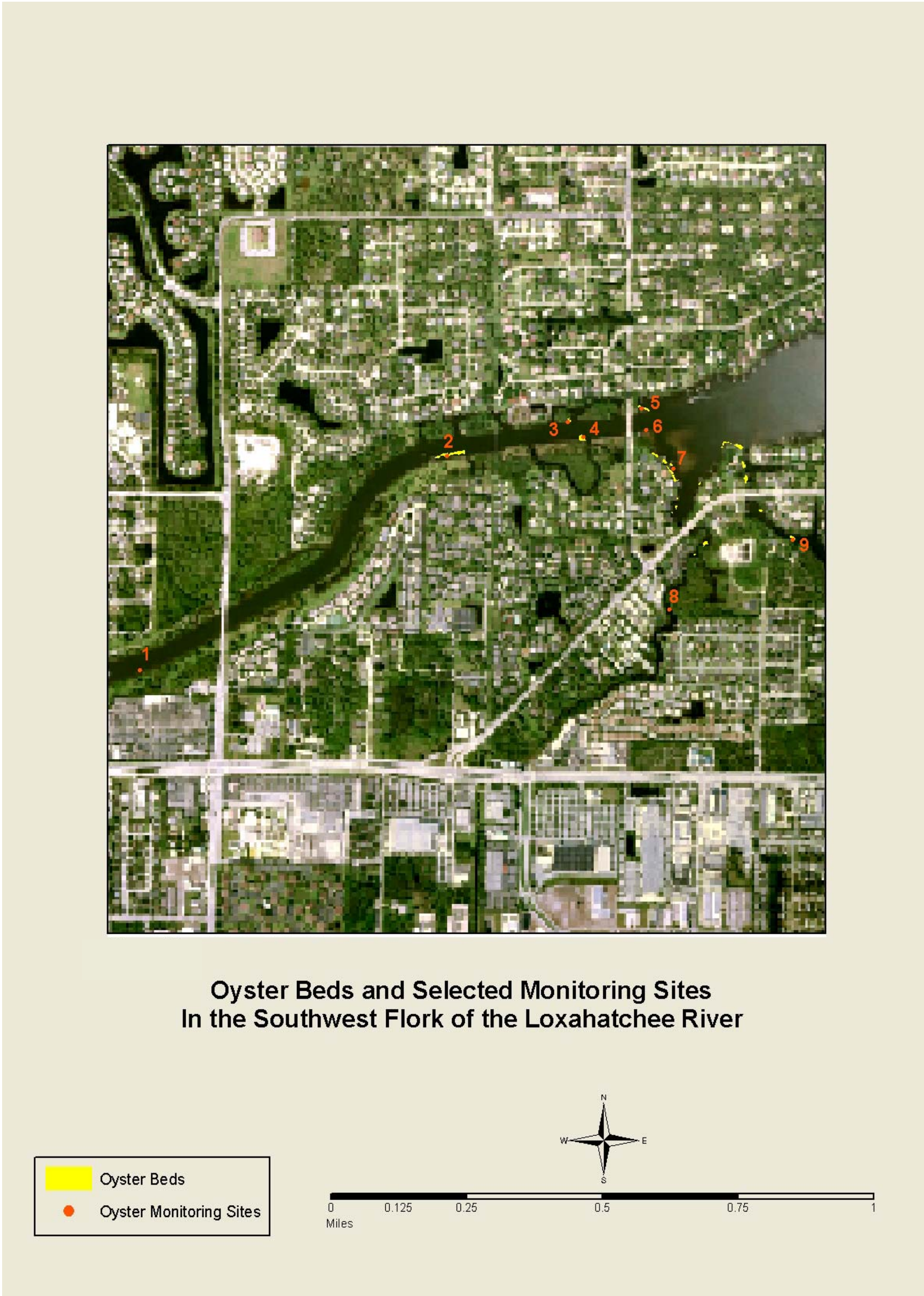


Figure 12-19. Live oyster beds in the South Fork of the Loxahatchee Estuary.

Modeling of Saltwater Intrusion in the Northwest Fork Loxahatchee River

A two-dimensional (2-D) hydrodynamic/salinity model was developed to study the influence of freshwater input on the salinity conditions in the river and estuary (**Figure 12-20**). The model was applied to scenarios with varying amounts of freshwater inflow. Both the field data and model simulation indicated that there is a strong correlation between freshwater inflow and the salinity regime in the estuary. Based on model output and field data analysis, a relationship was developed to predict salinity at various points in the estuary with respect to freshwater inflow rates and tidal fluctuations. The salinity/freshwater relationship was applied in the Loxahatchee River MFLs study (SFWMD, 2002). The model also provided a preliminary assessment of the impacts that inlet deepening and sea level rise have had on the salinity regime in the estuary.

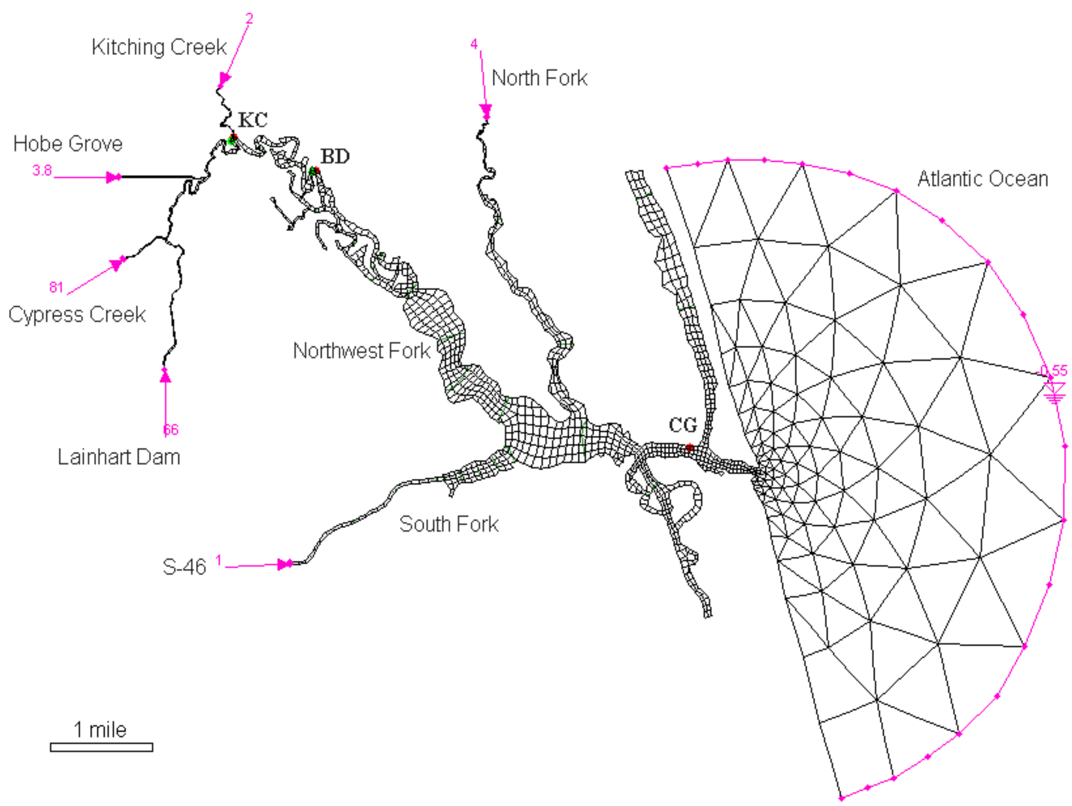


Figure 12-20. Domain map of Loxahatchee hydrodynamics/salinity model.

In parallel with the preliminary model setup, a data collection program was implemented. A bathymetric survey was conducted in Northwest Fork and North Fork in early 2003. Two flow gauges were established on Cypress Creek and Hobe Grove Ditch in November 2002. Combined with flow gauges that were previously established at the Lainhart Dam on the upper Northwest Fork and Kitching Creek, the four gauges monitor a majority of freshwater input to the Northwest Fork, which has been the focus of the salinity study. Four tide and salinity stations have been deployed in the estuary since November 2002. An additional tide/salinity gauge was installed in October 2003. For current velocity measurements, two bottom-mount Acoustic Doppler Current Profiler (ADCP) units have been deployed at various locations through out the estuary in 2003.

The 2-D estuary model was updated in late 2003 using the new bathymetry and freshwater inflow data. The updated model was tested against tide, salinity, and velocity data collected during the period from May through August 2003. The salinity/freshwater input relationship was revised and extended to include a wider range in the amount of freshwater inflow. Tide and salinity data collected from three stations were used in the model testing. The locations of the three verification stations are marked in the model domain map (see **Figure 12-20**) as Coastguard Station (CG), Boy Scout Dock Station (BD), and Kitching Creek Station (KC).

The SFWMD has adopted a phased, proactive approach in the Loxahatchee Estuary modeling study. While the existing 2-D computer model is being applied in restoration efforts to meet the immediate project needs, the next phase of Loxahatchee Estuary modeling has begun. A 3-D model is being calibrated and verified against newly acquired field data. When model verification is completed, the model will be applied for a preliminary feasibility study to assess the effectiveness of a saltwater barrier for salinity control in the Northwest Fork Loxahatchee River.

An important factor that has not been fully addressed by the previous data collection and modeling projects in the Loxahatchee Estuary is the effect of groundwater. The SFWMD has developed a work plan for an integrated model that will simulate both surface water and groundwater, and their interaction on the floodplain. A groundwater monitoring and data collection network was established in mid 2003. The network has produced information that will lead to further understanding of how groundwater affects the system. The data collected by the network will also provide field data for the calibration of the Loxahatchee River Integrated Surface/Groundwater Model. This model is currently being developed by the SFWMD, FDEP, and the University of South Florida to predict salinity levels in the river and floodplain, as well as to determine the floodplain hydroperiod.

DISTRICT MANAGEMENT PLANS AND IMPLEMENTATION ACTIVITIES

Several plans have been developed and are being implemented to improve and protect the water quality and quantity, timing, and distribution in the Loxahatchee River watershed, as summarized below.

Restoration Plan for the Northwest Fork of the Loxahatchee River

Over the past several years, plans have been developed by the SFWMD (both individual agency plans and plans in partnership with other agencies) for the Loxahatchee watershed. The Restoration Plan for the Northwest Fork of the Loxahatchee River was undertaken in 2004, and the first draft is currently expected to be issued in fall 2004. The purpose of this plan is to (1) provide an assessment of the ecological health of the freshwater (or riverine) and saline (or estuarine) segments of the Northwest Fork; (2) establish current conditions; and (3) identify restoration scenarios for this unique and important riverine system.

Minimum Flows and Levels Rule

Minimum Flows and Levels (MFLs) criteria for the Northwest Fork of the Loxahatchee River were developed to protect the remaining floodplain swamp community and downstream estuarine resources against significant harm [MFL Rule, Chapter 40E-8, Florida Administrative Code (F.A.C.]. This rule can be found on the District's Website at http://www.sfwmd.gov/org/wsd/mfl/loxmfl/index.html. Adopted in April 2003, the minimum flow is defined as "the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area." (SFWMD, 2002). More specifically, the criterion for the determination of an MFL violation is as follows:

> An MFL violation occurs within the Northwest Fork of the Loxahatchee River when an exceedance of the minimum flow criteria occurs more than once every six years. An "exceedance" is defined as when Lainhart Dam flows to the Northwest Fork of the river decline below 35 cfs for more than 20 consecutive days within any given calendar year.

Upon the adoption of the rule, it was recognized that the District would be unable to meet the specified MFL. Therefore, as required by the legislation, a recovery strategy was incorporated into the rule, which includes construction of the Northern Palm Beach County Comprehensive Water Management Plan (Northern Plan) projects, development of a restoration plan for the Northwest Fork, and adoption of a water reservation for the Northwest Fork of the Loxahatchee River.

Northern Palm Beach County Comprehensive Water Management Plan

The Northern Palm Beach County Comprehensive Water Management Plan (known as the Northern Plan) was accepted by the SFWMD governing board in May 2002, and can be found at the District's Website at http://www.sfwmd.gov/org/wsd/nPalm Beach Countywmp. The subregional Northern Plan focused on the southern L-8 basin, the City of West Palm Beach Water Catchment Area (or Grassy Waters Preserve), C-18, the Loxahatchee slough, and the Loxahatchee River, especially the Northwest Fork. The plan projects future water supplies for urban, agricultural, and environmental uses for 2020, and identifies projects that will bring supplemental water into the area upon completion.

The Northern Plan calls for a series of system improvements to be constructed to provide the projected 2020 public water supply demands of the area, hydrologic restoration of the Loxahatchee slough, and protection of the Grassy Waters Preserve and a target base flow of 65 cubic feet per second (cfs) to the Northwest Fork of the Loxahatchee River over the Lainhart Dam. The primary improvements include the following:

1. M Canal widening will be able to convey up to 400 cfs from a proposed reservoir to the Grassy Waters Preserve upon completion.

2. Loxahatchee slough structure, or G-160, will maintain an improved hydroperiod for the Loxahatchee slough and will convey minimum flows and restoration flows to the Northwest

Fork of the Loxahatchee River from the regional system. Construction of the G-160 structure was completed in January 2004.

3. Northlake Boulevard structure, or G-161, will reestablish linkage of the Grassy Waters Preserve with the Loxahatchee slough and the C-18 canal. Design of the G-161, Northlake Boulevard structure was initiated in 2004, and construction is expected to be completed 2005.

4. Regional reservoir storage with a minimum capacity of 48,000 ac-ft was recommended in the Northern Plan. A reservoir is being established at the Palm Beach Aggregates site in the southern L-8 basin. It was increased to 47,000 ac-ft in 2004, with additional storage to be acquired in the future.

This plan forms the basis for the North Palm Beach County CERP Project – Part 1, which is summarized below.

North Palm Beach County Comprehensive Everglades Restoration Plan Project – Part 1

The overall purpose of the North Palm Beach County CERP Project – Part 1 is to (1) increase water supplies to the Grassy Waters Preserve and Loxahatchee Slough; (2) provide flows to enhance hydroperiods in the Loxahatchee Slough; (3) increase base flows to the Northwest Fork of the Loxahatchee River; and (4) reduce high discharges to the Lake Worth Lagoon (LWL) and Loxahatchee Estuary. This project includes six separable elements: (1) Pal-Mar and J.W. Corbett Wildlife Management Area Hydropattern Restoration; (2) L-8 basin modifications; (3) C-51 and L-8 reservoirs; (4) LWL restoration; (5) C-17 pumping and treatment; and (6) C-51 pumping and treatment. These individual elements have been combined into a single project to address the interdependencies and tradeoffs between the different elements and to provide a more efficient and effective design for the overall project. Further details on this project can be found at http://www.evergladesplan.org/pm/projects/proj_17_nPalm Beach County_1.cfm.

Loxahatchee River National Wild and Scenic River Management Plan

In May 1985, a 7.5-mile pristine portion of the Northwest Fork of the Loxahatchee River was designated by the U. S. Department of the Interior for inclusion in the Wild and Scenic Rivers System, following its designation by the state of Florida as a Wild and Scenic River in 1983 (Chapter 830358, Laws of Florida). An outcome of the state and federal government actions was development and adoption of the Loxahatchee River National Wild and Scenic River Management Plan. The plan ensured that special consideration would be given to the watershed surrounding the river corridor, to protect and maintain natural flow conditions, good water quality, and high quality natural areas. Further details on this plan are presented online at http://www.riverfirst.com.

Loxahatchee River Preservation Initiative

The Loxahatchee River Preservation Initiative (LRPI) is an outgrowth of the 2002 Loxahatchee River Watershed Action Plan that was spearheaded by the FDEP Southeast District Office (FDEP-SED). A subcommittee representing local governments and other agencies formed the LRPI to coordinate state legislative funding requests for local projects, on a 50/50 cost-share basis, that are part of the "Action Plan" and contribute to the protection, restoration, and long-term health of the Loxahatchee River (see **Table 12-5**). Further details on this initiative can be found online at http://www.lrpi.org.

Table 12-5. A summary of projects that were appropriated ($2.5 million) during WY2003–WY2004 by the Florida legislature.

Local Government	**Project**
Town of Jupiter	Jones Creek Restoration
Palm Beach County	Loxahatchee Slough Restoration
Martin County	Kitching Creek/Flora Avenue Restoration
Jonathan Dickinson State Park	Habitat restoration within the corridor of the Northwest Fork of the Loxahatchee River
Palm Beach County	Riverbend Park Flow-way and Slough Restoration
Jonathan Dickinson State Park	Replacement of existing septic tanks with central wastewater collection and treatment to irrigation quality standards by the Loxahatchee River District

LAKE WORTH LAGOON

The Lake Worth Lagoon (LWL) extends for approximately 20 miles in central Palm Beach County, Florida (**Figure 12-21**). Lake Worth Creek, Little Lake Worth, Lake Worth Cove, and Mangrove Lagoon (i.e., the J.D. MacArthur Beach State Recreation Area) border the northern end of the LWL in North Palm Beach. The southern end of the LWL drastically narrows at Boynton Beach and Ocean Ridge, and the Atlantic Intracoastal Waterway channel runs the entire length of the lagoon. The LWL is typically 6 to 10 feet in depth.

The LWL watershed is highly urbanized, and encompasses over 450 square miles that ultimately drain to the North Lake Worth (Palm Beach) Inlet and South Lake Worth (Boynton) Inlet. This watershed includes the communities of North Palm Beach, Lake Park, Riviera Beach, Magnolia Park, Palm Beach Shores, West Palm Beach, Palm Beach, South Palm Beach, Lake Worth, Lantana, Hypoluxo, Manalapan, Boynton Beach, and Ocean Ridge. The lagoon was historically a freshwater lake with occasional brackish conditions caused by temporary inlets created by storms or high water conditions. However, it was rapidly converted to a marine environment by the early 1900s with the opening of permanent inlets. The current Palm Beach Inlet was dredged between 1918 and 1925. The Boynton Inlet was dredged in 1925.

Similar to many of South Florida's heavily urbanized coastal areas, the Lake Worth Lagoon has been negatively impacted by anthropogenic changes. Significant loss of wetlands, shoreline vegetation, seagrasses, and substrate habitat, coupled with increased watershed imperviousness, redirection of historical runoff, and significant increases in stormwater discharges, have all contributed to deteriorated habitat and impaired ecosystem function. Currently, the LWL receives too much runoff in the wet season and fewer freshwater discharges during the dry season, and it is subjected to extreme salinity fluctuations and high levels of turbidity and sedimentation. Accumulation of muck deposits have contributed to sediment up to several feet thick in some areas, creating an unnatural anaerobic substrate devoid of invertebrates and seagrasses. In addition, there is a continuing concern over the levels of nutrients, toxic substances, and pathogenic bacteria.

The lagoon is primarily polyhaline (18–30 ppt) in its interior, while waters near the inlets are generally euhaline (30–49 ppt). Sources of water include the Atlantic Ocean, watershed runoff from primary and secondary canal systems, and precipitation. The major sources of fresh water are the C-17 canal (Earman River), C-51 canal (West Palm Beach Canal), and the C-16 canal (Boynton Canal). The C-51 canal contributes approximately 50 percent of the fresh water that reaches the lagoon, with 75 percent of the flow northward and 25 percent southward (Chui et al., 1970).

The SFWMD coordinates research and management activities with the lead agencies for LWL habitat management and restoration, Palm Beach County Department of Environmental Resources Management, and the FDEP. Additional information concerning environmental enhancement and restoration activities for the LWL can be found on Palm Beach County's and FDEP's Website at http://www.co.palm-beach.fl.us/erm/enhancement/lwlagoon.asp and at http://www.dep.state.fl.us/southeast/envaffairs/EMAs/lakeworth/lakeworth.htm, respectively.

Figure 12-21. Geographic location of the Lake Worth Lagoon.

The LWL Management Plan currently focuses on the need for watershed management and improved habitat restoration in the lagoon in order to attain and maintain water and sediment quality that support the integrity of the ecosystem. In addition, this plan addresses the need for continued planning, regulation, local stormwater improvement projects, and increased public education and awareness. Further details on this plan can be found on Palm Beach County's Website at http://www.co.palm-beach.fl.us/erm/enhancement/lwlagoon.asp.

The SFWMD is currently addressing the impacts of freshwater discharges to the LWL through a variety of both short- and long-term activities. Cooperative efforts involve modeling, monitoring, planning, and construction projects. A major goal of these efforts is to manage freshwater inflows in a manner that will improve water quality and to provide for salinity regimes favorable to habitat reestablishment and sustainability. To date, the state has appropriated $9.5 million to the LWL Management Plan, with additional significant contributions from key partners. The LWL Partnership Grant has funded 32 restoration projects, at a total project cost of over $34 million. This includes matching funds contributed by each entity in the partnership. The projects funded include stormwater retrofitting, sewage pump-out stations, artificial reefs, habitat restoration, and sewage connection systems for septic tank communities.

Because much of the development with the LWL watershed occurred prior to the advent of stormwater regulations, untreated stormwater (non-point source pollution) from many surrounding areas runs directly into the lagoon or its tributaries, adversely impacting water quality. Only 19 percent of the lagoon's shoreline remains fringed by mangroves, and approximately 65 percent of the shoreline is bulkheaded. While implementation of the LWL Management Plan will assist in water quality improvement, the currently funded activities are not anticipated to be enough to improve the net future condition of the LWL. Net pollution loads, especially from non-point sources, are expected to increase as a result of continuing population growth and development. The FDEP has determined under the TMDL Program that canal freshwater discharges have led to the impairment of the LWL. However, because this impairment is not due to the introduction of a pollutant, the FDEP has not listed the LWL on the 303 (d) list of impaired water bodies. In the near future, it is anticipated that the existing level of water quality monitoring will continue and resource trends and conditions will be assessed periodically.

The SFWMD also has been working with Palm Beach County to develop and apply an integrated 3-D circulation model of the LWL to analyze flows from canal discharge, rainfall, runoff, groundwater inflows, and tidal influences.

The SFWMD, in cooperation with the FDEP and Palm Beach County, are continuing data collection and water quality monitoring efforts. The SFWMD has a cooperative agreement with the county to collect monthly water quality samples at six locations in the LWL. In addition, the SFWMD participates in the LWL Partnership Grant Program, and supports lagoon outreach activities.

The CERP North Palm Beach County – Part 1 Project is 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 7 of the 2005 SFER – Volume I). Additional evaluations are focused on removal or trapping of existing sediment deposits in the lagoon downstream of the S-155 structure. Further information on this project is presented online at http://www.evergladesplan.org/pm/projects/proj_17_nPalm_Beach_County_1.cfm. Additional information regarding the CERP is presented in Chapter 2 of the 2005 SFER – Volume II.

The Restoration Coordination and Verification (RECOVER) team has included the LWL in the Monitoring and Assessment Plan (MAP) to prioritize monitoring components and long-term assessment needs (http://www.evergladesplan.org/pm/recover/recover_map_2004.cfm). Additional information regarding RECOVER is presented in Chapter 7 of the 2005 SFER – Volume I.

Another project under way that will enhance future freshwater flow into LWL includes the L-8 basin General Reevaluation Report (GRR). This project will develop recommendations for implementing improved facilities and conveyance systems in the L-8 basin that will result in more effective water delivery to the lagoon.

Recently completed construction projects that will have a significant influence on the LWL include the S-155A drainage divide structure. This structure will raise the control elevation to the west, thereby reducing discharge to the eastern portion of the C-51 basin. Stormwater Treatment Area 1 East (STA-1E) and an associated pump station will capture stormwater discharges from portions of the southern L-8 and western C-51 basins. Operation of these facilities will capture and redirect a large volume of the flows now being discharged to the east and received by the lagoon.

BISCAYNE BAY

INTRODUCTION

Biscayne Bay is a large, shallow subtropical estuary located along the eastern shoreline of Miami-Dade County, directly adjacent or in close proximity to highly urbanized coastal areas (**Figure 12-22**). Several miles off the coast on the east side of the bay, there are a number of narrow offshore barrier islands. Much of the bay is designated by the state as an Aquatic Preserve, and Biscayne National Park encompasses a large portion of the central and south area.

Historically the Everglades, Florida Bay, and Biscayne Bay were part of a larger hydrologically connected natural system of coastal lagoons and wetlands in which Biscayne Bay served as the eastern hydrologic outlet of the Everglades. Fresh water flowed overland from the Everglades to the bay through natural sloughs and rivers and as groundwater through the Biscayne Aquifer. During the last century, this pattern has been altered by regional drainage, canal construction and operation, and urban development, as well as by construction of roads, levees, and other hydrologic barriers to surface flow. Based upon these alterations, the bay currently receives freshwater inflow from canal flows, minor overland flows, and groundwater.

Biscayne Bay varies considerably in a variety of physical characteristics, including width, depth, water quality, and degree of connection to the open marine waters of the Atlantic Ocean. The bay varies in width from being extremely narrow in the most northerly reaches to over 9 miles wide in the south-central areas. Water depths vary from less than 1 foot in intertidal shoreline areas, to over 40 feet in dredged navigation channels. In general, water quality within the bay varies from poor in deep areas that are subjected to heavy pollutant loading and little mixing, to good in the east-central areas where there is little overland pollution and high exchange with marine waters. Biscayne Bay surface waters are directly connected with open marine waters in some central and south-central bay areas and are connected via a series of natural, human-made and/or human-enhanced inlets at other locations where there are barrier islands. As a result of these varying conditions, flora and fauna species and ecological communities vary considerably throughout the bay.

The following section briefly describes the District's current Biscayne Bay projects and efforts, which includes MFLs, bay environmental restoration associated with CERP, land acquisition, stormwater improvements, the Miami River Commission, state of Florida legislative special appropriations projects, and water quality. Additional information on Biscayne Bay can also be found online at http://www.DiscoverBiscayneBay.org.

BISCAYNE BAY MINIMUM FLOWS AND LEVELS

MFL criteria are being developed for Biscayne Bay. Separate criteria will be developed for different subregions of Biscayne Bay because of varying ecological needs, physical constraints, and specific resources of those subregions. Currently, criteria development is in progress for the south-central area of the bay, which is associated with a watershed that includes the Cutler Drain (C-100), Black Creek (C-1), Princeton Canal (C-102), and Mowry Canal (C-103) drainage basins. Technical criteria for the south-central area of the bay are currently scheduled for completion in 2004.

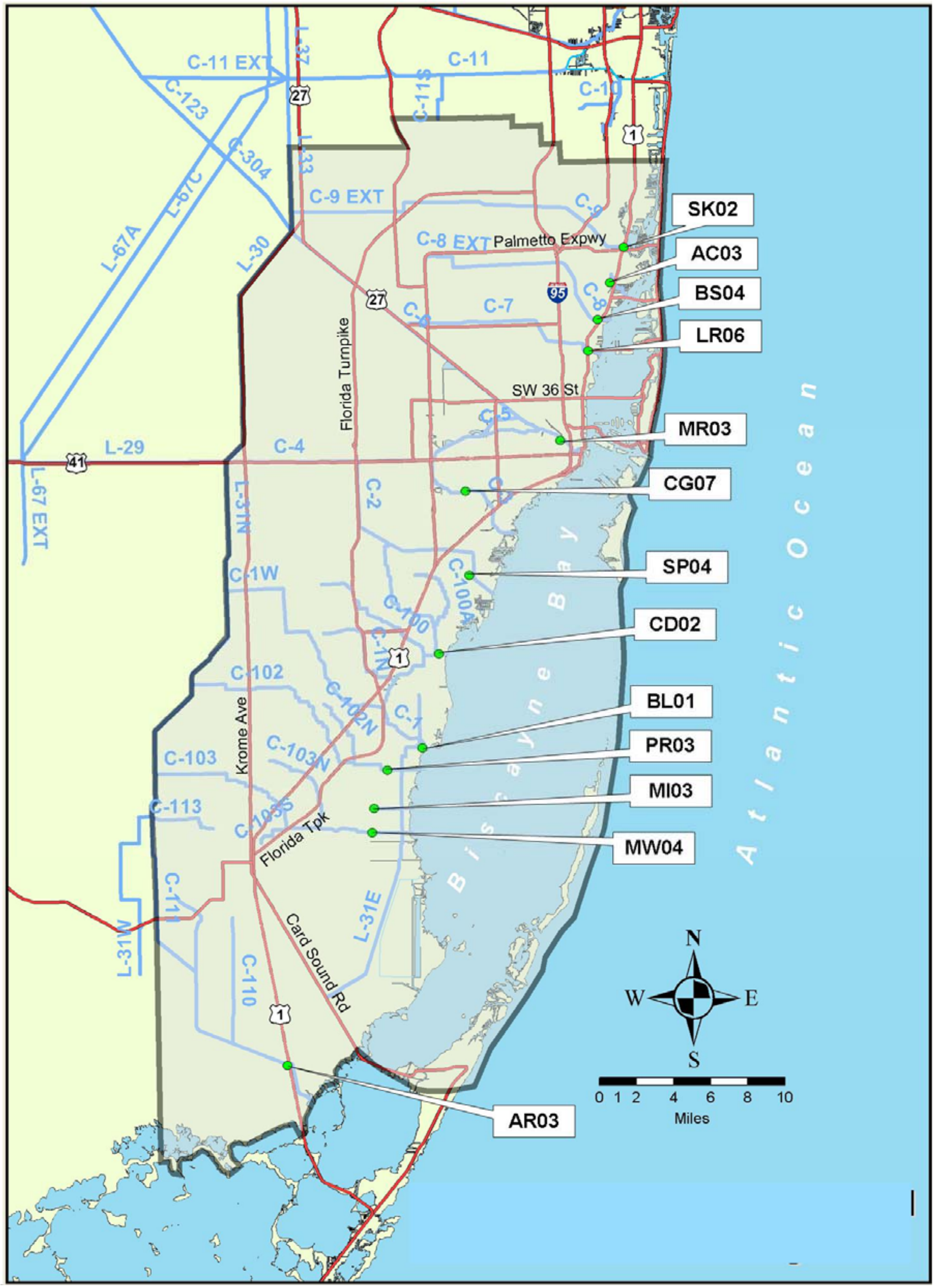


Figure 12-22. Location of tributary water quality monitoring stations in Biscayne Bay, as described in **Table 12-6**.

In 2005, it is expected that MFL criteria will be developed for some of the remaining northern, central and southern areas that includes the Snake Creek (C-9), Biscayne Canal (C-8), Little River Canal (C-7), the Miami River (C-6), Comfort Canal (C-5), Tamiami Canal (C-4), Coral Gables Canal (C-3), Snapper Creek (C-2), and Aerojet Canal (C-111) drainage basins.

SALINITY PATTERNS

Salinity in southern Biscayne Bay is being studied to better understand its relationship to climate and watershed hydrology. Understanding these relationships is necessary to formulate the performance criteria or targets used for the CERP project performance (see Chapter 2 of the 2005 SFER – Volume II), the resource status needed by RECOVER (see Chapter 7 of the 2005 SFER – Volume I), and MFLs. For example, the total quantity of freshwater inflows to Biscayne Bay is generally influenced by antecedent rainfall, storage capacity in the watershed, tide stage, and canal system operations. One of the primary tools utilized to predict salinity patterns in Biscayne Bay under various conditions is the TABS-MDS model (**Figure 12-23**) that was developed by the USACE Coastal and Hydraulics Laboratory. The District has applied this model in southern Biscayne Bay in combination with output from the South Florida Water Management Model (SFWWM). Salinity in Biscayne Bay lags freshwater inputs, and is less variable (**Figure 12-24**). Freshwater inflows typically reach a minimum, and salinity typically reaches a maximum, during April for each year.

COMPREHENSIVE EVERGLADES RESTORATION PLAN BISCAYNE BAY COASTAL WETLANDS PROJECT

The primary ecosystem restoration project for Biscayne Bay is the CERP Biscayne Bay Coastal Wetlands Project (BBCW). This project is currently in the planning phase, and construction is anticipated to begin in 2006. Additional information on this project can be found on CERP's Website at http://www.evergladesplan.org/pm/projects/docs_28_biscayne_bay.cfm. The primary purpose of this project is to redistribute freshwater runoff to Biscayne Bay in a more natural way. The project will seek to restore some of the creek system in the coastal wetlands, improve hydroperiods in low-lying wetlands near the bay, and partially compensate for the reduction in groundwater seepage to the bay by increasing managed water stages. The proposed improvements are expected to restore or enhance freshwater wetlands, tidal wetlands, and near-shore bay habitat.

COMPREHENSIVE EVERGLADES RESTORATION PLAN WASTEWATER REUSE TECHNOLOGY PILOT PROJECT

The Wastewater Reuse Technology Pilot Project is a component of CERP. This pilot project includes the design, construction, and operation of a pilot wastewater reuse plant in Miami-Dade County at or near the existing South Dade Wastewater Treatment Plant. As part of the project design, the feasibility of using up to 150 million gallons per day of highly treated wastewater effluent to rehydrate nearby degraded freshwater and coastal wetlands will be investigated. The ultimate receiving water for the wastewater effluent will be south-central Biscayne Bay, within Biscayne National Park, which is designated by the state as an Outstanding Florida Water. Additional information on this project can be found on CERP's Website at http://www.evergladesplan.org/pm/projects/docs_37_wastewater_pilot.cfm.

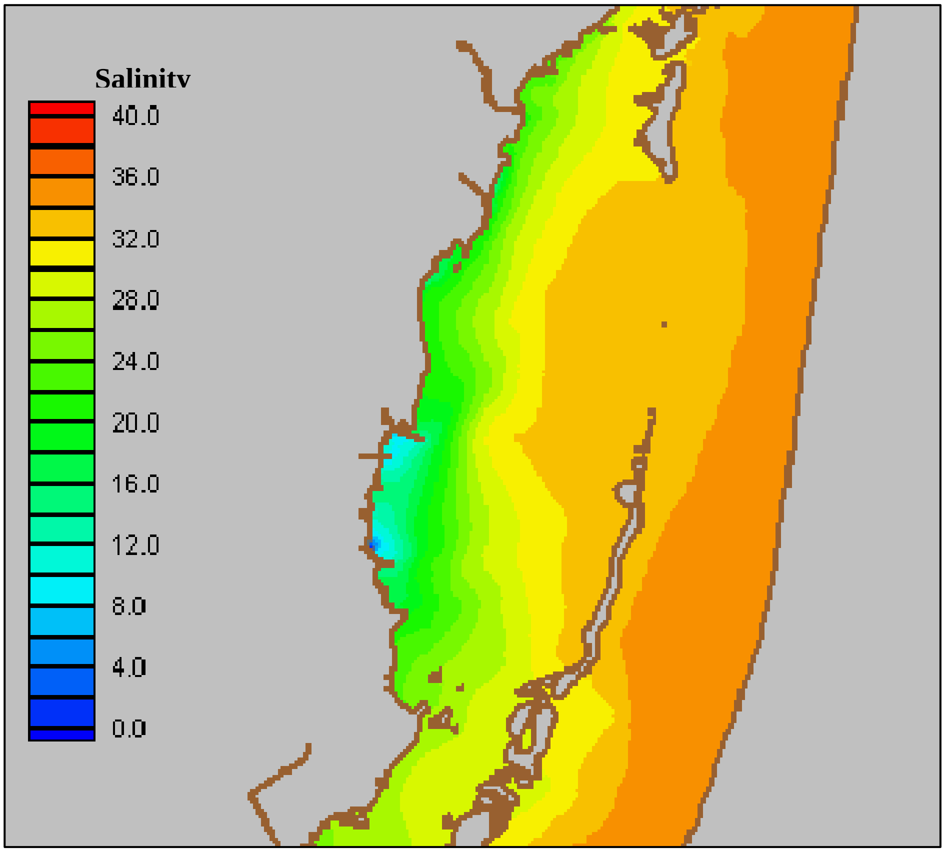


Figure 12-23. Isohalines produced by the TABS-MDS model in southern Biscayne Bay in an average wet season based on the South Florida Water Management Model (SFWMM) 2000 base 1 watershed simulation.

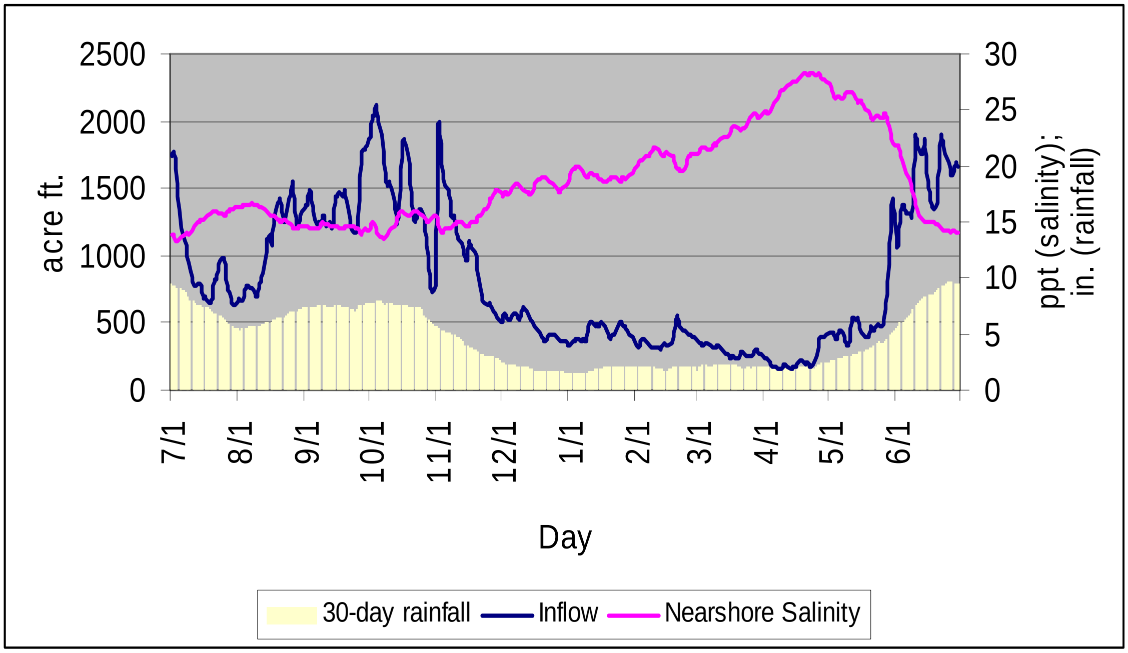


Figure 12-24. Average daily near-shore salinity, as simulated by the TABS-MDS model at 12 nodes along the shoreline in south central Biscayne Bay. Rainfall and freshwater inflows are from the SFWMM 2000 base 1 simulation. Rainfall is total number of inches over the preceding 30-day period.

The goals of the Wastewater Reuse Technology Pilot Project are to (1) identify advanced water treatment technologies that will produce reclaimed water that will not have adverse effects on natural systems (including freshwater and estuarine wetlands and Biscayne Bay), or human health; and (2) identify constituents of concern that are present in the wastewater, and investigate the ability of advances in water treatment technologies for their removal. The water quality treatment specifications for the selection of the advanced water treatment technologies will be based upon the non-degradation requirement criteria established for discharge to an Outstanding Florida Water.

LAND ACQUISITION

For Fiscal Year 2002 (FY2002), the Florida legislature appropriated \$3.5 million for the District to acquire lands in Miami-Dade County that will benefit or assist in the protection and restoration of Biscayne Bay. The District has expended these funds by acquiring land parcels in the south-central area of the county, near the eastern shoreline, that will be utilized for the CERP Biscayne Bay Coastal Wetlands Project.

Recognizing Biscayne Bay land acquisition as an important element for Biscayne Bay protection and restoration, and specifically for the Biscayne Bay Coastal Wetlands project, the District's C-111N canal project, and Model Lands Save Our Rivers projects, the District will be entering into a Memorandum of Understanding (MOU) with Miami-Dade County that commits \$24 million (\$12 million provided by each agency) for purchasing lands that will benefit Biscayne Bay through these projects.

MIAMI-DADE COUNTY STORMWATER RETROFIT PROJECTS

Rapid urbanization of the Biscayne Bay watershed areas within Miami-Dade County has resulted in increased stormwater runoff. The effects of this trend include flooding, reduced infiltration of water into the ground, and an increased level of non-point source pollution. Through implementation of stormwater management system improvements by municipalities, improvements in water quality and reduced quantities of stormwater runoff are being achieved.

The District is working with the local municipalities in the Biscayne Bay watershed area to provide funding and technical guidance, as needed, to improve their stormwater management systems. As a first step, municipalities are encouraged to develop and implement stormwater management master plans. These plans are in various stages of development for the primary basins within unincorporated Miami-Dade County, and for many of the incorporated areas. The plans include detailed analysis and storm event modeling, and result in identifying a prioritized list of stormwater management system upgrades. Approximately \$7 million in state funding administered through the District is being applied to Master Plan development. The District is also participating as one of three lead agencies in the South Miami-Dade Watershed Study and Plan (see the *Biscayne Bay Legislative Special Appropriations Projects* section of this chapter), a land-use planning study for 2025 and 2050, with an emphasis on preserving Biscayne National Park values and a sustainable south Miami-Dade County.

Designing and implementing stormwater management system upgrades comprise the second step of the effort to improve water quality and reduce stormwater runoff. The District is administering over 25 agreements with local municipalities in the Biscayne Bay watershed for infrastructure and canal system improvements. These projects involve approximately \$24 million in state funding support in recent years for stormwater management system improvements affecting the Biscayne Bay watershed.

MIAMI RIVER COMMISSION

The District continues its support of the Miami River Commission and its action plan, The Miami River: A Call to Action, through District governing board member participation on the commission, co-chairing of the Stormwater Subcommittee, and membership in the Stormwater and Miami River Dredging Subcommittees, found online at http://www.miamirivercommission.org/commission.htm.

In the STAs, the District provides a key role in pursuing further improvements in stormwater management affecting both the Miami River and Wagner Creek. Funding and technical support is being provided to further identify and correct pollution sources into the Wagner Creek tributary to the Miami River. The District is providing over $50,000 to identify possible locations or small areas to test for possible illegal connections of sanitary sewer lines to the stormwater collection system in four sub-basins of the Wagner Creek watershed. Additionally, $1 million has been authorized to the City of Miami to fund a portion of the dredging of Wagner Creek to remove and properly dispose of contaminated sediments. The District is encouraging the City of Miami to continue to pursue stormwater management system upgrades in the Miami River watershed, such as the Pinehurst area, which is receiving $450,000 in funding assistance, and including the addition of solid waste interceptors along the Miami River.

To support the Miami River Dredging Project, the District, on behalf of Miami-Dade County and the City of Miami, applied for a Cooperative Assistance Program Grant from the Florida Inland Navigation District (FIND) in the amount of $6 million over three fiscal years to help fund the local cost-share portion of the Miami River Dredging Project. The District is actively engaged with the FIND to support this funding request application.

BISCAYNE BAY LEGISLATIVE SPECIAL APPROPRIATIONS PROJECTS

For FY2002, the Florida legislature appropriated $2.5 million for Biscayne Bay protection, restoration, enhancement, and public interest projects. In addition, the Florida legislature appropriated $3.5 million for these same types of projects in FY2003. The District is responsible for the administration of the appropriated funds and for implementation of the associated projects, through coordination and partnerships with public and private entities.

Through coordination with the South Florida Ecosystem Restoration Task Force Working Group’s Biscayne Bay Regional Restoration Coordination Team, projects funded with these legislative special appropriations include the following:

- **Biscayne Bay Surface Water Quality and Biological Monitoring** – Bay water quality monitoring data collection and analysis for 105 stations throughout the bay and its watershed canals; epibenthic habitat monitoring at 11 fixed sites; and surveying bay bottom communities at 100 randomly chosen locations throughout the bay.
- **Biscayne Bay Water Quality Status and Trends** – Analyze the Biscayne Bay water quality monitoring data sets from the Miami-Dade County Department of Environmental Resources Management and Florida International University

(FIU) monitoring databases to determine water quality trends and conditions in the bay which are an important indicator of changing conditions in the bay; and determine additional bay water quality monitoring information needs for adequately calibrating and validating the Biscayne Bay water quality model being developed for the Biscayne Bay Feasibility Study. This study is a joint effort between the USACE and Miami-Dade County Department of Environmental Resources Management to develop computer simulation models of the Biscayne Bay ecosystem that will provide resource managers a tool to analyze and evaluate hydrologic, water quality, and biological impacts on the bay resulting from the implementation of proposed modifications or changes in the operation of the Central and Southern Florida (C&SF) Project.

- **Biscayne Bay Signage/Markers** – Replace damaged or missing resource protection signs and pilings; permit and install new resource protection, boat ramp and shoal signs in needed areas; replace the text signs at boat ramps with bilingual text and a map showing regulation zones and shallow bay areas; and provide for maintenance of new manatee protection signs.
- **Biscayne Bay Website** – Develop and maintain a Biscayne Bay Website to facilitate communication and information-sharing among the target audience of Biscayne Bay decision-makers, agencies, organizations and partners, with the general public interested in Biscayne Bay as a secondary audience; and serve as a central clearinghouse to collect information on Biscayne Bay protection, restoration and enhancement issues and efforts, and disseminate it efficiently to the target audience. The Biscayne Bay Website is located at http://www.DiscoverBiscayneBay.org.
- **Biscayne Bay Strategic Access Plan** – Establish guiding principles to improve public interaction with Biscayne Bay through equitable distribution, adequate infrastructure, utilization, environmental compatibility, public safety, and compatible recreation, visual and educational opportunities of access areas; and to identify future projects that will improve and will create a net increase in public access to the bay.
- **Biscayne Bay Economic Study** – Establish an economic baseline to identify, in a comprehensive manner, the economic value of Biscayne Bay to surrounding bay areas, Miami-Dade County, South Florida, and the state of Florida.
- **Biscayne Bay Environmental Education** – Establish an informed public that will utilize and manage Biscayne Bay carefully and realize the benefits of its long-term protection and restoration through the creation of a Biscayne Bay Environmental Education Alliance, to coordinate and leverage education activities, and fill gaps in programming; develop long-term, innovative and comprehensive environmental education program for Biscayne Bay; and create a volunteer coordinator and Biscayne Bay Keepers Program to train volunteers to test water quality at specific sites in the bay.
- **Biscayne Bay Coastal Biological Community Performance Measures –** Initiate collaborative study to characterize and document segments of baseline fish and macroinvertebrate (i.e., pink shrimp) community conditions in the coastal and nearshore area of southern Biscayne Bay for use as comparative data to detect trends that may result from changes to freshwater inputs.

- **Rehydration Study of Black Point Coastal Basin** – Determine the freshwater requirements for adequate coastal and nearshore restoration of the Black Point area.
- **Biscayne Bay Tidal Hydraulics at Coastal Spillways –** Purchase and install a Horizontal Doppler System at coastal water control structures located in south-central District-operated canals to continuously monitor freshwater discharges to Biscayne Bay, and perform a tidal hydraulics study to develop a field data-based model for accurate predictions of the flow-through gated spillways when tidal variations are present in the headwater and tailwater elevations. This will estimate tidally-driven flow based on the prevailing headwater, tailwater, and gate-opening conditions at the spillway.
- **Arch Creek Basin Stormwater Retrofit** – Perform stormwater retrofits to portions of the City of North Miami's surface water management system that will contribute to improvements to surface water quality discharges to Biscayne Bay.
- **South Miami-Dade Watershed Study and Plan** – A watershed land use planning study for 2025 and 2050 with emphasis on preserving Biscayne National Park values and a sustainable South Miami-Dade County; identify and protect lands, establish property rights of the owners of the land, support a viable economic community; and assure that land use and zoning practices are compatible with a sustainable South Miami-Dade County based on a comprehensive study of all relevant studies pertaining to the plan.
- **Miami-Dade County Watershed C-4 Basin, North Central Basins Stormwater Planning Component** – Gather information on and map the C-4 study area as part of the development of an integrated area-wide land use and water management plan for the north central Miami-Dade County.
- **Habitat Restoration Conceptual Design** – Create conceptual planning and design for habitat restoration at Chapman Field and Virginia Key.
- **Cape Florida Habitat Restoration** – Initiate exotic plant species removal and saw palmetto replanting on the remaining 10 acres of a 32-acre Eastern Coastal Strand Restoration Project.
- **South BB Salinity Meters** – Purchase and install salinity meters in the shallow near-shore areas of south-central Biscayne Bay located within Biscayne National Park; and perform salinity monitoring/data collection.
- **Detection, Mapping and Characteristics of Groundwater Discharges to Biscayne Bay** – Identify the locations of historical springs in Biscayne Bay, and detect and characterize freshwater flows from present-day springs that discharge to the bay; provide baseline information and a baseline analysis on the historical and present-day freshwater springs; and identify additional information and studies that are needed to more fully understand the role of present-day springs, and how they are affected by current and future water management practices in the bay watershed.
- **Biscayne Bay Paleoecological Salinity Study** – Identify historical changes (in broad context and on a decadal-to-centennial scale) in the Biscayne Bay ecosystem at selected bay sites and offshore sites, to correlate the changes with natural environmental events and anthropogenic alterations in the South Florida region; and highlight additional information and studies that are needed to more

fully understand how the bay and its watershed are affected by current and future water management practices.

- **Biscayne Bay Ecological Indicators –** Perform an intensive review and documentation of existing literature and information to determine the technical relationships among freshwater flow, salinity, and watershed/estuary hydrodynamics that impact key indicator biological communities or species present throughout Biscayne Bay; perform an intensive review and documentation of existing literature and information to evaluate parameters and factors beyond salinity that are directly or indirectly related to freshwater inflows to the bay which may cause of contribute to significant harm to seagrasses and associated fauna and faunal habitat requirements with the bay; identify various current and historical technical approaches to develop MFL rules for other estuaries in Florida, and recommend approaches that are most appropriate for Biscayne Bay; and identify the criteria and/or conditions that will signal significant harm.
- **Biscayne Bay Land Acquisition** – As discussed above, acquire lands in Miami-Dade County that will benefit or assist in the protection and restoration of Biscayne Bay. Purchase lands that will benefit Biscayne Bay through various projects through an MOU with Miami-Dade County.
- **Biscayne Bay Legislative Special Appropriations Projects Administration Support –** Provide temporary District administrative support for the legislative special appropriations funds and projects.
- **Biscayne Bay MFLs** – Provide computer modeling hardware, software and temporary senior level engineering and modeling support for developing Biscayne Bay MFL technical criteria (see the *Biscayne Bay Minimum Flows and Levels* section in this chapter).
- **South Florida Ecosystem Restoration Task Force Working Group Biscayne Bay Regional Restoration Coordination Team (BBRRCT) Support –** Provide facilitation expertise and services to the BBRRCT to continue to develop the team's organizational and governance structure, identify and categorize issues, develop an action plan, and clarify the team's role and long and short-term goals and responsibilities.

BISCAYNE BAY WATER QUALITY

Water quality is monitored at several locations within Biscayne Bay and tributaries through partnerships with Miami-Dade County and FIU. The water quality results are examined to detect long-term trends and alert resource management organizations of potential geographic areas of concern. Canal and river discharge quality from 1991–2003 is compared to measures given in the Biscayne Bay SWIM Plan (Alleman et al., 1995). Specific water quality targets are given for ammonia nitrogen (0.05 mg/L throughout the bay; 0.01 mg/L within Biscayne National Park) and nitrate/nitrite nitrogen (0.05 mg/L within Biscayne National Park). Where no specific targets are specified, trends are examined for degradation of ambient quality based on the Outstanding Florida Water Rule. Trends should remain flat or be declining. Results in **Table 12-6** are from monitoring stations located near tributary discharge into Biscayne Bay using data provided by Miami-Dade County Department of Environmental Resources Management. Results are summarized for Snake Creek (C-9), Arch Creek, Biscayne Canal (C-8), Little River (C-7), Miami River, Coral Gables Waterway (C-3), Snapper Creek (C-2), Cutler Drain (C-100), Black Creek

(C-1), Princeton Canal (C-102), Military Canal, Mowry Canal (C-103), and Aerojet Canal (C-111).

Table 12-6. Summary of water quality results and trends at specific locations within the tributaries that discharge into Biscayne Bay. TP= total phosphate phosphorus; AMM=total ammonia nitrogen; NO_x=nitrate and nitrite nitrogen.

🟩 = water quality concentrations meet targets as described in the text and exhibit a favorable trend.

🟨 = water quality concentrations meet targets some of the time as described in the text and exhibit an uncertain trend.

🟥 = water quality concentrations do not meet targets as described in the text and exhibit an unfavorable trend.

Station Location	TP	AMM	NO_x
Snake Creek (C-9) at SK02	🟩	🟩	🟩
Arch Creek at AC03	🟩	🟥	🟥
Biscayne Canal (C-8) at BS04	🟩	🟩	🟩
Little River (C-7) at LR06	🟩	🟨	🟥
Miami River (C-6) at MR03	🟩	🟨	🟥
Coral Gables Waterway (C-3) at CG07	🟩	🟥	🟥
Snapper Creek (C-2) at SP04	🟩	🟩	🟩
Cutler Drain (C-100) at CD02	🟩	🟩	🟥
Black Creek (C-1) at BL01	🟩	🟥	🟥
Princeton Canal (C-102) at PR03	🟩	🟩	🟥
Military Canal at MI03	🟩	🟨	🟥
Mowry Canal (C-103) at MW04	🟩	🟩	🟥
Aerojet Canal (C-111) at AR03	🟩	🟩	🟩

In general, analysis of water quality monitoring data for Biscayne Bay indicates that:

- From 1991–2003, TP concentrations have decreased in the canal water that discharges to the bay, although some of this trend may be explained by improving analytical methods.
- From 1991–2003, nitrogen concentrations, especially nitrate, have generally increased in the canal water that discharges to the bay.
- The best canal water quality overall was found in Snake Creek (C-9), Biscayne Canal (C-8), Snapper Creek (C-2), and Aerojet Canal (C-111).
- The "dry season" for south central Biscayne Bay, when both rainfall is low and salinity is elevated, typically occurs from December through May each year.

FLORIDA BAY AND FLORIDA KEYS

INTRODUCTION

Overview

Florida Bay covers a triangular area of 2,200 square kilometers at the southern tip of the State, between the Everglades and the Florida Keys (**Figure 12-25**). About 80 percent of this estuary is within the Everglades National Park (ENP or Park), and is classified as an Outstanding Florida Water. 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. Starting the late 1980s, a series of ecological changes were apparent, including widespread seagrass die-off, the occurrence of algal booms and high turbidity in what had been clear waters, widespread mortality of sponges, and decreases in some other invertebrates and fish species (Fourqurean and Robblee, 1999). It is generally thought that historical decreases in freshwater inflow from the Everglades and resultant increases in salinity have contributed to these ecological changes.

The District has sustained a program of monitoring, research, and modeling since the early 1990s to better understand the importance of water management as a driver of these and other ecological changes, to improve the ability to predict the impacts of changing water management, and to improve management structures and operations for the protection and restoration of the Florida Bay ecosystem. Such protection and restoration efforts have been mandated by the federal Settlement Agreement, the Everglades Forever Act, the C-111 Project, Modified Water Deliveries to the ENP, MFLs, and CERP. During WY2004, five projects/programs related to Florida Bay have been particularly active: (1) Combined Structural and Operational Plan (CSOP) of the Southern C&SF; (2) Florida Bay Minimum Flows and Levels; (3) CERP's Florida Bay and Florida Keys Feasibility Study (FBFKFS); (4) RECOVER; and (5) Florida Keys Stormwater and Wastewater Program. An overview of these projects/programs is presented below.

Combined Structural and Operational Plan: During the past year, extensive discussions have been held with regard to the strategy and detailed development of the Combined Structural and Operational Plan (CSOP) for Modified Water Deliveries and the C-111 Project (operations of L-29, L-31, and C-111). These operations influence the timing, distribution, quantity, and quality of water flowing into Florida Bay. CSOP progress over the past year includes drafting Performance Measures for Florida Bay. Plan development is currently in progress. Baseline information for this plan and its implementation is being provided by ongoing hydrologic, water quality, and biological monitoring. A CSOP monitoring plan was also completed during the past year.

Florida Bay Minimum Flows and Levels: Progress has been made toward drafting a report on recommended technical criteria, leading to MFL determination for Florida Bay. This includes execution of a contract to develop a simple hydrologic mass balance model to predict salinity in the bay as a function of flows and levels in the Everglades. It also includes a literature review on responses of seagrasses to salinity, development of a dynamic seagrass community model (including field and experimental data collection for model calibration), and execution of a contract for the development of statistical models of fish and invertebrate species responses to salinity and seagrass habitat changes.

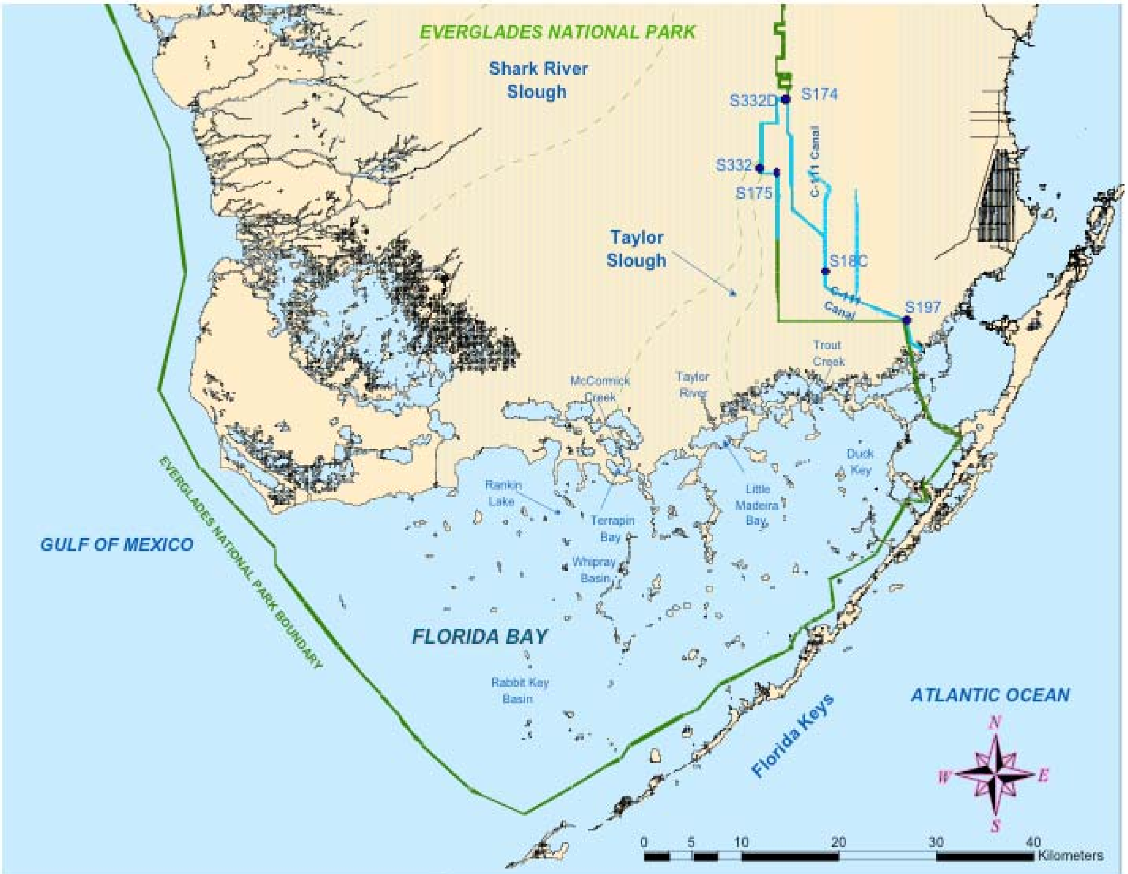


Figure 12-25. Geographic location of Florida Bay and Florida Keys.

Florida Bay and Florida Keys Feasibility Study: The Florida Bay and Florida Keys Feasibility Study (FBFKFS) of the CERP is the cornerstone of Florida Bay restoration. The purpose of the FBFKFS is to evaluate the ecological state and needs of Florida Bay; determine the sufficiency of the current CERP projects and operations to meet these needs; and recommend any modifications that may be needed to restore the bay ecosystem. The FBFKFS includes the development of hydrologic, hydrodynamic, water quality, and ecological models that will provide the District with the ability to predict responses to changing freshwater flow, nutrient inputs, or potential physical alterations, such as the removal of fill between the Florida Keys. During the past year, performance measures were drafted, development of a coastal hydrodynamic model and hydrologic model of the southern Everglades was initiated, and data for these models (from the monitoring and research of the District and other agencies) were compiled.

RECOVER: RECOVER's Monitoring and Assessment Plan (MAP) was drafted during the past year and includes Florida Bay monitoring as part of the Southern Estuaries Module. One key component of the MAP was the identification of key uncertainties that need to be addressed. One of these uncertainties (the fate and effect of Everglades dissolved organic nitrogen in Florida Bay) has been the focus of considerable research during the past year. Addressing this uncertainty is necessary because of concerns that increased freshwater flow with restoration will also increase nitrogen loading and algal blooms in the bay.

Florida Keys Stormwater and Wastewater Program: Water quality improvements for the Florida Keys marine environment and protection of their coral reefs have been central to plans adopted by the federal, state, and county governments. During the past year, the District has executed a set of six contracts to help implement the Water Quality Protection Plan for the Florida Keys National Marine Sanctuary and Monroe County. These contracts will improve stormwater and wastewater treatment at several sites in the Florida Keys and include: (1) Canal Water Quality Improvements Project (Village of Islamorada); (2) Marathon Government Center Stormwater Retrofit Project (Monroe County); (3) Stormwater Management Master Plan Project (City of Marathon); (4) Big Coppitt Wastewater Improvements Project (Monroe county); (5) Big Coppitt Stormwater and Xeriscape Improvements Project as part of the Florida Keys Overseas Heritage Trail (Monroe County); and (6) Water Quality Improvements Project Stormwater Construction (City of Key West).

Summary of Scientific Activities

This section provides brief descriptions of ongoing projects intended to protect and improve the water quality and ecological status of Florida Bay, Florida Bay's status in WY2004, and progress toward providing a scientific basis for improved water management, including the development of numerical models to integrate information and provide predictive power.

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) guides this effort, with the planning, coordination, communication, and review of monitoring, research, and modeling. Such a collaborative program helps the District by minimizing information gaps and costs, and maximizing information quality and sharing. Additional documentation on the Florida Bay program can be found online at http://www.aoml.noaa.gov/flbay/. During the past year, a synthesis of results from the PMC program was drafted, and is available online at http://www.aoml.noaa.gov/sfp/documents.shtml. This includes reviews of Florida Bay's palaeoecology, physical oceanography, water quality, algal blooms, seagrass communities, upper trophic levels, and identification of outstanding information needs. Furthermore, a review of the program (following presentation of results at the 2003 Florida Bay Conference at http://conference.ifas.ufl.edu/jc/FB.pdf) has been provided by an independent, peer review panel chaired by Dr. J.E. Hobbie.

The District's emphasis within the PMC program is on water quality monitoring, near-shore seagrass monitoring (in areas most affected by water management), measuring and assessing how changing freshwater flow affects nutrient loading, water quality, and plant community responses in the salinity transition zone (mangrove zone) and near-shore waters, and modeling seagrass community dynamics.

During the past year, program-related efforts have included:

- Continuation of water quality monitoring at fixed stations in the bay and along the southwest coastal estuaries (contract with FIU)
- Continuation of seagrass monitoring in southern Biscayne Bay and northeast Florida Bay coastal sub-bays (contract with Miami-Dade Department of Environmental Resource Management, or DERM)
- Upstream monitoring of Taylor Slough and C-111 basin water quality, periphyton, and plant community status (contracts with FIU, ENP, and SFWMD)
- Monitoring of freshwater and nutrient discharge from mangrove creeks into Florida Bay (contract with FIU, in cooperation with USGS)
- Development and application of rapid, fine scale water quality mapping technology for monitoring near-shore conditions (SFWMD)
- Chemical characterization of mangrove zone and Florida Bay dissolved organic matter (DOM) and experiments on photodegradation and biodegradation (bioavailability) of this DOM (by SFWMD and FIU contract)
- Field measurement of near-shore seagrass productivity and respiration (SFWMD)
- Laboratory measurement of salinity, sulfide, and temperature effects on seagrass productivity, respiration, and mortality (contract with Florida Atlantic University)
- Literature review of salinity effects on seagrass communities (contract with Battelle)
- Continued development of dynamic model of seagrass community (SFWMD with grant from USGS and ENP)
- Data synthesis of hydrologic, meteorological, and salinity data for salinity/hydrodynamic models (SFWMD)
- Development of mass balance hydrologic model, Flux Accounting and Tidal Hydrology at the Ocean Margin (FATHOM), to predict Florida Bay salinity (contract with Environmental Consulting and Technology, Inc.)
- Development of wetland hydrologic model (TIME) for southern Everglades (contract with USGS)
- Development of hydrodynamic models for Florida Bay EFDC and boundary oceanic waters HYCOM [contracts with Tetra Tech and National Oceanic and Atmospheric Administration (NOAA)]

- Development of statistical models of Florida Bay fish species, juvenile pink shrimp, and roseate spoonbills (contracts with NOAA and National Audubon Society)

ENVIRONMENTAL CONDITIONS AND ASSESSMENT: FLORIDA BAY WY2004

Hydrology and Hydrodynamics

Hydrologic and hydrodynamic studies in Florida Bay are being performed to increase the District's understanding of the connections between upstream inputs from canals and overland flows through the Everglades and the ecology of Florida Bay. Fresh water enters the bay via rainfall, discharges from natural channels, overland sheetflow, and groundwater flows. Discharges from the major creeks that flow through the mangrove zone on the bay's northern boundary have been gauged by USGS since 1996 (Hittle et al., 2001).

Salt water enters the bay across the vast Gulf of Mexico boundary and through passes between the Florida Keys. Due to the complex banks and basins within the bay, it is difficult to determine routes of circulation and the rate of Gulf inputs. Atlantic Ocean inputs are smaller than Gulf inputs, but important to the eastern and southern parts of the bay along the Florida Keys. The primary entry points for Atlantic water are a few major tidal passes through the Florida Keys, providing marine influence during periods of freshwater input from the Everglades and importantly, providing a means of dilution of hypersaline water when fresh input is low. Flow from the Atlantic has been strongly restricted since the closure of many natural tidal passes during development of the Flagler Railway across the Florida Keys in the early twentieth century.

The bay's hydrodynamic patterns are being modeled as part of the FBFKFS in order to predict the effects of the CERP on the bay ecosystem. The EFDC (Hamrick, 1992; Hamrick and Wu, 1997) model calculates flows based on measured fresh and salt inputs, tides, water levels, evaporation, precipitation, and the physical structure of banks and channels in Florida Bay. While this realistic and complex model is in development, the District is relying on another simpler yet powerful model of water and salt balance in the bay, FATHOM (Cosby et al., 2004; Cosby et al., 1999; Nuttle et al., 2000), which will be used to provide the District's initial recommendations for Florida Bay MFLs. FATHOM simulates salinity distribution and variation in Florida Bay based on hydrologic inputs that include monthly rainfall, evaporation, runoff, sea level and salinity and hourly tides at the model boundaries. Inputs have been recently updated to include spatially distributed rainfall and tides and direct measurements of freshwater runoff, reflecting a significant improvement in detail and reliability of the model (Cosby et al., 1999). Ongoing work is directed at further refinements of the bathymetry, inflows, hydrologic data, and time-varying salinity boundary condition along the western boundary with the Gulf of Mexico. Once calibrated and validated, FATHOM will provide quantitative estimates of water residence times in basins of the bay, salinity variations, and water levels under different hydrologic scenarios.

Developing these models will enable us to understand and predict the linkage of water management and the salinity and mixing regime of the bay. These predictions are essential for associated predictions of water management and restoration impacts on water quality and biological components of the bay.

Precipitation and Freshwater Flow to Florida Bay

Eastern bay rainfall was calculated as the mean of Little Madeira and Duck Key stations and central bay rainfall was calculated as the mean of Whipray Basin and Terrapin Bay stations (**Figure 12-25**). During WY2004, monthly rainfall in eastern and central Florida Bay fit the general wet season-dry season pattern observed in recent years (**Figure 12-26**). In the eastern bay, wet season (from June–November) rainfall in 2004 was almost identical to that in 2003 (within 2 percent), but in the central bay, wet season rainfall was considerably greater in 2004 than in 2003 (up 30 percent) due to unusually high rainfall during September and November 2003. Seasonal rainfall patterns over the bay were similar to those upstream in ENP (see Chapter 5 of the 2005 SFER – Volume I). Total annual rainfall over the eastern bay was less than over ENP wetlands, but central bay rainfall was higher than over these wetlands (ENP, 47 in.; central bay, 52 in.; eastern bay, 38 in.).

Discharges into the ENP wetlands from canals that are likely to impact freshwater flow into Florida Bay are presented for WY1997–WY2004, comparing cumulative monthly flows from 2004 to average flows over the period of 1997–2003 (**Figure 12-26**). (Note that this period of record was chosen because the USGS measurements of flows into Florida Bay started in 1996). Flow into the Everglades panhandle was calculated from the C-111 structures as flow at S-18C minus flow through S-197. Flow into Taylor Slough from canals was calculated as the sum of discharge from the L-31W structures, either as S-332 plus S-175 (from 1997–1999) or S-332D plus S-174 (from 2000–2004), into ENP at the Taylor Slough headwaters. Patterns of discharge from these canals followed typical seasonal patterns in 2004 (**Figure 12-26**). Flows into C-111 and Taylor wetlands were relatively high in August and November, and flow into the C-111 wetland was unusually high in June 2003. These flows generally coincide with rainfall patterns over ENP wetlands (**Figure 12-26**). Annual combined flow for the Taylor Slough and C-111 structures in 2004 was only slightly greater (0.35 billion m^3) than the long-term (1985–2003) average of 0.31 billion m^3. This historic average includes the low flows of the drought years 1990 (0.12 billion m^3) and 1991 (0.15 billion m^3).

Flows from three major creeks that flow into the bay, Trout Creek and Taylor Creek (flowing into the eastern bay) and McCormick Creek (flowing into the central bay) are shown in **Figure 12-27**. As with canal structures, monthly flows from the wetlands into the bay through these creeks increased from May–October and decreased from October–April. All three creeks exhibited negative (upstream) flows during some dry season months (**Figure 12-27**). Trout Creek had much higher flow than the other two creeks, with 2004 annual discharge of 0.17 billion m^3 from Trout Creek, 0.05 billion m^3 from Taylor Creek, and 0.03 billion m^3 from McCormick Creek.

During 2004, the flow pattern differed from 1997–2003 averages in two ways: (1) flows for all three creeks were higher than average early in WY2004, coinciding with structure flows and rainfall that was greater than average; and (2) peak flows occurred in November rather than in October, again coinciding with high November rain and canal discharge. The sum of discharges from the three creeks was only slightly less than the sum of inputs to Taylor Slough and C-111 wetlands from canals. In 2004, inputs to the wetlands was 0.35 billion m^3 and outputs from these wetlands to the bay (only via these creeks) was 0.25 billion m^3. This compared with the 1997–2003 annual average of 0.33 billion m^3 discharged into the wetlands and 0.25 billion m^3 flowing into the bay via creeks (76 percent of discharge into wetland). Based on measurements of nine mangrove creeks flowing into northern Florida Bay (most only measured occasionally), the three creeks presented here were estimated to account for about 60 percent of all creek flow

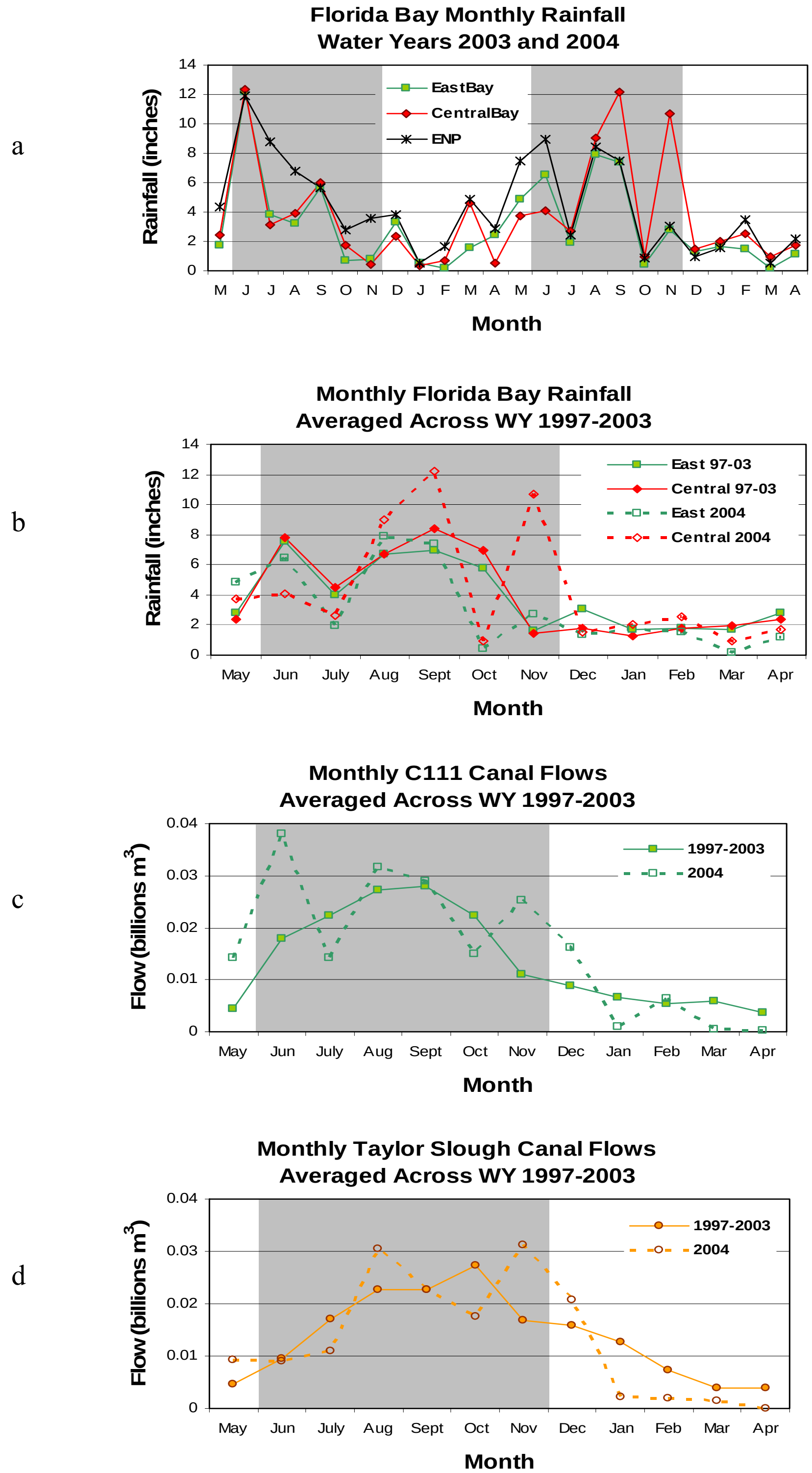


Figure 12-26. a) Florida Bay regional average monthly rainfall for WY2003 and WY2004, with wet season as shaded area. b–d) Compare values for each month from WY1997–WY2003 (solid lines), with values from WY2004 (dashed lines) for average monthly rainfall, and cumulative monthly flows from C-111 and Taylor Slough canals.

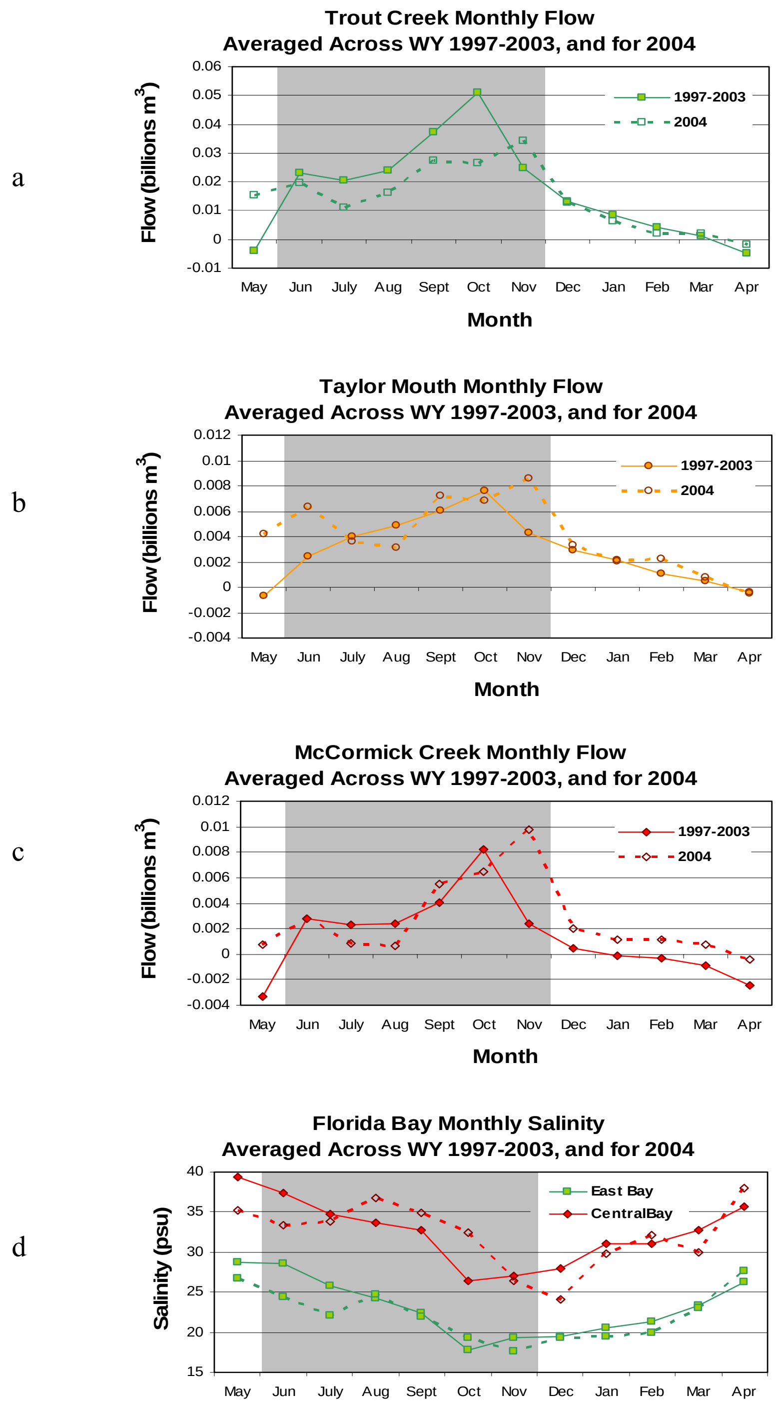


Figure 12-27. Florida Bay regional average monthly creek flows (from USGS) and salinity, with wet season as shaded area. Graphs a–c compare average values for each month from WY1997–WY2003 (solid lines), with available data from WY2004 (dashed lines) for cumulative monthly flows at a) Trout Creek, b) Taylor Mouth Creek, and c) McCormick Creek, and d) monthly salinity for eastern bay and central bay regions.

(Hittle et al., 2001). Thus, it appears that the magnitude total creek discharge into the bay is only slightly less than the magnitude of canal input into the southern Everglades wetlands.

The magnitude, distribution, and timing of salinity fluctuations in Florida Bay are determined by the freshwater inputs of fresh water from the Everglades and rainfall (generally event driven with dominance of cold fronts in the dry season and tropical waves and storms in the wet season), evaporation, exchange with marine waters of the Gulf of Mexico and Atlantic Ocean, and internal circulation. Because Florida Bay is shallow and its circulation is restricted, it is highly susceptible to rapid and abrupt changes in salinity and to hypersalinity events that affect the biology and chemistry of the bay. Data is collected continuously at stations in ENP's Marine Monitoring Network (MMN), continuously at creek mouth stations monitored by USGS, and monthly as part of SFWMD's water quality monitoring (contract with FIU), providing information on spatial and temporal trends in salinity throughout the bay. Monthly average salinity for representative MMN and USGS sites (Trout Creek, Duck Key, and Little Madeira Bay for the eastern bay and Whipray Basin for the central bay) were averaged with FIU data collected in the corresponding months and regions (eastern sites 9, 11, 23, and 24, and central sites 12–15).

In 2004, salinity in Florida Bay followed a typical seasonal pattern of increasing salinity during the dry season and decreasing salinity during the rainy season (**Figure 12-27**). Salinity reflected the effect of unusually late rainfall events in fall 2003. Much of the runoff from the Everglades discharges into eastern Florida Bay, and salinity is consistently lowest at the eastern bay stations. The temporal pattern of salinity for the eastern bay in 2004 was similar to recent years, averaging 22.2 psu, equivalent to ppt. The average salinity from 1997–2003 for this region was 23.2 psu. In August 2003, salinity increased following below average rainfall in July and below average discharge from Trout Creek (**Figures 12-26** and **12-27**), then again decreased with the occurrence of a major rain event in November.

In the central bay, salinity averaged 32.3 psu during 2004, almost identical to the historical average of 32.5 psu from 1997–2003. The notable aspect of salinity pattern in 2004 was the temporal lag in the minimum of the seasonal cycle, occurring in December rather than the more typical October. This late drop in salinity (by about 6 psu) occurred one month after an unusually late peak in rainfall over the central bay and peak flow from the mangrove creeks. The one month lag in salinity response may indicate the relative influence of Everglades runoff on bay salinity.

Water Quality

Water quality monitoring in Florida Bay provides a basis for evaluating the status and trends of this part of the Everglades Protection Area and also builds a foundation for understanding and predicting the effects of changing water management on the ecosystem. Over the last decade, a decrease in annual average TN and TP concentrations has been observed in water from all three regions of Florida Bay, especially the central bay (**Figure 12-28**). (Note that the full water year data are only available from 1992–2003). Concentrations of TN generally decreased from 1992–2002, with a drop of 66 percent in the eastern bay, 63 percent in the central bay (70-percent decline from 1994), and 56 percent in the western bay. These concentrations increased considerably in all regions from 2002–2003. Concentrations of TP also decreased over the last decade in central and western regions, but these changes were more variable than for TN. From 1992–2002, TP concentrations dropped by about 50 percent in both the central and western bay. As with TN concentrations, TP concentrations increased in all bay regions from 2002–2003. All three regions had dramatic increases in TP around 1999–2001, followed by sharp decreases. These peaks may be related to the passage of tropical storms over the bay and southern

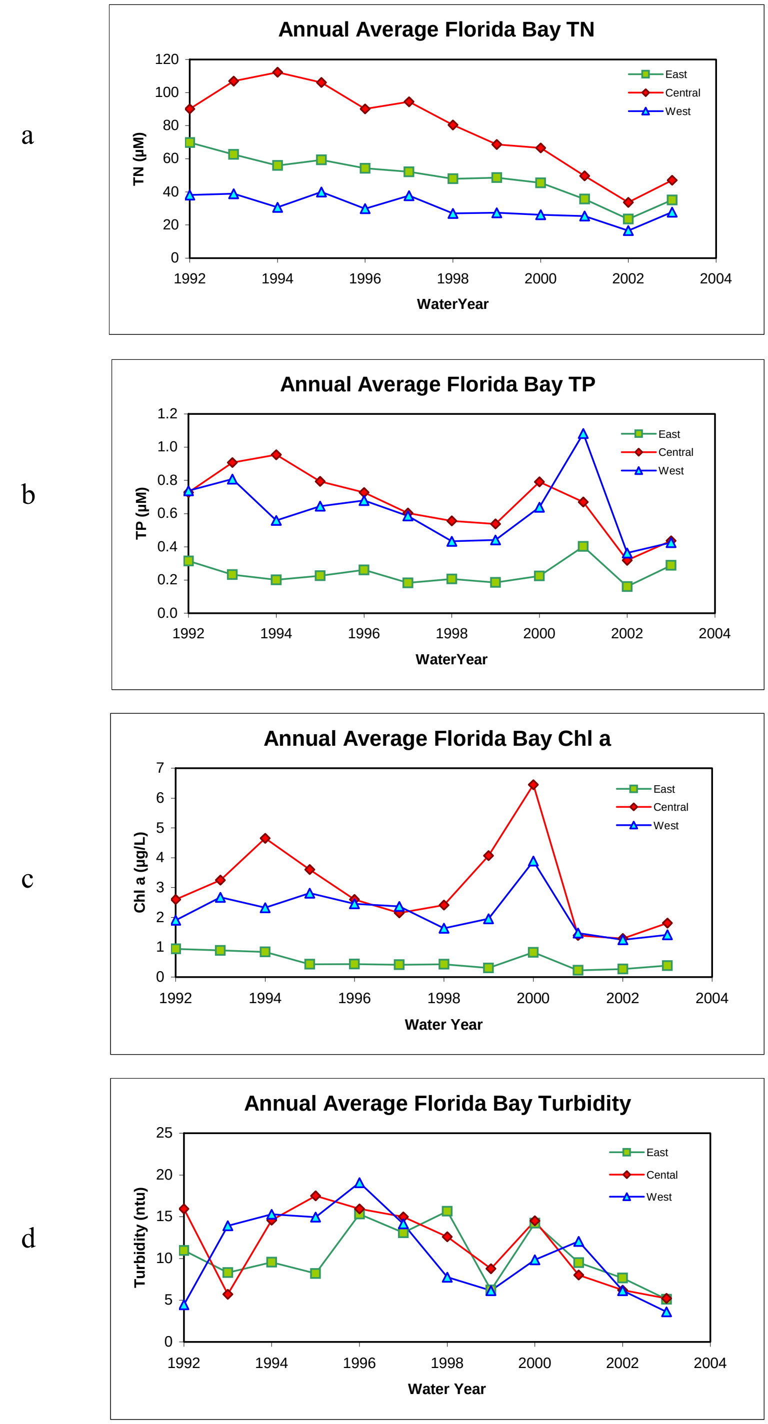


Figure 12-28. Historical Florida Bay regional water quality. Values are annual averages from WY1992–WY2003 (entire available period of record) for a) TN; b) TP; c) chlorophyll *a*; and d) turbidity for east bay (green squares), central bay (red diamonds), and western bay (blue triangles) regions.

Everglades in late 1999, particularly Hurricane Irene, with an exceptionally large runoff from the Everglades (Smith, 2001).

TN is higher and TP is lower in the eastern bay than in the western bay (**Figure 12-28**). The primary source of phosphorus in the western bay is from the Gulf of Mexico (Rudnick et al., 1999). Most of the fresh water directly flowing into Florida Bay from the Everglades flows into the eastern bay and this runoff is relatively high in nitrogen and low in phosphorus. This contributes to the existence of relatively high nitrogen and low phosphorus concentrations in the eastern bay and to the strong phosphorus limitation of the eastern bay (Boyer and Jones, 1999). Nutrient concentrations and loads from major mangrove creeks have been measured since 1996, and results show a trend of decreasing flow-weighted mean TN and TP concentrations in water entering the bay (Taylor Creek mouth data in **Figure 12-29**). This trend is similar to the trend of decreasing nutrient concentrations within the bay (**Figure 12-28**). Given the low magnitude of phosphorus loads into the bay from the Everglades (Rudnick et al., 1999), the trend of decreasing phosphorus concentrations is unlikely to be related to Everglades loading. However, a relationship between nitrogen loading from the Everglades and nitrogen concentrations in the bay is possible. Assessment of this relationship requires quantitative hydrodynamic and water quality models, which are being developed as part of the CERP's FBFKFS.

Results in **Figure 12-29** also indicate that the complexities of nutrient cycling and transport within the southern Everglades, not just canal sources, influence nutrient concentrations and loads of water flowing into Florida Bay. Flow weighted mean concentrations of water flowing from the wetland commonly exceeded concentrations in water flowing into the wetland from the L-31 canal (at S-332, S-175, S-332D, and S-174). The lowest concentrations were found in wetlands about 2 km downstream of these canal inputs, at the ENP road's bridge over Taylor Slough (TSB). Clearly, both nitrogen and phosphorus were removed by northern Taylor Slough wetlands as water flowed from the canal toward the bridge, but concentrations increased between the bridge and the bay. This indicates the existence of nutrient contributions from other sources (e.g., groundwater, nitrogen fixation) as water flows toward the bay. Such information is crucial for assessment the water quality effects of water management operations, such as under CSOP, and Florida Bay restoration planning under the FBFKFS.

The response of phytoplankton to changing freshwater flow is of particular concern to the CERP because increased flow rates may potentially stimulate algal blooms (Brand, 2002). This issue is being investigated as part of the RECOVER and FBFKFS programs. Water quality monitoring of the bay shows that average annual chlorophyll *a* concentration, an indicator of phytoplankton, has a long-term decreasing trend similar to that those of TP in all three regions of Florida Bay (**Figure 12-28**). The central bay, where relatively phosphorus-rich waters from the Gulf mix with relatively nitrogen-rich waters from the eastern bay, and where the residence time of water may be months, is the region with the highest chlorophyll *a* concentrations (**Figure 12-28**). High chlorophyll *a* concentrations in 1999 and 2000 may be related to tropical storms and associated high runoff from the Everglades in fall 1999 (Smith, 2001).

Turbidity, which is a function of phytoplankton density and suspended sediment, also showed a decreasing trend following peaks in 1995–1996 (**Figure 12-28**). This general decrease may be partly the result of increased stabilization of the sediments by seagrass beds recovering from the die-off events of the late 1980s and early 1990s (Zieman et al., 1999).

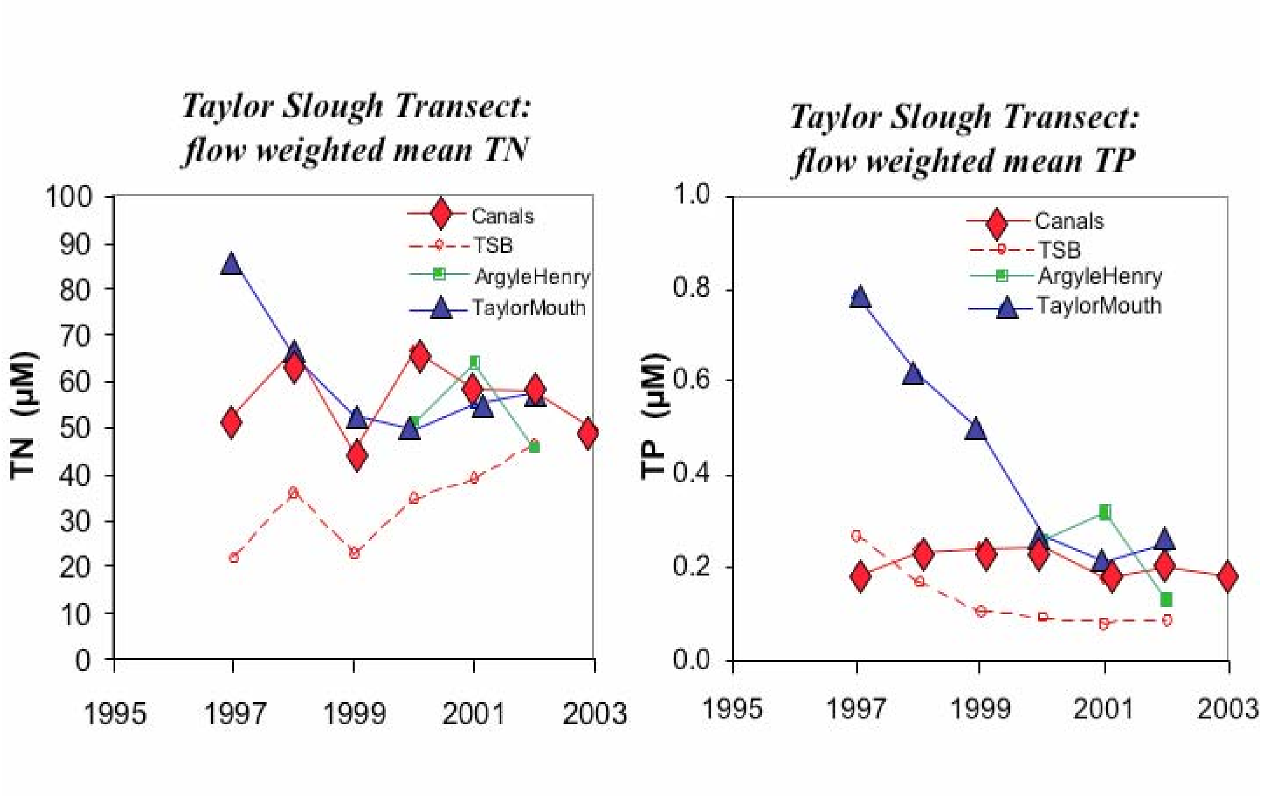
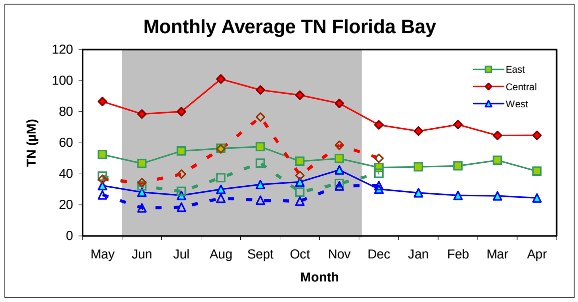


Figure 12-29. Flow-weighted mean nutrient concentrations (TN and TP) in water at sites within Taylor Slough. These sites, from north to south, include inputs from the L-31 and L-31W canals (from S-332 plus S-175 or S-332D plus S-174), at TSB, Argyle Henry Pond (a pond about 4 km north of the mouth of Taylor Creek and at the ecotone between fresh water and saline wetlands), and the mouth of Taylor Creek. Annual values are for calendar years. Argyle Henry and Taylor Creek results are from FIU investigators (D. Childers, principal investigator) under contract with SFWMD, with flow data from USGS (C. Hittle, principal investigator).

Average monthly TN and TP concentrations in WY2004, when data are available, are compared to long-term (1992–2003) monthly average concentrations in **Figure 12-30**. Nutrient concentrations and turbidity in WY2004 were below the long-term average in all three bay regions, with the exception of June 2003 (**Figure 12-30**). High TP in the eastern and central bay in June 2003 coincided with above average flows in the C-111 canal (**Figure 12-26**), indicating a possible connection between water flow and TP concentration in the eastern bay. As in past years, peaks in chlorophyll *a* concentrations were observed in the central and western regions during the wet season (**Figure 12-30**).

a



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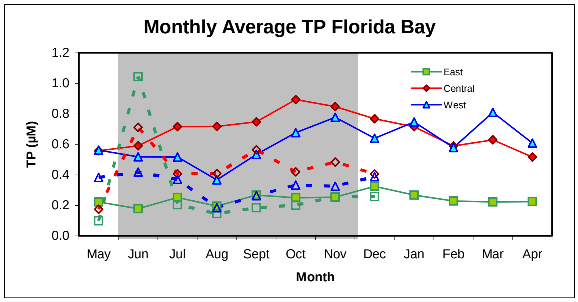

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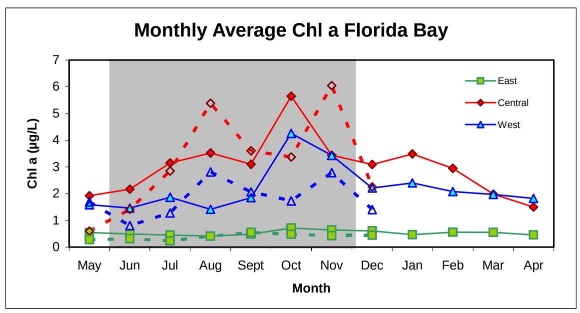

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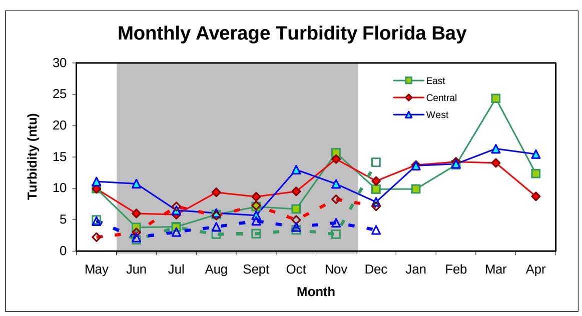

Figure 12-30. Florida Bay regional average monthly water quality, with wet season as shaded area. Graphs a–d compare average values for each month from WY1992–WY2003 (solid lines) with available data from WY2004 (dashed lines) for a) TN; b) TP; c) chlorophyll *a*; and d) turbidity for east bay (green squares), central bay (red diamonds), and western bay (blue triangles) regions.

Dissolved Organic Nitrogen

Everglades restoration has generally focused on the loading, fate, and effects of nitrogen, because the Everglades are known to be limited by nitrogen availability. However, primary production in estuaries and other coastal marine ecosystems generally is commonly limited by the availability of nitrogen, and this may be the case in western and central Florida Bay. One hypothesis of interest to the SFWMD is that nitrogen loading to the bay from the Everglades may increase with increasing freshwater flow, causing stimulation of algal blooms (Brand, 2002; CROGEE, 2002). There is some evidence consistent with this hypothesis:

- Phytoplankton bioassays suggest that production may be nitrogen-limited in western Florida Bay, and to a lesser extent, in central Florida Bay (Tomas et al., 1999).
- Freshwater runoff from the Everglades is relatively high in nitrogen, but relatively low in phosphorus (compared to marine boundary); this runoff is one of several major nitrogen sources for the bay, but nitrogen loading increases with freshwater flow rates (Rudnick et al., 1999).
- Phytoplankton blooms occur where relatively high nitrogen and phosphorus coincide, especially in central Florida Bay, which receives phosphorus from the Gulf of Mexico, and nitrogen from the Everglades (Brand, 2002).
- A correlation between the inter-annual variability of algal blooms and freshwater discharge can be shown (Brand, 2002).

This correlative evidence is insufficient to test the above hypothesis, and it is premature to accept or reject it. Such an evaluation requires quantitative knowledge of the fate and effects of nitrogen from the Everglades in Florida Bay, as specified in RECOVER's MAP. Research to provide necessary data is now being performed. Water quality modeling (as part of the CERP's FBFKFS) will utilize results from this research to assess CERP impacts on Florida Bay water quality and provide restoration recommendations to CERP.

Almost all of the nitrogen flowing from the Everglades into Florida Bay is in the form of DOM (Rudnick et al., 1999). The fate of this DOM depends upon its qualitative composition and its rate of decomposition. DOM composition varies from proteins that can be readily decomposed by microorganisms making humics that are highly resistant to decomposition (Stepanauskas et al., 1999). Some forms of refractory DOM can be photodegraded by exposure to sunlight, converting DOM to inorganic and biologically available compounds (Moran and Zepp, 1997; Miller and Moran, 1997; Obernosterer, 2004). Thus, the fate of DOM (and its associated nitrogen) from the Everglades depends upon chemistry, the enzymatic activity of microorganisms, and abiotic decomposition.

During WY2004, the SFWMD and FIU (Boyer et al., 2003) began experiments to determine the source of DOM to the bay, its molecular composition, and its bioavailability. Spatial mapping of DOM in Florida Bay begun in 1999 and has shown that DOM is transported from the Everglades to Florida Bay in fresh water (**Figure 12-31**). These surveys also demonstrate that DOM concentrations decreased rapidly with distance from the shoreline (Kelly et al., 2004). Experimental evidence reveals that DOM remains in the mobile, soluble phase and is chemically altered along salinity gradients; the molecular weight of dissolved compounds decreases with salt exposure, perhaps altering their bioavailable (Boyer et al., 2003).

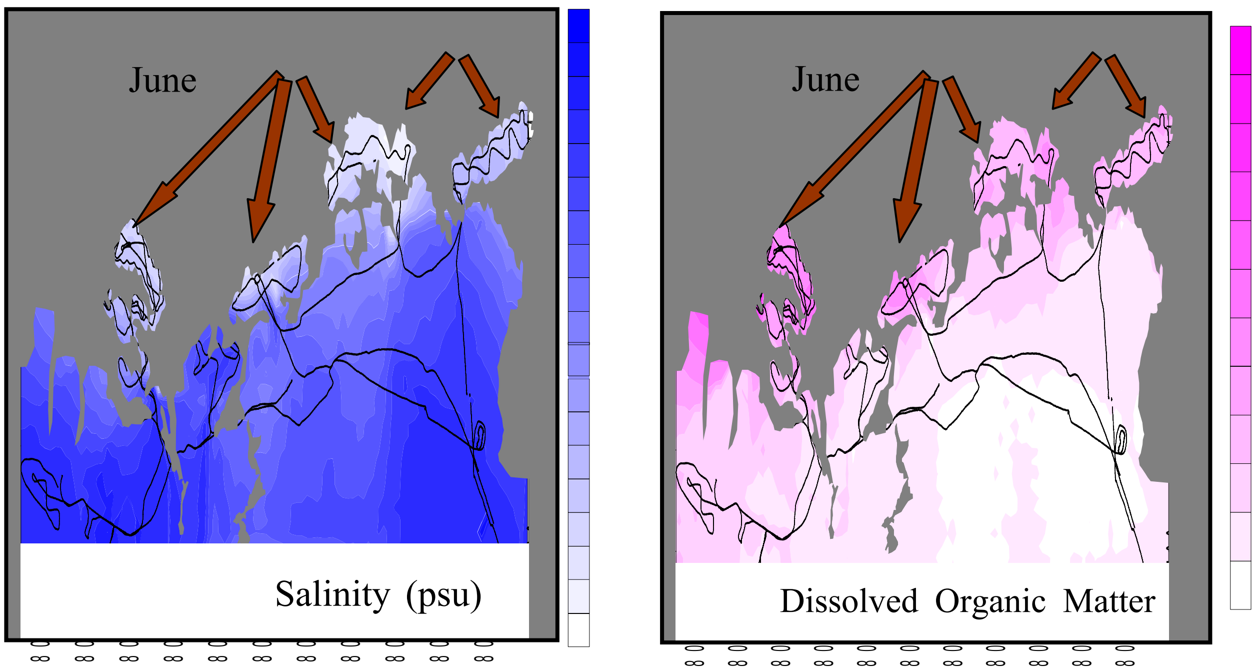

Figure 12-31. June 2003 shipboard mapping of salinity in psu (left), and colored dissolved organic matter in relative fluorescence units (right).

Experiments were also conducted by the SFWMD to measure the short-term (five-hour) effects of Everglades DOM on phytoplankton and other microbes, and longer-term (two-week and two-month) decay of this DOM in Florida Bay. The DOM source tested in these experiments was a pond in the mangrove zone, north of Florida Bay. Five seasonal, short-term experiments found no significant stimulation or inhibition of phytoplankton or epiphyte productivity or respiration with DOM additions in dark or light bottles (Kelly et al., 2003).

Two longer-term bioavailability experiments compared organic nutrient losses and oxygen consumption in dark bottles containing either eastern Florida Bay water (from Duck Key) or the pond water. The preliminary experiments tested the effects of water source, phosphorus concentration, and the presence or absence of sediments (with associated microbes). Salinity and water column bacterial additions were equal for all bottles (with four replicates per treatment). Changes in oxygen consumption, organic and inorganic nutrients, and bacteria were measured and DOM decay rates were estimated from oxygen (O_2) results, using a two-pool first-order model (Westrich and Berner, 1984). Time series of O_2 consumption showed the significant influence of water source and an interactive phosphorus and sediment effect. At least 14 percent of the DOM from the mangrove pond, and 28 percent of the DOM from eastern Florida Bay appears to be bioavailable. Decay rates of these DOM pools are similar and rapid (about 2 percent per day; **Table 12-7**). The difference in the percent of DOM that is bioavailable may be explained by the concentration of dissolved organic carbon (DOC), with concentrations in pond water being three times higher than in Florida Bay water (15 versus 5.5 milligrams per liter, or mg/L, respectively). Therefore, DOM from Florida Bay is more bioavailable, but there is less DOM than in the Everglades mangrove zone.

Additionally, these experiments indicated that DOM decay rates are likely to vary geographically and temporally within Florida Bay as a function of phosphorus availability and sediment suspension. In treatments with both sediment particles and phosphorus, lower DOM decay constants were found, but a larger bioavailable carbon pool in the presence of phosphorus, suggesting that phosphorus may enhance microbial decay of less labile DOM. These preliminary results 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.

Table 12-7. Mean and standard deviations of first order decay constants and bioavailable DOM pool size estimates from eastern Florida Bay (Duck Key) and a mangrove pond. Values are based on DO uptake rates during two month incubations, and included treatments with and without inorganic phosphorus additions and surface sediment additions.

	Duck Key Decay Constant k (d^{-1})	Duck Key Minimum Bioavailable (mg C /l)	Pond 5 Decay Constant k (d^{-1})	Pond 5 Minimum Bioavailable (mg C /l)
No P, No Sed	0.028 ±0.006	1.54 ± 0.13	0.021 ±0.007	2.04 ± 0.30
No P, Plus Sed	0.037 ±0.007	1.64 ± 0.19	0.023 ±0.009	2.68 ± 0.57
Plus P, No Sed	0.031 ±0.004	1.58 ± 0.23	0.024 ±0.005	2.06 ± 0.33
Plus P, Plus Sed	0.018 ±0.004	2.95 ± 0.40	0.013 ±0.002	4.83 ± 0.66

Seagrass Community Model

The Florida Bay seagrass model is a spatially averaged, basin-specific model of the seagrass community in Florida Bay. Its purpose is to assist managers in understanding the physical and biological controls of seagrass dynamics and in predicting responses to hydrologic restoration. In the model, rates of photosynthesis, respiration, and mortality for seagrasses vary with input data on environmental factors such as temperature, salinity, nutrient availability, and light (**Figure 12-32**), resulting in daily changes in seagrass standing stock. The model is designed based on field and mesocosm data for Florida Bay species from several sources (Fourqurean et al., 1992a; 1992b; 1993; Gras et al., 2003; Koch, 2004) to be linked with models of upper trophic level organisms to develop ecological criteria for the Florida Bay MFL project, and to answer questions about the effects of Everglades restoration for the Florida Bay and Florida Keys Feasibility Study.

Two of the four seagrass species common in Florida Bay, turtle grass (*Thalassia testudinum*) and marine shoal grass (*Halodule wrightii*), are currently described in the model. The *Thalassia* submodel has been calibrated for Rabbit Key Basin, Rankin Lake, Little Madeira Bay, Duck Key, and Trout Cove. The *Halodule* submodel has been calibrated for Little Madeira Bay and Trout Cove, and a dual-species model of *Halodule* and *Thalassia* has been calibrated for Little Madeira Bay. A model for widgeon grass (*Ruppia maritima*) is currently under development for the northeastern transition zone. The model is producing validation simulations that track empirical data with an r^2 of > 0.80 for *Halodule* and > 0.90 for *Thalassia*.

The model is being used to examine effects of water management and natural climatic events on the Florida Bay seagrass community. An exploration of the effect of hypersalinity (> 40 psu) on *Thalassia* in Rankin Lake showed that both the timing and strength of hypersalinity is important to seagrass production. A modeled increase in the magnitude or duration of a hypersalinity event in 2001 resulted in a decrease in the net annual production of *Thalassia*. Shifting the onset of high salinity conditions earlier in the year by as few as 15 days caused salinity and low temperature stress to coincide, decreasing net annual production by 20 percent (see **Figure 12-32** for the temperature response curve of *Thalassia*). Hypersalinity events that coincided with high water temperatures in mid summer were also detrimental to seagrasses. A restoration plan to relieve anomalous salinity stress in Florida Bay proposes to increase water deliveries to Taylor Slough. The District utilized the model to project the likely effects on downstream seagrass beds where the condition of increased hydrologic flow from the Everglades was simulated by lowering salinity in Little Madeira Bay. The model experiment resulted in a decrease in *Thalassia* biomass (**Figure 12-33**), and a concomitant increase in *Halodule* yielding a more diverse autotrophic foundation for the ecology of the bay in the nearshore zone.

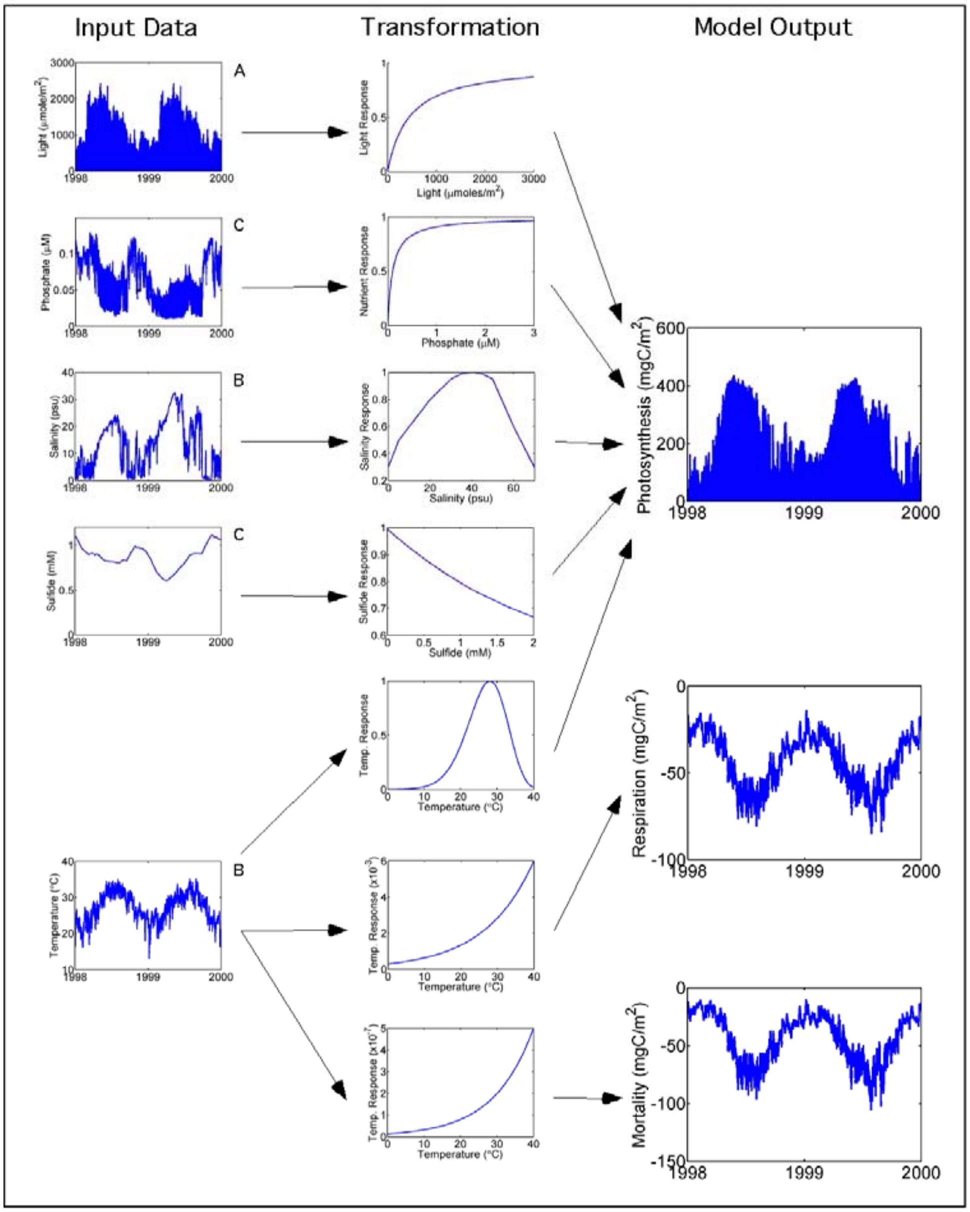

Figure 12-32. Inputs and outputs of the numerical model for *Thalassia testudinum* in Little Madeira Bay. Seagrass biomass response is calculated from environmental inputs and species-specific response curves fit to experimental mesocosm data. Nutrient limitation is based on the minimum Mechaelis-Menton calculation for nitrogen and phosphorus. Effects of environmental and biological factors on photosynthesis are multiplicative (Cloern, 1978), and attenuate the maximum rate of 20-percent biomass growth per day. Total biomass change for each time step is calculated as the sum of photosynthesis, respiration, and mortality (Kremer and Nixon, 1978; Madden and Kemp, 1996). The letters beside the input data plots identify the source of the data: a) Little Madeira Bay light monitoring data, Dr. Paul Carlson, FDEP; b) USGS monitoring platform at the mouth of Taylor River; and c) Simulation data from Florida Bay seagrass model.

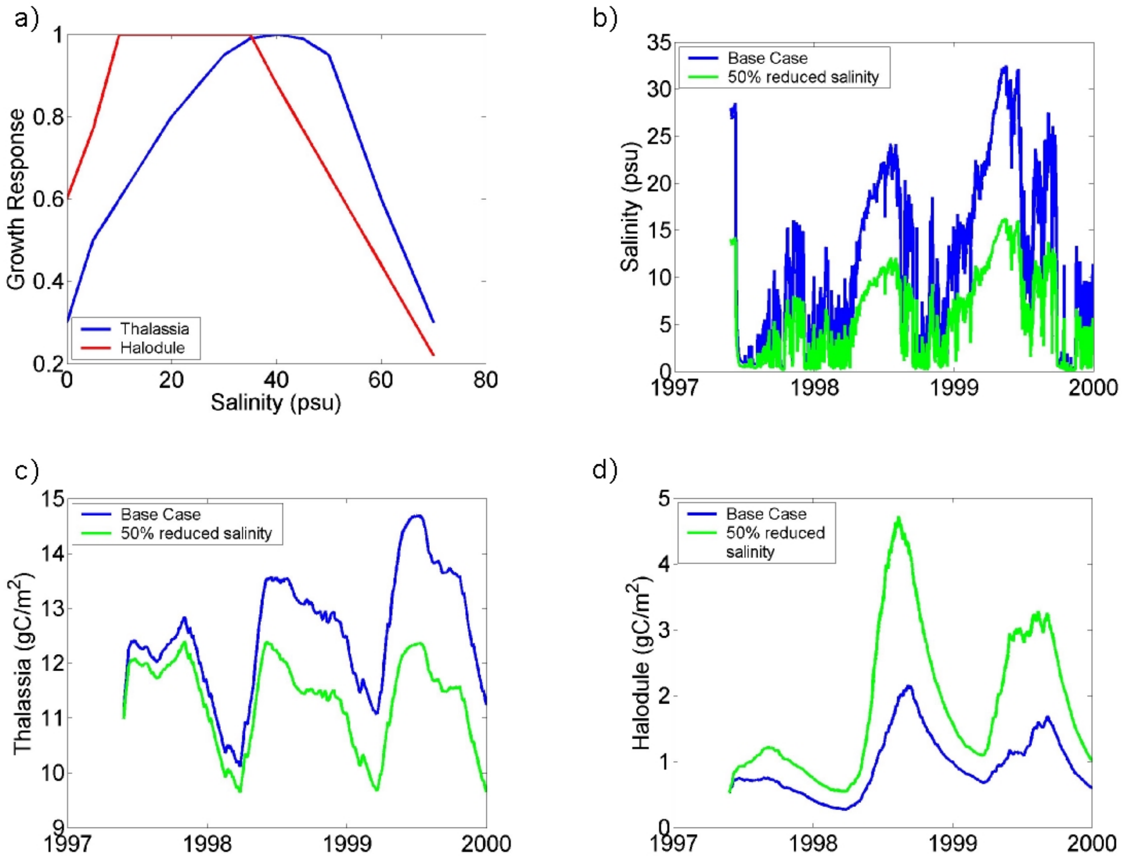

Figure 12-33. Inputs and results of a decreased salinity scenario using the dual-species model calibrated for Little Madeira Bay. a) Salinity response curves for both species used in the model from dedicated mesocosm experiments on Florida Bay plants show that *Halodule wrightii* has a broader range of optimal salinities. The curve for *Halodule* has a plateau because the data used to build the curve showed no significant change between 10–35 psu). b) The salinity data used to force the model. The base case data is from the USGS monitoring platform at the mouth of Taylor River Mouth. c) Simulation results for *Thalassia* standing crop showing a decrease in *Thalassia* with lower salinities. d) Simulation results for *Halodule* standing crop showing an increase in *Halodule* with lower salinities.

Higher Trophic Levels

The higher trophic levels (HTLs) consist of the animals that comprise the consumer community in the Florida Bay food web. Studies of higher trophic level communities in Florida Bay during 2003 and 2004 focused on describing how animals respond to environmental conditions, primarily salinity and water levels in saline wetlands north of the bay. Long-term monitoring projects were continued on several important species [e.g., the endangered American crocodile (Mazzotti and Cherkiss, 2003), roseate spoonbills (**Figure 12-34**), and other wading birds (http://www.sfwmd.gov/org/wrp/wrp_evg/projects/wading01/SFWadingBirdReport03.pdf)] and important species of the recreational fishery (Schmidt et al., 2003). Significant efforts are also under way to develop predictive models that simulate how HTLs will respond to freshwater discharge scenarios, including water shortages (MFLs) and hydrologic restoration.

The SFWMD commissioned a literature review on four important fishery species (pink shrimp, spotted seatrout, common snook, and grey snapper) and one dominant forage species (bay anchovy) to address habitat condition for development of Florida Bay MFL criteria (Johnson et al., 2004). This study also focused on the relationship between life stage and salinity metrics. Their conclusions included an assertion that "a reduction in the coverage, intensity, and duration of hypersaline conditions" in Florida Bay would be favorable to these five species, some of which occupy the system during part of their life cycles.

Exploratory models built with field survey data show the importance of estuarine conditions in supporting existing and historically common species in Florida Bay. Johnson et al. (2002a; 2002b) used General Additive Models (GAMs) to determine if habitat variables were correlated with the abundance and distribution of eleven key forage species (see **Table 12-8**). Several of the important variables that determine high habitat suitability were directly or indirectly affected by the timing and distribution of water into Florida Bay (e.g., freshwater flow, salinity, SAV type, and density). All eleven species examined showed some significant relationship to freshwater flow, and seven were specifically correlated with salinity. Seagrass type and density were significant to most species. Importantly, most species demonstrated a preference for mixed SAV beds rather than monospecific beds dominated by a single species. This is in agreement with Thayer et al. (1999). It is expected that expansions of GAM models in late 2004 will support MFL development and evaluation of restoration scenarios as part of the FBFKFS. Improvements will include rainfall and flow as spatial input variables, incorporation of additional field data, development of GAMs for additional species (including juvenile spotted seatrout), and increased use of assemblage level (versus single-species) output (e.g., forage fish biomass, species diversity and evenness, etc.) to examine effects of water management scenarios.

Other Florida Bay HTL models in development are based on a combination of real data and theoretical relationships between species and environmental variables, i.e., conditions that define the "suitability" of a habitat for a given species. The U.S. Fish and Wildlife Service (USFWS) established Habitat Suitability Index (HSI) modeling in the early 1980s as part of its Habitat Evaluation Program. HSIs combine several indices of habitat preference (defined from expert opinion, literature sources, and empirical data) into one overall score. In recent years, estuarine and marine scientists have expanded HSIs into a complex suite of models that employ fine-scale, spatially-explicit input data layers (e.g., bottom type, depth, temperature, salinity, DO) to produce output maps of habitat "potential" for a given species (Rubec et al., 1998, Bartell et al., 2004). In these models, empirical relationships that define the response of a species to habitat conditions are applied to various habitats to determine their potential suitability for a particular species.

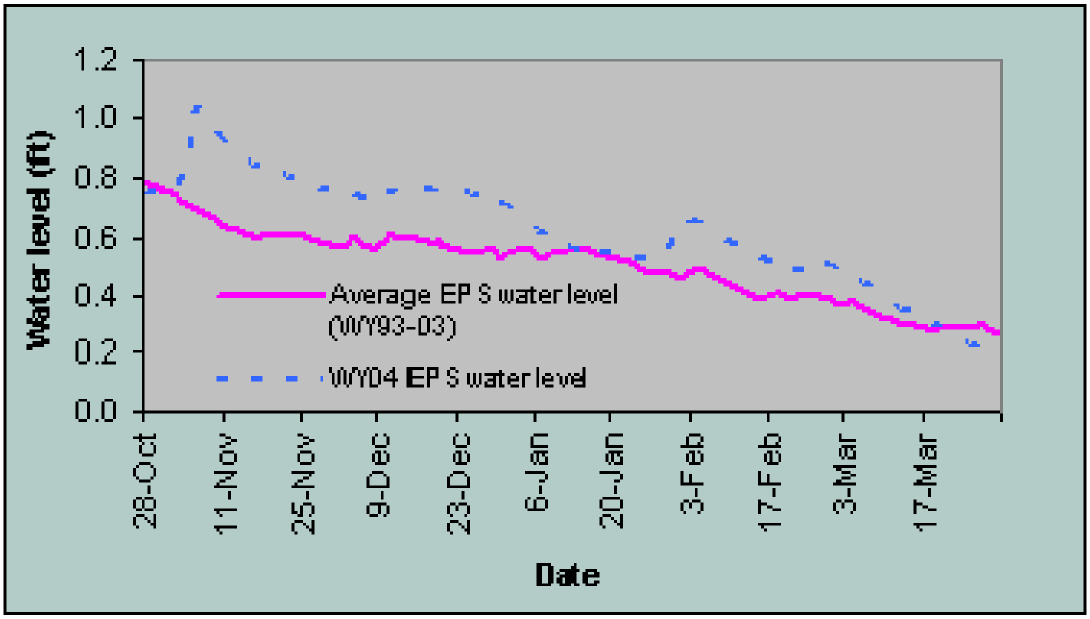

Figure 12-34. Water levels in the ENP panhandle (data from the ENP). Note that the SFWMD has funded a project for WY2005 with the National Audubon Society to build more robust statistical relationships between southeastern Everglades hydrology and measures of nest productivity in spoonbill colonies of northeastern Florida Bay.

Table 12-8. Summary of GAM results (Johnson et al., 2002a; 2002b).

Species	Salinity	Freshwater Flow	SAV density	SAV type preference
Pink shrimp	NS	Pos	dense	Hw, mix, Tt, algae, Sf (signif grass vs. none)
Pinfish	NS	Neg	dense	Sf, mix, Tt, Hw
Mojarras	Neg (only > 40)	neg/pos	dense	Sf, mix, Hw, Tt (signif. grass vs. none)
Bay anchovy	Neg	Pos	NS	none, Hw, mix, Tt, Sf
Gulf toadfish	NS	Pos	moderate	NS
Code goby	NS	Pos	sparse/dense (not moderate)	Tt, Hw, mix
Goldspotted killifish	neg/pos	Neg	moderate (poorest at sparse)	Hw, mix, Tt
Gulf pipefish	Neg	Pos	dense	Hw, mix, Tt
Clown goby	Neg	Pos/Neg	sparse	mix, Sf, Tt, none, Hw, algae
Rainwater killifish	Neg/Pos	Neg	dense	Sf, algae, Hw, Tt, mix
Dwarf seahorse	Neg (only > 40)	Pos	moderate (poorest at sparse)	Sf, mix, Hw, Tt

NS = no significant trend
Neg = Significant negative trend with variable
Pos = Significant positive trend with variable
Neg/Pos = Trend with variable negative, then turning positive
Pos/Neg = Trend with variable positive, then turning negative

Hw = Halodule wrightii
Tt = Thalassia testudinum
Sf = Syringodium filiform
mix = mixed SAV species
none = no SAV species
algae = macroalgae species

MONITORING ROSEATE SPOONBILL NESTS IN FLORIDA BAY

Roseate spoonbill (*Ajaia ajaja)* nesting in Florida Bay in WY2004 was notable for its asynchrony and poor overall nest productivity. Initial analyses of 2004 nesting season's data from colonies in northeastern and northwestern Florida Bay colonies by J. Lorenz of the National Audubon Society (personal communication) suggest that this was a less than favorable year for spoonbills. While prey biomass was sufficient in both areas (especially for the northeastern colonies), water levels remained relatively high through much of the winter. A rise in water level associated with rain events occurred in mid to late January (**Figure 12-34**). High water levels and the January reversal of the water recession probably inhibited prey concentration that allows for efficient foraging. These factors may also have contributed to this year's highly asynchronous nest initiation and overall low nesting effort (in both regions, the season was marked by the lowest number of nests since the mid 1980s). Reproductive success was also well below average for colonies in both regions, although a second (late season) wave of nesting in mid-March at Tern Key (northeastern region) did improve overall reproduction for this colony.

Dynamic population models are also being considered for Florida Bay assessments. The spiny lobster model of Butler (2003) is an example of an advanced model for Florida Bay HTL communities. In this individual-based model, recruitment is predicted as a function of habitat variables (bottom structure, salinity regime, and phytoplankton blooms) and life-history traits of individual lobsters. The incorporation of phytoplankton blooms is a unique feature of this model and addresses potential impacts to changes in water quantity and quality with various restoration scenarios. Mortality of sponges (a primary refuge for juvenile spiny lobsters) that followed the cyanobacteria blooms of the early to mid 1990s continues to be a concern in Florida Bay (http://www.aoml.noaa.gov/flbay/draft/q5.pdf).

NAPLES BAY

INTRODUCTION

Naples Bay is the receiving water body of a subtropical watershed of approximately 120 square miles in western Collier County, Florida (**Figure 12-35**). It 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 historical watershed was predominately a patchwork of swamps, marshes, and sloughs that rejuvenated the aquifers, supported plant and animal life, and supplied water for both urban and rural human populations. The mid twentieth century brought a gradual change in the watershed’s landscape from a natural setting to agriculture and urban land uses. The need to provide urban infrastructures in the form of roads, drainage, utilities, and recreational facilities resulted in virtual elimination of historic flow-ways to the bay and neighboring estuarine waters. As a result, the bay’s water quality and aquatic biota have been adversely impacted. The following section presents an overview of the District’s activities focusing on projects in the Naples Bay watershed that are addressing hydrological and ecological restoration efforts, which are currently being initiated.

SUMMARY OF HYDROLOGICAL PROBLEMS

Both the primary water inlets like Gordon River, Rock Creek, and Haldeman Creek, and the historic flow-ways to Naples Bay have been altered by road and drainage development over the last 40 years. Large freshwater discharges through a network of man-made canals and stormwater outlets cause large fluctuations in the salinity levels and current patterns. This creates enormous shocks to the aquatic biota of the bay, and often results in too little freshwater input to the surrounding saline areas. The rapid decline in salinity to near freshwater levels has caused prolonged salinity stresses and eliminated or displaced a high proportion of the benthic, midwater and fish plankton communities in the bay. Suppressed plankton development has resulted in very low relative abundance of mid-water fish, and has caused a considerable drop in shellfish harvest levels. Seagrass meadows are no longer prevalent in the bay. Instead, bare sandy mud and algal areas predominate. The impact on commercial and recreational fisheries has been significant. Uncontrolled stormwater runoff and increased boat traffic in the navigational channel have also degraded water quality and aquatic biota.

The following sections provide descriptions of restoration projects and resource assessment projects conducted in Naples Bay during WY2004.

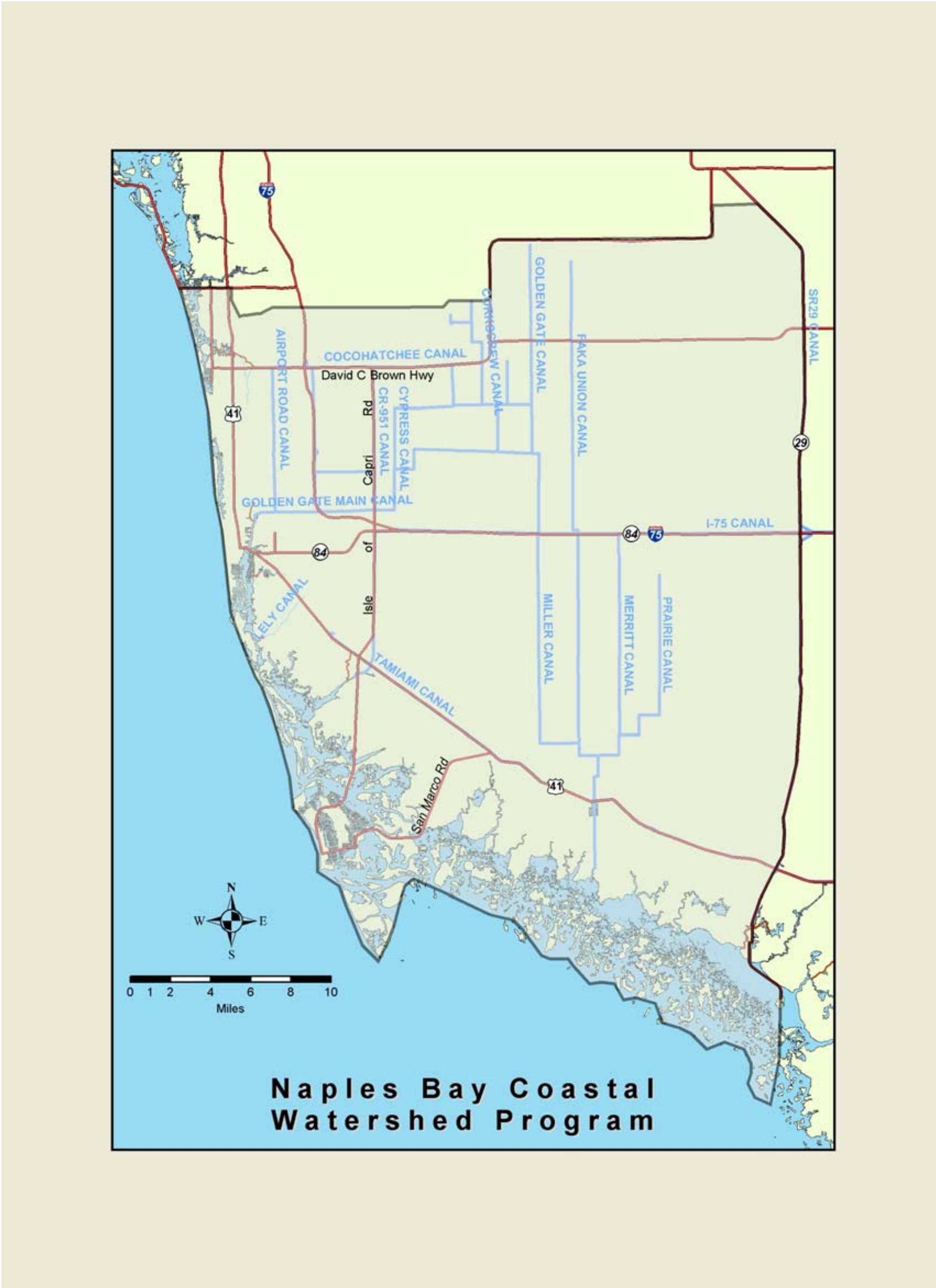

Figure 12-35. Geographic location of Naples Bay.

ENVIRONMENTAL ASSESSMENT CRITERIA

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

CURRENT SCIENCE, ENGINEERING AND RESTORATION ACTIVITIES

Resource Assessment

WATER QUALITY MONITORING

As part of large water quality monitoring project (South Florida Coastal Water Quality Monitoring Network) funded by the District, two stations in Naples Bay are sampled on a monthly basis. One station is inside the bay, while the other is in the Gulf of Mexico at the mouth of the bay; both have been sampled since 1999. Data have not yet been analyzed.

Mapping of Naples Bay and Faka Union Bay Oyster Reefs

One of the major goals of Naples Bay restoration is the protection and restoration of oyster reefs. The objective of this work is to test the utility of Chirp and side-scan sonar in Naples Bay. Preliminary data concerning the distribution of subtidal oyster reefs, shallowly buried oyster reefs, and substrate sedimentology will be collected, and a more extensive deployment will be attempted in FY2005. The project will ultimately provide a further characterization of the effects of Southern Golden Gate Estates (SGGE) water management practices, and potential areas for oyster reef restoration.

Future Activities

Resource assessment activities are just beginning in Naples Bay, and several studies will start next year. These include data collection and bathymetric mapping of Naples Bay and historic habitat distribution in Naples Bay.

RESTORATION ACTIVITIES

Future Activities

Restoration activities are just beginning in Naples Bay. The development of a SWIM Plan is currently being contemplated.

ESTERO BAY

INTRODUCTION

Estero Bay is a long, narrow and very shallow body of water, with its northwestern border beginning at Bowditch Point on Estero Island, and reaching as far as Bonita Beach on the south. Estero Island, Black Island, Long Key, Lover's Key and Big Hickory Island are the barrier islands that separate the bay from the Gulf of Mexico (**Figure 12-36**). Designated in 1966, Estero Bay is Florida's first Aquatic Preserve designated by the state. The watershed of the bay includes central and southern Lee County and parts of northern Collier and western Hendry counties. The principal freshwater inflows come from Hendry Creek, Mullock Creek, Estero River, Spring Creek, and the Imperial River.

Estero Bay is a lagunal-type estuarine system with a barrier beach transected by several passes to the Gulf of Mexico. The lagoon, or bay, is oriented along a north-south axis with freshwater tributaries distributed along the eastern shore and passes to the Gulf along the western shore. The tributaries are estuarine in character. Thus, salinity gradients in the bay and those in the tributaries can form a complex temporal and spatial mosaic.

Population growth and development in the Estero Bay watershed have been rapid, and there is concern regarding potential threats to sensitive natural resources in the bay and the watershed is widespread. This rapid development has changed the amount, timing, and quality of runoff into the bay. Historic flow-ways in the region followed the natural drainage features originating from the Immokalee Highlands through a series of strands, sloughs and surface sheetflows to the tidal areas of the estuary. These natural features consisted of an array of wetlands or swamps connected by sloughs, which are divided by low ridges which were dry for a portion of the year. The historic water flows were extremely slow and penetrating due to vegetation and physical geography. Hydroperiods extended well into the winter/spring dry season. The Estero River and Imperial River systems served as the headwaters to these major flow-ways and sub-basins. However, the canals, roads, impervious surfaces, and other features that attended urbanization overdrained the water table, and drastically altered the flow patterns of the natural drainage basins. These events have greatly reduced the areas of functional wetlands, lowered groundwater levels, reduced aquifer recharge, and contributed to concentrating the flow of stormwater runoff instead of allowing the traditional sheetflow across the land.

This change in hydrology has resulted in ecological impacts on the uplands, remaining wetlands, and especially on the estuaries of the region. Salinity is a major ecological variable that controls important aspects of estuarine community structure and food. The flow alterations have resulted in large fluctuations of salinity and water quality, which in turn are impacting critical estuarine biota.

To manage and preserve the Estero Bay ecosystem, it is necessary to understand the salinity patterns of the bay in relation to freshwater inflow and water exchange with the Gulf of Mexico, describe the mixing and freshwater residence times within the bay, and estimate sediment inputs and resuspension. Such information is necessary to facilitate management decisions geared toward defining flow and sediment loading limits that provide desirable ranges in salinity and water quality by providing necessary hydrological information.

Figure 12-36. Geographic location of Estero Bay.

The District is responsible for setting an MFL in Estero Bay by 2006. To help establish MFLs, the District is using a version of the Valued Ecosystem Component (VEC) approach developed by the USEPA. The approach has been modified to focus on the dominant communities (submerged grass beds, oyster bars) that ordinarily provide habitat in estuarine ecosystems in South Florida. Enhancing and maintaining these communities by providing an appropriate salinity balance should lead to a generally healthy and diverse ecosystem. The freshwater inflows needed to maintain this salinity balance form the basis for establishing MFLs.

Establishing an MFL for Estero Bay presents some challenges. First, the bay has several tributaries that are estuarine in character. Setting a minimum flow for the bay as a whole may not protect the estuarine character of the tributaries. Similarly, setting minimum flows for each tributary separately may not protect the bay. Another problem is that Estero Bay has not been well studied. Some historical records for freshwater inflow exist, but there is little information that relates freshwater inflow to salinity in Estero Bay. Currently, there is little information available to assess the impact that alterations to freshwater inflow may have on the bay and its biota. The monitoring and assessment projects that the District funds are intended to address these challenges.

The following sections describe the environmental and biological criteria that are used to assess the health and condition of Estero Bay. The performance of the system during WY2004 is evaluated using these criteria. Descriptions of restoration projects and significant findings of resource assessment projects conducted over WY2003 also are given.

ENVIRONMENTAL ASSESSMENT CRITERIA

Freshwater Inflow

As part of the CERP Southwest Florida Feasibility Study (SWFFS), which is available online at http://www.evergladesplan.org/pm/studies/swfl_modeling_tools.cfm, acceptable flow ranges are being considered 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*). They are intended to define flow envelopes that maintain appropriate salinity at creek mouths where oysters are located. The minimum flow results in salinities between 15–25 ppt, which are optimal for adults. Flows greater than the maximum result in salinities below 5 ppt, which are lethal to juvenile oysters. Ten-Mile Canal is a source of water for Mullock Creek. Mullock Creek eventually empties into Estero Bay. Discharges from Ten-Mile Canal create appropriate salinity at the mouth of Mullock Creek.

Valued Ecosystem Components

Both oysters and seagrass are present in Estero Bay, are being monitored, and have been selected as VECs to support the MFL for this bay.

ENVIRONMENTAL CONDITION OF ESTERO BAY

Freshwater Inflow

Freshwater inflow to the selected tributaries that were evaluated as part of the SWFFS were further examined regarding their historical deviation from the SWFFS recommended flows (**Table 12-9**). In WY2004, the number of days that high and low flow criteria were met was within the historical range (95-percent confidence interval, or 95% C.I.) for the Ten-Mile Canal and the South Branch of the Estero River. For the Imperial River, relatively fewer days fell in the low flow range, while the maximum flow was exceeded more often.

Table 12-9. Hydrologic and salinity ranges for tributary inflow into Estero Bay. The number of days in WY2004 when flow was within low flow range is compared to the historical mean ± 95% C.I. The number of days in WY2004 when flow exceeded the recommended maximum is compared to the historical mean ± 95% C.I.

Tributary	Salinity Parts per thousand (ppt)	Flow (cfs)	Water Years	Days/Year	Years (n)	Period of Record
Ten Mile Canal	15 –25	4–50	Historical	143 ± 22.5	15	1989–2003
Ten Mile Canal	15–25	4–50	2004	165	1	2004
Ten Mile Canal	5	215	Historical	30 ± 15.1	15	1989–2003
Ten Mile Canal	5	215	2004	18	1	2004
South Branch Estero	15–25	3–9	Historical	71 ± 20.8	16	1988–2003
South Branch Estero	15–25	3–9	2004	92	1	2004
South Branch Estero	5	32	Historical	39 + 13.9	16	1988 - 2003
South Branch Estero	5	32	2004	52	1	2004
Imperial River	15–25	4–26	Historical	169 ± 35.3	16	1988–2003
Imperial River	15–25	4–26	2004	94	1	2004
Imperial River	5	94	Historical	109 ± 29.8	16	1988–2003
Imperial River	5	94	2004	161	1	2004

Seagrasses

Trends in the aerial extent of seagrasses in Estero Bay show a slight reduction from WY1999–WY2003 (**Table 12-10**) of 86.43 acres. It is proposed that establishing an MFL in Estero Bay will improve the spatial and structural characteristics of submerged plant communities.

Table 12-10. Aerial extent of seagrass in Estero Bay for WY1999 and WY2002–2003.

Year	Acres of Seagrass
WY1999	2490.84
WY2002 and 2003	2404.41

Oysters

Historical information on the aerial extent of oyster reefs in Estero Bay is not available. Based on WY2004 data, there are presently 59.64 acres of oysters in Estero Bay. Anticipated reductions in flow would result in estuarine salinities suitable for the growth and enhancement of oyster reefs in areas above the mouths of the tributaries. It is anticipated that there will be an approximate 250-acre increase in oyster reef coverage in the next 10 to 15 years, with an annual increase of about 10–20 percent. Given the shift in estuarine conditions, it is anticipated that the focus of oyster reef development will be north of the tributary mouths and shallow embayments. With the placement of shell substrate and certain reef material equaling 100–150 acres in strategic places, reef growth is expected to accelerate, forming approximately 500 acres of oyster reefs in about 15 years.

CURRENT SCIENCE, ENGINEERING AND RESTORATION ACTIVITIES

Resource Assessment

The results of several ongoing activities listed below will support the development of an MFL for Estero Bay.

SALINITY AND SEDIMENT RUNOFF MONITORING

This study is designed as an approximate five-year project starting on June 2001 and ending in September 2006. The objectives of this study are to collect the necessary information within Estero Bay to (1) describe the salinity patterns of the bay in relation to freshwater inflows (tributary flow and rainfall) and tidal exchange with the Gulf of Mexico; (2) meet the data needs of a hydrodynamic and salinity model to be produced by the District after this study; (3) further study the use of acoustic and turbidity instruments for the estimation of continuous record of suspended sediment concentrations (SSC) in estuarine environments; (4) understand the relationship of total suspended solids (TSS) to Acoustic Backscatter Strength (ABS) and turbidity at the tributary sites; and (5) compute TSS load at these locations. To attain these objectives, this project includes the monitoring of a suite of hydrologic parameters at selected sites within Estero Bay.

BATHYMETRIC SURVEYS

The development of a hydrodynamic and water quality model of Estero Bay is necessary to support the MFL and to better understand the bay for restoration and protection. To facilitate development of a useful model, updated bathymetry needs to be obtained. In a cooperative agreement with the District, the USGS have collected the bathymetric data and developed a present day bathymetry of Estero Bay. This project supports several District efforts including the proposed MFL development for Estero Bay due in 2006 and the Southwest Florida Feasibility Study, both of which will utilize the hydrodynamic model results. The project also supports other non-modeling efforts, such as the determination of the oligohaline zone in the Estero Bay system.

HYDRODYNAMIC MODELING

The District received a 3-D hydrodynamic/salinity model for Charlotte Harbor in 2002. The model grid includes Estero Bay and this grid is being modified for higher resolution to support MFL development. Data collected as part of the Bathymetry Survey and Salinity and Sediment Runoff Project will be used to calibrate and verify the model.

Hydrologic History of Estero Bay

One of the problems in applying the VEC approach to MFL development has been determining where and when these VECs historically existed in a particular estuary. Accurate chronological information is important for several reasons. It ensures that components of the ecosystem that have been present historically are identified for protection. It prevents protection and maintenance of an ecosystem that has arisen artificially as a result of recent agricultural, industrial, or urban development. Such information also allows consideration of restoration goals within a historical context.

The objectives of this project are to identify three major historical components needed for MFL development in Estero Bay as follows: salinity patterns, VEC habitat (e.g., oysters), and sedimentation rates.

Bivalve Survey

This project uses the composition of the bivalve community in Estero Bay to indicate and quantify responses to changes in salinity. Three east-west, cross-bay transects are sampled monthly. The placement and orientation of the transects allow comparison between regions of the bay that experience different seasonal fluctuations in salinity. Results will be used to establish freshwater needs of the bay proper. Other projects will address the needs of the tributaries.

Submerged Aquatic Vegetation Monitoring

Monitoring submerged aquatic vegetation (SAV) in Estero Bay is performed using spatially and thematically accurate Arc/INFO seagrass SAV databases. These databases were created by Avineon for the coastal waters of the District, from Boca Grande south to Wiggins Pass, using January 2003 true-color aerial imagery. This area was flown again in January 2004. New seagrass databases will be created using these images and trend analyses will be preformed.

Oyster Monitoring

In Southwest Florida, oysters have been identified as a VEC. In WY2004, oyster maps for Estero Bay were created by the Florida Gulf Coast University using aerial helicopter surveys flown during the winter months when low tides are more extreme. Data from digital photography was transferred into a Geographic Information Systems (GIS) database and the aerial extent and spatial distribution of the reefs was determined. Ground-truthing of the reef localities occurred through subsequent fieldwork.

Future Activities

Additional survey efforts are planned to assess freshwater inflow impact on SAV and fisheries resources. These will include using hydroacoustic methodology, which will be included with information from the above-described aerial imagery, to better determine SAV spatial and temporal change. Other efforts will include field data collection of water column biota. These additional efforts are required to determine MFL and the preferred distribution of flows for Estero Bay.

RESTORATION ACTIVITIES

Restoration of Shellfish in Estero Bay

Florida Gulf Coast University, in collaboration with the Lee County School District, the District, the Florida Sea Grant, and the City of Cape Coral, constructed three oyster reefs (10 m^2 each) in the Estero Bay using recycled oyster shell and stabilizing mesh in order to establish suitable substrate for oyster recruitment. This community-based restoration involved the general public, as well as high school and undergraduate students (43 volunteers and 7 boats). Reefs will be monitored to determine restoration success. This project was funded through the Estero Bay Initiative. The Estero Bay Initiative is a program authorized by the Florida legislature, which funds stormwater management and environmental restoration projects in the bay.

Imperial Bonita Estates Stormwater Retrofit

The SFWMD has provided funds to the City of Bonita Springs for drainage enhancements in the Imperial Bonita Estates area to alleviate flooding and to provide water quality improvements for the stormwater runoff that enters the Imperial River and ultimately Estero Bay. The project involves improving an existing drainage ditch, upsizing culvert pipes, and constructing weirs to naturally filter and decelerate water flow. A swale along the north boundary of the area will be extended to the west, cleared of vegetation and debris, and a berm breach repaired so that improper discharge from a pond in the subdivision to the north can be linked to a Lee County Department of Transportation storm sewer. Funding for this effort was provided through the Estero Bay Initiative.

Bonita Villas Stormwater Repairs

The SFWMD has provided funds to the City of Bonita Springs to restore the stormwater system of the Bonita Golf Club Villas. The restoration efforts involve (1) removing vegetation from the perimeter berm and rebuilding that berm; (2) removing overgrown vegetation from a retention lake; (3) cleaning, repairing, and replacing the interiors of the intake structures and discharge pipes; (4) cleaning and re-grading the outfall swale to the proper elevation; and (5) installing a new trash rack at the intake structure.

CALOOSAHATCHEE RIVER AND ESTUARY

INTRODUCTION

The Caloosahatchee Estuary is located on the southwest coast of Florida. The major source of fresh water is the Caloosahatchee River, which runs 65 kilometers from Lake Okeechobee, to the head of the estuary at the Franklin Lock and Dam (S-79). Geographically, the estuary extends about 40 kilometers downstream to Shell Point, where it empties into San Carlos Bay. Major environmental concerns for the Caloosahatchee are altered freshwater inflows, eutrophication, and habitat loss.

In their recent book, Postel and Richter (2003a) reported that human actions alter rivers in numerous ways that diminish water quality and threaten fish and wildlife resources. However, one threat to river health looms over all others, "…the alteration of natural river flows by dams, diversions, levees and other infrastructure. Dams and diversions now alter the timing and volume of river flows on a wide geographic scale. Rather than flowing to the natural rhythms of the hydrologic cycle, they are turned on and off like elaborate plumbing works…" (Postel and Richter, 2003b). With its three dams, network of drainage canals, and artificial connection to Lake Okeechobee, the Caloosahatchee River and Estuary could serve as a prime example of how human interaction has affected natural river flow, a problem that now threatens 60 percent of the world's large rivers.

The Caloosahatchee River historically bisected its basin and probably only received water from outside its watershed or from Lake Okeechobee during extreme regional flooding events that sent water to the marshlands at the headwater of the river. Now the river functions as a primary canal (C-43) that conveys both basin runoff and regulatory releases from the lake. The canal has undergone a number of alterations to facilitate this increased freshwater discharge, including channelization, bank/levee stabilization, and the addition of the three lock and dams. The final structure (S-79) maintains specific water levels upstream, discharges fresh water into the estuary and acts as a barrier to salinity and tidal action, which historically extended far upstream.

Depending on the day of the year, the long-term mean daily discharge ranges from 300 to 3,000 cfs. However, daily and monthly inflows often exceed this long term average, with prolonged inflows commonly exceeding the 4,500 cfs that adversely influences the San Carlos Bay area. Flows above this threshold (occasionally exceeding 10,000 cfs) can push fresh water into Pine Island Sound and the Gulf of Mexico, impacting ecologically and commercially important high salinity marine resources ordinarily unaffected by Caloosahatchee River discharges. During the dry season, the combination of limited rainfall, lack of water storage in the basin and withdrawals to meet human demands for irrigation and potable water often result in periods of no freshwater discharge to the estuary. Salt water can intrude all the way upstream to S-79 eliminating the oligohaline zone, truncating the salinity gradient and threatening species that require low salinity to complete their life cycle (Chamberlain and Doering, 1998a and 1998b; Doering et al., 2002; SFWMD, 2003).

Excessive variation in discharge and salinity, occurring in the Caloosahatchee Estuary (Chamberlain and Doering, 1998a), can maintain estuarine biota in a constant flux between those favoring higher salinity and those favoring lower salinity (Bulger et al., 1990). At the extreme, appropriate salinity conditions do not last long enough for organisms to complete their life cycle and the estuary can become devoid of some populations, even keystone species that support major ecosystem components along an estuary's salinity gradient.

Environmental research by the SFWMD began in the Caloosahatchee Estuary during the mid-1980s and focused on the impacts associated with the extreme variability in freshwater inflow from S-79 (Chamberlain, 1998a). The purpose of the research was to determine the proper timing and volume of water quantity required to support valued ecosystem components, such as submerged oligohaline and marine grasses and oysters, as well as the impacts of flows on general biotic indicators such as plankton and benthic invertebrates (SFWMD, 1998). This research included both experimental (Doering et al., 1999; Doering and Chamberlain, 2000; Kraemer et al., 1999) and field surveys (Chamberlain et al., 1995), which have resulted in the development of optimum S-79 flow ranges and delivery patterns for the estuary (Chamberlain and Doering, 1998b; Doering et al., 2002; Volety et al., 2003). This information has formed the basis for development of hydrologic performance measures for CERP, SWFFS (2003), and Lake Okeechobee, as well as meeting legislative mandates for the establishment of MFL (SFWMD, 2003).

The discharge of water at the Franklin Lock and Dam (S-79) is also is a major determinant of macro-nutrient concentrations and other aspects of water quality in the Caloosahatchee Estuary. Influence of this discharge can be detected nearly 60 kilometers downstream in Pine Island Sound (Doering and Chamberlain, 1998 and 1999). This control of water quality stems from the overwhelming dominance of the Caloosahatchee River at S-79 as a source of nutrients and other materials to the downstream estuary.

The requirement for water quality improvement in the Caloosahatchee Estuary has been an issue since the 1980s, when the Florida Department of Environmental Regulation (FDER; currently known as the FDEP) conducted waste load allocation studies (DeGrove, 1981; Baker, 1990). Based on elevated chlorophyll *a* levels and depressed concentrations of DO, the FDER concluded that the Caloosahatchee had reached its nutrient loading limits. Similarly, McPherson et al. (1990) concluded that increased nitrogen loading would result in undesirable increases in phytoplankton and benthic algae. Target concentrations for chlorophyll *a* (20 µg/L), TN (1.0 mg/L), and TP (0.15 mg/L) were suggested as upper limits for acceptable water quality in the Caloosahatchee (DeGrove, 1981). More recently, Janicki Environmental (2003) estimated critical TN loads to the Caloosahatchee Estuary at S-79 based on chlorophyll *a* levels downstream, while Chamberlain et al. (2003) began exploring the potential linkages between estuarine water quality parameters and potential targets.

Loss of habitat has also been of concern. Hardening of the shoreline, increased freshwater discharge, and oyster mining are thought to have singly or in combination reduced mangrove, seagrass, and oyster bar habitats (e.g. Harris et al., 1983).

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 WY2004 is evaluated using these criteria. Descriptions of restoration projects and significant findings of resource assessment projects conducted over WY2003 also are given.

ENVIRONMENTAL ASSESSMENT CRITERIA

As stated earlier, information in the literature and research conducted by the District has resulted in flow criteria or performance measures for discharge at S-79 that are being used for CERP, SWFFS and operation of Lake Okeechobee. This research has also supported the development of salinity criteria for the Caloosahatchee River and Estuary MFLs (SFWMD, 2003).

These criteria and performance measures were derived from relationships between the distribution, abundance, growth, and survival of estuarine organisms and changes in salinity or freshwater discharge. Salinity tolerances of submerged grasses were initially used to identify minimum and maximum inflows at S-79. Mean monthly flows less than 300 cfs are thought to allow salinity in the upper estuary to exceed the tolerance of tape grass (*Vallisneria americana*) (targets: monthly average salinity ≤ 10 ppt at Ft. Myers Yacht Basin, daily average < 20 ppt). Flows greater than 2,800 cfs depress salinity in the lower estuary and threatens the marine shoal grass (*Halodule wrightii*) typical of this region (Chamberlain and Doering 1998b; Doering et al., 2002). Research has shown that these flows are beneficial to other organisms as well (Chamberlain and Doering, 1998b; Volety et al., 2003). The MFL salinity criteria were initially designed to protect tape grass upstream of Fort Myers, but are also beneficial for other organisms that utilize this low salinity region of the estuary (Chamberlain and Doering, 1998b; Doering et al., 2002).

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 which serves as an indicator of estuarine health in the upper estuary (**Figure 12-37**), these are oysters and marine seagrasses representing the more downstream seaward portions of the system. Preliminary performance measures have been suggested for these biological resources in the Caloosahatchee Estuary (SWFFS, 2003) based on historical survey results. Performance measures for discharge at S-79 and MFL salinity criteria are presented on **Table 12-11**.

Table 12-11. CERP performance measures for freshwater discharge at S-79 and MFL salinity criteria at Fort Myers, FL (SFWMD, 2003; SWFFS, 2003).

Freshwater Discharge At S-79	CERP Performance Measure
Low Flow for Estuary (mean monthly)	Number of months < 300 cfs
High Flow for Estuary (mean monthly)	Number of months > 2800 cfs
Discharge from Lake Okeechobee	Minimize number of days
Low Flow Duration	Frequency of consecutive months < 300 cfs (1 month, 2 months etc.)
High Flow Duration	Frequency of consecutive months > 2800 cfs (1 month, 2 months, etc.)
Optimum distribution of inflow	Closeness to preferred frequency distribution
Minimum Flow and Level at Ft Myers, FL	
Salinity Criteria (daily average)	Shall not exceed 20 ppt in a given year
Salinity Criteria (30-day average)	Shall not exceed 10 ppt in a given year

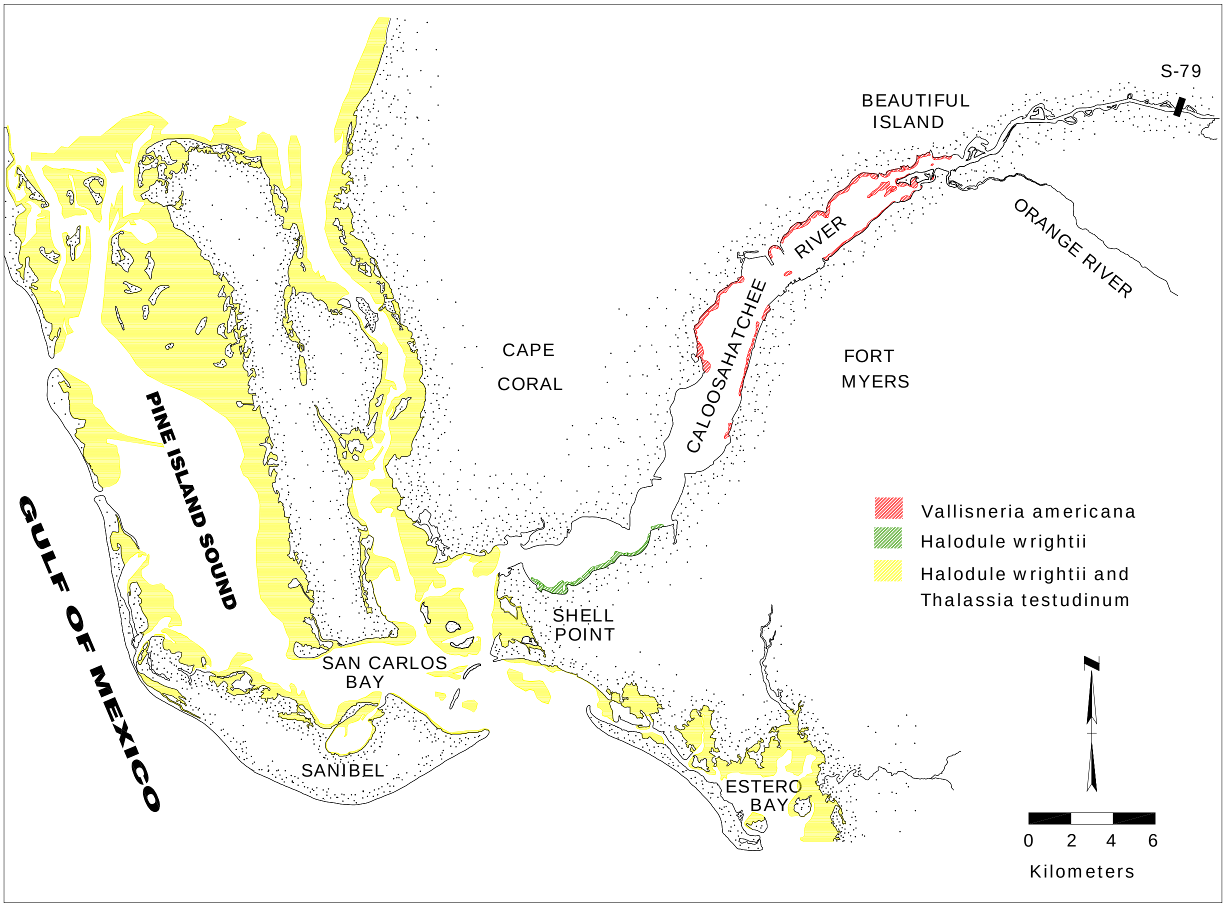

Figure 12-37. Caloosahatchee Estuary and surrounding area. The general historic range of dominant SAV species are indicated, when condition are good for maximum distribution (*Vallisneria americana* farthest upstream and *Halodule wrightii* near the downstream mouth, Shell Point). *Syringodium filiforme* is also a significant species in Pine Island Sound. Oysters present from just upstream of Shell Point to downstream areas.

Salinity at Fort Myers

Evaluation of the MFL salinity criteria confirms that the upper Caloosahatchee Estuary experienced daily average salinities below 10 ppt for the entire year (**Table 12-12**). The period of record for salinity at Fort Myers extends back to 1991. WY2004 is only the second out of 13 water years in which neither of the two criteria was exceeded (criteria: average salinity of < 10 ppt at Ft. Myers Yacht Basin; daily average of < 20 ppt).

Tape Grass in the Upper Caloosahatchee

Due to high salinity experienced during the 2001 drought, tape grass beds (*Vallisneria americana*) in the upper Caloosahatchee estuary (**Figure 12-37**) essentially vanished, and have been in recovery since that period (**Figure 12-38**). During WY2004, the beds have made a remarkable recovery, attributable to favorable salinity conditions (**Figure 12-38**).

Table 12-12. Caloosahatchee MFL salinity criteria at Fort Myers from WY1992–WY2004.

Water Year	Maximum Daily Average	Maximum 30-Day Average
1992	20.86	17.82
1993	18.68	16.01
1994	13.77	12.05
1995	5.47	5.26
1996	14.23	12.90
1997	23.34	17.30
1998	16.30	14.29
1999	19.40	17.14
2000	18.41	16.26
2001	24.62	23.31
2002	26.74	25.62
2003	16.16	14.34
2004	9.63	6.74

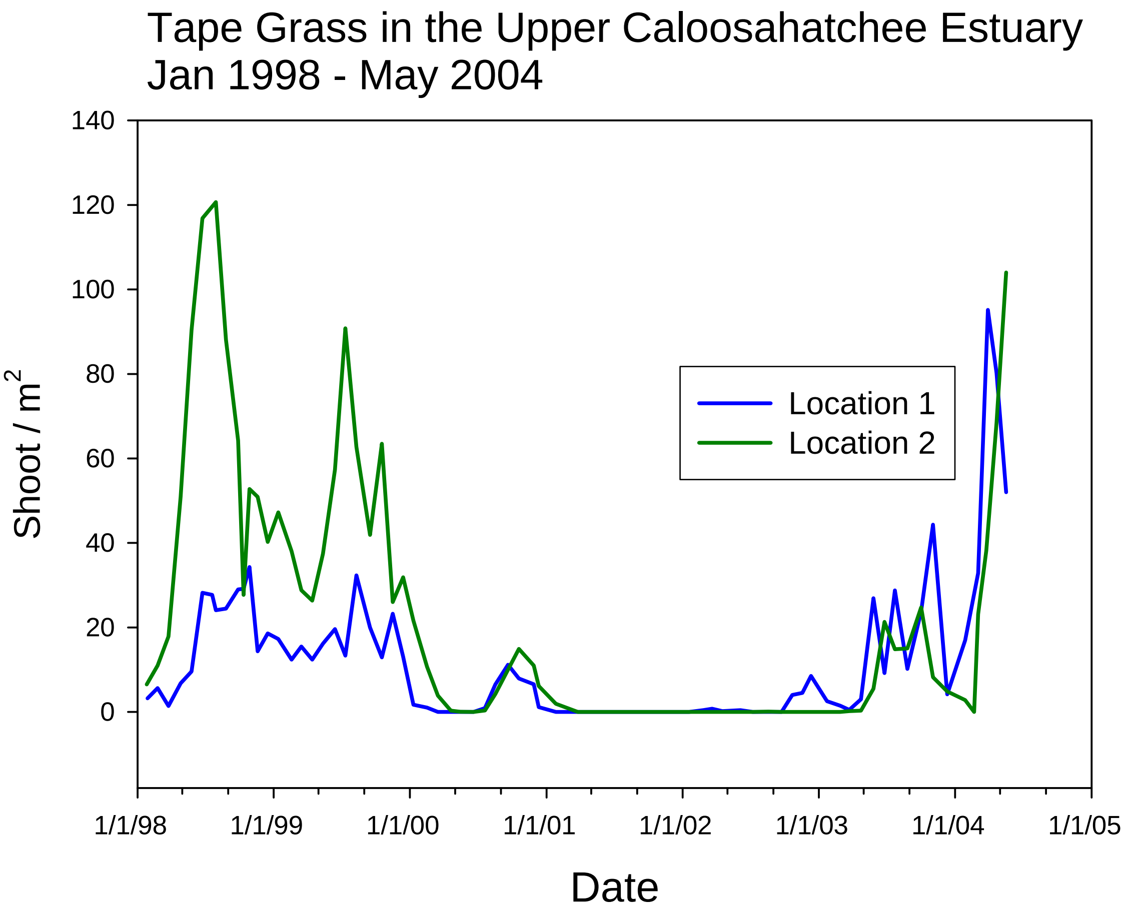

Figure 12-38. Tape grass (*Vallisneria americana*) shoot density in the upper Caloosahatchee Estuary. Data are from stations maintained by the Sanibel-Captiva Conservation Foundation and Mote Marine Laboratory. Location 1 is near Beautiful Island. Location 2 is located near the terminus of Old Bridge Road in North Fort Myers.

Oysters

Historical information on the aerial extent of oyster reefs in the Caloosahatchee Estuary is limited. Sackett (1888) in his survey report to the U. S. Engineering Office described sections of the lower Caloosahatchee (upstream of Shell Point) as difficult to navigate due to the abundance of oyster reefs. Primarily due to changes in freshwater inflow, dredging, and shell mining activity in the later half of the twentieth century, oyster abundance in its historical range has been greatly reduced. Based on WY2004 aerial surveys, there are presently only 3.02 acres of oysters in the Caloosahatchee Estuary. Most of these are located in the Shell Point region (**Figure 12-37**). A preliminary target for the aerial extent of oyster reefs in the lower estuary is a 40-acre increase in the next 10–15 years with the proper changes in flow and salinity. With the addition of hard substrate, this target can be increased to 200–300 acres of oyster reefs.

Marine Seagrass

Seagrasses have been surveyed in the Calooshatchee Estuary by aerial photography since the 1940s. Harris et al. (1983) compared aerial surveys at the time with these historical surveys and reported a significant reduction in seagrass coverage. Unfortunately, methodological and other differences in subsequent surveys preclude a reliable trend analysis (Corbett et al., 2003). Based on the previously described experimental and field survey efforts, it is proposed that restoring hydrology in the Caloosahatchee Estuary will protect and improve the spatial and structural characteristics of submerged plant communities (Chamberlain and Doering, 1997 and 1998b; Doering et al., 2002). There appears to have been a dramatic increase in aerial extent of seagrass (*Halodule wrightii*) in the lower Caloosahatchee Estuary (**Figure 12-37**) over the last few years (**Table 12-13**). However, this increase may be due to reduced water clarity at the time of the surveys rather than a real change.

Table 12-13. Aerial extent (acres) of marine shoal grass (*Halodule wrightii*) in the lower Caloosahatchee Estuary (upstream of Shell Point) in WY1999 and WY2002–2003.

Water Year	Seagrass Patchy	Seagrass Contiguous	Total Acres
1999	0.0	2.02	2.02
2002–2003	23.96	80.70	104.66

CURRENT SCIENCE, ENGINEERING AND RESTORATION ACTIVITIES

Resource Assessment

SALINITY MONITORING

The District maintains a series of electronic monitoring stations that collect salinity and temperature data every 15 minutes (Chamberlain and Doering, 1998a). There are currently five operational sites: S-79, Route 31 Bridge, Ft. Myers Yacht Basin, Mid Point Bridge, and the Sanibel Causeway. Data are used to (1) monitor compliance with the Caloosahatchee MFL, (2) support water management of Lake Okeechobee, (3) aid in ecosystem evaluations, and (4) support development of hydrodynamic and water quality models.

WATER QUALITY MONITORING

Prior to 2000, the District sampled water quality as part of long-term field research efforts or during periods of important water discharge periods. Currently, the District conducts only limited in-situ measurements associated with acoustic SAV monitoring. Routine data are collected as required by an outside contractor in order to quantify effects of releases of water from Lake Okeechobee to the Caloosahatchee. Eleven stations, ranging from S-79 to San Carlos Bay are sampled. In addition, the CERP funds Lee County to collect water quality at four sites distributed between S-79 and the Mid Point Bridge. Current sampling at these locations corresponds to stations sampled prior to 2000 in order to maintain a historical connection for trend assessment. In addition, a study by ERD (2003) was recently completed that assessed material loading and water quality in selected tributaries below S-79, concurrent with water quality downstream in the estuary. This study confirmed that the Caloosahatchee River is the major source of nutrients to the downstream estuary, except under very dry conditions.

SUBMERGED AQUATIC VEGETATION MONITORING

Beds of submerged aquatic vegetation (SAV) provide important habitat for numerous organisms and are indicators of a healthy estuary. The status of SAV beds in the Caloosahatchee comprises one of the performance measures which will assess the success of the CERP. Prior to 2000, routine manual monitoring of SAV by the District was conducted periodically for extended time periods to assess changes related to freshwater inflow. The Sanibel Captiva Conservation Foundation Marine Laboratory was recently contracted to conduct a long-term program for manual monitoring SAV in the upper (three sites) and lower (two sites) Caloosahatchee River and San Carlos Bay (two sites). Species being monitored include *Vallisneria americana, Ruppia maritima, Halodule wrightii,* and *Thalassia testudinum*. This monitoring occurs monthly in the upper Caloosahatchee River and bimonthly in the lower Caloosahatchee River and in San Carlos Bay. Water quality measurements, including vertical profiles of DO, salinity, temperature, pH, conductivity, chlorophyll *a*, turbidity, and photosynthetically active radiation (PAR), are collected during monitoring events. In addition to this contractual effort, eight sites located from Beautiful Island to Pine Sound have been surveyed since 1996 using hydroacoustic technology (Sabol et al., 2002). This methodology allows for a greater spatial coverage of sampling for the same effort as traditional manual methods (Chamberlain et al., 2004).

Using data from both experimental research and field collection, progress continues in the ecological modeling of *Vallisneria* by the District (Hunt et al., 2003). Contractual work performed for the District by the University of Florida is interfacing with this effort as part of the university's larger modeling efforts to predict monthly and long-term changes in coverage of SAV related to freshwater inflow and associated water quality conditions.

OYSTER MONITORING

Oysters are also monitored in the Caloosahatchee Estuary, as further discussed in the *Southern Charlotte Harbor* section of this chapter.

GRASS BED HABITAT

Submerged grass beds provide important habitat in both the low and high salinity areas of the Caloosahatchee Estuary. Beds of tape grass (*Vallisneria americana)* are located in the upper low salinity zone of the estuary, while marine seagrasses (shoal grass, *Halodule wrightii* and turtle grass, *Thalassia testudinum*) inhabit the more saline marine reaches of the system. These habitats are being sampled through contract with Mote Marine Laboratory to ascertain the extent of utilization by estuarine animals (e.g., fish and shellfish), and to determine how this utilization is affected by freshwater discharge from the Caloosahatchee River. Information from these studies will contribute to better management of discharges from Lake Okeechobee, as well as the operation of the reservoirs and storage wells that are planned for the C-43 basin under CERP.

Recently, tape grass has been severely reduced in the Caloosahatchee River. In an attempt to help reestablish tape grass in the river, a study was conducted to transplant tape grasses area in-situ in containers under several treatment conditions. Although the transplants survived, their performance was not as expected. However, results showed that caged containers significantly more grass than uncaged containers. These results have led to speculation that grazing may interfere with recovery of tape grass beds in the Caloosahatchee River.

A second study was designed to create a series of alternative scenarios of conditions that would help identify the grazers that are potentially limiting tape grass restoration. Results showed that exclusion cages allow lush and full growth of tape grass. Cages that exclude potential grazers only from above are ineffective, as well as cages that allow limited access from the sides when water levels exceed the height of the cage. Further studies are being conducted to specifically identify the grazers.

HYDRODYNAMIC MODELING

The District is currently continuing to make improvements to the Caloosahatchee Hydrodynamic/Salinity Model. This model was used to support the 2003 update of the Caloosahatchee MFL and to develop Existing Legal Sources for the Caloosahatchee River. Work has begun to develop versions of the model that can be used to support evaluation of alternatives for the C-43 Basin Project, available online at http://www.sfwmd.gov/org/exo/ftmyers/c43, and Southwest Florida Feasibility Study. One of the limitations of the original model was that all freshwater input entered the model domain at the Franklin Lock and Dam (S-79) at the head of the estuary. This year, the model is being modified to handle freshwater input from the tidal basin located to the west of S-79.

WATER QUALITY ASSESSMENT

In estuaries and other aquatic systems, excessive nutrient inputs are commonly expressed as phytoplankton blooms. These blooms are associated with reduced light penetration which restricts the depth distribution of seagrass and other benthic vegetation and depressed oxygen concentrations, which can result in mortality of fish and other fauna. Because chlorophyll *a* links nutrient enrichment with environmental impact, it is commonly included in water quality monitoring programs and employed as an indicator of eutrophication. Water quality criteria or standards for chlorophyll *a* are sometimes viewed as a necessary component of an effort to set bounds on nutrient inputs to estuaries.

Using data from several monitoring programs, the potential use of chlorophyll *a* as an indicator of eutrophication was examined to address the relationship between nutrient loading and chlorophyll *a*, the role of chlorophyll *a* in light attenuation, and the relationship between chlorophyll *a* and DO concentration. The relationship between nutrient loading and chlorophyll *a* varied spatially, being negative at the head of the estuary and positive in San Carlos Bay. In the estuary, color and/or total suspended solids explained most of the variability in light extinction, while chlorophyll *a* was most important in San Carlos Bay. In estuarine segments, high chlorophyll *a* was associated with lower DO in bottom waters at lag times of one or two months. Chlorophyll *a* appears to be a good indicator of the impacts of eutrophication in the Caloosahatchee. Because of spatial variability in the relationships between chlorophyll and nutrient loading and light attenuation, the implications of nutrient load reductions may be different for different regions of the Caloosahatchee system.

RESTORATION ACTIVITIES

Caloosahatchee River Oxbows

The Caloosahatchee oxbows are all that remain of the original, narrow meandering river following the channel dredging conducted by the USACE in the 1930s and 1950s. Prior to channelization and dredging, the river bends slowed the water, facilitating the deposition of sediment and absorption of nutrients in the water column, and providing habitat for native fauna and flora. Following the channelization, water flowed directly down the straight deepened channel, creating eroding vertical banks without littoral habitat. Today, the oxbows, historic remnant meanders, represent the only aquatic habitat left in the riverine system.

Of the 35 oxbows between WP Franklin Lock in eastern Lee County and SR 29 in LaBelle, Hendry County, about 18–20 are in need of restoration assistance to recover aquatic productivity and function. Each oxbow has unique properties that require site-specific solutions. An oxbow in Hendry County has received permits for its restoration, and the planning is moving forward. The restoration of this oxbow is expected to serve as a demonstration project for future oxbow work.

Orange River

Lehigh Acres is located in the Orange River basin and within the service area of the East County Water Control District (ECWCD). Harn’s Marsh is a 578-acre flood detention facility within ECWCD boundaries. The Harn’s Marsh Restoration project is a result of a comprehensive hydrologic study of the area to identify problems and solutions. Construction of a control weir is planned at the outlet of Harn’s Marsh into the Orange River, which will raise water levels in Harn’s Marsh, restrict flows from Harn’s Marsh, and lower peak flow discharge into the Orange

River. In addition, control weirs that currently discharge into Harn's Marsh will be repaired, modified, or replaced to allow flexible operation to provide maximum flood storage in the marsh. Separate wet and dry season control elevations will be maintained. Higher water levels year round due to these improvements will provide the BMPs for the marsh. The improvements will create an additional 1,450 ac-ft of storage and longer detention times in Harn's Marsh and will improve water quality being discharged into the Orange and eventually Caloosahatchee rivers.

East Lee County Caloosahatchee Tributaries Restoration

The Lee County Surface Water Master Plan recommends that the county's rivers and creeks be cleaned of fallen debris and exotic vegetation to allow optimum performance of outfalls and avoid flooding while still maintaining good quality aquatic habitat. Lee County and the District have worked together in a cost-sharing arrangement for the cleaning of numerous creeks and rivers throughout the county. As part of this continuing cooperative effort, Lee County and the District have agreed that numerous tributaries flowing into the Caloosahatchee River east of the W.P. Franklin Locks are in danger of becoming seriously infested with exotic vegetation. While the removal of exotic vegetation is considered necessary to improve drainage, it is also acknowledged that removal of the vegetative growth from the banks may leave them susceptible to erosion. Replanting those areas with desirable native vegetation is now an important consideration. In addition to bank stabilization, replanting is important for maintaining or improving water quality, as well as reestablishing habitat for the native wildlife.

SOUTHERN CHARLOTTE HARBOR

INTRODUCTION

Charlotte Harbor is Florida's second largest open-water estuary, and one of the state's major environmental features. It is bordered by three counties (Lee, Charlotte, and Sarasota) and has a broad barrier island chain and a largely intact mangrove shoreline with significant parts in public ownership and management. It is the site of three National Wildlife Refuges and four aquatic preserves. Its watershed stretches from the headwaters of the Peace River in Polk County to the southern end of Estero Bay in Lee County, a distance of more than 100 miles.

Charlotte Harbor and its adjoining lands and waters constitute a comparatively large ecosystem. The Charlotte Harbor Estuarine System includes Charlotte Harbor, Pine Island Sound, Matlacha Pass, San Carlos Bay, and the Caloosahatchee Estuary (**Figure 12-39**). Only the southern portion of the Charlotte Harbor system lies within the District's boundaries. Southern Charlotte Harbor (within District boundaries) includes southern portions of Pine Island Sound and Matlacha Pass, San Carlos Bay, and the Caloosahatchee Estuary.

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. In Southern Charlotte Harbor, the Calooshatchee River meets the harbor at Shell point.

In 1987, the Surface Water Improvement and Management Act (SWIM) (Chapters 373.451–373.4595, F.S.) was enacted. The law directed the state's water management districts to prioritize water bodies, develop plans for their management, and fund restoration projects in these special watersheds. The Southwest Florida Water Management District (SWFWMD) designated Southern Charlotte Harbor watershed as a SWIM water body, one of 29 watersheds in Florida. The SFWMD has added the Southern Charlotte Harbor watershed to this list of priority water bodies.

The following sections describe the environmental and biological criteria that are used to assess the health and condition of Southern Charlotte Harbor. The performance of the system during WY2004 is evaluated using these criteria. Descriptions of restoration projects and significant findings of resource assessment projects conducted over WY2003 also are given.

Figure 12-39. Geographic location of Southern Charlotte Harbor.

ENVIRONMENTAL ASSESSMENT CRITERIA

Freshwater Inflow

For establishment of flow criteria, see the *Caloosahatchee Estuary* section of this chapter.

A performance measure and target for freshwater discharge at S-79 has been set to meet salinity criteria in San Carlos Bay (**Table 12-14**).

Table 12-14. Performance measure and target for freshwater discharge at S-79.

Performance Measure	Freshwater Discharge at S-79	Target
High Flow (mean monthly)	Number and frequency of months > 4,500 cfs	Not to exceed one consecutive month in three years

Seagrass and Oysters

While no performance measures for seagrasses or oysters have been formally accepted, both are monitored as indicators of the health of Charlotte Harbor. Preliminary targets for oysters have been suggested and are presented below.

ENVIRONMENTAL CONDITION OF CHARLOTTE HARBOR

Freshwater inflow at S-79

Historically, flows have averaged greater then 4,500 cfs for 1.27 months per year (**Table 12-15**). In WY2004, mean monthly flows greater than 4,500 cfs occurred for four months. Mean monthly flows exceeded the set target of "not to exceed one consecutive month" once in WY2004, placing ecological resources in San Carlos Bay and Lower Charlotte Harbor at risk.

Table 12-15. C-43 and Southwest Florida Feasibility Study hydrologic performance measures for monthly flows.

Performance Measure	Historical (WY1966–WY2002)	WY2004
Greater than 4,500 cfs	1.27 +/- 0.62	4

Seagrasses

Trends in the aerial extent of seagrasses in Lower Charlotte Harbor show an increase from WY1999–WY2003 (**Table 12-16**) of approximately 5,291 acres. It is proposed that restoring hydrology in Caloosahatchee estuary will improve the spatial and structural characteristics of submerged plant communities.

Table 12-16. Aerial extent of seagrass in Charlotte Harbor during WY1999 and WY2002–WY2003.

Year	Acres of Seagrass
WY1999	38,195.16
WY2002 and 2003	43,486.25

Oysters

Historical information on the aerial extent of oyster reefs in Charlotte Harbor is not available. Based on WY2004 data, there are presently 15.04 acres of oysters in Lower Charlotte Harbor (**Table 12-17**). A preliminary target for aerial extent of oyster reefs in Lower Charlotte Harbor is a sixty acre increase in the next 10–15 years with the proper changes in flow and salinity. With the addition of hard substrate, this target can be increased to 150–200 acres of oyster reefs.

Table 12-17. Aerial extent of oyster reefs in Charlotte Harbor during WY2004.

Year	Acres of Oyster
WY2004	15.04

CURRENT SCIENCE, ENGINEERING AND RESTORATION ACTIVITIES

Resource Assessment

SALINITY MONITORING

The District maintains a series of electronic monitoring stations that collect salinity and temperature data every 15 minutes (Chamberlain and Doering, 1998a). There is currently one site in Charlotte Harbor at the Sanibel Causeway. Data are used to monitor compliance with the Caloosahatchee MFL, support water management of Lake Okeechobee, and support development of hydrodynamic and water quality models.

SUBMERGED AQUATIC VEGETATION MONITORING

Monitoring SAV in Charlotte Harbor is performed using spatially and thematically accurate Arc/INFO seagrass (SAV) databases. These databases were created by Avineon for the coastal waters of the District, from Boca Grande south to Wiggins Pass, using January 2003 true-color aerial imagery. This area was flown again in January 2004. New seagrass databases will be created using these images and trend analyses will be preformed.

OYSTER MONITORING

In Southwest Florida, oysters have been identified as a VEC. Oysters are natural components of southern estuaries and were documented to be abundant in the system. This project is in response to the CERP Monitoring Assessment Plan (MAP) (see Chapter 7 of the 2005 SFER – Volume I). Florida Gulf Coast University has been contracted to conduct a long-term program for monitoring oysters (*Crassostrea virginica*) in the lower Caloosahatchee Estuary (two sites) and San Carlos Bay (three sites) in order to determine if the restoration of beneficial patterns of freshwater inflow, salinity, and water quality to the Caloosahatchee Estuary will achieve the expected distribution, community structure, and viability of oysters. Adult abundance and health, spat recruitment, and juvenile growth and survival are measured twice annually, monthly (March–October), and monthly (year-round) respectively. Water quality measurements are taken during monitoring events.

Oyster maps were created by Florida Gulf Coast University using aerial helicopter surveys flown during the winter months when low tides are more extreme. Data from digital photography was transferred into a GIS database and the aerial extent and spatial distribution of the reefs was determined. Groundtruthing of the reef localities occurred through subsequent fieldwork.

Fisheries Enhancement and Assessment

The fisheries resources in Southern Charlotte Harbor and the Caloosahatchee Estuary are poorly understood. In early 2004, the Florida Marine Research Institute expanded their Fisheries Independent Monitoring (FIM) Program into Lower Charlotte Harbor. This District contract is a component of the MAP. The FIM Project is long-term and is designed to estimate relative abundance of fish and to provide information on the status and trends of fish populations. This project will also provide information on fish community composition and estuarine habitat use.

In addition, the District has contracted Sanibel-Captiva Conservation Marine Laboratory to determine the preferred habitat for juvenile red drum and the optimum release strategy, including life stage, for hatchery-reared fish in Lower Charlotte Harbor. This project will help establish the fisheries enhancement potential that a regional redfish stock enhancement program will have in local waters, determine the tag retention rate and survivorship of juvenile redfish, and determine the effect that habitat type for site release as it relates to survivorship. This was funded through the Charlotte Harbor Initiative. The Charlotte Harbor Initiative is a program authorized by the Florida legislature that funds stormwater management and environmental restoration projects in the harbor.

RESTORATION ACTIVITIES

Reestablishing Mangroves along Disturbed Shorelines

In many Southwest Florida coastal areas, development has left behind a shoreline that, while damaged, is capable of being restored to a productive mangrove shoreline. Recently, methods have been developed that insure success in planting mangroves from seedlings along a variety of disturbed coastal areas. Sanibel Captiva Conservation Foundation Marine Laboratory was contracted to conduct a pilot study in Clam Bayou on Sanibel Island to determine if restoration can be achieved in the Charlotte Harbor system. The Marine Lab incorporated volunteers to replant red mangroves in the Dinkins Bayou using this new technique to help ensure seedling success. During this restoration, a field experiment will be conducted to test the effects of soil amendments, and the effectiveness of polyvinyl chloride (PVC) sleeves on mangrove seedlings growth rates. Monitoring of this mangrove restoration project will continue through 2005. This project was funded through the Charlotte Harbor Initiative.

Removal of Exotics and Reestablishment of Native Vegetative Mosaic

The Charlotte Harbor Buffer Preserve is one of the last regional holdouts for some rapidly disappearing ecosystems and provides a matrix of increasingly rare habitats for a host of state and federally listed endangered and threatened species, such as the piping plover, wood stork, bald eagle, gopher tortoise, eastern indigo snake, golden leather fern, and beautiful pawpaw. Exotic pest plants such as melaleuca, Brazilian pepper, Australian pine, earleaf acacia, and aquatic soda apple are threatening these habitats, and these exotics have led to a loss of fish and wildlife habitat. Removal of exotic species can improve the environmental integrity of the Charlotte Harbor area, as well as preserve, restore, and enhance seagrass beds, coastal wetlands, and functionally related uplands. It can also contribute to improved water quality. In 2004, the District assisted in the removal of exotics in the Charlotte Harbor Buffer Preserve through funding from the Charlotte Harbor Initiatives. Additional information regarding exotic species is presented in Chapter 9 of the 2005 SFER – Volume I.

Lee County Drainage Improvements

The Gator Slough and Powell Creek watersheds have been altered by urbanization, construction of roadway grades, and diking for agricultural activities over the last thirty years. This has resulted in unnatural diversions and decreased base flows. The large volume of runoff entering Matlacha Pass is also having detrimental effects on the vegetative and aquatic life at the Gator Slough discharge point. Through the Charlotte Harbor Initiative, funding has been secured to assist in the construction of a system to capture excess runoff in the Gator Slough system and prevent runoff into Matlacha Pass and for the environmental clean-up and drainage improvement of Powell Creek. Planned improvements will not only provide for a hydrologic restoration to the Gator Slough/Powell Creek System, but will also restore a more historic base flow condition in the lower reaches of the natural Powell Creek system.

Northwest Lee County Surface Water Improvements

Funds have been provided to Lee County through the Charlotte Harbor Initiative to develop a surface water management plan for the northwest region of Lee County that includes an overall assessment of existing conditions. This region consists of four principle watersheds: Yucca Pen, Durden Creek, Greenwell Branch, and Longview Run. These watersheds drain into Charlotte Harbor. This plan will involve delineation and development of hydrologic/hydraulic models. The surface water management plan will include identification of issues of concern, existing level of service deficiencies for flooding, and evaluation and sizing of all proposed control structures along Burnt Store Road to convey the 25-year flood for the projected capacity at build-out.

Restoration of Shellfish in Charlotte Harbor

Florida Gulf Coast University, in collaboration with the Lee County School District, the SFWMD, Florida Sea Grant and the City of Cape Coral, constructed five oyster reefs (10 m^2 each) in the lower Caloosahatchee River (two sites) and San Carlos Bay (three sites) using recycled oyster shell and stabilizing mesh in order to establish suitable substrate for oyster recruitment. This community-based restoration involved the general public, as well as high school and undergraduate students (52 volunteers and 11 boats). Reefs will be monitored to determine restoration success. This project was funded through the Charlotte Harbor Initiative.

SANIBEL-CAPTIVA ROAD CULVERT CONNECTION PROJECT

This project provided the City of Sanibel with matching funds to assist in an environmental restoration project designed to improve tidal flow and water quality in Clam Bayou and Dinkins Bayou at the west end of Sanibel Island by connecting them with a culvert under Sanibel-Captiva Road. Road construction since the 1920s on Sanibel closed off this historic connection, which was once the main channel of Blind Pass. Clam Bayou, an extraordinarily productive mangrove lined estuary, is now completely blocked off from tidal flows except when rare and ephemeral tidal pass connections to the Gulf of Mexico occur during and just after major storm events. This has left Clam Bayou in an impounded condition, with fish kills and very serious mangrove die-offs occurring when major rainfall volumes are trapped in the basin. Oyster bars and submerged marine seagrass beds in the bayou are extremely stressed by degraded conditions. Over 116 acres of red mangrove forest were killed during a 2001 water impoundment event. Dinkins Bayou is still connected to Pine Island Sound at Blind Pass, but is also degraded in that it is suffering from low tidal circulation and poor water quality due to the closure of that pass. This project involves the removal of invasive exotic tree species and the removal of fill roads in wetlands.

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