Chapter 10: Lake Okeechobee Protection Program — State of the Lake and Watershed

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SUMMARY

Lake Okeechobee is a valuable resource with competing uses for the residents, agriculture, and environment of South Florida. The lake serves as a water supply for nearby towns, agriculture, and downstream ecosystems, and provides flood control for the surrounding areas. The lake is home to migratory water fowl, wading birds, and the federally endangered Everglade Snail Kite (*Rostrhamus sociabilis plumbeus*). It is also a multimillion-dollar recreational and commercial fishery. This chapter provides an overview of Lake Okeechobee, its surrounding watershed, background material regarding the major issues impacting the lake's flora and fauna, and ongoing projects to address those issues under the Lake Okeechobee Protection Program.

The lake is the subject of three major environmental challenges: (1) excessive phosphorus loads; (2) unnaturally high and low water levels; and (3) rapid spread of exotic and nuisance plants in the littoral zone. The South Florida Water Management District (SFWMD or District), Florida Department of Environmental Protection (FDEP), Florida Department of Agriculture and Consumer Services (FDACS), U.S. Army Corps of Engineers (USACE), and Florida Fish and Wildlife Conservation Commission (FWC) are working cooperatively to address these interconnected issues in order to rehabilitate the lake and enhance the ecosystem services that it provides while maintaining other project purposes such as water supply and flood control.

The excessive loads of phosphorus originate from agricultural and urban activities that dominate land use in the watershed. Total phosphorus (TP) loading now averages 580 metric tons (mt) per year (average, 2001–2005), which is more than four times higher than the recently established Total Maximum Daily Load (TMDL) of the 140 mt per year (five-year rolling average) considered necessary to achieve the target in-lake TP goal of 40 parts per billion (ppb). The loadings from Water Year 2005 (WY2005) (May 1, 2004 through April 30, 2005) were extremely high, at 950 mt of phosphorus, and directly related to the exceptional 2004 summer season that included three hurricanes (Charley, Frances, and Jeanne), and the remnants of a fourth (Hurricane Ivan), which impacted the Lake Okeechobee watershed. During the three months of August to October, the lake received a total volume of water from inflows and rainfall of 3.2

million acre-feet [394,714 hectare meters (ha-m)]. This is a bit smaller than an average WY total volume input (3.7 million acre-feet or 456,388 ha-m). The lake also received 83 percent of the TP load for the WY in these three months.

The lake water levels increased by 5.75 ft (1.75 m), from a low of 12.27 ft (3.74 m) (National Geodetic Vertical Datum [NGVD] 1929) on August 1, 2004 to a high of 18.02 ft (5.49 m) (NGVD) on October 13, 2004. Large amounts of phosphorus-laden sediments were resuspended from the central region of the lake and distributed throughout the lake. The net sediment contribution of phosphorus to the water column was over 95 mt for the three-month period from August to October, based on monthly phosphorus budgets. Numerous winter cold fronts moved through with consistent and strong winds that continued to resuspend sediments in the lake from November to April. The increase in suspended sediments was accompanied by an increase in phosphorus to historical highs that reached an average of 442 ppb in December 2004 and an average of 237 ppb for the water year. The high water levels and high suspended sediments resulted in reduced light availability within the lake's nearshore and littoral zones that resulted in a significant decline of submerged aquatic vegetation (SAV).

Efforts were made to reduce water levels in the lake by constant discharges into the St. Lucie and Caloosahatchee rivers from September to mid-November 2004. Discharges then were reduced and released in pulses through the remainder of WY2005 following a pulse release schedule. Lake stage declined by 3.17 ft (1 m) to 14.85 ft (4.53 m) (NGVD) as of April 30, 2005. Pulse releases continued beyond this time period to further reduce lake stage.

Although there is a long history of regulatory and voluntary incentive-based programs to control phosphorus inputs to Lake Okeechobee, there has not been any substantial reduction in loading during the last decade. Consequently, the lake continues to exhibit signs of hyper-eutrophication, including blooms of noxious blue-green algae (cyanobacteria), loss of benthic invertebrate diversity, and spread of cattail (*Typha spp.*) in shoreline areas. As a result, the Florida legislature passed the Lake Okeechobee Protection Act (LOPA) in 2000, mandating that the TMDL be met by 2015 and that the SFWMD, FDEP, and FDACS work together to implement an aggressive program to address the issues of excessive phosphorus loading and exotic species expansion. In addition, the SFWMD and USACE are implementing components of the Comprehensive Everglades Restoration Plan (CERP) that will address in part the phosphorus issue, and also provide alternative storage locations so that water levels in the lake can be regulated in a manner that has greater environmental benefits while still supporting water supply and other water resource functions.

The SFWMD, in cooperation with FDEP and FDACS, developed the Lake Okeechobee Protection Plan (LOPP) as required by the LOPA, which was submitted to the Florida legislature in January 2004. The LOPP contains a phased, watershed-based, comprehensive approach to reduce phosphorus loading to the lake. Because the legislature has provided substantial funding for the implementation of the LOPA since 2000, the cooperating agencies have been able to implement a large number of phosphorus reduction projects including phosphorus source control grant programs for agricultural landowners, dairy best available technology pilot projects, soil amendment projects, isolated wetland restoration, remediation of former dairies, and regional public/private partnerships. In addition, the LOPP contains elements of research and monitoring as specified by the act. A comprehensive monitoring program for water quality in the lake and watershed and ecological indicators in the lake has been implemented. The SFWMD conducts the monitoring program for water quality at the project and sub-basin levels in the watershed, which extends beyond the historical network of flow/load monitoring stations at basin outlet structures. Ongoing research and model applications continue to provide the predictive understanding necessary to evaluate the effectiveness of water management alternatives on phosphorus load reductions.

The Lake Okeechobee Watershed Project (LOWP) of CERP, as currently planned, will contribute 39 percent of the phosphorus load reduction needed to meet the TMDL and store approximately 273,000 acre-feet (ac-ft) of water. The load reduction will help meet the TMDL. The offsite storage will help reduce high lake stage and reduce flood control discharges to the estuaries. The project is moving forward on schedule. The draft Lake Okeechobee Project Implementation Report (PIR) is scheduled for completion in mid-2006. Similar to the Lake Okeechobee Protection Program, CERP and LOWP are adaptive programs, so if responses are not occurring as expected, or if research and demonstration elucidates important new information, the restoration programs can be modified to optimize their effectiveness.

Conditions in Lake Okeechobee are reported as five-year averages for consistency with the phosphorus TMDL and to reduce the variability that can be attributed to climate and hydrology. For WY2001–WY2005 the averages for TP, TN, SRP, and DIN are 142 ppb, 1.65 ppm, 38 ppb and 236 ppb, respectively. The WY2005 averages for these nutrients are 237 ppb, 2.1 ppm, 57 ppb and 530 ppb, respectively, and are higher than the five-year averages, because they reflect the impacts of the extreme weather events and constant sediment resuspension that occurred in the last year. The five-year TP concentration is over three times higher than the goal of 40 ppb that was used to establish the TMDL. The five-year average of total nitrogen to total phosphorus (TN:TP) is 12.3 and dissolved inorganic nitrogen to soluble reactive phosphorus (DIN:SRP) is 5.8. These values favor dominance of blue-green algae, which presently accounts for most of the algal biomass in the lake. The water clarity goal in shoreline areas, which is to have light visibility to the lake bed from May to September, are attained approximately 30 percent of the time in the past five years, and the goal for algal bloom frequency, which is five percent of all samples exceeding 40 ppb of chlorophyll *a*, is exceeded approximately threefold in the past five years.

Improvements in TP have not occurred in the last decade because external loads have remained high and lake sediments contain thousands of tons of phosphorus that buffer changes in water column TP. The response of the lake to load reductions, when they occur, is expected to take 20–30 years because of this internal sediment buffer. Despite these problems, and the knowledge that the lake response to load reductions will be slow, large-scale sediment management — dredging or chemical application — is not a recommended option for accelerating changes in water quality in the lake (BBL, 2003). This reflects the large size of the lake and the widespread distribution of a relatively thin layer of phosphorus-rich sediment on the bottom, along with associated engineering, economic, and ecological constraints. However, new technologies for targeted sediment removal are being investigated due to hurricane impacts and heightened concerns about in lake sediment resuspension.

In August 2004, there were 54,857 acres (222 km^2) of submerged aquatic vegetation (SAV) in Lake Okeechobee, the maximum coverage encountered since annual mapping surveys were instituted in 1999. The impacts of hurricanes Frances and Jeanne, which included storm surges (seiches) of up to 10 ft (3 m), wind-driven waves, strong currents, and a rapid increase in lake stage, resulted in immediate uprooting and damage to much of the lake's emergent and submerged aquatic vegetation. Ongoing research using models, laboratory studies, and monitoring of SAV beds in Lake Okeechobee will aid in the assessment of long-term impacts of these storms on lake recovery and management of lake levels.

Independent of the extraordinary events of September 2004, the SFWMD and USACE are in the process of refining the operating schedule for the lake, developing release rules that will be more favorable to maintaining its long-term ecological health, reducing large discharges to downstream ecosystems while also reducing the impact on water supply. Until there are large alternative storage projects, this will be a difficult balancing act, because the lake receives water from a large watershed, it provides the main source of irrigation water in drought, and its major outlets are to estuarine systems that are impacted by large releases of fresh water.

Restoration of natural habitats for fish and wildlife continues, following the removal of the 4.84 miles (7.8 km) of perimeter agricultural berms surrounding Ritta Island at the south end of the lake. This restoration was fulfilled by the removal of exotic vegetation and backfilling the adjacent ditches with the berm material to reestablish natural hydrologic connections between the island's wetland habitat and the lake. The removal of two other former agricultural berms on Kreamer and Torry islands will not be conducted until the effects of berm removal on Ritta Island are documented. Replanting work for pond apple and cypress is planned on the restored shoreline of Ritta Island. A 100-acre (0.4 km^2) section of degraded wetland on Torry Island has been replanted in native pond apple as part of this restoration effort.

INTRODUCTION

Lake Okeechobee (located at 27° N latitude and 81° W longitude) is a central feature of the interconnected South Florida aquatic ecosystem and the U.S. Army Corps of Engineer's (USACE's) regional flood control project. The lake receives water from the Kissimmee River, Lake Istokpoga, Fisheating Creek, and other sub-basins, and water from the lake flows into the Everglades Protection Area, the St. Lucie River, and the Caloosahatchee River (**Figure 10-1**). Although Lake Okeechobee has a surface area in excess of 427,500 acres (1,730 km^2), it is extremely shallow, with mean and maximal depths of 8.9 ft (2.7 m) and 18 ft (5.5 m), respectively (James et al., 1995a). The lake originated approximately 6,000 years ago, during oceanic recession (Gleason and Stone, 1975), and under natural conditions was considered moderately eutrophic (Brezonik and Engstrom, 1998; Engstrom et al., in review) and larger in spatial extent, with vast littoral wetlands to the west and south (Havens et al., 1996.. The southern littoral region was contiguous with the Florida Everglades, and during periods of high lake levels, water flowed to the Everglades as broad sheetflow (Steinman et al., 2001). Modern-day Lake Okeechobee differs in size, range of water depths, connections with other parts of the regional system, and water quality (Havens et al., 1996; Steinman et al., 2001). The lake presently receives water from a 4,015-mi^2 (10,400-km^2) watershed (**Figure 10-2**), with headwaters in a chain of lakes located to the north, near the city of Orlando, Florida.

Although all lakes provide services to nature and society (Postel and Carpenter, 1997), Lake Okeechobee is probably at the extreme end of the continuum in terms of the number of services it provides, the diversity of users, and the tremendous economic interest in its health and fate. The lake provides water supply to urban areas, agriculture, and downstream ecosystems; it supports a multimillion-dollar sport fishery (Furse and Fox, 1994), a commercial fishery, various recreational activities, and provides habitat for migratory waterfowl, wading birds, alligators, and the Everglade Snail Kite (Aumen, 1995). The lake is also used for flood control during the summer wet season. The lake currently faces three major environmental challenges: (1) excessive total phosphorus (TP) loads; (2) unnaturally high and low water levels; and (3) rapid spread of exotic and nuisance plants.

This chapter provides a comprehensive update of lake and watershed conditions from Chapter 10 of the *2005 South Florida Environmental Report – Volume I* (SFER), focusing on phosphorus loading and water levels. Results of recently completed research projects are presented, as well as status updates for ongoing watershed and in-lake management projects. Project time lines, information about funding sources, and other aspects of project planning are also included. Information regarding exotic plant control programs, and associated research projects to optimize those programs, are presented in Chapter 9 of this volume.

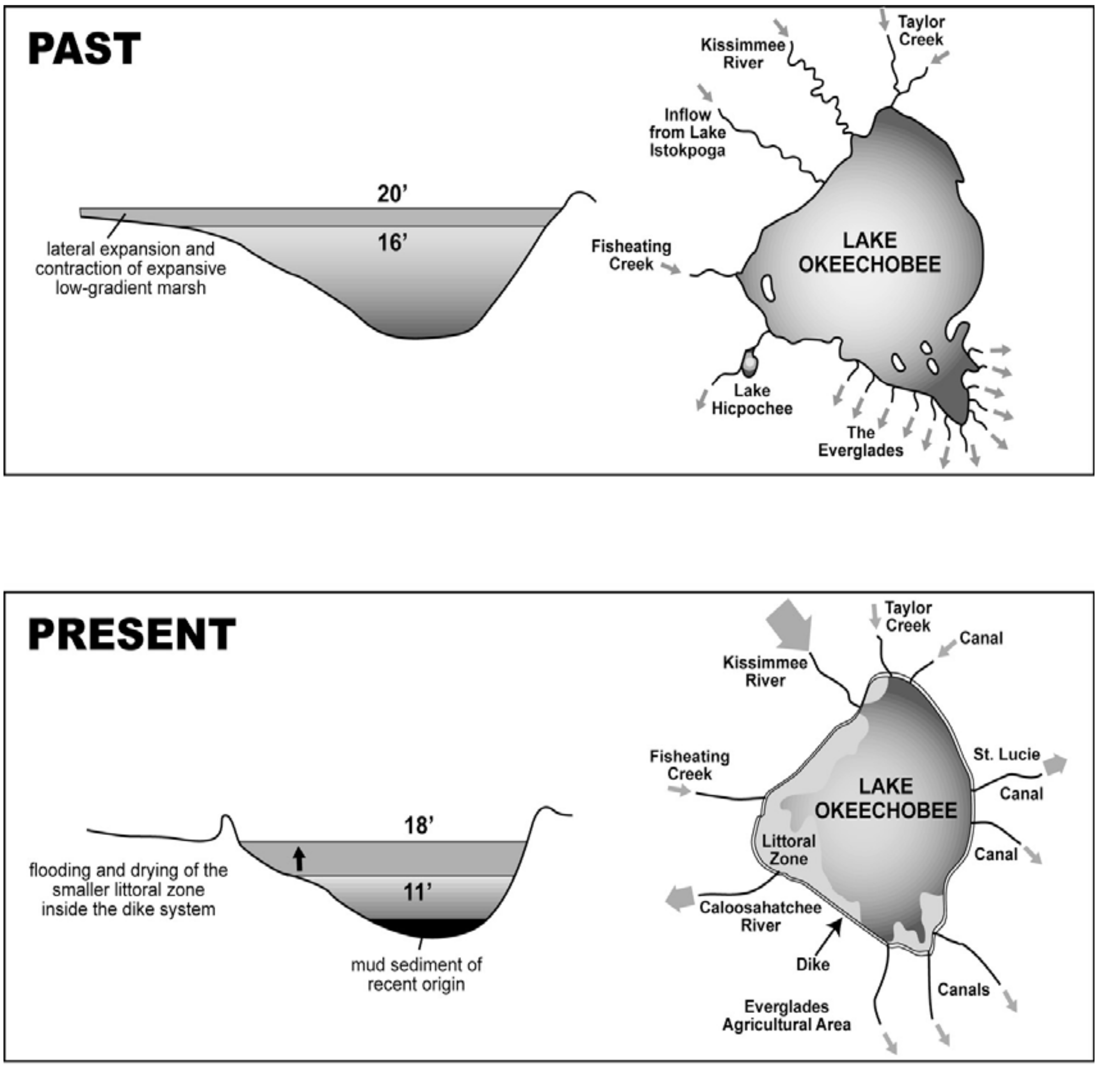


Figure 10-1. Schematic diagrams of Lake Okeechobee showing past (pre-1920) versus present morphometric and hydrologic conditions of the lake and surrounding lands. Depth is highly exaggerated in the side view of the ecosystem.

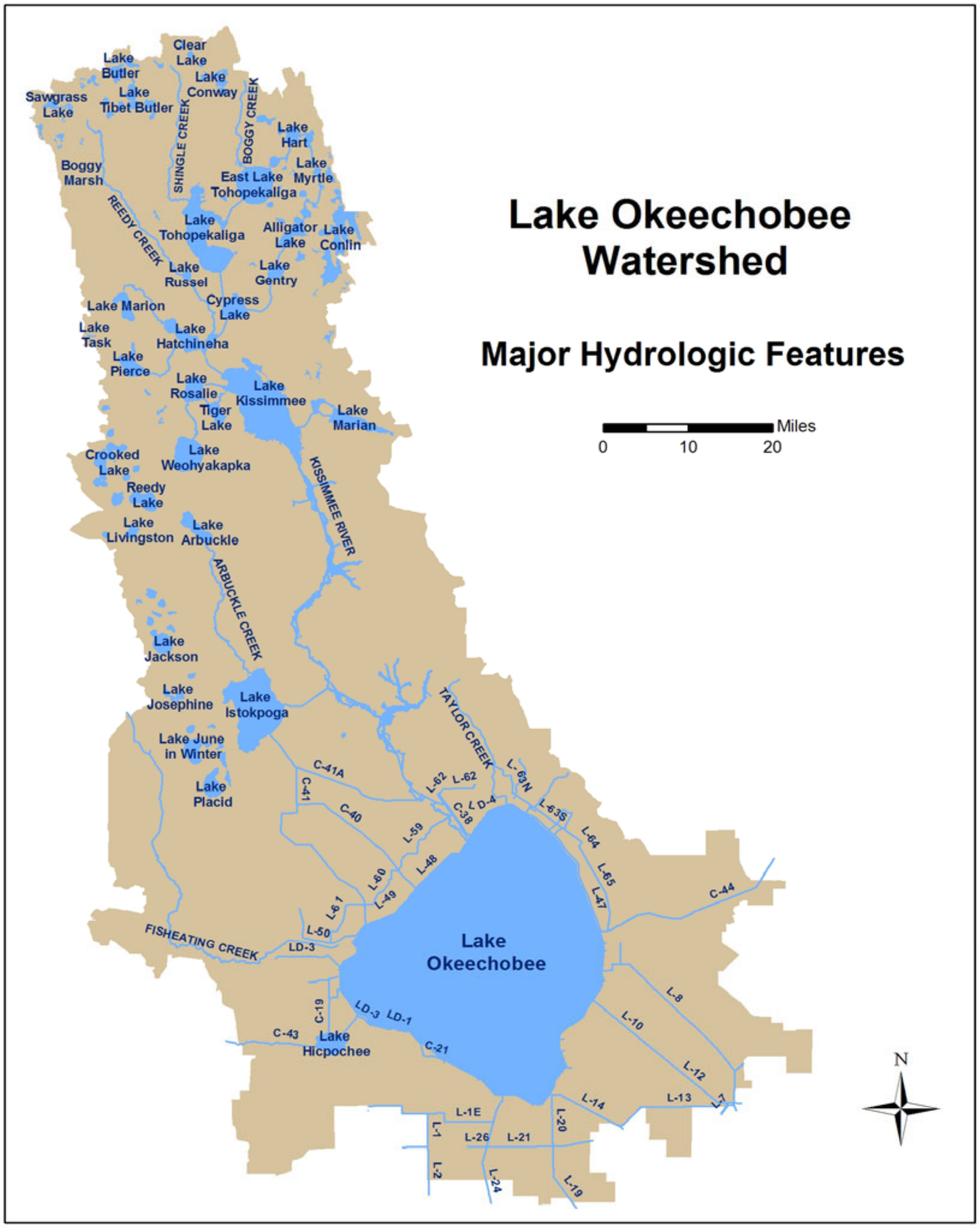


Figure 10-2. Major hydrologic features of the Lake Okeechobee watershed (L-levee, C-canal).

OVERVIEW OF THE LAKE OKEECHOBEE PROTECTION PROGRAM

The Lake Okeechobee Protection Act (LOPA) committed the state of Florida to restore and protect Lake Okeechobee. This will be accomplished by achieving and maintaining compliance with water quality standards in the lake and its tributary waters. The approach is a watershed-based, phased, comprehensive, and innovative protection program designed to reduce phosphorus loads and implement long-term solutions based upon the Total Maximum Daily Load (TMDL) rule for Lake Okeechobee developed by the Florida Department of Environmental Protection (FDEP, 2001). This TMDL is a long-term (five-year) rolling average of 140 mt to be attained by 2015. The TMDL consists of 105 mt yr^{-1} from the watershed and 35 mt yr^{-1} from atmospheric deposition. Atmospheric deposition is defined as both wet and dry fall input directly to the lake (FDEP 2001). The LOPA also requires aggressive programs to control exotic plants and a long-term program of water quality and ecological assessment, research, and predictive model development.

Elements of the program include (1) the Lake Okeechobee Protection Plan (LOPP), (2) the Lake Okeechobee Construction Project, (3) the Watershed Phosphorus Control Program, (4) the Research and Water Quality Monitoring Program, (5) the Internal Phosphorus Management Program, (6) the Exotic Species Control Plan, and (7) an Annual Progress Report. The South Florida Water Management District (SFWMD or District), in cooperation with the FDEP and the Florida Department of Agriculture and Consumer Services (FDACS), developed the LOPP, which was submitted to the Florida legislature on January 1, 2004 (SFWMD et al., 2004). The LOPP describes in detail how water quality standards, particularly for phosphorus, will be met in Lake Okeechobee and its downstream receiving waters by 2015. The watershed phosphorus control program uses a multifaceted approach to reduce phosphorus loads through continued implementation of existing regulations and BMPs, development and implementation of improved BMPs, improvement and restoration of the hydrologic functions of the natural and managed systems, and use of alternative technologies for nutrient reduction. Alternative technologies for phosphorus reduction, currently implemented, include chemical treatment at dairy outflow and algal turf scrubber (ATS™). The Lake Okeechobee Construction Project is being implemented in two phases: (1) pilot stormwater treatment areas (STAs) in the four priority basins and (2) the Lake Okeechobee Watershed Project (LOWP) of the Comprehensive Everglades Restoration Plan (CERP). This chapter constitutes the sixth annual report to the legislature summarizing the water quality and habitat conditions of the lake and its watershed, implementation activities including the status of the Lake Okeechobee Construction Project, and challenges and unresolved issues.

LAKE AND WATERSHED STATUS

2004 HURRICANE SEASON

From August 13–September 26, 2004 the state of Florida was hit by an unprecedented four hurricanes (**Figure 10-3**). Of these four, three (Charley, Frances, and Jeanne) impacted the Okeechobee watershed directly, and the remaining one (Ivan) indirectly, resulting in a total volume from inflows and rainfall to the lake for the three months of August to October of 3.2 million ac-ft, which is nearly equivalent to an average water year (WY, May 1 to April 30) input of 3.7 million ac-ft (456,388 ha-m). The increased inflow resulted in increased loads of phosphorus as well, with an estimated 792 metric tons (1 mt is equivalent to 1,000 kg) of phosphorus being added in these three months. This is 83 percent of the 950 mt of phosphorus received by the lake from May 1, 2004 to April 30, 2005 (WY2005).

The 2004 hurricanes resulted in major impacts throughout the Lake Okeechobee watershed. Winds from these hurricanes knocked down trees, damaged or destroyed hundreds of houses, damaged roofs and small buildings, and created long periods of power outages. Some equipment used to measure flow or water quality was damaged as well.

Rainfall produced flood conditions in many areas, causing erosion around levees and canal structures, as well as a few breaches in canals. Most notable was a problem with high water levels in several dairy lagoons located in the watershed. Okeechobee County and state emergency management personnel received a request from the FDEP to procure portable pumps to provide relief to lagoons that were showing signs of compromise due to high water levels caused by the storms. Three pumps were delivered to Okeechobee County and picked up by those farmers whose systems had the greatest potential for failure. Water from the three dairy lagoons was pumped on adjacent pastures away from ditches or tributary drains. This was done to minimize the potential of direct runoff into surrounding tributaries. The pumps were used long enough following the last storm to lower lagoon water levels back to normal. Due to the large amount of water that covered the watershed after the storms, there was no way measure the effect of pumping water from the lagoons onto adjoining pastures.

Flooding of agricultural pastures also caused debris problems in secondary tributaries throughout the watershed. Two tributaries in Okeechobee County – Taylor Creek and the Granda Flow Way, qualified for federal cost-sharing assistance through the Natural Resources Conservation Service (NRCS) for debris removal. Data collected by the U.S. Geological Survey (USGS) at 16 sites in the northern basins of Lake Okeechobee, and at a majority of sites monitored by the District in this region, suggest that widespread inundation of urban and agricultural lands resulted in an increase in phosphorus runoff during and after the storms.

Hurricanes Frances and Jeanne directly influenced the lake with sustained winds between 55 and 67 mph (25 and 30 m/sec) and gusts to 80 mph (35.8 m sec^{-1}) (**Figure 10-4**). In addition, the storms resulted in seiches of up to 10 ft (3 m) (Chimney, 2005). Estimated current velocity was very high (**Figure 10-5**, see the *Development of the Lake Okeechobee Environment Model* section of this chapter). Rainfall from the hurricanes, based on NEXRAD radar data averaged over Lake Okeechobee, was 2.2 and 2.7 inches (5.6 and 6.9 cm) from Frances and Jeanne, respectively. The large amount of inflowing water and rainfall changed the lake water level from 12.27 ft (3.74 m) (NGVD, 1929) on August 1, 2004 to 18.02 ft (5.49 m) (NGVD) on October 13, 2004 (**Figure 10-6**), an increase of 5.75 ft (1.75 m) or approximately 2.5 million ac-ft (308,370 ha-m) of water. The seiches, along with wind-driven waves and currents and the rapid increase in lake stage, resulted in immediate uprooting and damage to much of the lake's emergent and submerged aquatic vegetation.

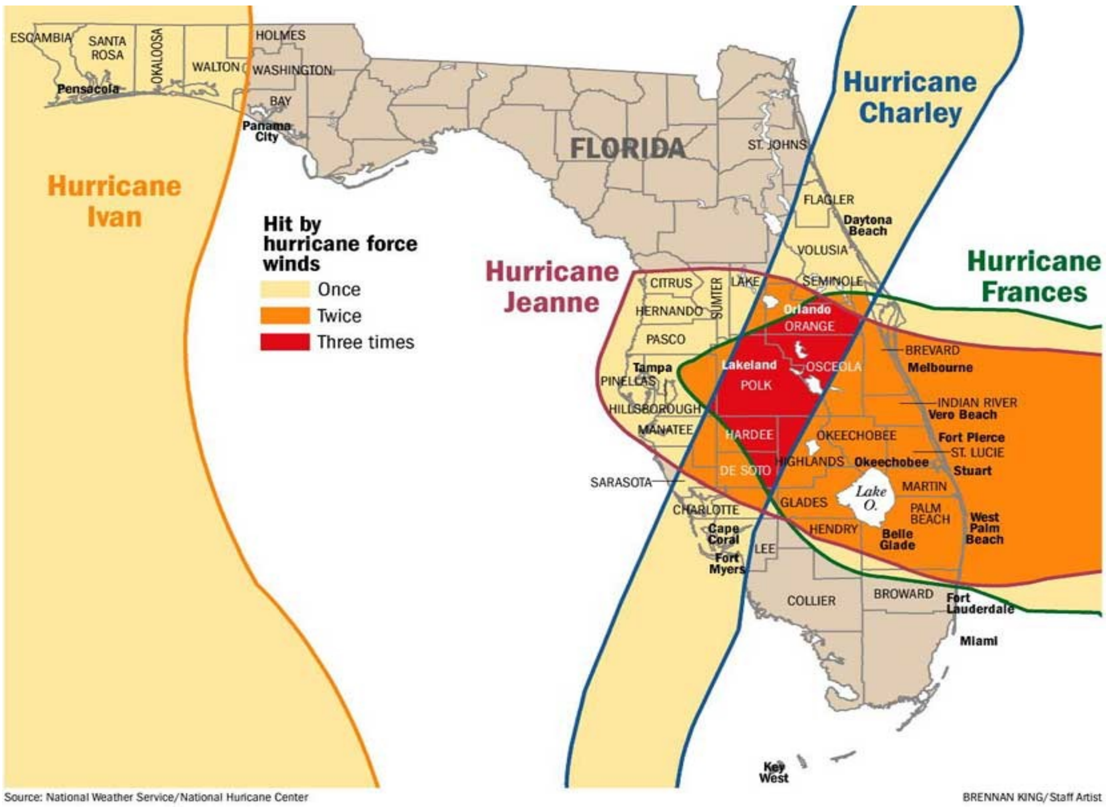


Figure 10-3. Hurricane force winds created by four storms hitting Florida in 2004 (Charley, August 13; Frances, September 4; Ivan, September 16; and Jeanne, September 25).

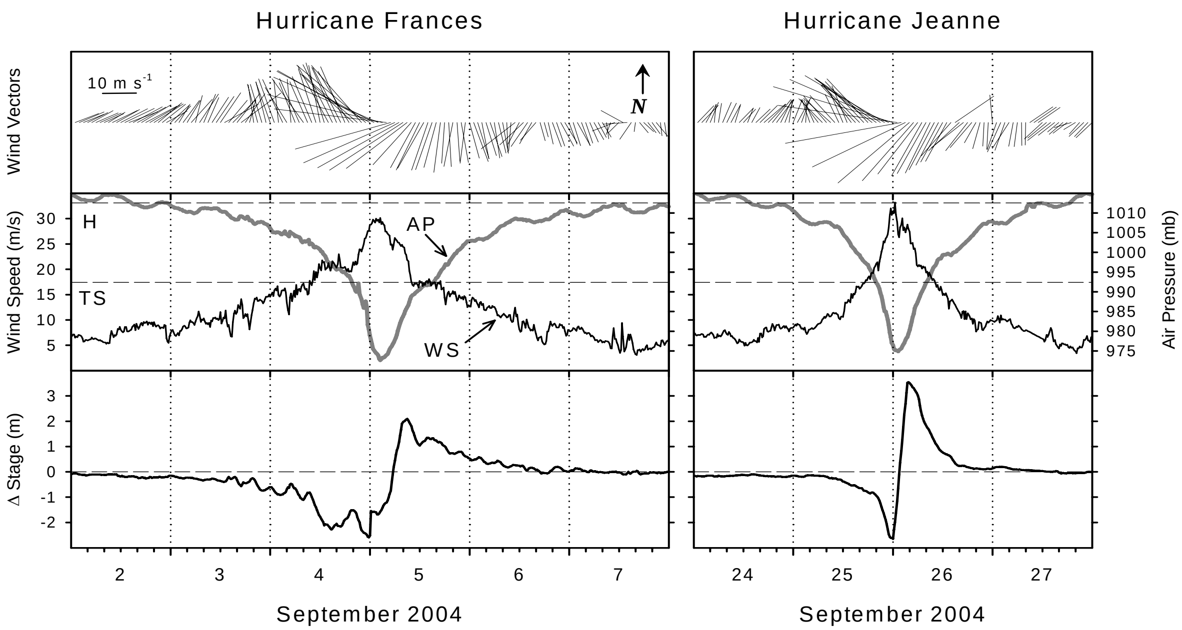


Figure 10-4. Impacts of hurricanes Frances and Jeanne on Lake Okeechobee showing the wind rose, wind speed, air pressure, and difference in lake level height from the north to the south part of the lake (figure from Chimney, 2005).

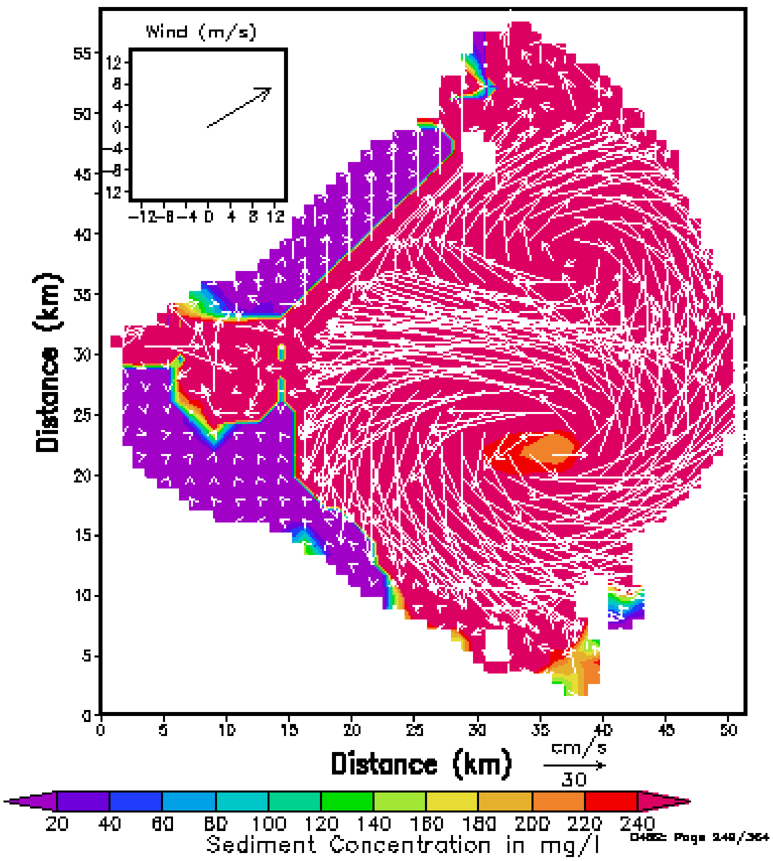


Figure 10-5. Simulated results from the Lake Okeechobee Environment Model of the circulation pattern and velocity field during Hurricane Frances**.** Arrows are velocity vectors for surface water movement and colors indicate concentrations of suspended sediments in the lake water.

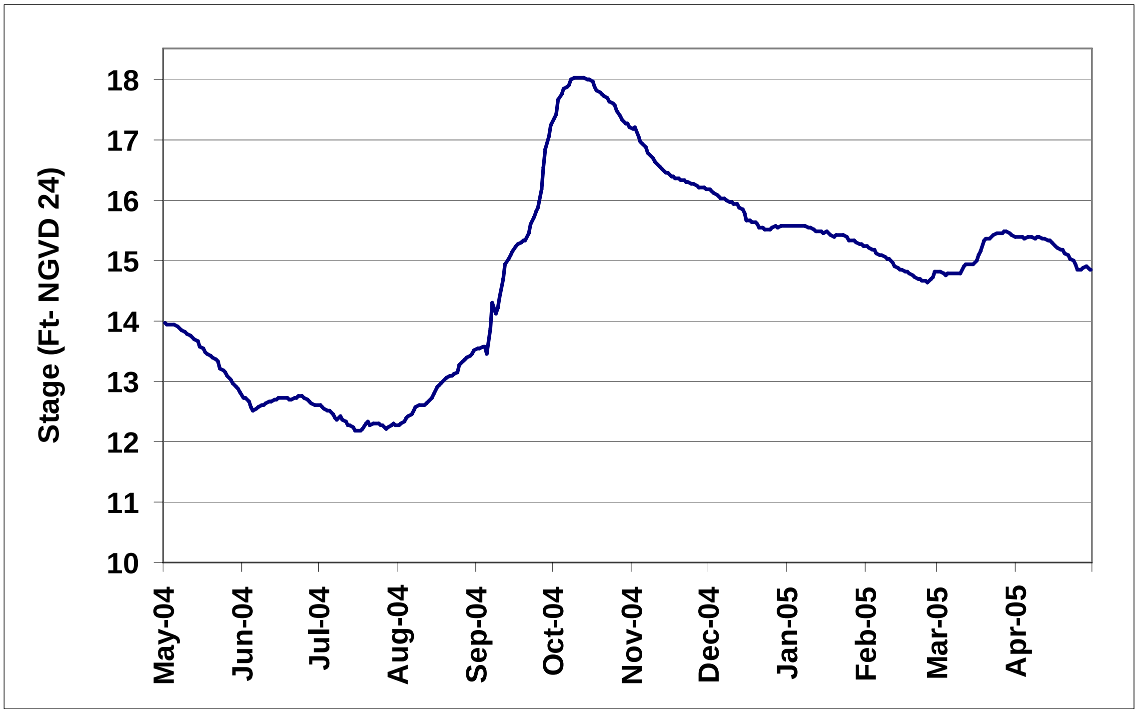


Figure 10-6. Stage height in Lake Okeechobee during Water Year 2005 (WY2005) (May 1, 2004 through April 30, 2005).

Efforts were made to reduce lake stage through constant discharges into the St. Lucie and Caloosahatchee rivers from September to mid-November 2004. Discharges then were reduced and released in pulses through the remainder of WY2005 following a "pulse release" schedule (www.sfwmd.gov/org/pld/hsm/reg_app/lok_reg/wse_support/pulse_release_schedule.pdf). Lake stage has declined by 3.17 ft (1 m) to 14.85 ft (4.53 m) (NGVD) on April 30, 2005. This represents a reduction of at least 1.35 million ac-ft (166,520 ha-m) of water. Discharges continued beyond this time period to further reduce lake stage.

Direct post-hurricane measurements of water quality were not made until October 11, 2004. Data from the long-term monitoring stations (L001–L008) show that suspended solids and TP more than doubled from August to October (**Figures 10-7**, Panels A and B). This increase continued into December, hitting maximum values of 397 ppm and 642 ppb of suspended solids and TP, respectively. There is a significant relationship between suspended solids and TP, which indicates that a large amount of phosphorus was resuspended into the water column along with the solids (**Figure 10-8**, Panel A). Cold fronts that move through South Florida from November to April bring constant winds in excess of 6.2 mph (2.8 m sec^{-1}). These winds create waves that resuspend sediments. The north to south wind speed, three days prior to sample collection, also accounted for a small but significant amount of the variation in both total suspended solids and TP (**Figure 10-8**, Panel B). The two relationships are very similar in slope, again indicating that much of the phosphorus was resuspended into the water column along with the suspended sediments.

Contour maps produced using all the in-lake monitoring data for selected months (August, October, and December 2004; January, February, and April 2005), show the relationship between suspended solids and TP (**Figures 10-9a** and **10-9b**). The highest values tended to be toward the deeper central regions, where the greatest amount of phosphorus-laden sediment can be found. Differences in the patterns are attributed to changes in circulation that vary depending on the strength, duration, and direction of winds (Jin et al., 2002; Jin and Ji, 2004) and resuspension (see below). A laboratory settling experiment that used lake water from this time period found that it took 13 days for the sediments to settle out completely from the lake water under calm conditions (**Figure 10-10**). Based on the slow settling rates of sediment and the positive relationship between wind speed, solids, and phosphorus, it appears that winds from passing cold fronts increased the suspended solids in certain months (e.g., December and February) while fewer and weaker cold fronts in other months (e.g., January and April) allowed for settling of material and lower concentrations of TSS and TP. (**Figures 10-7, 10-9**).

The high suspended solids and resulting low light penetrations that persisted throughout winter 2004–2005 contributed to the continued declines in SAV. Between July 2004 (pre-hurricanes) and October 2004 (post-hurricanes) average SAV biomass, as measured at 78 SFWMD quarterly monitoring sites, declined from 32.32 ± 49.87 grams (g) dry weight (wt) m^{-2} to 4.65 ± 9.35 g dry wt m^{-2}, probably as a result of direct wind, wave, seiche, and lake stage impacts (**Figure 10-11**). However, from January 2005 to April 2005, SAV biomass continued to decline, from 4.46 g dry wt m^{-2} to 0.04 g dry wt m^{-2}. Although declines over the winter period are expected due to seasonal conditions such as lower temperatures, the significant declines observed are primarily a result of long-term light deprivation related to water quality and lake stage effects.

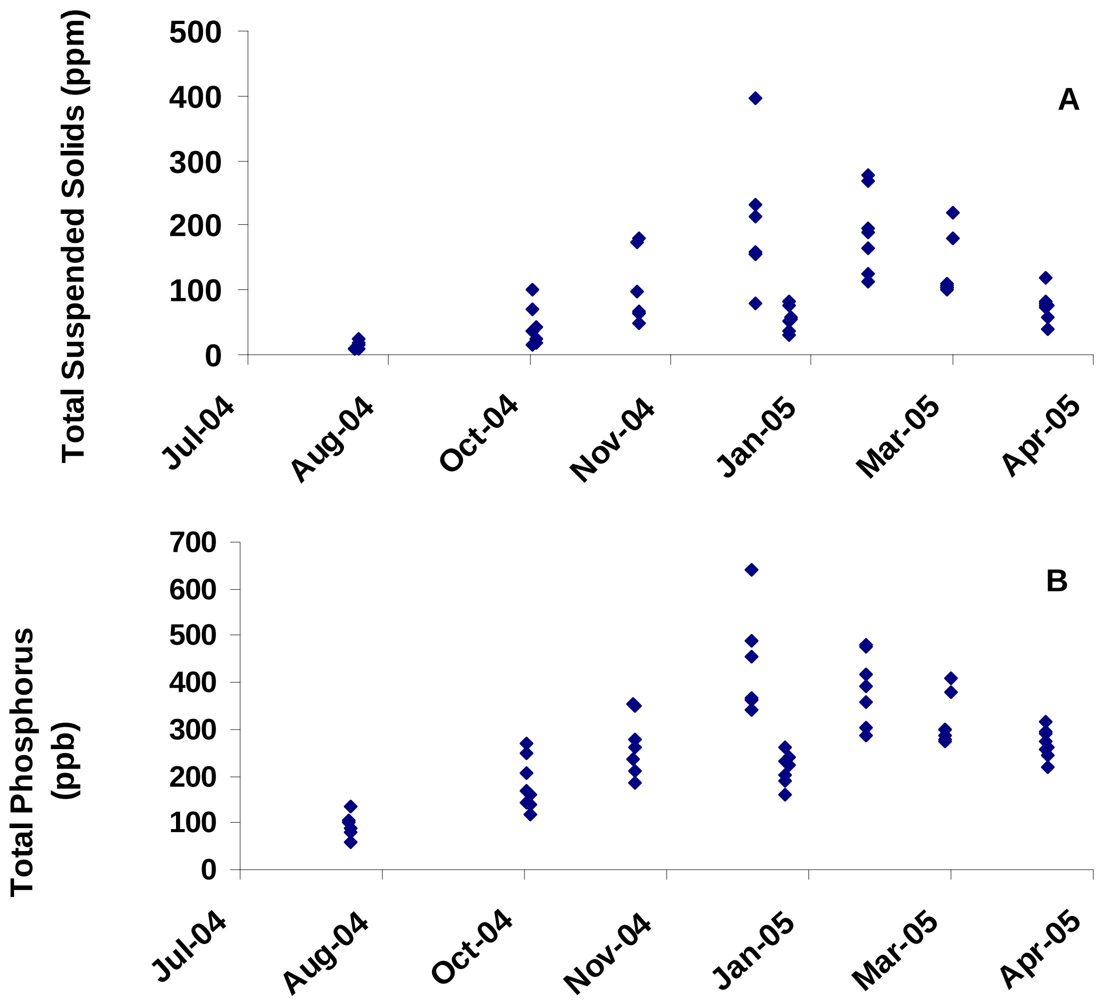
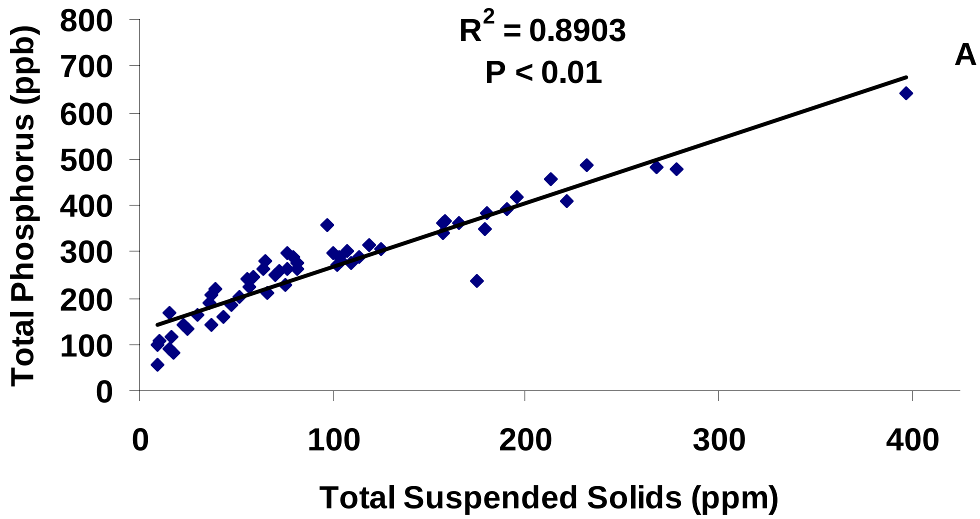


Figure 10-7. (A) Total suspended solids (TSS), and (B) total phosphorus (TP) from August 2004–April 2005 at the long-term monitoring stations (L001–L008) in Lake Okeechobee.



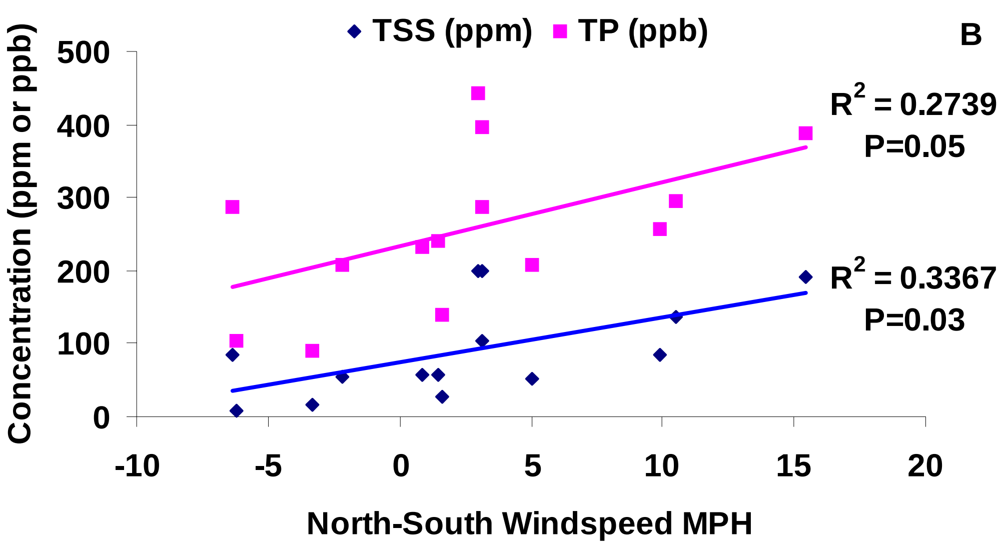


Figure 10-8. (A) Relationship between TP and TSS, and (B) relationship of north-south wind speed three days prior to sample collection to TP, and TSS.

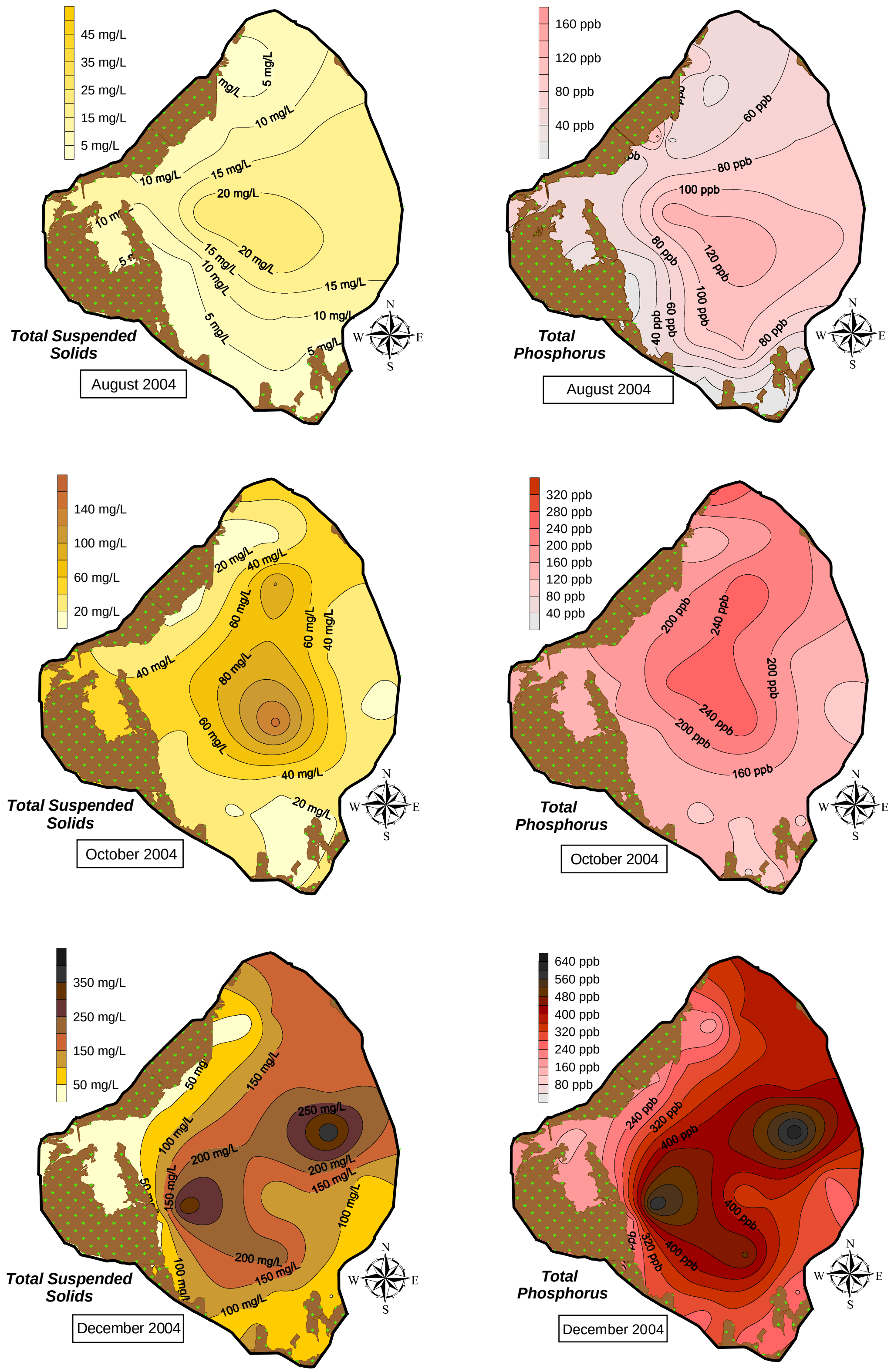


Figure 10-9a. Isopleth maps of TSS and TP for Lake Okeechobee (August–December 2004).

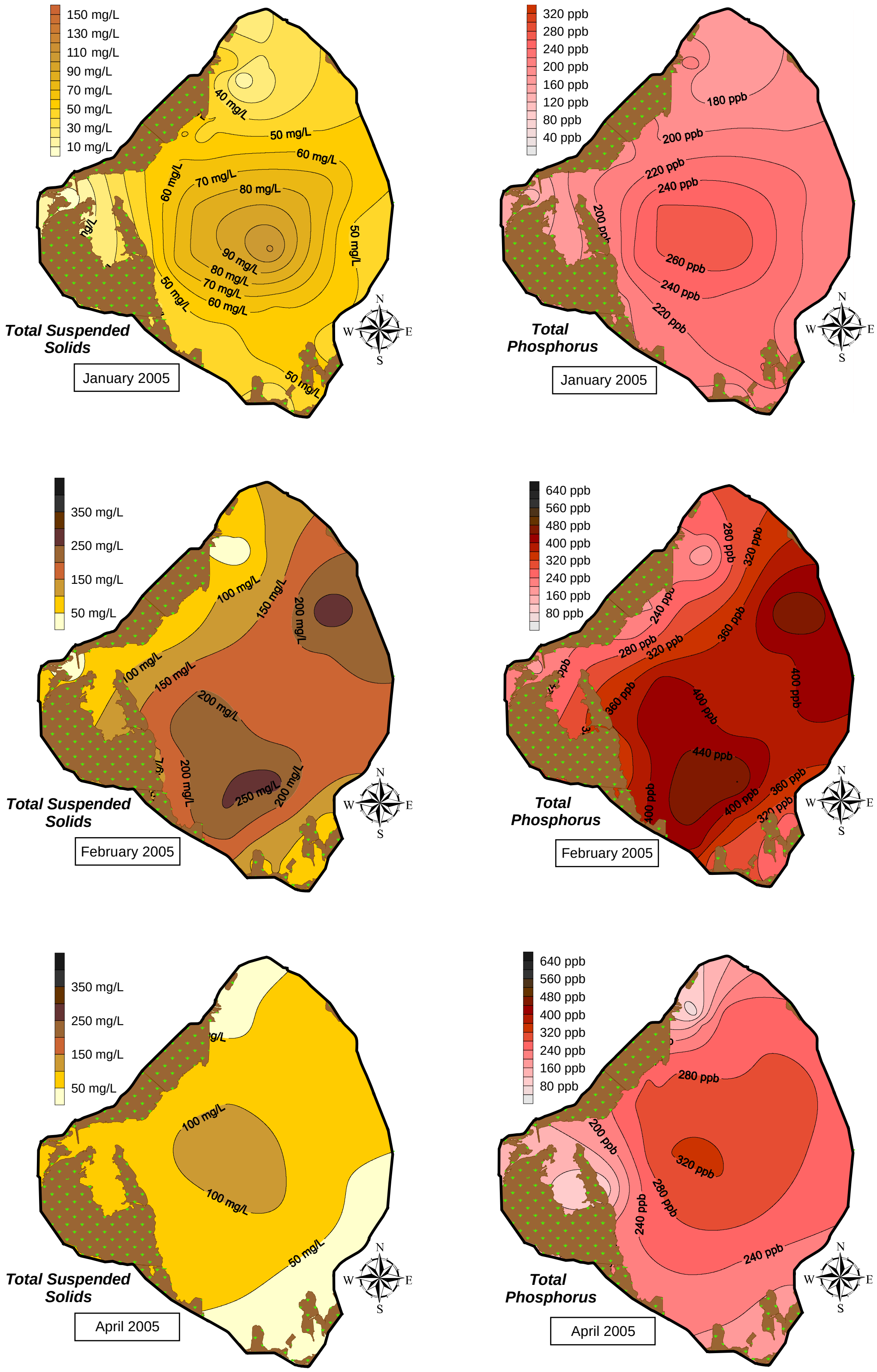


Figure 10-9b. Isopleth maps of TSS and TP for Lake Okeechobee (January–April 2005).

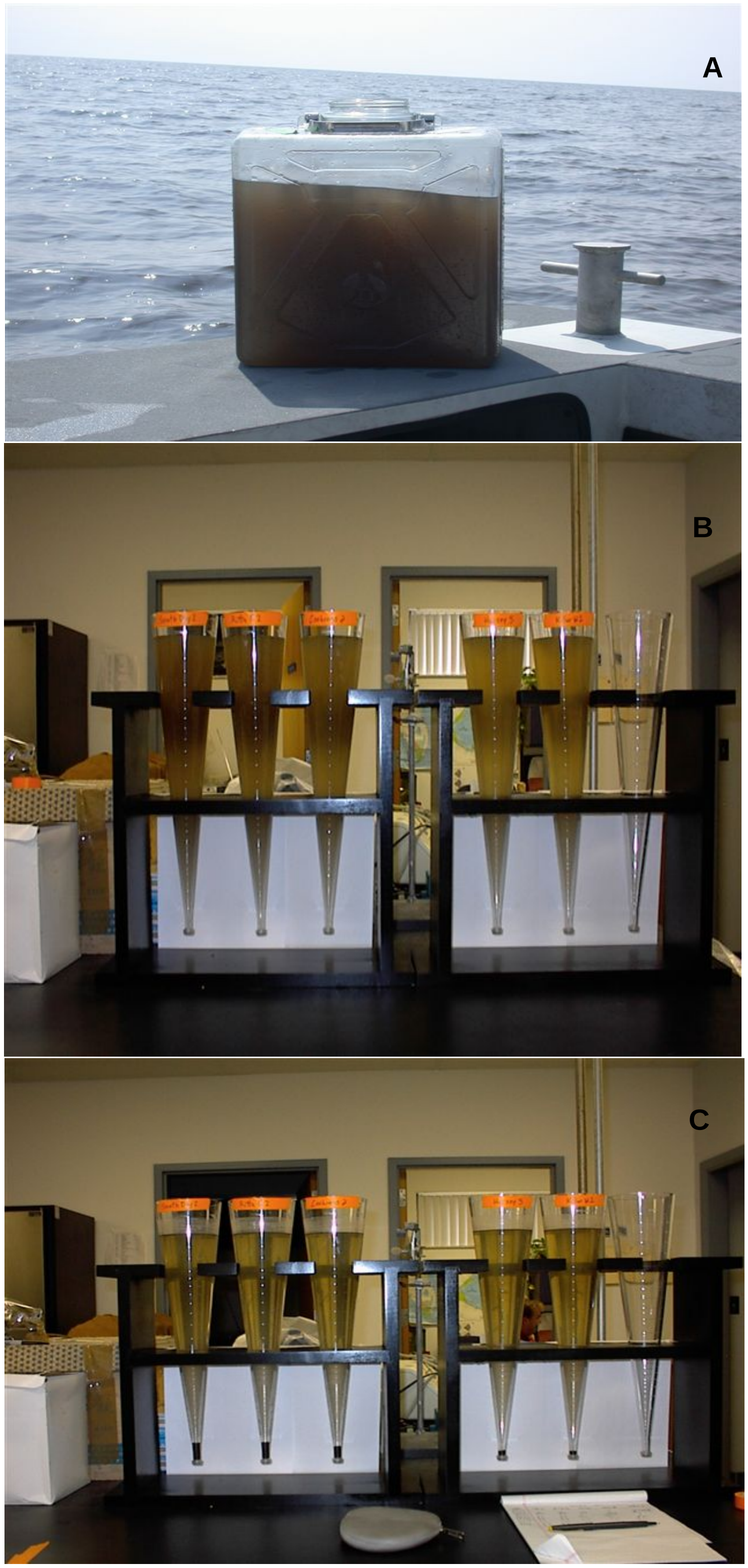


Figure 10-10. Solids settling experiments showing (A) water collected from the lake, (B) settling chambers at Day zero, and (C) settling chambers at Day 13 (photos by Therese East and Bruce Sharfstein, SFWMD).

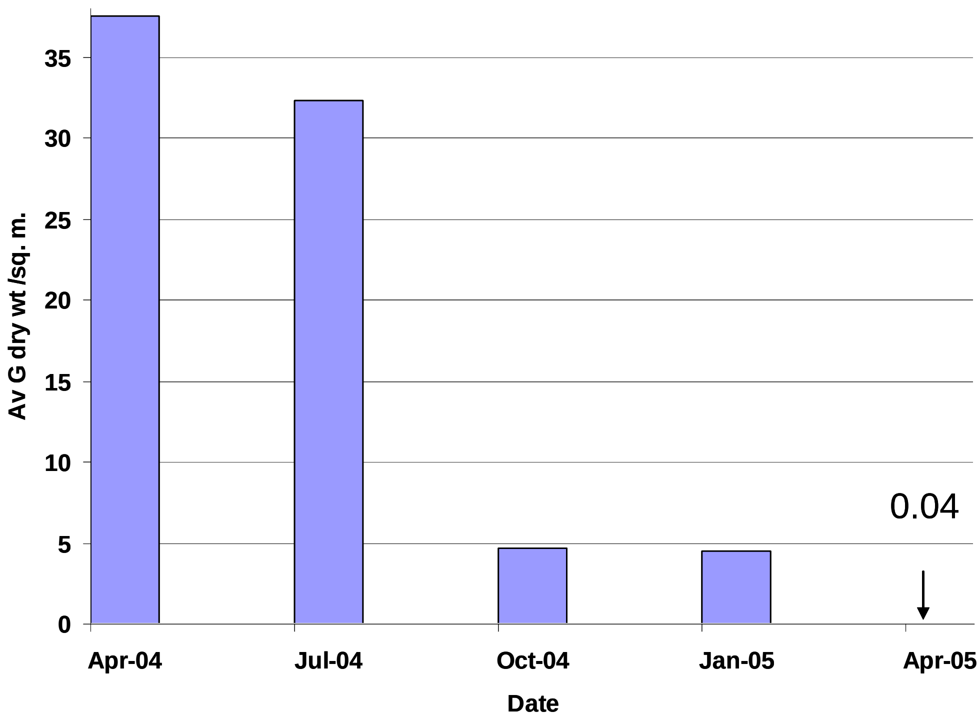


Figure 10-11. SAV biomass estimates from April, July, October 2004 and January and April 2005 sampling events.

LAKE STATUS

The current status of Lake Okeechobee is described in regard to (1) phosphorus budgets, (2) nutrient and phytoplankton dynamics, (3) submerged aquatic vegetation, and (4) emergent plants and wildlife. For the attributes covered under these items, a subset was adopted as quantitative performance measures for the LOPA (SFWMD et al., 2004; see www.sfwmd.gov/org/wrp/wrp_okee/projects/LOPPAnnualRptPosted122203.pdf). These measures collectively describe the status of the ecosystem and its responses to restoration programs once they are implemented. These measures are five-year averages to be consistent with the TMDL reporting, to reduce the year-to-year variation attributed to climate and hydrology, and to document any underlying trends. These values are compared to quantitative restoration goals (**Table 10-1**). The Lake Okeechobee Protection Program Annual Report provides a technical foundation for these restoration goals. The averages for WY2005 are included in this table to document the impacts of the extreme events on the lake conditions.

For WY2001–WY2005 the averages for TP, TN, SRP, and DIN are 142 ppb, 1.65 ppm, 38 ppb, and 236 ppb, respectively (**Table 10-1**). The WY2005 averages for these nutrients are 237 ppb, 2.1 ppm, 57 ppb, and 530 ppb, respectively. These WY2005 values are higher than the five-year averages because of the extreme weather events and constant sediment resuspension that occurred in this water year. The five-year TP concentration is over three times higher than the goal of 40 ppb that was used to establish the TMDL. The five-year average of total nitrogen to total phosphorus (TN:TP) is 12.3, and dissolved inorganic nitrogen to soluble reactive phosphorus (DIN:SRP) is 5.8. These values favor dominance of blue-green algae, which presently accounts for most of the algal biomass in the lake. The water clarity goal in shoreline areas, which is to have light visibility to the lake bed from May to September, are attained approximately 30 percent of the time in the past five years, and the goal for algal bloom frequency, which is 5 percent of all samples exceeding 40 ppb of chlorophyll *a*, is exceeded approximately threefold in the past five years. Other Class I/III constituents have been measured on this lake but have not been analyzed for inclusion in this report.

An important consideration in evaluating lake data is the concept of “ecological zones” that have been identified in the lake. These zones are most prominent when lake water levels are low, which promotes heterogeneity based largely on plant growth and reduced circulation between shallow and deep regions of the lake (James and Havens, 2005). When water levels are high, submerged plants die back and there is increased circulation between the zones, producing a more homogeneous lake (Maceina, 1993; Havens et al., 2001b; James and Havens, 2005).

These ecological zones have been described in detail in Chapter 10 of the 2005 SFER – Volume I (SFWMD, 2005) and in published literature (Havens, 2003; Phlips et al., 1993a). Based on plant diversity and abundance, there are three distinct regions (**Figure 10-12**) that also have different water quality and physical characteristics (Havens, 2003): (1) a littoral zone along the west and south shoreline with a diverse plant community, shallow water depths (0–3.3 ft or 0–1 m), and low TP concentrations (5–20 ppb) (Havens et al., 1999; Hwang et al., 1998; Havens et al., 2004b); (2) an adjacent nearshore zone of slightly deeper water (< 1.6–3.3 ft or < 0.5–1.0 m) on a shelf that supports submerged plants and wave-tolerant emergent plants such as giant bulrush (*Scirpus californicus*) and moderate TP concentrations (30– 60 ppb); and (3) a central pelagic zone that is deep (8.2–16.4 ft or 2.5–5.0 m), turbid, light limited, does not support any rooted plants or attached algae (Havens et al., 1995), and high TP concentrations of (> 100 ppb).

Phlips et al. (1993a) based their ecological zones on light, nutrient, and algae abundance (**Figure 10-13**). As with Havens (2003) they include littoral and central zones, and an edge zone that corresponds to the nearshore zone of Havens (2003). They also include a north zone where

Table 10-1. Summary of Lake Okeechobee rehabilitation performance measures, goals for the lake rehabilitation program and the existing (baseline) conditions. Unless otherwise indicated, existing conditions are five-year averages (1999–2003), as specified in the Restoration Assessment Plan of the Lake Okeechobee Protection Program (LOPP).

Performance Measure	Goal	Five-Year Average	WY2005 Average
Total phosphorus (TP) Load	140 mt/y	580 mt/y	950 mt/yr
Pelagic TP	40 ppb	142 ppb	237 ppb
Pelagic TN	N/A	1.65 ppm	2.1 ppm
Pelagic SRP	N/A	38 ppb	57 ppb
Pelagic DIN	N/A	236 ppb	530 ppb
Pelagic TN:TP	> 22:1	12.3:1	8.9:1
Pelagic DIN:SRP	> 10:1	5.8:1	9.2:1
Plankton Nutrient Limitation	Phosphorus > Nitrogen	Nitrogen >>> Phosphorus	Nitrogen >>> Phosphorus
Diatoms:cyanobacteria*	> 1.5	0.63	
Algal bloom frequency	< 5% of pelagic chlorophyll a exceeding 40 µg/L	15%	
Water clarity**	Secchi disk visible on lake bottom at all nearshore SAV sampling locations from May–Sep	32%	
Nearshore TP	Below 40 ppb	77 ppb	
Submerged aquatic vegetation (SAV)***	Total SAV > 40,000 acres Vascular SAV > 20,000 acres	38,000 acres total 18,000 acres vascular	54,857 acres total 26,669 acres vascular
Extremes in low lake stage (current water year)	Maintain stages above 10 ft		Goal attained
Extremes in high lake stage (current water year)	Maintain stages below 17 ft; stage not exceeding 15 ft for more than 4 months		Goal not attained
Spring recession (current water year)	Stage recession from near 15.5 ft in January to near 12.5 ft in June		Goal not attained

*Mean for WY2000–WY2005 period; **Frequency for period 2000–2004; *** Mean yearly acreages from 2000–2004 maps. N/A – not applicable, N/C – not cited

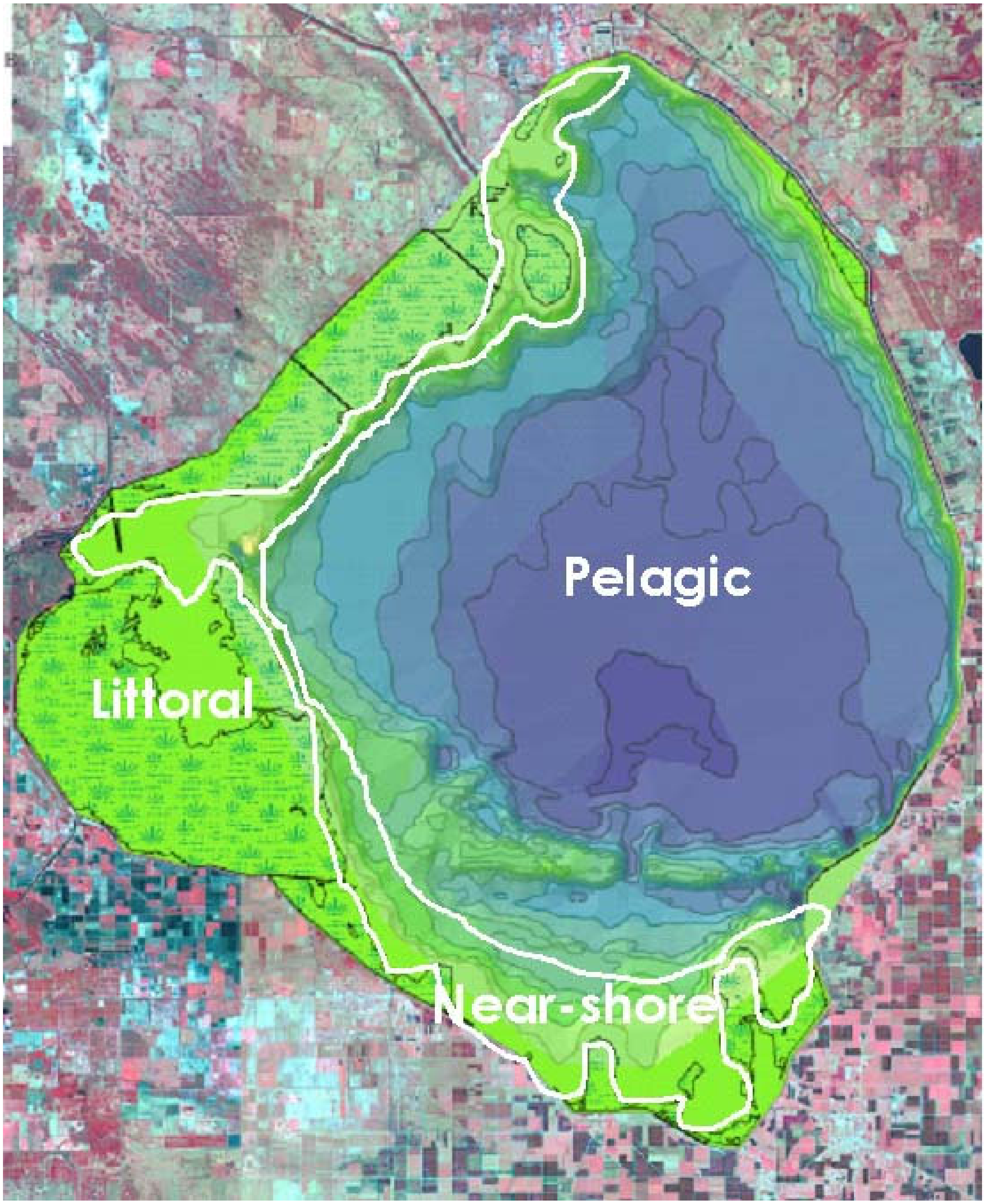


Figure 10-12. Three major habitat zones in Lake Okeechobee shown as an overlay on a 2002 lake bathymetric map. These zones are based on dominant primary producers (Havens, 2003).

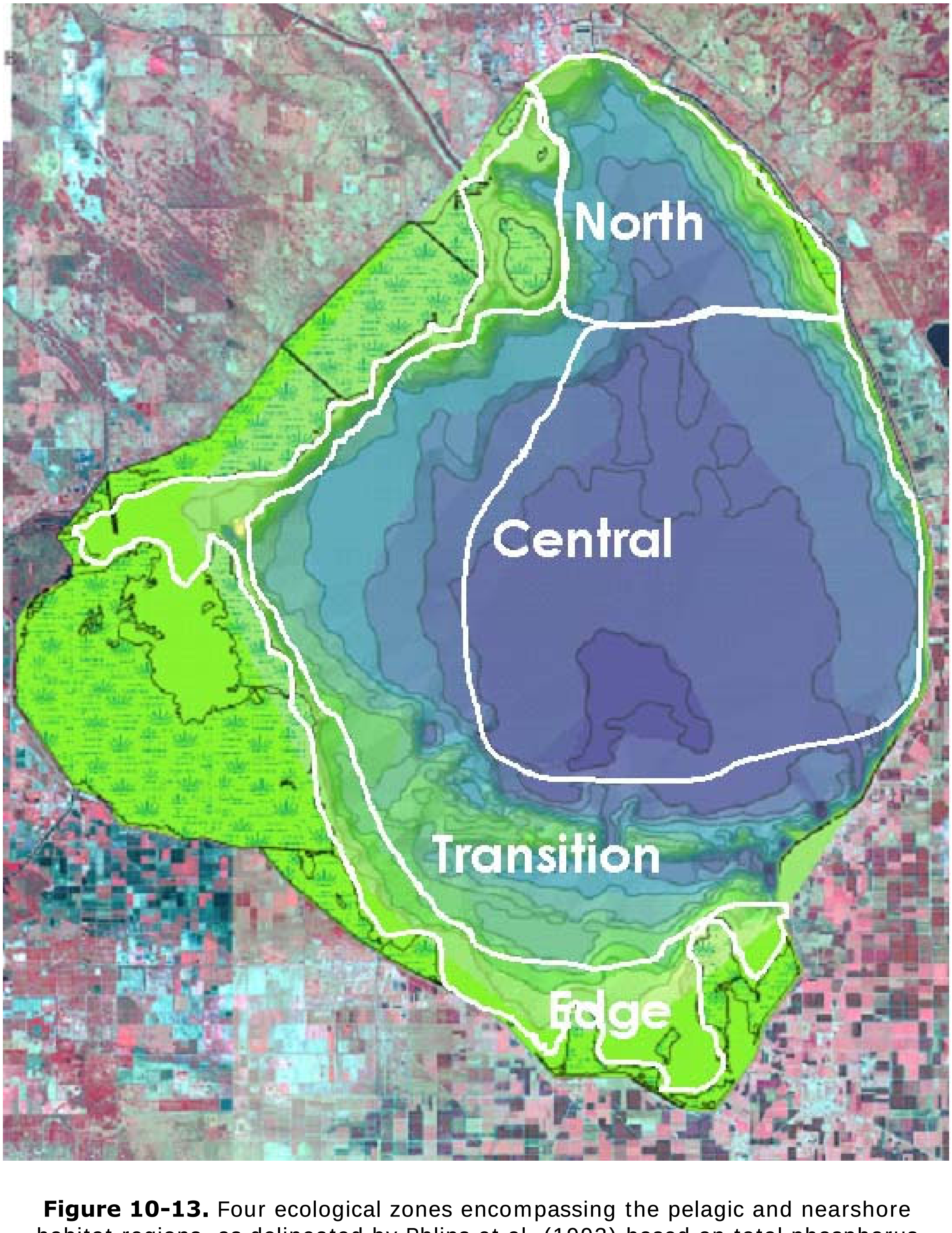


Figure 10-13. Four ecological zones encompassing the pelagic and nearshore habitat regions, as delineated by Phlips et al. (1993) based on total phosphorus and nitrogen concentrations, underwater irradiance, and the relationship of phytoplankton biomass to those attributes.

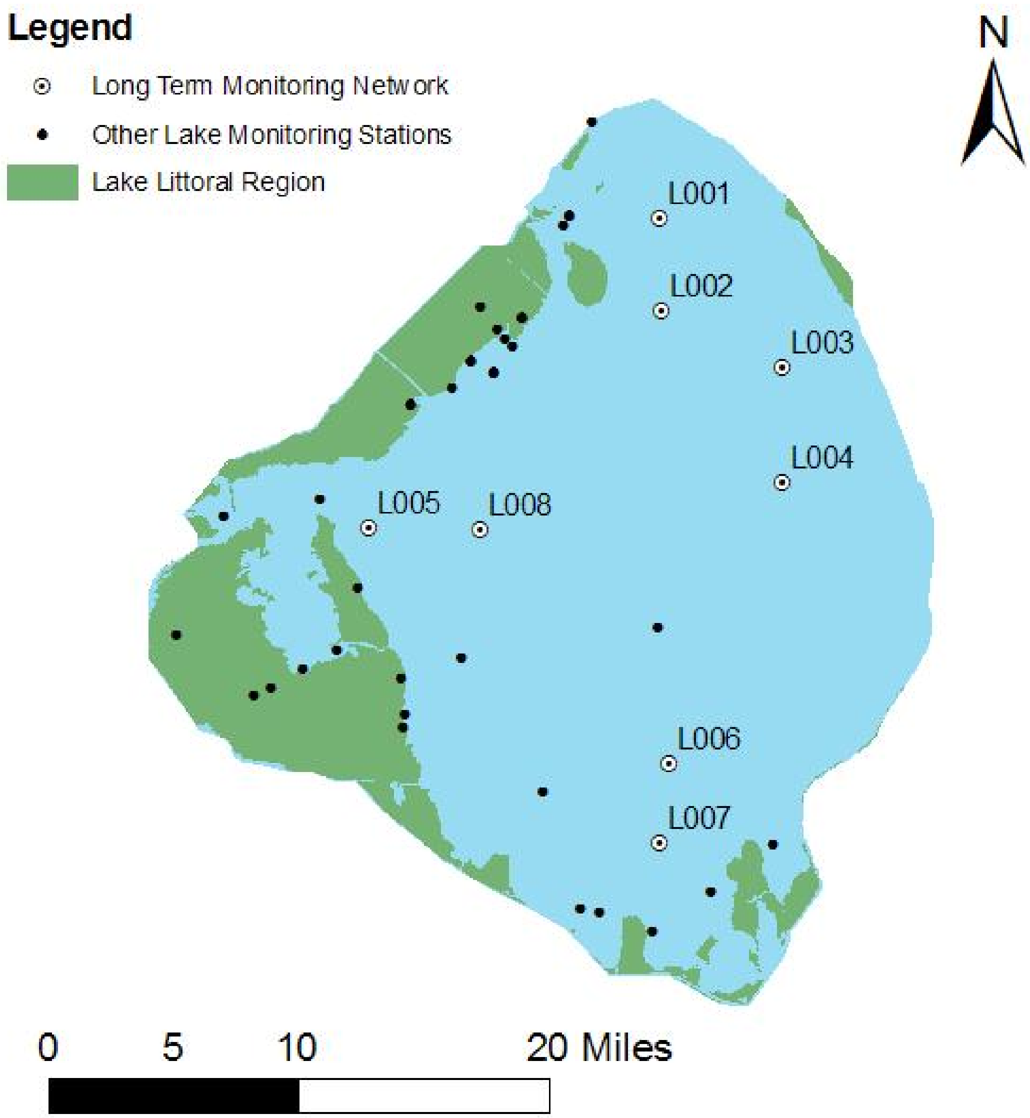


Figure 10-14. Water quality sampling stations in Lake Okeechobee, with the eight long-term stations used for Total Maximum Daily Load (TMDL) assessment and phosphorus mass balance calculations indicated (L001–L008).

the major discharges of phosphorus to the lake are located, along with high TP concentrations (> 100 ppb), moderate depths, and algae that are limited by nitrogen and light (Aldridge et al., 1995; Phlips et al., 1997). A transition zone between the central zone and edge zone has features intermediate between these zones. This region of the lake frequently experiences algal blooms. The current monitoring network within the lake includes all of these zones (**Figure 10-14**).

Phosphorus Budgets, Loads, and Lake Water Total Phosphorus

Understanding the phosphorus mass balance of a lake and the relationship between external phosphorus loads, internal recycling, and lake water phosphorus concentrations is critical for making accurate predictions regarding lake responses to load reduction in the watershed. This section summarizes historical and contemporary information about the phosphorus budget of Lake Okeechobee.

METHODS

Yearly phosphorus budgets were updated for this report using methods and procedures described in Chapter 10 of the 2005 SFER – Volume I (SFWMD, 2005) and the stations that measure both phosphorus and flows discharging to or from Lake Okeechobee (**Figure 10-15**). The only difference is that all plots and tables have been modified and are based on the water year (May 1 through April 30) in order to provide consistency with other chapters in this report. This change does not change the overall trends or results from Chapter 10 of the 2005 SFER – Volume I. However, year-to-year variation is changed due to the different sets of months that are summed and the beginning and ending months of each water year.

RESULTS AND DISCUSSION

Total phosphorus loads to the lake from tributaries and estimated atmospheric deposition (FDEP, 2001) in WY2005 totaled 950 mt, and discharges from the lake were 606 mt (**Table 10-2**). Atmospheric deposition, defined here as both wet and dry fall, is estimated at 35 mt/year (FDEP, 2001). The average lake phosphorus mass also was large (1,125 mt). These values were much larger than the historical averages of input, output, and mass (515, 197 mt $yr^{-1,}$ and 448 mt, respectively). The net sedimentation coefficient, σ_y (y^{-1}), which is the sediment accumulation divided by the average lake mass for WY2005 (0.1) is substantially lower than 0.81 reported by James et al. (1995a) or 0.79 by Janus et al. (1990). Both of these authors noted that the net sedimentation coefficient in the mass balance was declining, and this trend continues (**Figure 10-16**, Panel A). It appears that Lake Okeechobee is losing its capacity to assimilate phosphorus. In 1998 this value was negative, which indicates that the sediments were a net source of phosphorus in that water year. The overall reduction in the net sedimentation coefficient may be due to saturation of phosphorus-binding sites on lake sediment particles (Fisher et al., 2001) and/or a reduction of water-column calcium (James et al., 1995b), an element that plays a key role in sequestration of phosphorus in sediments of Lake Okeechobee (Olila and Reddy, 1993; Moore et al., 1998) and is measured as part of the SFWMD's monitoring program. Possible explanations for the reduction of calcium in the water column are a reduction of supply such as reduction of external calcium loads (James et al., 1995) or reduced contact of the water column with the underlying limestone formation (Parker et al., 1955) as the mud sediment has increased (Havens and James, 1999). Another explanation is an increase in uptake by increased amount of inorganic phosphorus that forms calcium phosphate, which is insoluble and is found in mud sediments (Reddy, et al., 1995).

A modified Vollenweider model was developed for shallow Florida lakes and applied to Lake Okeechobee (Kratzer, 1979; Kratzer and Brezonik, 1984; SFWMD, 1981). This modified model was used to set the original loading targets to the lake (SFWMD, 1989). The model worked well for the 1970s (Kratzer and Brezonik, 1984; James and Bierman, 1995), but after 1981 it under predicted phosphorus concentrations in the water column (James and Bierman, 1995; Havens and James, 1997; **Figure 10-16**, Panel B). This under-prediction was attributed to the reduced assimilative capacity of sediments (James and Bierman, 1995; Havens and James, 1997). The observed concentrations of TP in the water column increased from 40 ppb in 1974 to about 100 ppb in 1983. Concentrations remained near 100 ppb until 1999, when they began to increase. The current WY2005 value of 237 is the highest yearly average observed, which is attributed to the hurricane impacts in this water year.

The yearly phosphorus loads and water inflow are highly variable, with WY2005 phosphorus load and surface inflow the second and fourth largest recorded, respectively (**Figure 10-17**, Panel A). Inflow volume explains more than 80 percent of the year-to-year variation in TP loading (**Figure 10-17**, Panel B) and 20 percent of this variation is explained by the inflow TP concentration. The tremendous inter-annual variability of inflow to the lake masks the influence of decades of programs to control phosphorus loads.

Looking instead at the TP concentration of inflowing water (**Figure 10-18**) and the five-year rolling averages which reduce much of the inter-annual variability, overall trends can be observed. An increase from the 1970s to the mid-1980s is observed and followed by a decline through the 1990s. The decline in inflow phosphorus coincides with similar declines in major tributaries to the lake (Flaig and Havens, 1995). An increase in the late 1990s is observed with phosphorus concentrations increasing to approximately 200 ppb between WY1999 and WY2002 and then declining below 150 ppb in WY2003 and WY2004. In WY2005, there was a large increase in concentration to 212 ppb attributed to the hurricane impacts in August–September 2004 and the associated runoff.

Table 10-2. Water year phosphorus budget for Lake Okeechobee (mt).

May-Apr Water Year	Mean Lake P Mass	Net Change in Lake Content[1]	Load In[2]	Load Out	Net Load[3]	Sediment Accumulation[4]	Net Sedimentation Coefficient (σ_y)
1974	161	-102	424	70	354	457	2.84
1975	188	83	774	202	573	489	2.60
1976	217	95	351	53	298	203	0.94
1977	254	-69	460	46	414	483	1.90
1978	292	213	480	50	429	216	0.74
1979	391	202	702	179	523	321	0.82
1980	558	54	843	191	653	599	1.07
1981	364	-377	151	72	79	456	1.25
1982	216	65	440	51	389	324	1.50
1983	505	265	1189	403	786	521	1.03
1984	497	-4	369	199	170	174	0.35
1985	460	-227	500	243	257	484	1.05
1986	301	-154	421	79	341	495	1.64
1987	410	394	562	60	502	108	0.26
1988	591	44	488	162	326	282	0.48
1989	419	-340	229	152	78	418	1.00
1990	360	-73	365	151	213	286	0.80
1991	332	122	401	31	370	247	0.74
1992	398	52	408	61	347	295	0.74
1993	409	154	519	209	310	156	0.38
1994	445	-228	180	154	25	253	0.57
1995	484	202	617	271	346	145	0.30
1996	611	134	644	352	292	158	0.26
1997	481	-266	167	161	6	272	0.57
1998	610	510	913	594	319	-191	-0.31
1999	532	-543	312	241	70	613	1.15
2000	735	106	685	322	363	257	0.35
2001	383	-320	134	209	-75	245	0.64
2002	430	264	624	87	536	273	0.63
2003	594	143	639	328	311	168	0.28
2004	578	150	553	310	244	94	0.16
2005	1,126	237	950	606	344	107	0.10
Average	*448*	*25*	*515*	*197*	*319*	*294*	*0.84*

1 Net change from beginning of water year (May) to beginning of next water year (May)
2 Includes 35 mt per year to account for atmospheric deposition.
3 The difference between Load In and Load Out.
4 The difference between Net Change in Lake Content and Net Load (positive value is accumulation in sediments).

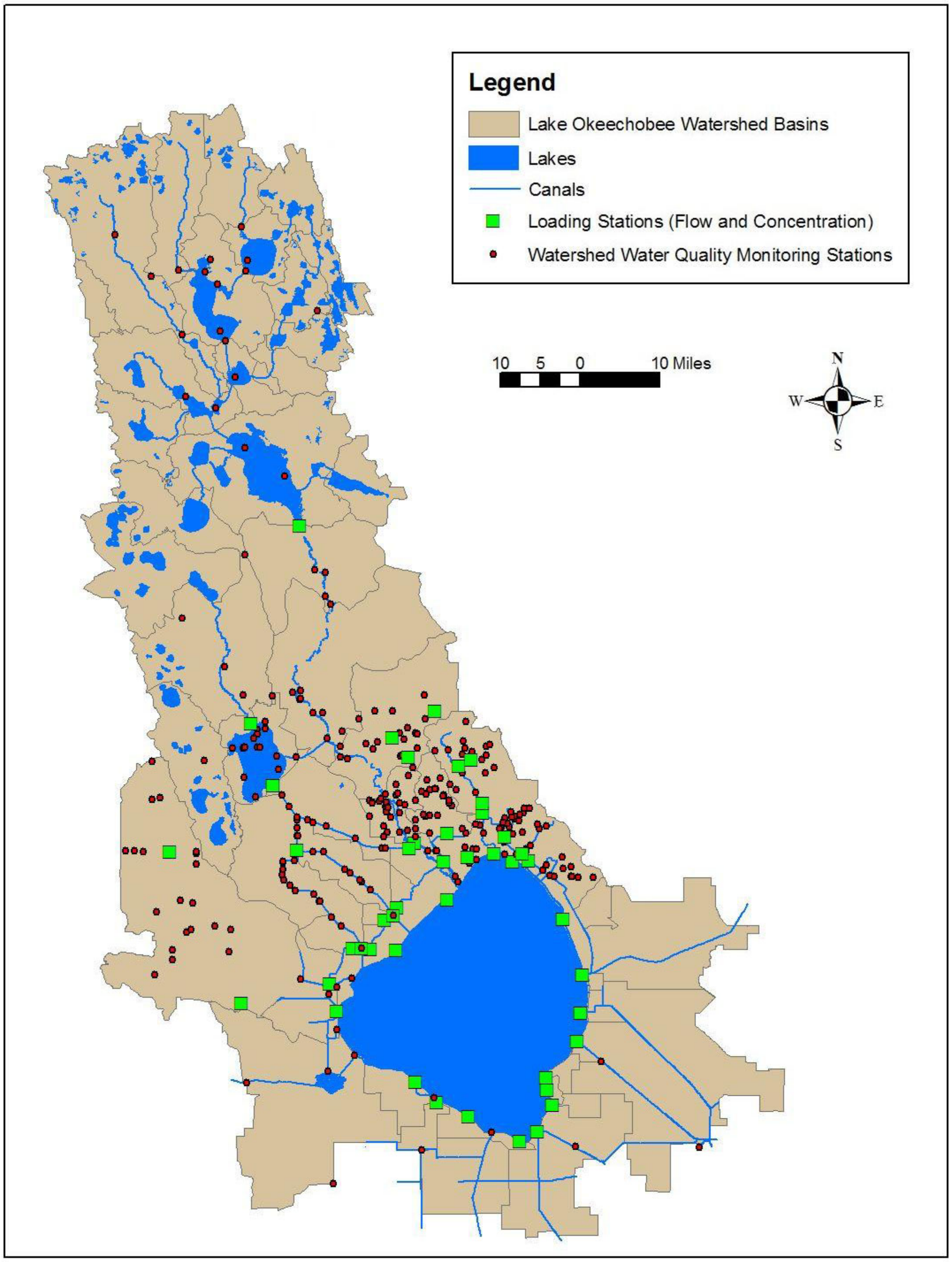


Figure 10-15. Location of sampling stations where TP loads are determined from tributary basins that drain into Lake Okeechobee (green squares). Other watershed water quality sampling stations also are shown (red dots).

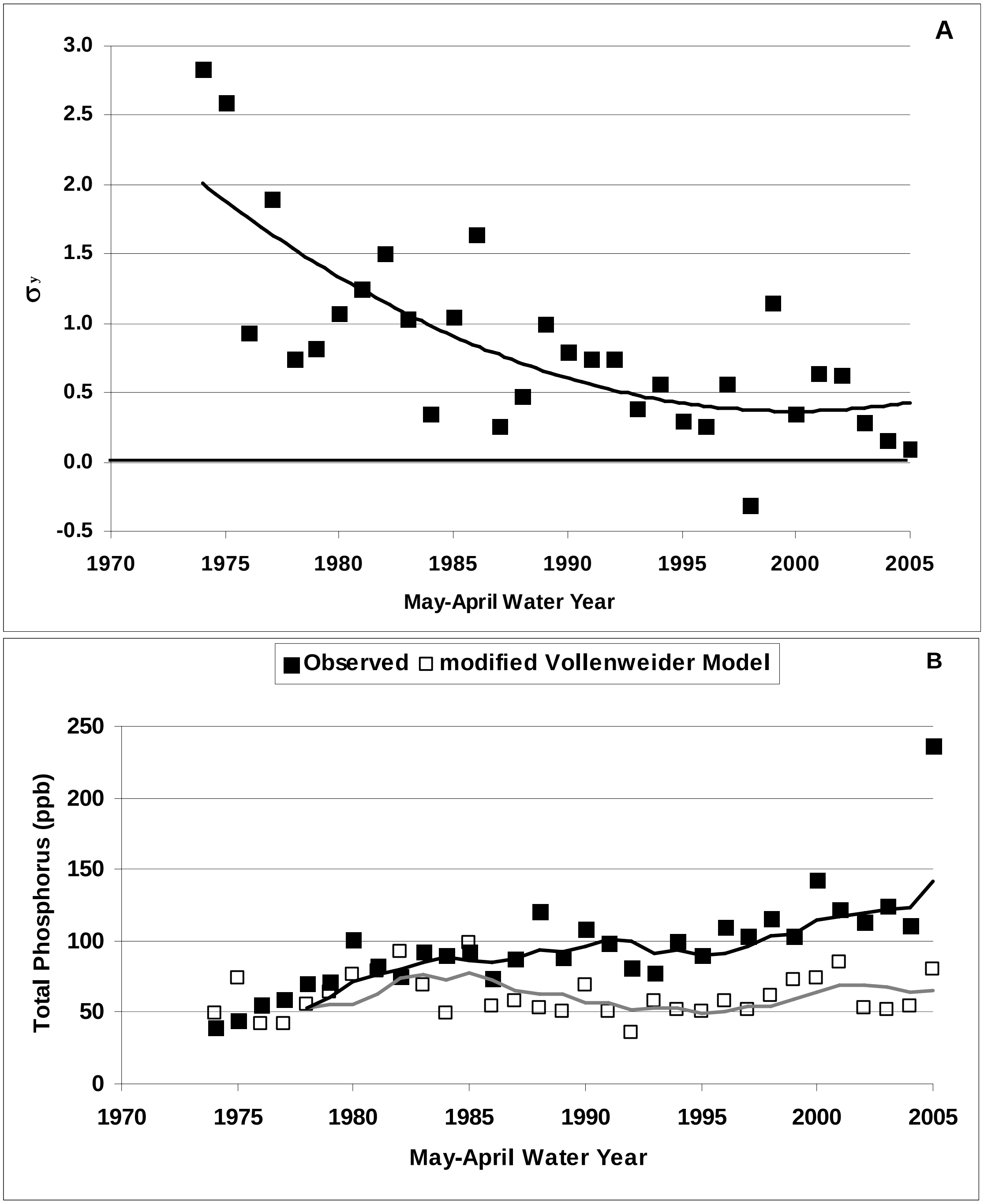
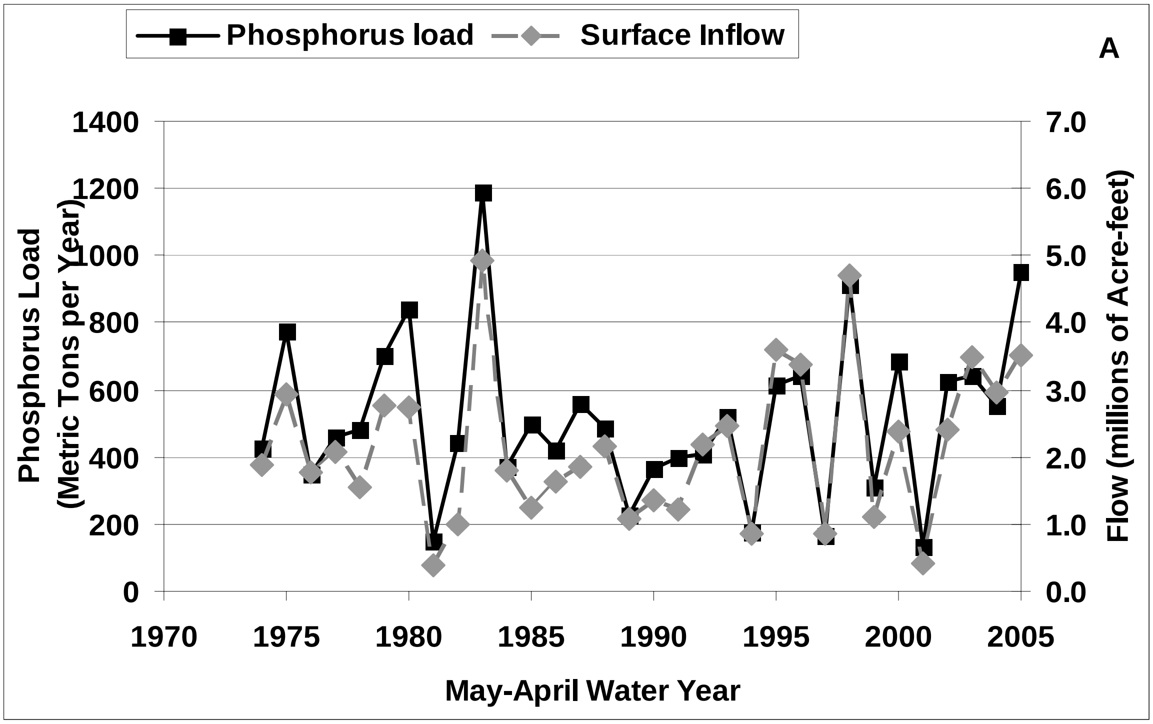


Figure 10-16. (A) Historical changes in the net sedimentation coefficient [σ_y)] calculated from the water year phosphorus budget of Lake Okeechobee showing a downward trend over time (trend line is a second order polynomial). (B) Historical changes for TP concentrations in lake water, comparing measured values with yearly values, calculated from a modified Vollenweider model (Kratzer, 1979). Trend lines are five-year moving averages.



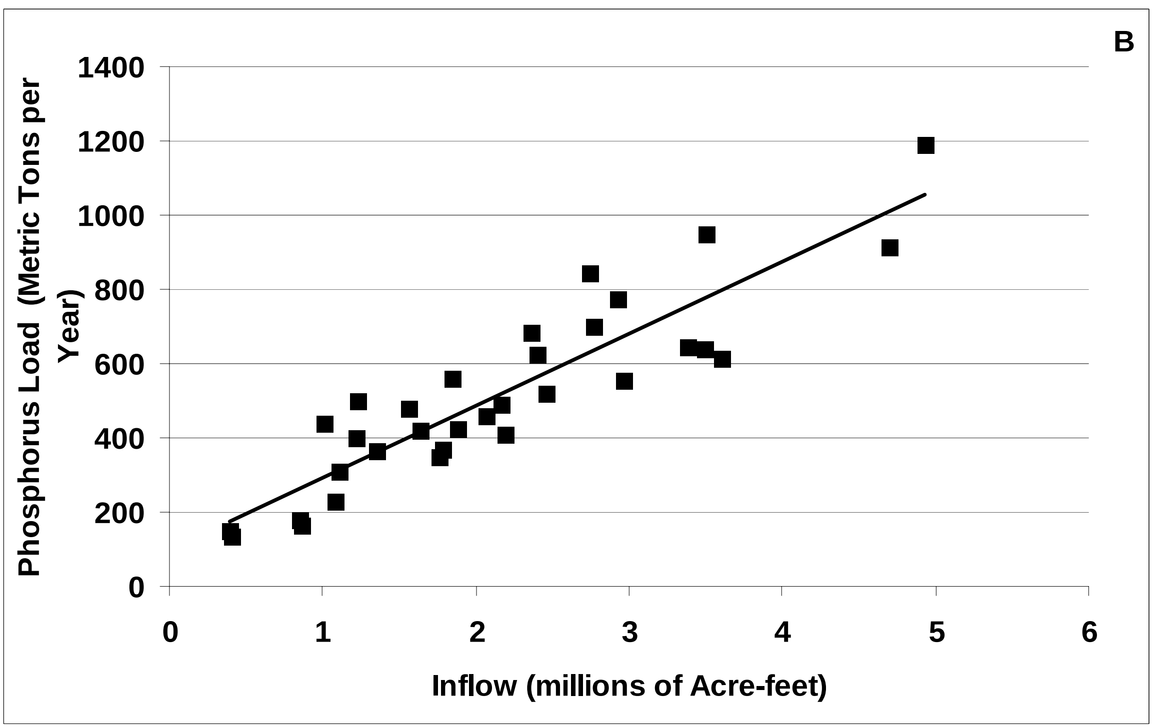


Figure 10-17. (A) Time lines of water year phosphorus load and inflow entering Lake Okeechobee from its tributaries. (B) The relationship between water year external phosphorus loading and inflow water volume.

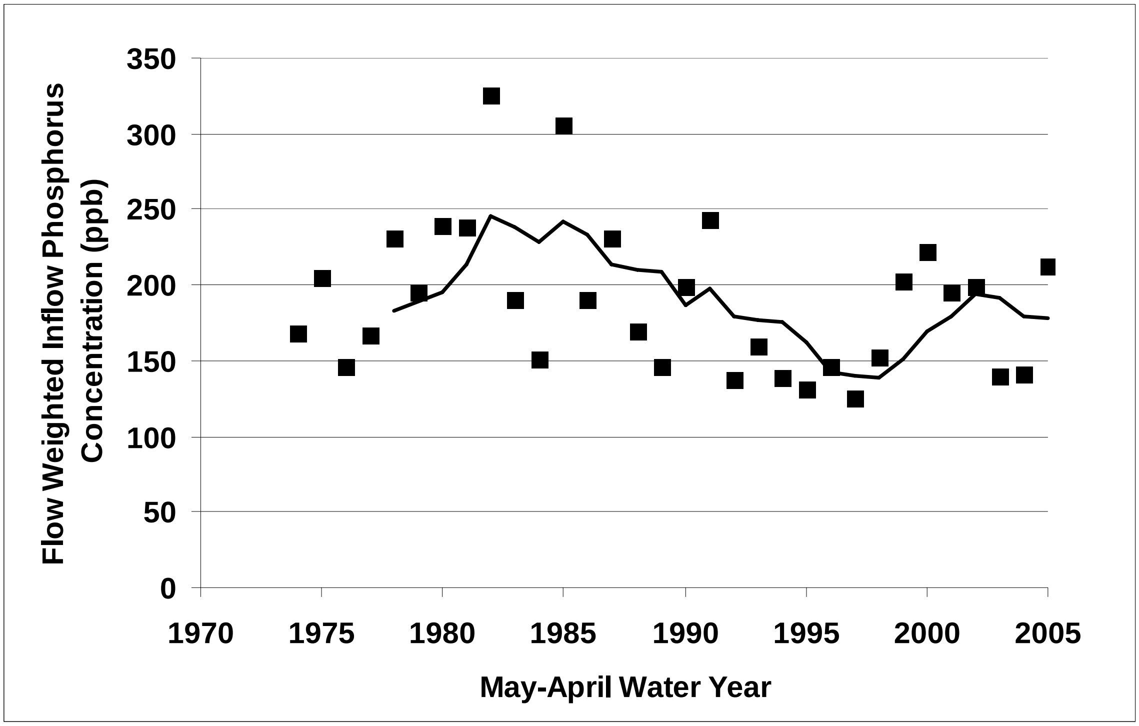


Figure 10-18. TP concentrations (flow weighted) of tributary inflow water to Lake Okeechobee. Data are water year means from 1973–2005. The trend line is a five-year moving average.

Phosphorus concentrations of lake water (average from stations L001–L008) increased during the 1970s and then remained relatively stable with a mean near 100 ppb until 1995 (**Figure 10-16B**). Phosphorus concentrations then increased to above 100 ppb in recent years. The variation of phosphorus is not related to water depth as reported by Canfield and Hoyer (1988), who observed a positive relationship between water level and annual TP concentration from 1974 to 1983 and Janus et al. (1990), who also observed a positive relationship between depth and annual TP concentration from 1974 to 1988 (significance was not specified). Havens and James (2005) used updated datasets (annual means from 1973 to 2002) and found no relationships between TP concentration and inflow, depth, or inflow phosphorus concentration. This indicates the overriding influence of internal phosphorus cycling (between sediments and water) in controlling phosphorus concentrations in Lake Okeechobee.

The lack of correlation between lake water phosphorus and external loads, and the historical decline in predictive ability of a modified Vollenweider model (Kratzer, 1979; **Figure 10-16,** Panel B), are consistent with results from other shallow eutrophic lakes with long histories of high external phosphorus loading (e.g., Sas, 1989; Jeppesen et al., 1991; Sondergaard et al., 1993; van der Molen and Boers, 1994). As with these other shallow lakes, there is a large storage of phosphorus in sediments of Lake Okeechobee that can be released to the water column through diffusion (Moore et al., 1998; Fisher et al., 2005) or resuspension (see **Figures 10-8** and **10-9**). A box and arrow diagram of phosphorus developed from a more complex mechanistic model: the Lake Okeechobee Water Quality Model (LOWQM), (James et al., 2005) estimates the sediment water fluxes averaged over the calibration period of the model (1982 to 2000). The LOWQM assumes that all dissolved inorganic phosphorus is available for uptake by algae. Organic phosphorus must be mineralized to be used by algae. The model results predict that there is a net load of inorganic phosphorus from sediments to the water column, which is approximately four times larger than the external load of inorganic phosphorus (**Figure 10-19**). There is also a net flux of organic and algal phosphorus from the water column to the sediments. Since the latter is greater than the former, the sediments act as a net sink. Once external loads are reduced, Lake Okeechobee would begin to display a decline of in-lake phosphorus when sediments and water reach a new equilibrium (Brezonik and James, 1995). This will take decades.

The LOWQM does not consider ecological zones; however, it does explicitly simulate sediment-water interactions in the phosphorus and nitrogen cycles, and it predicts the biomass of cyanobacteria and two other algal groups including diatoms and green algae (James et al., 2005). This model has been used to make long-term predictions about lake response to external phosphorus load reductions and in-lake sediment management alternatives.

Two uncertainties that influence the predicted LOWQM response time of the lake to load reductions are the burial rate of sediments and the depth of the active sediment layer. A faster burial rate would mean that phosphorus is removed quicker from the lake sediments resulting in a quicker response to external load reductions. The burial rate used in the LOWQM was determined by Brezonik and Engstrom (1998) who used a lead isotope (^{210}Pb) to determine the age of sediments with depth. This study indicated that sediments in the central region of the lake accumulate at the rate of approximately 0.095 cm/year. The active sediment layer is defined in the LOWQM as 6 cm (James et al., 2005). A concern about the depth of this layer is that hurricane impacts may result in remixing the sediments at depths greater than 6 cm. If deeper sediments are remixed, the pool of active phosphorus in the sediments is greater and will take longer to remove by burial. A study completed in 2003 indicated that the lake sediments had not been disturbed greatly in the past 75 years (Schottler and Engstrom, 2005). However, recent impacts of the 2004 hurricanes on Lake Okeechobee sediments are currently being evaluated and will be compared to the results of the 2003 study.

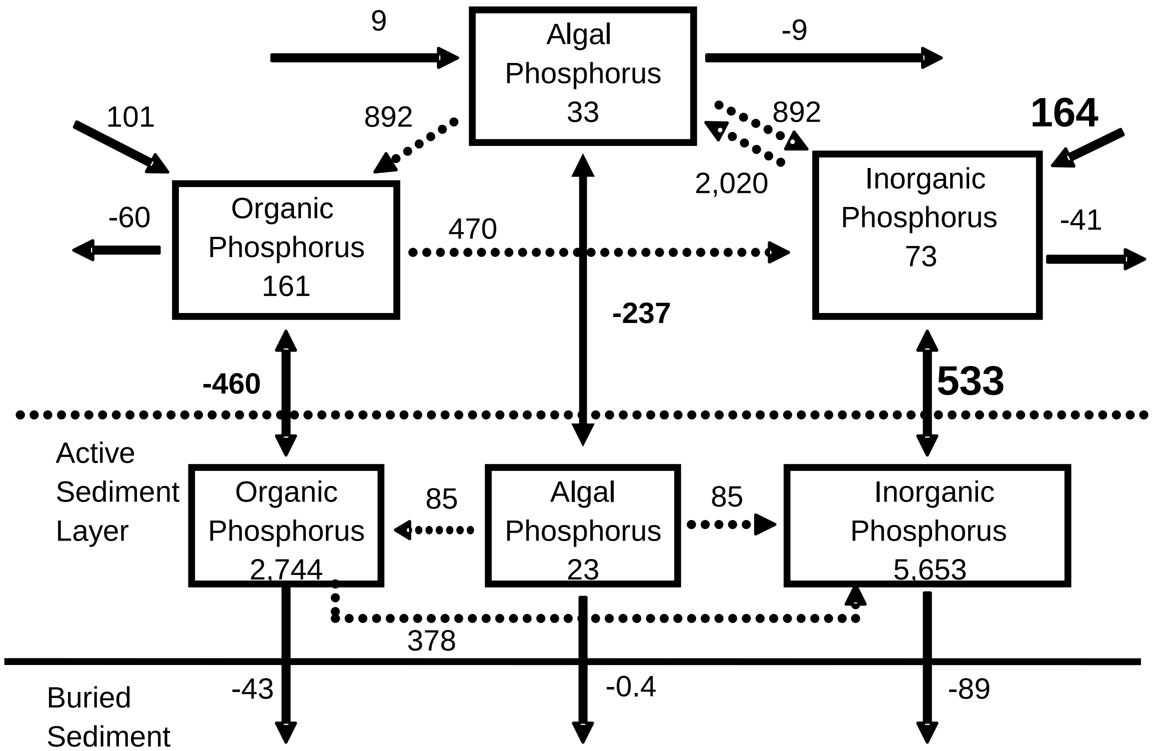


Figure 10-19. Box (mass - mg/m^2) and arrow (flux – mg $P/m^2/yr$) diagram of phosphorus estimated from a calibrated simulation of the Lake Okeechobee Water Quality Model (years 1982 to 2000). Values are mean annual averages. Dotted arrows represent transformation of phosphorus, solid arrows represent fluxes. Negative values represent removal from the water column or from the active sediment layer to buried sediment.

Submerged Aquatic Vegetation

SAV plays a key role in shallow lakes because it influences the biomass of phytoplankton and the transparency of water through a number of processes. These include stabilization of sediments by roots, reduction of shearing stress to sediment surfaces, uptake of nutrients by periphyton (algae which grows on plants and benthic substrates) attached to SAV, and precipitation of phosphorus with calcium when intense photosynthesis results in high water column pH (Murphy et al., 1983; Dennison et al., 1993; Scheffer, 1998; Vermaat et al., 2000). Lakes with dense SAV can have clear water and low phytoplankton biomass and then switch to having turbid water with algal blooms if the plants are lost (Scheffer, 1989; 1998). Some lakes even have shallow areas with SAV and clear water adjacent to deeper areas with no SAV and turbid water (Scheffer et al., 1994). This is the situation that exists in Lake Okeechobee as suggested by Phlips et al. (1993b), and then documented by Havens et al. (2004a) and James and Havens (2005). The nearshore zone switches between a SAV/clear water state when water levels are low to a phytoplankton/turbid water state when there are periods of prolonged high water levels (Havens et al., 2001a; Havens, 2003; Havens et al., 2004a, James and Havens, 2005).

METHODS

The SAV community is sampled in two projects that vary in temporal and spatial scale. On a quarterly basis the SFWMD collects SAV samples along 15 transects (**Figure 10-20**) that extend from the shoreline to deeper water in the south, west, and north nearshore regions known to support SAV under favorable conditions. No transects are located along the east shore, which has deeper water and high turbidity, and does not support SAV. Along each transect, there are a number of fixed sampling locations with known GPS coordinates. The station closest to the shore is sampled first, and then subsequent stations are sampled out to deeper water until a station is encountered with no plants. Triplicate samples of approximately 0.3 m^2 are collected at each station with a pair of garden rakes modified to produce a tong-like device. Dry weight biomass is determined for each species of vascular plant and macroalgae (e.g., *Chara*). Additional details on the sampling methods and laboratory processing are provided in Havens et al. (2004a). Maps showing results of transect surveys are updated on a quarterly basis on the District's web site at www.sfwmd.gov/org/wrp/wrp_okee/2_wrp_okee_inlake/quarterlysampling.html.

On a yearly basis, the entire nearshore zone is mapped in order to determine the spatial extent of each SAV species. Mapping is done during a period of two to three weeks in July–August (the peak of SAV biomass) on a 1 x 1 km resolution sampling grid developed in Geographic Information Systems (GIS) and loaded into Global Positioning Systems (GPS) units so that the center-point of each grid cell can be located in the field. Samples are collected in the same manner as in the quarterly sampling, but only species presence/absence and a qualitative estimate of biomass (sparse, moderate, dense) are made. Depth, transparency, and sediment type also are recorded. Sampling is done in consecutive rows of grid cells, again working toward deeper water until a cell is encountered with no plants. Depending on the spatial extent of SAV, between 300 and 600 sites are sampled per year in this project. Because field data are entered into electronic logging devices in the field and then downloaded into GIS, map development occurs almost immediately after sampling. Additional details regarding field sampling and map development are provided in Havens et al. (2002). Maps for the major SAV taxa from 2000–2005 can be viewed on the South Florida Water Management District's web site at www.sfwmd.gov/org/wrp/wrp_okee/2_wrp_okee_inlake/savmaps.html.

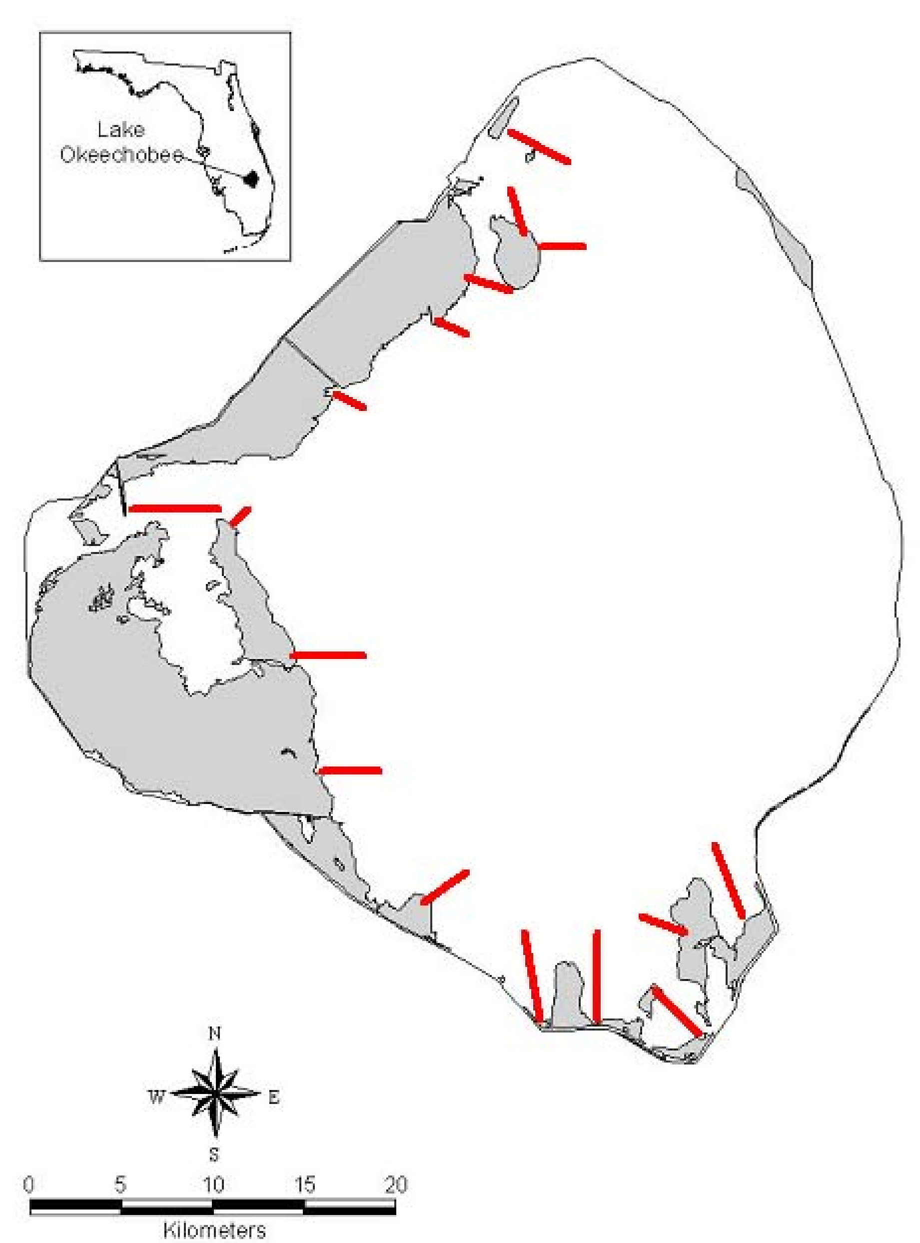


Figure 10-20. Map of Lake Okeechobee showing the locations of nearshore transects where quarterly sampling of submerged aquatic vegetation (SAV) biomass occurs.

RESULTS AND DISCUSSION

The most recent SAV map (August 2004) indicates approximately 54,857 acres (222 km^2) of plants (**Figure 10-21**); this is a substantial increase over the 31,135 acres (126 km^2) found in August 2003 (**Figure 10-22**), and is attributed to low water conditions that occurred in spring 2004 (**Figure 10-23**). This allowed for good light penetration in the nearshore water column, which in turn led to increased growth rates of plants. The spatial extent and biomass of SAV have been substantially reduced by wind, wave, and high water caused by three hurricanes that passed directly over or just to the north of the lake in August–September 2004 (hurricanes Charley, Frances, and Jeanne). Although 2005 mapping results will not be completed by the publication date of this report, the most recent quarterly sampling results (April 2005) indicate that SAV biomass has fallen to levels lower than any encountered since routine surveys were instituted in 1999. In April, only 19 percent of the sites routinely sampled during quarterly surveys had plants, and the average plant dry weight biomass for all vegetated sites was 0.04 g m^{-2}. This reflects the continued high water and poor light conditions for plant growth and survival.

As indicated by the quarterly survey results noted above, the SAV assemblage was dominated by *Chara* in 2000–2001, and then switched to a mixed community of vascular plants in 2002–2004. In 2005, *Chara* expanded out into deeper water areas and once again became the dominant plant in the submerged assemblage.

The yearly maps of SAV coverage are used to provide scores for one of the priority performance measures that is reported to the U.S. Congress for Restoration Coordination and Verification (RECOVER) (see Chapter 7B of this volume for additional information on RECOVER). The performance target for this measure is to maintain 49,420 acres (200 km^2) of total SAV, with at least 50 percent due to vascular taxa. Under existing circumstances, this spatial extent is attained in certain years, although in a relatively high percentage of years it is lower due to sustained high water.

A potentially important component of the plant community in the nearshore region is periphyton. The District is in year three of a five-year study of periphyton attached to submerged and emergent vegetation in the nearshore zone. Preliminary results may be available in the next report.

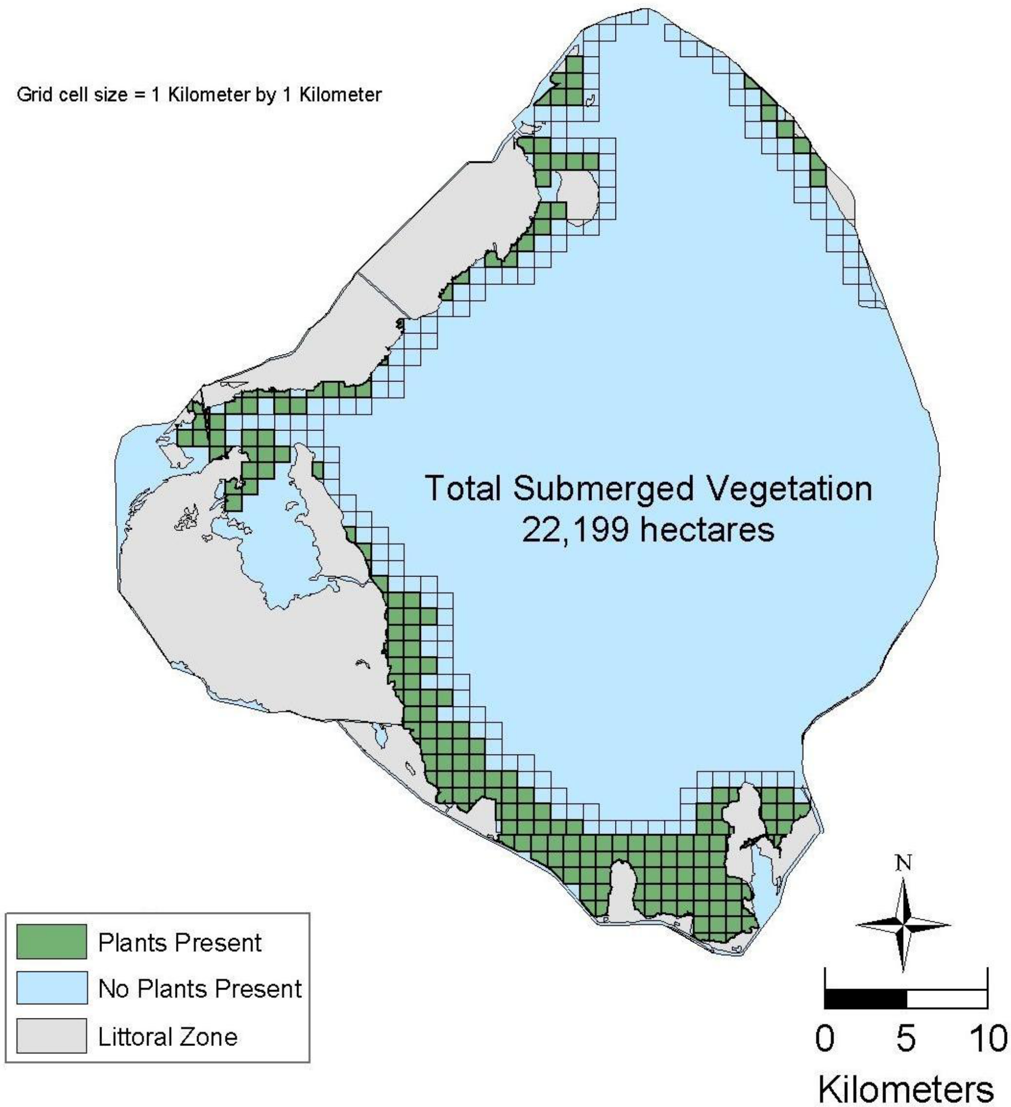


Figure 10-21. Map of SAV developed in August 2004. Grid cells correspond to sampling locations. Blue and green cells indicate no plants and plants, respectively. As indicated in the text, these data are qualitative. The spatial distribution of individual species can be found on the District's web site at www.sfwmd.gov/org/wrp/wrp_okee/2_wrp_okee_inlake/savmaps.html.

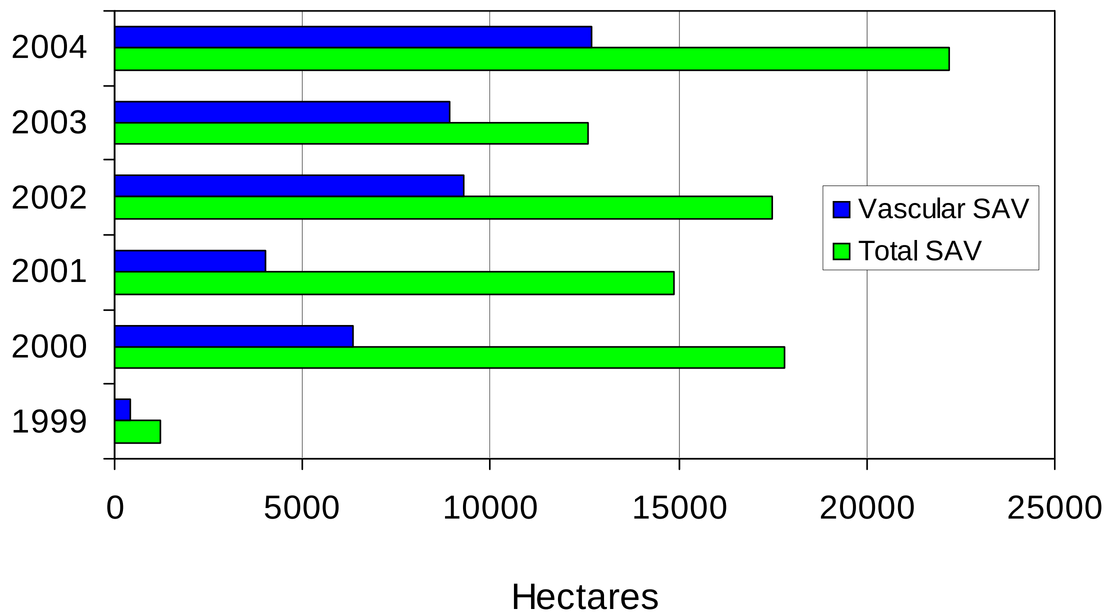


Figure 10-22. Spatial extent of total and vascular SAV in Lake Okeechobee during the six years when spatial sampling has been conducted. The 1999 data is an estimate based on qualitative surveys from boat, without a defined sampling grid. The difference between total and vascular SAV reflects the spatial extent of the lake's bottom with a monoculture of *Chara*.

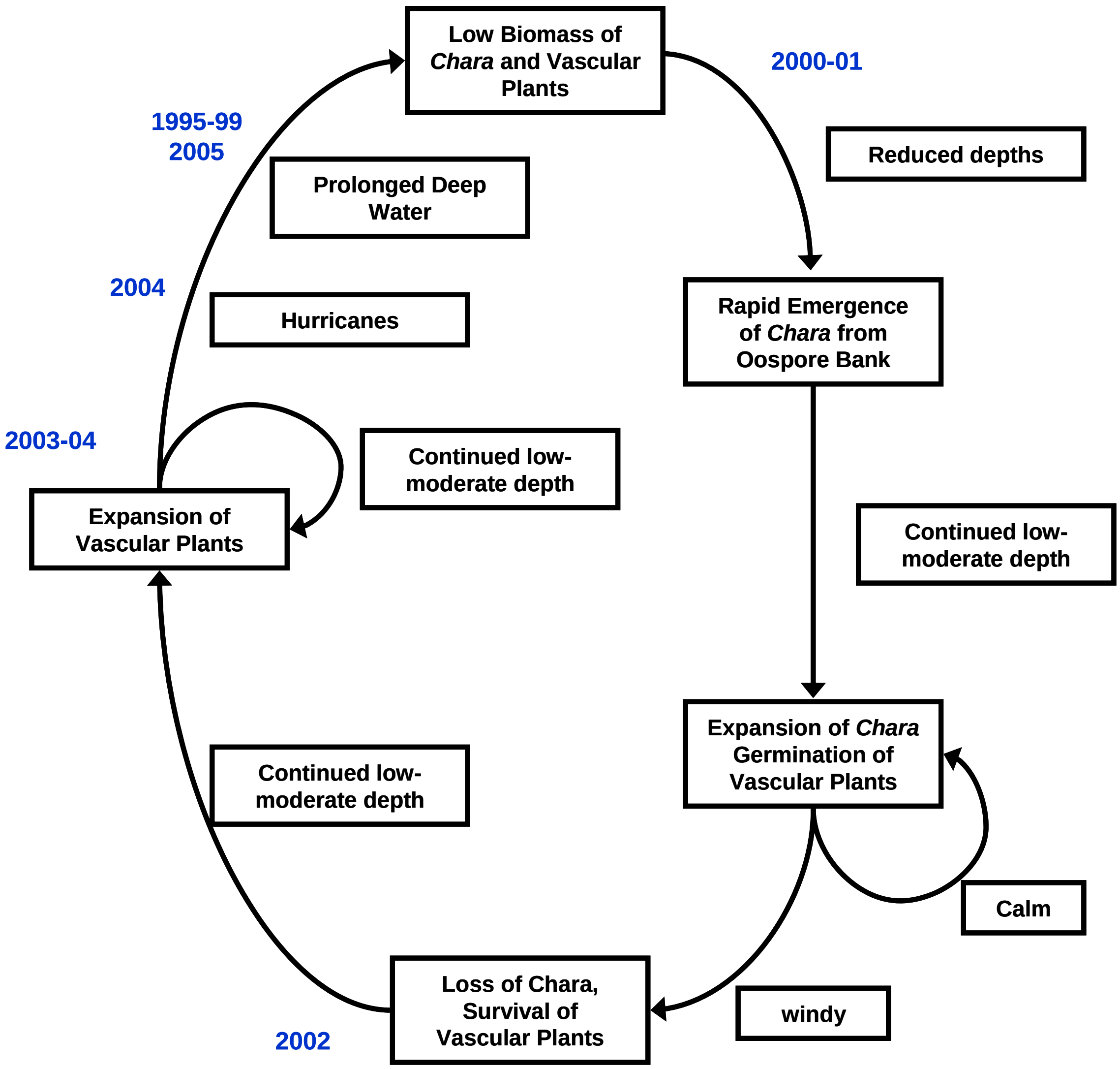


Figure 10-23. Conceptual model to explain occurrence of three states in Lake Okeechobee: (1) no submerged plants, (2) dominance by *Chara*, or (3) dominance by vascular submerged plants. Developed on the basis of information presented in Havens et al. (2004a).

Emergent Aquatic Vegetation

The western 25 percent (106,255 acres or 430 km^2) of Lake Okeechobee is a diverse littoral community that provides spawning and foraging habitat for fish, wading birds, migratory water fowl, and the federally endangered Everglade Snail Kite (*Rostrhamus sociabilis plumbeus*) (Aumen, 1995; Bennetts and Kitchens, 1997). The littoral zone has been extensively studied, with a primary focus on effects of hydroperiod and sediment type on emergent plants (Richardson et al., 1995), responses of periphyton and invertebrates to increased nutrient inputs (Havens et al., 1999; 2001b; 2004a), and temporal variations in vegetation structure (Richardson and Harris, 1995). In recent years, there has been more intensive focus on the interface between the littoral and nearshore zones because this area appears to be most dynamic in terms of changes in vegetation structure.

METHODS

GIS maps quantifying the areal coverage and describing the spatial distribution of emergent vegetation across the lake's 106,255 acre (430 km^2) marsh are developed every five to seven years by the SFWMD. This time interval was chosen to optimize costs, staff time, and the ability to detect changes. Photographic images of the area are recorded with 1:12,000 scale color infrared (CIR) aerial photography. Major vegetation classes are delineated from their unique CIR signatures using a transfer stereoscope, and vegetation distribution maps are developed in Arc Info© (ESRI, Redlands, CA). The process also included extensive ground-truthing. Two-hundred stratified random samples of plant communities were located and coordinates determined. These coordinates were visited in the field to estimate thematic and spatial accuracy. The most recently completed map (1996) had classification accuracy near 90 percent. A current map (2003) will be completed later this year.

In addition to this large-scale effort, the SFWMD develops maps every other year to assess the spatial extent and distribution of torpedograss (*Panicum repens*) because this exotic plant is the focus of an ongoing eradication program. Mapping is also performed every other year to quantify the spatial extent of the "bulrush zone," a band of emergent plants dominated by bulrush (*Scirpus californicus*) that generally defines the interface between the emergent marsh and the open pelagic zone. The dynamic emergent plant communities that occur immediately landward (west) of the bulrush zone also are mapped in this project.

The SFWMD also has an ongoing remote sensing project to determine whether accurate vegetation maps can be developed using hyperspectral and radar data. These methods may be most useful for programs that require vegetation classification at a rather coarse level, such as the mapping of yearly torpedograss distribution.

RESULTS AND DISCUSSION

The most recent littoral zone vegetation map (Hanlon and Brady, in review) indicates that there are 77,838 acres (315 km^2) of emergent plants (**Figure 10-24**). Cattail (*Typha spp.*) and mixed cattail with other emergent plants are the most abundant classes, covering more than 24,710 acres (100 km^2). Torpedograss is the second most abundant class (13,343, acres or 54 km^2), followed by spikerush, (*Eleocharis cellulosa*, 9,637 acres or 39 km^2), fragrant water lily (*Nymphaea odorata*, 8,154 acres or 33 km^2), and willow (*Salix caroliniana*, 4,942 or 20 km^2). These results are quite different from what was reported in a vegetation map developed in the early 1970s (Pesnell and Brown, 1977), when the littoral zone had less than 19,768 acres (80 km^2) of cattail located only along the western edge of that region, with dominant taxa in the interior regions of beakrush (*Rhynchospora baldwinii*), spikerush, mixed native grasses, and cord grass. Beakrush and cord grass are short hydroperiod plants that occurred in the higher elevation areas of the littoral zone where monocultures of torpedograss now occur. Much of the habitat formerly occupied by spikerush in the longer hydroperiod areas has now been taken over by cattail and water lily. These later changes are linked to higher water levels and/or transport of phosphorus into the interior littoral zone along boat trails (Havens, 1997; Hanlon and Brady, in review).

Mapping of bulrush and other shoreline emergent plants indicates that in the late 1990s, when water levels were high for several years and substantial wave energy reached the littoral edge, there were losses of emergent vegetation 984 ft (300 m) to 1,640 ft (500 m) wide and up to several km long along the western shore. Those areas became open water by 1999. The spatial extent of bulrush also was reduced, but not to the extent observed for other plants. During 2000–2002, the emergent plant community recovered in the area between the bulrush and littoral zones, when over 1,977 acres (8 km^2) of spikerush and mixed grasses developed in that area. This response may be partially responsible for the changes in population dynamics of largemouth bass described in the next section of this chapter.

Vegetation Management Activities

The major exotic and invasive species of plants in Lake Okeechobee marsh include Torpedograss, Cattail, Brazilian Pepper (*Schinus terebinthifolius*), Maleleuca (*Melaleuca quinquenervia*), Hydrilla (*Hydrilla verticillata*), Water Lettuce (*Pistia stratiotes*), and Water Hyacinth (*Eichhornia crassipes*). Some areas of the marsh have recently experienced dramatic vegetative changes due in part to management activities that were initiated by the SFWMD during the 2000 drought. Since 2000, more than 17,000 acres (69 km^2) of torpedograss and 4,700 acres (19 km^2) of cattail have been treated in Lake Okeechobee. Mature stands were burned (conditions permitting) and new growth was chemically treated. Native vegetation including spikerush and fragrant water lily has established in many of the torpedograss treatment sites and open water and submerged vegetation now dominate many of the cattail treatment sites. Large-scale changes in the littoral landscape will continue this year, following an additional 4,900 to 7,400 acres (20 to 30 km^2) of torpedograss treatment. Changes in the emergent marsh community will be monitored and quantified through the development of GIS-based vegetation maps.

Zooplankton Research

Zooplankton play an important role in the lake's ecosystem by functioning both as a regulator of phytoplankton population dynamics and as an energy link between fish and lower trophic levels. A long-term plankton monitoring project was initiated in 1994 and consists of collecting plankton samples at four open-water sites on a monthly basis to determine biomass and taxonomic composition of zooplankton, phytoplankton, bacteria, ciliates, and flagellates. Additional sites also are sampled to monitor the abundance of the exotic zooplankton species *Daphnia lumholtzi*. Because the availability of nutrients (phosphorus and nitrogen) and light can affect plankton growth and productivity, water from each of the four sites is assayed for phytoplankton growth and limitation status at different levels of phosphorus, nitrogen, and light over a 48-hour period in the laboratory. Bacterial growth rates at the four open-water sites are also estimated in the laboratory because zooplankton, ciliates, and flagellates feed on bacteria. This is another important pathway by which energy is transferred to higher levels in the food chain. Future research plans are to expand this monitoring project to include littoral or nearshore sites, particularly in submerged and emergent plant beds, and fish community structure to more comprehensively evaluate the food web in both ecological zones. This work is scheduled to begin early in the calendar year 2006.

Population Dynamics of Largemouth Bass and Black Crappie

The fish assemblage of Lake Okeechobee includes over 25 taxa that vary in relative biomass among the pelagic, littoral, and nearshore zones (Furse and Fox, 1994; Bull et al., 1995). Dominant species (based on their numeric density) include threadfin shad (*Dorosoma petenense*), black crappie (*Pomoxis nigromaculatus*), bluegill (*Lepomis macrochirus*), white catfish (*Ameiurus catus*), gizzard shad (*Dorosoma cepedianum*), redear (*L. microlophus*), and Florida gar (*Lepisosteus platyrhincus*). At this time, long-term sampling is performed by the Florida Fish and Wildlife Conservation Commission (FWC) for just two species of economic importance: largemouth bass (*Micropterus salmoides*) and black crappie. Largemouth bass are particularly important, with more than 500 permitted fishing tournaments occurring on the lake each year, adding more than $20 million to the local economy. This update focuses on changes in the population dynamics of largemouth bass and black crappie. Starting in 2006, RECOVER is expected to include systematic sampling of all species of fish in the lake so that updates in 2007 and beyond will include more comprehensive information.

METHODS

In October of each year, the FWC conducts annual sampling at 22 sites around Lake Okeechobee by electrofishing. The areas sampled for fish cover the entire spatial extent of the nearshore zone, plus the interior littoral zone area known as Moonshine Bay. Electrofishing gear consisted of a 5.5 m aluminum boat equipped with a 90 horsepower engine, 5,000 watt generator, and a VVP-15 coffelt electroshocker unit. The electroshocker is turned on at each of the 22 sites three times for 15 minutes, totaling 990 minutes of effort per year. All stunned largemouth bass are collected, measured to the nearest millimeter of total length, weighed to the nearest gram, and released live. Length structure is analyzed by apportioning length frequency distributions into 2-cm length groups (i.e., those measuring between 2 cm and 3.99 cm equaled the 2-cm length group). Length frequency plots and catch rates (CPUE; the number of fish caught per minute of fishing or fish minute^{-1}) are then generated for each year. Annual length frequency plots are examined for changes in distribution patterns while observed catch rates are used to evaluate changes in density.

Black crappie is sampled each January with a 10-m otter trawl. The period of record for this sampling event is 1973–2005. Results are tabulated and analyzed using methods similar to those used for largemouth bass.

RESULTS AND DISCUSSION

There was a dramatic change in both the density and population size structure of largemouth bass during this study (**Figure 10-25**), coinciding with the onset of the diverse community of SAV and emergent shoreline plants in 2002 (**Figure 10-22**). During the bass surveys conducted in 1999–2001, common features were low CPUE values, ranging from 0.11 to 0.18 fish minute^{-1}, and a near absence of juvenile fish, indicating failed recruitment. In sharp contrast, the CPUE in 2002 was 0.41 fish minute^{-1}, and there was strong recruitment as evidenced by large numbers of 10 to 22 cm fish in the population. This pattern continued in 2003 and 2004, when the CPUE was 0.48 and 0.4 fish minute^{-1}, respectively. The fish results indicate that the establishment of a structurally diverse aquatic plant community is essential for successful bass recruitment in this lake. While data on post-2004 hurricanes recruitment data of largemouth bass will not be available until October 2005, concern has been expressed that the serious decline in SAV caused by the storms may have serious negative impacts on recruitment this spring.

From 1976 through the mid-1980s there was a large-scale commercial harvest program of black crappie and other fish on the lake. The crappie population was so dense that the fish were stunted, rarely exceeding 180 mm. Due to the harvest program the population crashed in the late ’70s **(Figure 10-26).** In 1981 a drought resulted in high densities, a result of a greatly reduced population responding to expanding excellent environmental conditions. Because of the good conditions the strong year classes survived for a longer period, 7–9-year-old fish were common. However, by the mid-1980s growth rates were depressed due to the high densities and as the older fish died out, the population did as well (Miller, et al., 1990). In the current water year (2005) the high lake stages, increased turbidity (reduced clarity) of the lake waters, and destruction of SAV caused by the two hurricanes of September 2004 resulted in serious impacts to the adult Black Crappie population, with trawl results for January 2005 the lowest ever recorded during the period of record.

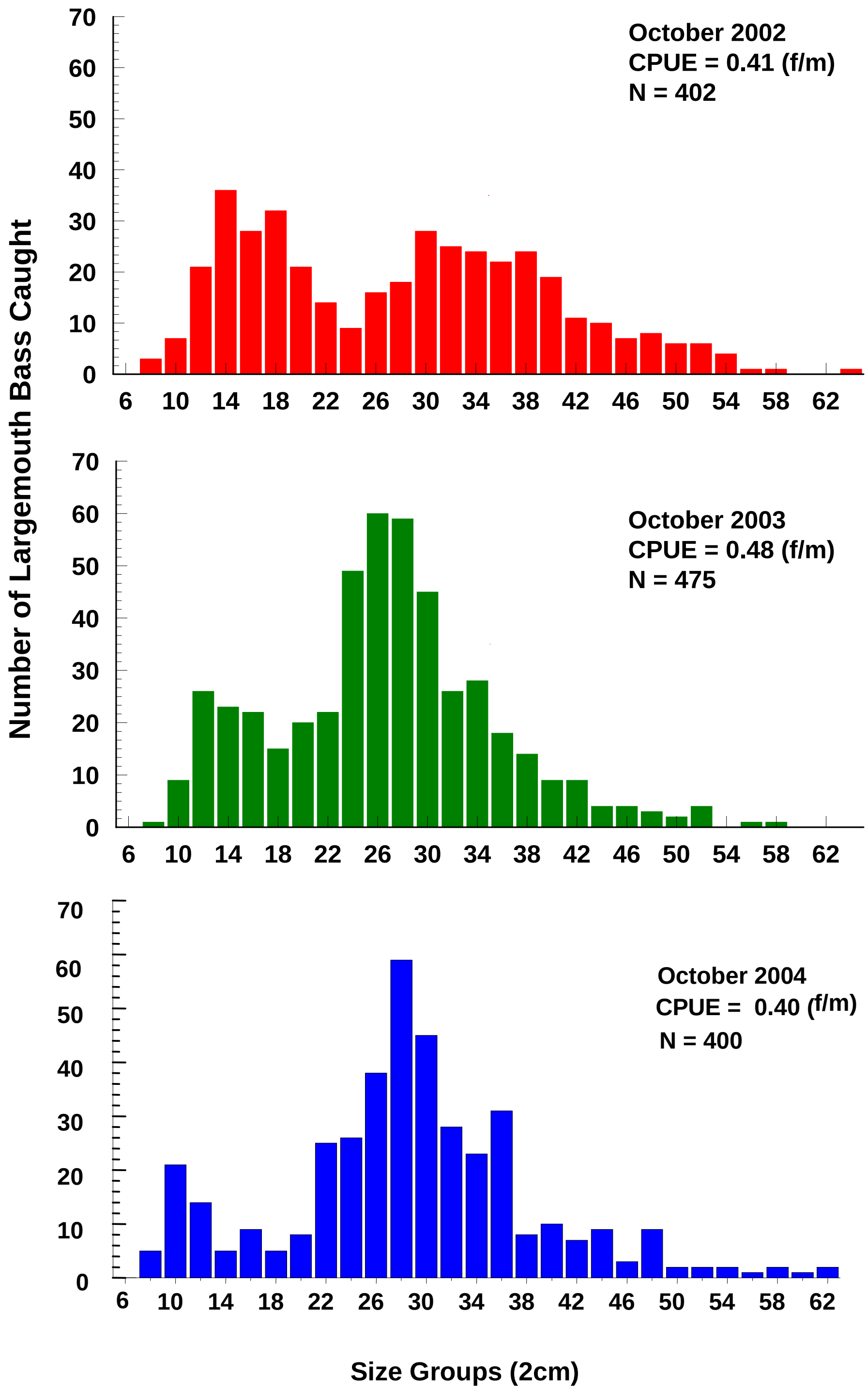


Figure 10-25. Size frequency distributions of largemouth bass caught in nearshore zone of Lake Okeechobee in October 2002–2004 by ectroshocking. Note the successful recruitment in 2002 and 2003, the years when ıigh density of diverse vascular SAV occurred in the lake. This figure is copied frorr Havens et al. (2005).

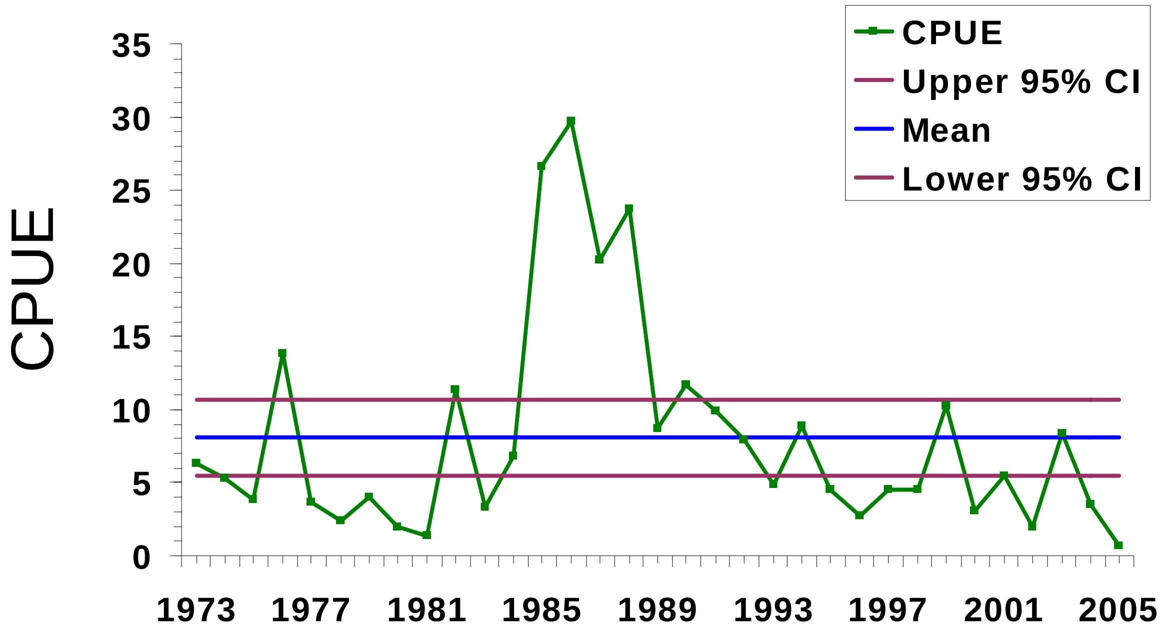


Figure 10-26. Catch rates of black crappie (*Pomoxis nigromaculatus*) collected with 10-meter otter trawl in January from Lake Okeechobee, (1973–2005).

WATERSHED STATUS

The Lake Okeechobee watershed spans from just south of Orlando to areas bordering the lake on the south, east, and west. This watershed, known as the LOPP area, includes 61 drainage basins with a drainage area of 5,500 square miles (14,245 km^2) (**Figure 10-27**). The continuous urban and agricultural development in South Florida is causing rapid land use changes in the watershed. Therefore, periodic land use updates are required to support planning and management activities. The most recent land use data were updated during WY2005 in association with several research projects conducted in the watershed (**Figure 10-28**). The primary updates made in the past year are in the Lake Istokpoga drainage basins where a lot of areas were listed as “Other” have been changed to citrus.

Nutrient levels in the runoff are directly related to land use and land management practices (Hiscock et al., 2003). The major land use in the northern Lake Okeechobee basins is improved pasture for beef cattle grazing. The major land use consists of sugarcane in the southern basins. Citrus groves represent a large land use in the eastern basins. The major land uses in the Upper Kissimmee Basin are improved pasture and urban. Citrus represents a large land use in the Lake Istokpoga Basin. Although dairy farms in the northern basin only cover 2 percent of the land use area, they can represent a considerable source of phosphorus to some tributaries and up to 8 percent of the total external loading to the lake.

Surface water discharges and phosphorus loading rates from the major tributary basins were calculated for WY2005 (**Table 10-3**). Data are based on continuous flow monitoring stations (**Figure 10-15**) and TP samples collected on a weekly basis. Among the major tributary basins, the largest surface water inflow comes from the Kissimmee River, followed by Fisheating Creek and Taylor Creek/Nubbin Slough. Total amounts of surface inflow to the lake vary considerably from year to year (**Figure 10-17**A). However, the relative magnitude of inflow from the various tributary basins generally follows the indicated pattern. The discharge from Lake Kissimmee contributed the largest input of TP loads to Lake Okeechobee, followed by Taylor Creek/Nubbin Slough, Fisheating Creek, C-41 and S-154 basins, and Lake Istokpoga. The TP load to the lake in WY2005 from all tributary basins and atmospheric deposition was 950 mt, with almost 82 percent of the loading occurring in the months of August through October as a result of hurricanes Charley, Frances, and Jeanne. The five-year rolling average TP load from WY2001–WY2005 was 580 mt, which is more than four times higher than the 140 mt y^{-1} TMDL for phosphorus.

Under contract with the SFWMD, JGH Engineering developed a graphical user interface including a detailed material budget of phosphorus imports and exports and phosphorus loads in the LOPP area (JGH Engineering et al., 2005). This budget considered all imports including fertilizer, feed, and animals, and exports including phosphorus loads in surface water runoff, milk, harvested crops, and animals for the entire Lake Okeechobee watershed. The phosphorus budget tool is used to display current conditions and to assess the changes of phosphorus imports, exports, and loads based on changes in land use practices. For the LOPP area, the estimated atmospheric input was 287 mt per year (data not shown). The land use based net import of phosphorus (import minus export) was 8,085 mt per year, of which about 23 percent of the net import was attributed to row crops, 21 percent to improved pasture, and 19 percent to sugarcane production (**Table 10-4**). Improved pastures contributed 33 percent of the runoff load, followed by medium-density residential (15 percent), and citrus grove (14.5 percent). For the northern Lake Okeechobee watershed, approximately 83 percent of the net phosphorus import was stored in the watershed and 17 percent was discharged to the lake (Hiscock et al., 2003). This relative storage is 7 percent lower than reported in 1991. Hiscock et al. (2003) concluded that this was a result of reduced assimilative capacity of soils and wetlands for phosphorus in the Lake Okeechobee watershed.

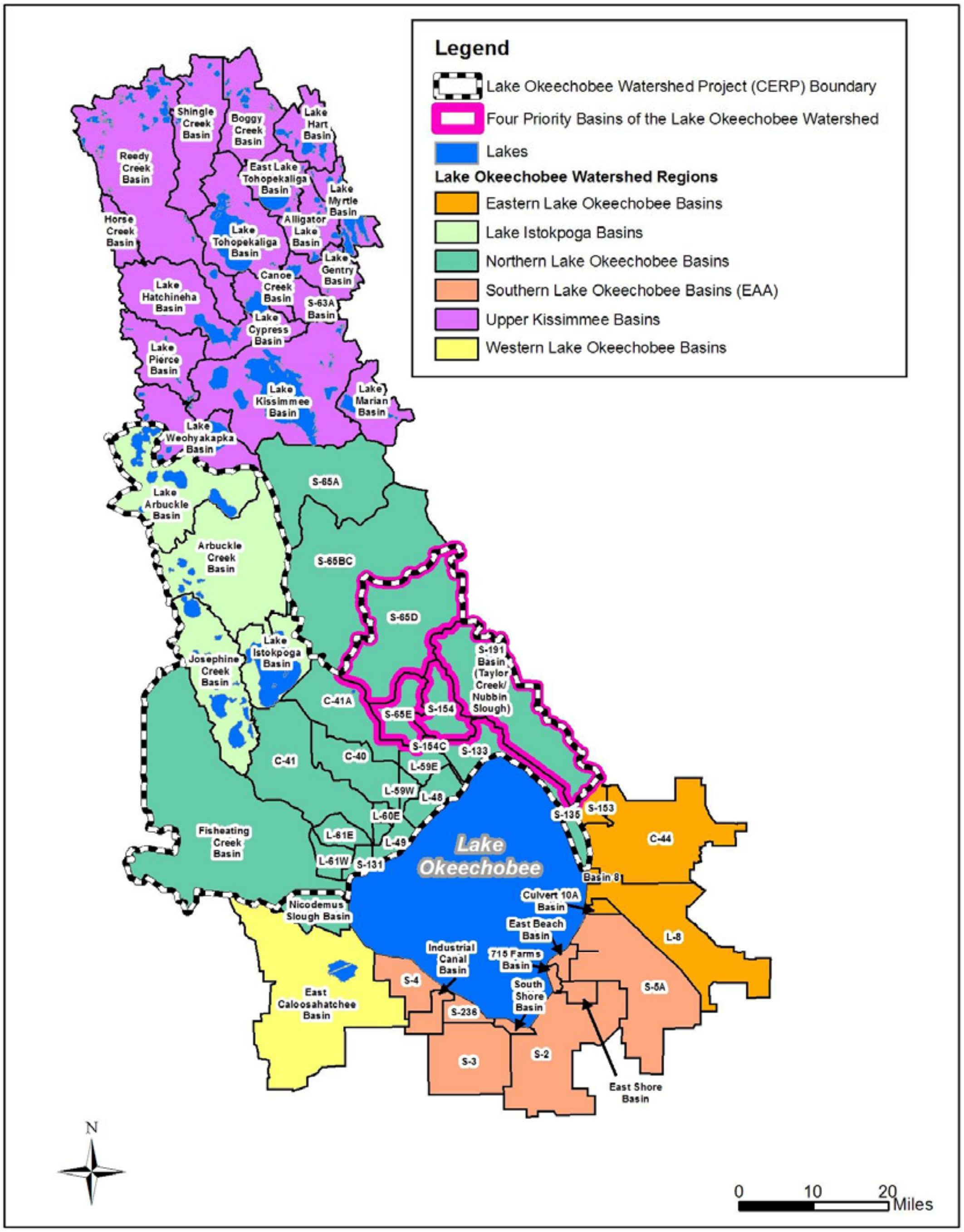


Figure 10-27. Lake Okeechobee watershed basins, regions, and priority basins.

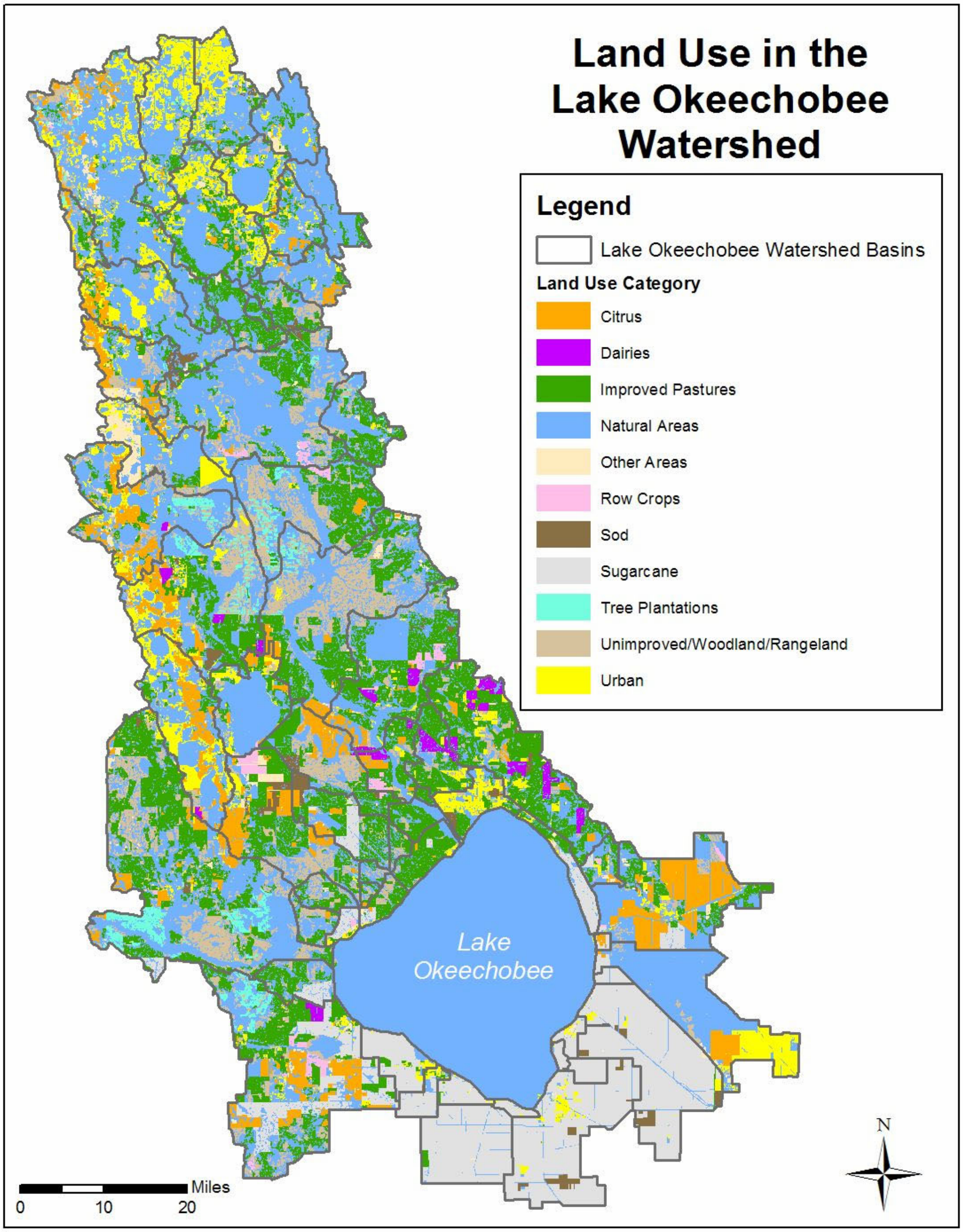


Figure 10-28. Land use map for the Lake Okeechobee watershed (2004–2005).

Table 10-3. Surface water inflows and TP concentrations and loading rates for the major tributary basins in the Lake Okeechobee watershed for WY2005.

Source	Discharge (acre-feet)	Discharge (Million cubic meters)	Area (sq. miles)	Average TP Concentration (ppb)	TP Load (mt)
715 Farms (Culv 12A)	187	0.2	4	88	0.02
C-40 Basin (S-72) - S68	40,496	50.0	87	651	32.54
C-41 Basin (S-71) - S68	130,401	160.9	176	450	72.38
S-84 Basin (C41A) - S68	64,709	79.8	180	280	22.31
S-308C (St. Lucie-C-44)	55,414	68.4	190	218	14.93
East Beach DD (Culv 10)	1,715	2.1	10	114	0.24
East Shore DD (Culv 12)	6,696	8.3	13	103	0.85
Fisheating Creek	258,784	319.2	462	352	112.41
Industrial Canal	13,791	17.0	23	161	2.74
L-48 Basin (S-127 total)	28,115	34.7	32	310	10.76
L-49 Basin (S-129 total)	17,041	21.0	19	102	2.13
L-59E	96,947	119.6	15	167	19.94
L-59W	25,421	31.4	15	518	16.24
L-60E	7,097	8.8	6	149	1.30
L-60W	5,612	6.9	6	251	1.73
L-61E	7,011	---	22	---	n/a
L-61W	10,669	---	22	---	n/a

Table 10-3. Continued.

Source	Discharge (acre-feet)	Discharge (Million cubic meters)	Area (sq. miles)	TP Concentration (ppb)	TP Load (mt)
Taylor Creek/Nubbin Slough (S-191)	167,363	206.4	188	720	148.56
S-131 Basin	12,468	15.4	11	167	2.57
S-133 Basin	39,730	49.0	40	427	20.91
S-135 Basin (S-135 total)	30,472	37.6	28	267	10.04
S-154 Basin	56,534	69.7	37	941	65.60
S-2	21,520	26.5	166	133	3.54
S-3	538	0.7	101	295	0.20
S-4	59,359	73.2	66	206	15.12
S65 A through E Basins	497,186	613.3	749	71	43.45
South FL Conservancy DD (S-236)	20,136	24.8	15	91	2.25
South Shore/South Bay DD (Culv 4A)	0	0.0	7	nc	0.00
Nicodemus Slough (Culv 5)	3,344	n/a	28	---	
Rainfall	---	---	---	---	35.00
S65 (Lake Kissimmee)	1,397,036	1723.3	---	138	238.67
Lake Istokpoga (S-68)	404,511	499.0	---	96	47.87
S5A Basin (S-352-WPB Canal)	0	0.0	---	---	0.00
East Caloosahatchee (S-77)	0	0.0	---	---	0.00
L-8 Basin (Culv 10A)	41,414	51.1	---	103	5.25
Totals	**3,521,718**	**---**	**---**	**219**	**950**

n/a – data not available
n/c – sample not collected due to lack of flow

Table 10-4. TP budget (in metric tons) by land use for the Lake Okeechobee watershed (atmospheric deposition is not included).

Land Use	Area (ha)	Imports	Exports	Net Import		Runoff P	
Rangeland	71,874	18.7	17.9	0.8	0.01%	1.4	0.12%
Improved pasture	289,045	2,035.0	362.3	1,672.7	20.69%	403.7	32.80%
Wetlands	248,761	0.0	0.0	0.0	0.00%	67.1	5.45%
Forested uplands	147,633	0.0	11.1	-11.1	-0.14%	2.1	0.17%
Dairy	11,435	727.5	223.9	503.6	6.23%	7.0	0.57%
Barren land	25,937	0.0	0.0	0.0	0.00%	23.1	1.88%
Other urban	30,150	815.1	0.0	815.1	10.08%	62.6	5.09%
Unimproved pasture	64,661	20.1	18.4	1.7	0.02%	26.6	2.16%
Row crop	9,186	2,020.6	176.1	1,844.5	22.81%	16.0	1.30%
Citrus	101,477	685.2	399.9	285.3	3.53%	178.7	14.52%
Water bodies	91,722	0.0	0.0	0.0	0.00%	23.2	1.89%
Golf course	4,804	310.0	0.0	310.0	3.83%	4.7	0.38%
Sod farm	13,283	342.8	835.6	-492.8	-6.10%	44.7	3.63%
Ornamentals	2,817	67.3	48.3	19.0	0.24%	12.0	0.98%
Commercial forestry	20,803	0.0	3.3	-3.3	-0.04%	0.2	0.01%
Sugarcane	161,808	3,811.8	2,249.6	1,562.2	19.32%	86.9	7.06%
Aquaculture	244	0.0	0.0	0.0	0.00%	0.5	0.04%
Poultry	46	10.8	2.3	8.5	0.10%	0.0	0.00%
Abandoned dairy	1,975	9.2	3.2	6.0	0.07%	29.3	2.38%
Residential-Mobile units	3,034	111.0	0.0	111.0	1.37%	0.2	0.02%
Residential-Low density	37,053	183.3	1.3	182.0	2.25%	2.5	0.20%
Residential - Medium density	32,430	670.6	10.1	660.5	8.17%	185.3	15.06%
Residential - high density	11,306	524.4	5.2	519.2	6.42%	35.0	2.84%
Field crops	10,704	476.9	398.3	78.6	0.97%	17.7	1.44%
Horse farms	799	15.5	0.0	11.7	0.15%	0.2	0.02%
Total	**1,392,987**	**12,856**	**4,767**	**8,085**	**100%**	**1,231**	**100%**

WATERSHED MANAGEMENT AND RESEARCH

WATERSHED MANAGEMENT

In an effort to reduce phosphorus loads to Lake Okeechobee, the 1987 Surface Water Improvement and Management Act (SWIM) [Section 373.451–459, Florida Statutes (F.S.)] set forth the requirement for a 40 percent reduction in phosphorus loading to Lake Okeechobee. In 1989, the SFWMD produced the Lake Okeechobee SWIM Plan, which identified Lake Okeechobee as a priority water body threatened by phosphorus pollution. The primary source of phosphorus loading to Lake Okeechobee was agricultural non-point source runoff from its northern basins, which upsets the balance of natural flora and fauna of the lake's ecosystems. In 2000, recognizing the existing programs were not sufficiently reducing phosphorus loads to the lake in meeting the SWIM target, the Lake Okeechobee Protection Act (Section 373.4595, F.S.) was passed by the legislature to establish a restoration and protection program of the lake. Based on the 10-year average from 1991–2000, phosphorus loading to the lake was 497 mt, which was 357 mt over the TMDL limit.

The Lake Okeechobee Protection Plan (SFWMD et al., 2004) defined the phosphorus load reduction goals achievable for each activity so that the phosphorus TMDL will be met by 2015. This plan also defined current and proposed phosphorus-reduction projects that require future funding, the lead agency responsible for implementing the activities and the anticipated phosphorus load reduction percentage after all activities are completed (**Table 10-5**). The percent load reduction was estimated based on the 10-year average from 1991–2000 (baseline period). The actual load reductions, as measured at the lake inflow structures, may be delayed due to phosphorus that has accumulated in soils and tributaries over time. Long-term assessment will continue through the life of the activities to quantify project performance.

Table 10-5. Ongoing and future phosphorus reduction activities in the Lake Okeechobee watershed, with lead agencies and estimated percent of total load reduction (to meet the TMDL goal of 140 mt).

Category	Estimated Percent TP Load Reduction	Lead Agency
TP Load Reduction Activities Underway		
Owner & Typical Cost Share BMPs	14%	Agriculture – FDACS Non-agriculture – FDEP
Other P Reduction Projects (P Source Control Grant Program, Public/Private Partnerships)	18%	SFWMD
Regional Public Works Projects (ECP, Kissimmee River Restoration, Critical Projects)	17%	SFWMD
TP Load Reduction Activities Requiring Future Funding (2004-2015)		
Typical Cost Share BMPs that Require Funding	11%	SFWMD
Other Regional Projects (Expansion of Nubbin Slough STA)	1%	SFWMD
Comprehensive Everglades Restoration Plan Lake Okeechobee Watershed Project (2003-2013)	39%	USACE and SFWMD

WATERSHED PHOSPHORUS CONTROL PROGRAMS

The Lake Okeechobee watershed phosphorus control program includes: (1) continued implementation of existing regulations and voluntary agricultural and non-agricultural BMPs, (2) development and implementation of improved BMPs, (3) improvement and restoration of hydrologic function of natural and managed systems, and (4) use of alternative technologies for nutrient reduction. In February 2001, the SFWMD, FDEP, and FDACS entered into an interagency agreement to address how to implement the programs and coordinate with existing regulatory programs [Lake Okeechobee Works of the District (LOWOD), Dairy Rule, and Everglades Forever Act (EFA) restoration programs]. Under the Lake Okeechobee Protection Act (LOPA) (Section 373.4595, F.S.), the FDACS is charged with implementing a voluntary BMP program (Rule 5M-3) on all agricultural lands within the Lake Okeechobee watershed. In general, farmers are eligible to receive between 75% and 87.5% cost share, either through FDACS or a combination of FDACS and NRCS funds. FDEP is responsible for developing non-agricultural non-point source BMPs. The implementation of phosphorus-reduction projects and large-scale regional projects, research and monitoring, and exotic plant control is the responsibility of the SFWMD.

FDACS Agricultural Programs

A considerable effort has been expended since 2002 on the implementation of agricultural BMPs and water-quality improvement projects to immediately reduce the discharge of phosphorus from the watersheds to the lake. The FDACS BMP program consisted of two phases. The first was implementation of interim BMPs based on assessments contained in existing cow/calf and citrus water-quality BMP manuals. The second involves development of more detailed conservation and nutrient management plans. Experience has shown that it is more efficient to proceed to the conservation and nutrient management planning stage; therefore, the interim assessments are no longer being performed.

The FDACS and the NRCS have executed an interagency Memorandum of Agreement (MOA) that commits the available resources within the two agencies to hasten delivery and implementation of nutrient and conservation management planning to agricultural landowners in the watershed. To accelerate the development of conservation plans in another effort, the FDACS has contracted with the University of Florida Institute of Food and Agricultural Sciences (UF/IFAS), in conjunction with NRCS, to provide training for third-party vendors who wish to participate in the development of nutrient management and/or conservation plans.

Since cow/calf production is the largest agricultural land use in the Lake Okeechobee watershed, it is anticipated that the implementation of BMPs identified in conservation plans will substantially improve water quality in the watershed. Conservation plans developed by NRCS have been completed on 80,089 acres (324 km^2). In a cooperative effort the FDACS and the NRCS have obtained a federal appropriation to date of $950,000 to expedite conservation planning in the Lake Okeechobee watershed. The funds have been used to identify and train technical service providers and conservation planners who are willing to work in the Lake Okeechobee watershed to develop conservation plans for cow/calf, citrus, row crop and other agricultural operations. The FDACS has contracted with Environmental Management Solutions (EMS) for services related to the expedited conservation planning effort. This creative endeavor has resulted in an additional 153,594 acres (622 km^2) of conservation plans in various stages of development.

The Agricultural Nutrient Management Assessments (AgNMAs) for all active dairies in the four priority basins (S-191, S-154, S-65D, and S-65E) (**Figure 10-27**) were completed in 2002, representing over 31,000 acres (125 km^2). An additional 6,700 acres (27 km^2) of former dairies also have completed nutrient management assessments. The two goals of the AgNMPs were whole-farm nutrient balance and an edge-of-farm phosphorus discharge concentration of 150 ppb. Each dairy shared common phosphorus sources, but each also had unique circumstances. The AgNMPs indicated that it would cost a total of $105 million to achieve both of these goals for all dairies in the watershed. The interagency team directed funds to be expended on the surface water management component aimed at lowering phosphorus at the edge-of-farm discharge point. Dairies are in the initial planning, engineering, and design phase of this process.

Collectively, the nutrient management assessment and conservation planning activities cover 271,383 acres (1,098 km^2) in the watershed. An additional 564,200 acres (2,283 km^2) of agriculture operations in the watershed also have agreed to participate either in the BMP process or in the development of a whole farm treatment project based on modeling. One of the challenges to implement this program is attrition of participation due to the pressure from development and purchases of land for other uses. Approximately 13,046 acres (53 km^2) of land that either had BMP plans or were in the process of having one written have backed out due to land sales in the past year alone.

The FDACS has adopted an administrative rule (5M-3) that adopts BMP manuals for citrus producers and cow/calf operations and AgNMAs for dairy operations, and discusses the process for implementing these BMPs in the four priority basins. The FDACS is in the process of adopting this rule watershed-wide to include all 61 basins. It is also developing a non-regulatory, incentive-based BMP implementation program for other agricultural activities including vegetables and row crops modeled after the Indian River Lagoon Citrus BMP Program. The BMP manuals are in the final stages of development. Through this rule, the implementation of a FDACS farm assessment, Notice of Intent to implement a BMP plan, or a NRCS plan will provide the landowner with a presumption of compliance with the state water-quality criteria. Landowners who choose not to participate in the FDACS BMP program will be required to monitor the quality of water leaving their properties through the LOWOD permitting program and to demonstrate compliance with existing and future phosphorus targets and requirements set forth in the SWIM plan or an established tributary TMDL.

FDEP Non-Agricultural Programs

A phased approach is used to reduce phosphorus loadings to Lake Okeechobee from non-agricultural areas in the Lake Okeechobee watershed. The largest contributors of phosphorus loading from non-agricultural areas to Lake Okeechobee are animal feed and fertilizer distributors, golf courses, and failing wastewater systems (septic tanks and package plants). Efforts since the inception of the LOPA include implementation of interim measures (BMPs), master planning for stormwater and wastewater, implementation of stormwater retrofits, the designing of larger urban stormwater projects, and public education.

The first phase was to implement interim measures. The interim BMPs include those identified in the Florida Land Development Manual, UF/IFAS lawn fertilization rates, and UF/IFAS turfgrass BMPs. These nonstructural BMPs primarily target homeowners and businesses. UF/IFAS extension agents are working with homeowners, as well as lawn maintenance companies, on better lawn management. The implementation of these BMPs follows a non-regulatory incentive-based approach.

The next phase is to develop more detailed plans for addressing phosphorus loading to Lake Okeechobee from stormwater and wastewater sources within the urbanized areas in the watershed. There are currently no central urbanized areas within the four priority basins, so the focus of the non-agricultural program has been outside the four priority basins in those urban areas that border Lake Okeechobee. Stormwater master plans have been developed for two of the urban areas surrounding Lake Okeechobee — the city of Okeechobee/Okeechobee County and the city of Moore Haven/Glades County. The Okeechobee Service Center of SFWMD has worked cooperatively with Okeechobee County to add more details to the plans. Stormwater master plans are being developed for the remaining urban areas within the Lake Okeechobee watershed, and will be essential for addressing the stormwater issues in these areas. Because a majority of the urban areas was developed prior to the adoption of state stormwater regulations, the existing infrastructure is typically inadequate to properly deal with storm water. Stormwater retrofits, such as detention/retention facilities and swales, are needed to improve the water quality of the urban stormwater runoff. The FDEP and the SFWMD are working together to fund the installation of two additional baffle boxes, which trap sediments and trash, by the end of 2005.

In 2004, wastewater master plans were completed for these areas to address the need to upgrade failing septic tanks and package wastewater treatment plants by connecting them to the central sewer system. The plans address the need to expand the capacity of the central wastewater treatment plant (the Okeechobee Utility Authority) to accept the additional wastewater from those areas that are currently using failing septic tanks and package wastewater treatment plants, as well as to address increasing growth.

Public education is an essential component for reducing phosphorus entering storm water in the urbanized areas. The UF/IFAS through the Florida Yards and Neighborhoods Program, provides weekly newspaper articles in the Okeechobee newspapers that address proper lawn maintenance practices. Additionally, a brochure has been developed in conjunction with the fertilizer industry to promote the use of low- or no-phosphorus fertilizers and the use of appropriate BMPs when utilizing such chemicals. This brochure is available at retail stores where fertilizers are sold. UF/IFAS monitors the number of people requesting assistance information regarding this program.

SFWMD Phosphorus Control Programs

A considerable effort has been expended in WY2005 on BMPs in the LOPP area to reduce phosphorus discharges to the lake. The SFWMD, in coordination with the FDACS and FDEP, has developed and implemented 25 phosphorus-reduction projects and has more than 40 projects under construction or in the planning/design/feasibility study phase. These projects were implemented under programs such as the Phosphorus Source Control Grants, Isolated Wetland Restoration, Dairy Best Available Technologies, Public/Private Partnerships, Former Dairy Remediation, and Structure Retrofit and Tributary Dredging (**Table 10-6**). Load reduction from these phosphorus-reduction projects is estimated at 18 percent of the load reductions necessary to meet the lake's TMDL. All of these projects have some level of performance monitoring to facilitate the evaluation and potential future use of these types of technologies.

PHOSPHORUS SOURCE CONTROL GRANTS

The intent of the Lake Okeechobee Phosphorus Source Control Grant (PSCG) program is to fund the early implementation of projects that have the potential for reducing phosphorus exports to Lake Okeechobee from the watershed. Currently the program consists of 13 projects (**Table 10-6**) with a total cost of $7.5 million. The FDEP provided funds from the 2003–2004 state general revenue designated for TMDL implementation projects to add the last grant project. An interagency team evaluated the projects and ranked them using established evaluation criteria.

Table 10-6. TP load reduction projects that have been implemented/planned under Watershed Phosphorus Control Programs.

General Project Category	Specific Project Name	Project Description	Status
Phosphorus Source Control Grant Program	Tampa Farms Composting Facility	Composting chicken manure exported from watershed	Ongoing
	Milking "R" Chemical Treatment	Optimizing dairy stormwater treatment system	Ongoing
	QED McArthur Farms 3	Dairy farm wastewater treatment system	Ongoing
	Davie-Dairy Cooling Pond	Concrete cooling ponds	Ongoing
	Candler Ranch	Runoff treatment - iron humate filter	Non-operational
	Lazy S Ranch	Runoff treatment - iron humate filter	Ongoing
	Evans Properties Bassett Grove	Citrus grove stormwater system retrofit	Complete
	Lofton Ranch	Wetland restoration	Ongoing
	Smith Okeechobee Farms	Wetland restoration and stormwater retention	Ongoing
	Okeechobee Utility Authority Ousley Estates	Gravity sewer system replacing septic and package plants	Complete
	Hydromentia	Aquatic Plant Based Water Treatment System Pilot Project – water hyacinths and algal turf scrubber	Complete
	AquaFlorida	Conceptual design of a regional stormwater treatment area	Complete
	Solid Waste Authority	Tri-county biosolids pelletization	Ongoing
Dairy Best Available Technology	Dry Lake 1	Edge of farm stormwater retention/detention with chemical treatment using alum.	Construction was completed and monitoring is underway
	Butler Oaks		
	Davie Dairy 1 and 2		
	Milking R Dairy		Construction will be completed by August 2005

Table 10-6. Continued.

General Project Category	Specific Project Name	Project Description	Status
Silica Soil Amendment Evaluation Project	Larson Dairy 6	Soil amendment application to bind residual phosphorus	Complete
	Milking R		
Isolated Wetland Restoration Program	Kirton Ranch	Wetland enhancement and restoration to reduce phosphorus loads and retain storm water flows by increasing regional water storage in the Lake Okeechobee watershed	Ongoing
	Lemkin Creek		
	Eckerd Youth Center		
	Pool E Feasibility Study		
Former Dairy Remediation	Lamb Island Dairy Remediation	Remediation of properties that were previously dairy utilizing stormwater detention, wetland treatment, lagoon remediation, and soil amendments	Ongoing
	Lamb Island Dairy Tributary Stormwater Treatment Project		
	Five former dairy sites		
Regional Public/Private Partnership	Davie Dairy 1 and 2	Chemical treatment of 800 acres of offsite runoff	Ongoing
	GreenCycle and QED	Dairy waste separation and treatment facilities and an organic fertilizer plant utilizing dairy and chicken manure	Terminated
Other Regional Projects	Lemkin Creek Urban STA	Urban STA for the city of Okeechobee	Ongoing
	Tributary Dredging and Structure Retrofits	Sediment removal and modification of water control structures for water quality improvement	Complete
	L-63 Culverts Replacement	Structure retrofits for the replacement of existing culverts and stop logs with precast bridges and weirs across the creek sections	90% complete
	Flow Diversion to Nubbin Slough STA	To obtain additional flow to be treated by the Nubbin Slough STA	To be awarded by the city of Okeechobee
	Nubbin Slough STA Expansion	Increasing phosphorus treatment capacity by utilizing District-owned property	Ongoing

The funded projects range in size and complexity, and grant recipients consist of landowners, public facilities, and private corporations.

All PSCG projects had a target implementation date of September 30, 2004 with an operational life of 10 years or more. As of June 2005, four have been completed, seven projects are operational and being monitored, one is constructed but not yet operational (Candler Ranch, iron humate filter) and one (Solid Waste Authority, biosolids pelletization) is under construction. Of the 13 PSCG projects, 11 are agricultural and include isolated wetland restoration, stormwater retention areas, chemical treatment of runoff, concrete cooling ponds for dairy cows, and composting of chicken manure. There is one urban PSCG project: replacement of septic systems and package wastewater treatment systems with a gravity sewer system in Okeechobee, which was completed during WY2005.

DAIRY BEST AVAILABLE TECHNOLOGIES

In October 2000, the District initiated the Dairy Best Available Technologies Project to identify, select, and implement Best Available Technologies (BATs) to significantly reduce TP loading from dairy operations in the Lake Okeechobee watershed. After a thorough evaluation of alternatives by an interagency project team, edge-of-farm stormwater treatment was selected for implementation on three dairy properties in the Lake Okeechobee watershed (**Table 10-6**). These projects consist of capturing stormwater runoff (especially from all of the high-nutrient pasture areas); reusing the runoff onsite in current operations if possible; and if offsite discharge is necessary, chemically treating the storm water prior to its release. The three Dairy BATs projects are fully constructed, and performance monitoring was initiated in May 2004. TP load monitoring is a component of the project so that performance can be accurately determined. Project performance is being evaluated at various TP discharge concentration goals ranging from 150 ppb to 40 ppb. Annual TP load reductions could range from 80–90 percent. The FDEP provided funds from the 2002–2003 state general revenue funds designated for TMDL implementation projects to be used for the design and implementation of a fourth BAT site, the Milking R Dairy. The fourth site is currently under construction with an estimated completion date of December 2005.

ISOLATED WETLAND RESTORATION

The Lake Okeechobee Isolated Wetland Restoration Program (LOIWRP) is designed to enhance and restore wetlands, reduce phosphorus loads, and retain stormwater flows by increasing regional water storage in the Lake Okeechobee watershed. Historically, isolated wetlands covered a considerable percentage of land area in the four priority basins, capturing stormwater runoff and helping to retain phosphorus in the watershed. However, many of these wetlands have been drained to increase the amount of land in agricultural production, allowing more phosphorus to reach Lake Okeechobee.

As a cost-share program, the LOIWRP pays for all wetland restoration costs including land survey, design, permits, construction, initial exotic and nuisance plant removal, fencing and monitoring; plus the value of the easement. The landowner will be responsible for paying property taxes and for the operation and maintenance of the restored area. Landowners have the choice of entering into a 30-year or perpetual easement agreement for the portion of their property that is enrolled in the program. The District is administering the LOIWRP with the cooperation of a multiagency team that includes the FDACS, FDEP, NRCS, U.S. Fish and Wildlife Service (USFWS), and UF/IFAS. The program currently has a total of four projects: (1) Kirton Ranch was completed in March 2004, (2) Lemkin Creek is state-owned property in the design phase, (3) Eckerd Youth Center is state-owned property in planning phase, and (4) District-owned land in Pool E is in the feasibility study phase (**Table 10-6**). The instrumentation at Kirton Ranch site was damaged during the September 2004 hurricane season (**Figure 10-29**). Repairs were completed in March 2005 (**Figure 10-30**).

Figure 10-29. Kirton Ranch Project control structures damaged after hurricanes Frances and Jeanne in September 2004 (photo by Jace Tunnell, SFWMD).

Figure 10-30. Kirton Ranch Project reconstruction of water control structures after hurricanes Frances and Jeanne in March 2005 (photo by Jace Tunnell, SFWMD).

There are currently about 44,902 acres (182 km^2) of restorable wetlands in the four priority basins. The LOIWRP estimates that approximately 1,826 acres (7 km^2) of wetlands will be restored through this program with a drainage/treatment area of 14,100 acres (57 km^2) if all four projects are implemented. The phosphorus load reduction for the one completed project, Kirton Ranch, which restored 410 acres (1.7 km^2) of wetlands, is estimated to be 1.2 mt yr^{-1} (a 71 percent reduction).

Several other wetland restoration or enhancement programs outside the LOIWRP are available for landowner participation. The University of Florida staff is leading an interagency team that has developed a Wetland Enhancement Program which assists landowners in selecting a wetland program that best fits the landowner's operations. The program is funded through the U.S. Department of Agriculture's Cooperative State Research, Education, and Extension Service's Competitive Grants in the National Integrated Water Quality Program, and puts together a comprehensive list of all programs available for wetland restoration in the Lake Okeechobee watershed. Landowners will be more fully educated on their options, and therefore participation in the various programs should increase, resulting in more restored wetlands and improved water quality.

FORMER DAIRY REMEDIATION

The Lamb Island Dairy Remediation Project has been constructed and water samples are being collected quarterly, with the final sampling event scheduled for mid-August 2005 (**Table 10-6**). Minor site improvements are being made, and as-built construction plans will be prepared prior to project close-out.

Five former dairy remediation projects are in various stages of implementation for the privately owned former dairies that are now cow/calf operations. The currently planned remediation practices include retaining runoff from old high-intensity areas (HIAs), rehydrating onsite wetlands, amending high-phosphorus soils, and reducing the flow of storm water offsite. Designs are complete on three farms and construction is scheduled for fall 2005.

As a result of inaccessibility due to the 2004 hurricanes, and one property being sold, designs on the remaining two farms will not be complete until the latter part of 2005, with construction scheduled for early 2006. Following construction completion, water-quality monitoring for phosphorus concentration reductions will continue for a one-year period during flow events.

REGIONAL PROJECTS/PUBLIC-PRIVATE PARTNERSHIPS

There were initially two projects under the Public/Private Partnership Program: Green-Cycle/QED and Davie Dairy. Davie Dairy is a participant in the District's Dairy BATs project (see the *Dairy Best Available Technologies* section of this chapter) and has completed construction of an edge-of-farm detention area with chemical treatment of farm runoff under that program (**Table 10-6**). Through the Public/Private Partnership Program, the dairy treats an additional 800 acres of offsite runoff through their treatment system, which provides 0.45 mt of phosphorus reduction on an annual basis. Private contributions were estimated at 24 percent of the total project cost. The Green-Cycle/QED project was canceled due to nonperformance on the part of Green-Cycle. The District is exploring other options to address the issue of residuals in the watershed.

OTHER REGIONAL PROJECTS

Through the coordination effort by FDEP, Okeechobee County, and the District, Lemkin Creek urban STA project is designed to treat urban stormwater runoff from southwest Okeechobee County and reduce phosphorus loading to the lake (**Table 10-6**). Phase I of the project includes water storage and wetland rehydration. Phase II consists of land acquisition for approximately 330 acres (1.3 km^2) of agricultural lands. It is expected that approximately 50 percent of the urban runoff from the city of Okeechobee would be captured and treated by the STA.

The L-63 culvert replacement project is designed to retain water at upstream creeks as a part of structure retrofit project. This project consists of the replacement of existing culverts and stop logs with precast bridges and weirs across the canal at the outflow of Henry Creek, Nubbin Slough, and Mosquito Creek. A sediment trap is placed just upstream of the weirs, and a vegetation barrier is located at the upstream side of the structure. The sediment trap is expected to trap phosphorus-laden sediments, and the vegetation barrier is used for blocking surface aquatic vegetation prior to discharging to the lake. Mosquito Creek includes an additional component – an Obermeyer gate – for retaining the first flush of storm water, which carries an increased amount of sediments, at the beginning of the wet season. To date, the project is about 90 percent complete.

The flow diversion to Nubbin Slough STA project consists of two components: (1) to restore a portion of western Nubbin Slough Basin historical runoff currently delivered to Mosquito Creek by diversion to the Nubbin Slough, and (2) to replace undersized and/or damaged culverts installed along the Nubbin Slough east tributary. This project is managed by the county of Okeechobee through a cooperative agreement with the District. Authorization for design and construction of this project will occur in the summer of 2005.

Another regional project is the expansion of the Nubbin Slough STA. Runoff from Taylor Creek Basin will be routed into an additional 1,200 acres (4.9 km^2) surrounding the critical STA footprint. The expansion project is currently in the design phase.

REGULATORY

Regulatory programs play an important role in the Lake Okeechobee restoration effort. Several programs are in place to provide assurances that the regulated facilities will meet water quality standards in waters of the state including: (1) Dairy Rule/National Pollutant Discharge Elimination System Permitting; (2) Domestic Wastewater Regulations; (3) Municipal Separate Storm Sewer System Regulations; (4) Works of the District Permitting; and (5) Evaluation of Land Use Changes.

WORKS OF THE DISTRICT PERMITTING

The LOWOD permitting program [Chapter 40E-61, Florida Administrative Code, (F.A.C.)] was a stand-alone program designed in 1989 to identify high phosphorus source areas and bring them into compliance with established phosphorus concentration standards through corrective actions. The primary function of the program was to permit and monitor parcels in 14 of the 31 "controllable" tributary basins of Lake Okeechobee. These 14 basins exceeded the SWIM TP discharge concentration performance standard of 180 ppb to the lake at the time that the SWIM legislation was passed in 1987. This TP concentration limitation was established in the District's Technical Publication 81-2 (SFWMD, 1981).

The LOPA and TMDL statutes impose many new responsibilities on the District that were not contemplated in 1989, when the LOWOD program was created. As part of these new responsibilities, the District is currently required to achieve phosphorus levels consistent with the new Lake Okeechobee TMDL at all of its facilities discharging into the lake by 2015. As a result, the LOWOD (Chapter 40E-61, F.A.C.) is under review and amendments are presently being recommended to better support the mandate of the LOPA. These amendments will shift the program focus more toward water-quality monitoring and assessment in lieu of a standard regulatory role in the watershed, although regulatory authority such as Environmental Resource

Permitting (ERP) can also be exercised, if needed. In addition, four other amendments are being considered: (1) include all 61 basins identified in the LOPP and covered under the LOPA, (2) define phosphorus concentration targets within the watershed as those consistent with the basin inflow targets listed in the current SWIM plan update (SFWMD, 2003b) or an established tributary TMDL, (3) address land use changes, and (4) recognize the role of incentive-based BMP programs being implemented throughout the watershed.

The revised LOWOD program will include the following activities to support the LOPA mandate: (1) monitor and assess water-quality and phosphorus source areas throughout the entire Lake Okeechobee Watershed Project area, (2) prioritize high phosphorus source areas throughout the entire 61 basins within the Lake Okeechobee watershed to direct appropriate resources, (3) verify changes in land use that will not result in increased phosphorus loads to Lake Okeechobee through the evaluation of pre- and post-land use scenarios; (4) evaluate the effectiveness of BMPs on reducing phosphorus concentrations at the sub-basin level and phosphorus loads to Lake Okeechobee at the sub-basin and basin level, and (5) permit parcels not covered under an incentive-based BMP program.

Six public meetings have been held to discuss the amendments to the LOWOD Rule, Chapter 40E-61, F.A.C. Comments from these public meetings have been reviewed and included when appropriate in the first draft of the rule amendments. The amended LOWOD Rule is on schedule to be completed and approved in 2006.

DAIRY RULE/NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM PERMITTING

The FDEP regulates the dairy farms and other confined animal operations located in the Lake Okeechobee watershed under State Law, Chapter 62-670.500, F.A.C. (Dairy Rule). The purpose of the rule is to control pollution of waters of the state due to the discharge of wastewater and runoff from dairies and other confined animal operations in the Lake Okeechobee watershed to surface and groundwater. The system of practices specified in Chapter 62-670.500(5) through (8), F.A.C., for the collection and recycling of wastewater by proper land disposal, together with the associated management practices, is established for the purpose of determining compliance with water quality standards. Implementation of these practices will be presumed to provide reasonable assurance that the facility will meet water quality standards in waters of the state.

Additionally, the U.S. Environmental Protection Agency (USEPA) reinterpreted its federal rules regarding National Pollution Discharge Elimination System (NPDES) permitting of Concentrated Animal Feeding Operations (CAFOs). The state was required to implement these federal rules by December 2004. Based on USEPA rules, all of the dairies and some of the other CAFOs (horses, hogs, and chickens) located within the Lake Okeechobee watershed must obtain NPDES permits. The permitting requirements include the development and implementation of a nutrient management plan, record keeping, transfer of waste to third parties, and annual reporting. As current state permits expire, the FDEP will be issuing new permits that meet the requirements of both the state and the NPDES.

DOMESTIC WASTEWATER REGULATIONS

Generally, the FDEP requires that entities who intend to collect/transmit, treat, dispose of, and/or reuse domestic wastewater obtain a state and/or federal NPDES wastewater permit. A domestic wastewater permit specifies the construction and operating requirements for the wastewater treatment plant and the associated reuse or disposal systems (effluent, reclaimed water, and residuals). The USEPA has delegated the authority to issue NPDES permits for domestic wastewater facilities not owned by the federal government to the FDEP. Currently, of the 251 domestic wastewater facilities within the Lake Okeechobee watershed, only seven are classified as NPDES facilities due to surface water discharges.

The discharge of wastewater to surface waters cannot cause or contribute to water-quality problems and must be in compliance with any applicable TMDLs for that associated water body. Additional information can be found on the FDEP's web site at www.dep.state.fl.us/water/wastewater/index.htm.

Another component of the domestic wastewater stream, which is regulated under the LOPA, is the management of residuals (bio-solids) from a wastewater treatment plant. Section 373.4595(3)(6)(a), F.S., requires all entities disposing of domestic wastewater residuals within the Lake Okeechobee watershed and the remaining areas of Okeechobee, Glades, and Hendry counties to apply the material at agronomic rates based on phosphorus. This requirement has reduced the quantity of material that historically had been land applied in the watershed. Typically, less material can be applied to a site when it is applied at agronomic rates based on phosphorus as compared to nitrogen. As a result of this, several land application sites have chosen to discontinue land applying bio-solids. Currently, there are four sites north of Lake Okeechobee and 15 sites south of the lake that have been approved to receive residuals. The application of liquid or solid material pumped from septic tanks and similar domestic sewage treatment systems, also referred to as septage, also is subject to the same requirements, according to Section 373.4595(3)(7), F.S. The Florida Department of Health permits the application of septage, and is responsible for ensuring that the application at these sites is according to phosphorus-based agronomic rates. Currently, there are two sites north of the lake that are approved to receive septage.

MUNICIPAL SEPARATE STORM SEWER SYSTEM REGULATIONS

NPDES permits are required for many Municipal Separate Storm Sewer Systems (MS4s), which are publicly owned conveyances designed for the discharge of storm water to surface waters of the state. An NPDES permit is required to protect water quality of surface waters currently receiving discharges from MS4s. As part of a permit, operators of a regulated MS4 must develop a stormwater management program that includes public education and outreach, public participation/involvement, illicit discharge detection and elimination, construction-site runoff control, post-construction runoff control, pollution prevention/good housekeeping, and regular reporting. Regulated MS4s are brought under regulation through three mechanisms: automatic designation based on population size, designation by FDEP, and public petition for designation by FDEP. One designation criterion for regulation will include any MS4 that discharges to a water body with a designated TMDL. Additional information is available on the FDEP's web site at www.dep.state.fl.us/water/stormwater/npdes. These designation criteria will require all urban areas discharging into Lake Okeechobee to be regulated under the NPDES program. At this time, the date by which these urban areas must be covered under permit has not yet been identified. However, consultants have already worked with the city of Okeechobee and Okeechobee County to complete an NPDES permit application.

EVALUATION OF LAND USE CHANGES

The LOPA requires that "Prior to authorizing a discharge into works of the District, the District shall require responsible parties to demonstrate that proposed changes in land use will not result in increased phosphorus loading over that of existing land uses." To meet this requirement, the District developed a two-tiered approach to help landowners assess the impact of land use changes on phosphorus loads leaving a land parcel. The first-tier approach is the computation of net phosphorus imports from phosphorus budgets for both the current and proposed land uses. If the net import for a proposed land use is less than or equal to the net import for an existing land use without increasing annual runoff volumes, the no increase in phosphorus load requirement is considered to have been met. The methodology is easy to use and can be implemented in a short period of time. If the first-tier approach does not meet the phosphorus load requirements, the second-tier approach requires the use of a computer model to simulate phosphorus loads. Again, if the simulated load for a proposed land use is less than or equal to the simulated load for an existing land use, the LOPA phosphorus requirement is considered to be met. This approach was developed to estimate phosphorus loads using a more rigorous approach than computing net phosphorus imports.

LAKE OKEECHOBEE CONSTRUCTION PROJECT

The Lake Okeechobee Construction Project is being implemented in two phases. In Phase I, projects have been constructed in the four priority basins, including two pilot Stormwater Treatment Areas (STAs), the construction of a stormwater detention pond as part of the Lake Okeechobee Critical Projects (a joint program between the SFWMD and USACE), a sediment removal pilot project, and design work on a large-scale STA in the S-191 basin. Phase II is known as the Lake Okeechobee Watershed Project (LOWP) of CERP that accounts for 39 percent of phosphorus load reduction needed to meet the TMDL target of 140 mt yr^{-1}.

Phase I Lake Okeechobee Construction Project

Phase I of the Lake Okeechobee Construction Project is intended to bring immediate phosphorus load reductions to Lake Okeechobee, consistent with the recommendations of the South Florida Ecosystem Restoration Working Group's Lake Okeechobee Action Plan (Harvey and Havens, 1999). The current status and performance of the projects that comprise Phase I are described below.

LAKE OKEECHOBEE WATER RETENTION/PHOSPHORUS REMOVAL CRITICAL PROJECT

Plans and specifications were completed for the Taylor Creek (Grassy Island Ranch) STA in December 2002, and for the Nubbin Slough (New Palm/Newcomer Dairy) STA in June 2003. Construction contracts have been awarded for both STAs, and a combined groundbreaking ceremony was held on June 30, 2004. Construction was completed in early fall of 2005 for the Taylor Creek STA. Construction is scheduled for completion in January 2006 for the Nubbin Slough STA.

The reduction of phosphorus loads to Lake Okeechobee is estimated as 2.8 mt of phosphorus per year for the Taylor Creek STA and 6.5 mt of phosphorus per year for the Nubbin Slough STA. These estimates are based on simulations using the steady-state STA model, using lower inflow concentrations after BMPs are implemented, and accounting for assimilation in tributaries.

LAKE OKEECHOBEE TRIBUTARY SEDIMENT REMOVAL PILOT PROJECT

The Tributary Sediment Removal Pilot Project was completed in June 2004 and no significant removal of particulate phosphorus was observed with the instrumentation of two sediment removal units: a Continuous Deflective Separation (CDS) unit and a Tributary Sediment Trap (TST). It was concluded that these technologies for sediment removal of particulate phosphorus in tributaries discharging to Lake Okeechobee are not feasible nutrient-reduction alternatives. The use of these technologies is more suited to an urban environment where particulate sizes would likely be larger. Recently, the SFWMD entered a cooperative agreement with the city of Okeechobee to install these two sediment removal units in urban areas.

Installation of these two technologies will not only support the SFWMD's efforts to support the LOPP, but also enhance the city of Okeechobee's Storm Water Master Plan.

Phase II Lake Okeechobee Construction Project

The objectives of LOWP of CERP are to reduce phosphorus loading to Lake Okeechobee, attenuate peak flows from the watershed, provide more natural water-level fluctuations in the lake, and restore wetland habitat. These goals will be accomplished by constructing reservoir storage approaching 273,000 ac-ft (33,674 ha-m) in volume and constructing stormwater treatment facilities capable of removing approximately 140 mt of phosphorus from the tributary flows prior to release to Lake Okeechobee. The project will also select about 3,500 acres (14.2 km^2) of watershed land for wetland and habitat restoration. At this time, the LOWP of CERP is in the alternative formulation and evaluation phase that identifies size, location, and operating strategies that will meet the project goals in the most cost-effective manner. The draft Lake Okeechobee Project Implementation Report (PIR) is scheduled for completion in April 2007. Detailed information about LOWP is available on the CERP web site at www.evergladesplan.org/pm/projects/proj_01_lake_o_watershed.cfm.

WATERSHED RESEARCH, ASSESSMENT, AND MONITORING

Research and Studies

The SFWMD, in cooperation with the FDEP and FDACS, has implemented a comprehensive research and water quality monitoring program for the lake and watershed. Several other agencies and interested parties participate in the monthly interagency team meetings and various project teams. Watershed research and assessment studies are reviewed and prioritized each year by the interagency team to ensure that information needs are addressed and watershed projects have been designed and implemented successfully. The data obtained will fill information gaps that have been identified by the interagency participants, assist in focusing on areas of concern, and determine performance of watershed management efforts.

A number of research and demonstration projects were started, continued, or completed in 2005 (**Table 10-7**). The LOPA required that on-farm and tributary water management practices be assessed. The Watershed Assessment Model (WAM) (SWET, 2002) was used to assess stormwater retention for seven land uses that are suitable to detain water onsite including abandoned/closed dairy pasture, citrus groves, dairy pasture, field crop, low- and medium-density residential, beef pasture, and row crops in the four priority basins. Modeling results indicated that an 18 percent phosphorus load reduction could be achieved with a water detention depth of 0.5 in (1.27 cm) for all pastures (beef, dairy, and abandoned dairy) and 0.25 in (0.64 cm) for non-pasture land uses mentioned above (Zhang and Whalen, 2005). Seven percent of this load reduction is attributed to water volume reduction and 11 percent is due to phosphorus concentration reduction. This amount of load reduction is close to the goal outlined in the LOPP under the implementation of water management alternatives as a part of the FDACS typical suite of BMPs.

Table 10-7. Lake Okeechobee watershed research, demonstration, and assessment projects that have been completed or are ongoing during WY2005.

Project Name (Investigator)	Major Objectives/Conclusions	Status
Residuals and Chicken Manure Land Application (Southern Datastream)	Assessed the potential impacts of residuals and chicken manure application on the quality of water reaching Lake Okeechobee. The specific project goals were to (i) document environmental problems associated with residual and chicken manure use through water quality monitoring, (ii) establish application rates for residuals and chicken manure that are economical and environmentally sound and (iii) educate landowners in the watershed on the proper management and use of the waste materials. This study generated information on the reactivity, mobility, and bioavailability of waste-bound phosphorus in soils that will aid in establishing Best Management Practices for residuals and chicken manure use in the Lake Okeechobee watershed.	Complete
Estimated Phosphorus Load Reductions under Various Water Management Alternatives (SFWMD)	Determined the detention volume (in terms of an equivalent runoff depth detained) that can provide a phosphorus load reduction of approximately 20% at the basin level. A computer model was applied to the four drainage basins that contribute high phosphorus loads to the lake. The typical land uses that are suitable to detain water onsite include abandoned/closed dairy pasture, citrus groves, dairy pasture, field crop, low- and medium-density residential areas, improved pasture, unimproved pasture, woodland pasture, and row crops. Scenario one included a water detention depth of 0.25" runoff for all land uses mentioned above, and an estimated 9% load reduction was obtained. Scenario two increased the water detention depth to 0.50" for all land uses except for residential, citrus, field crop, and row crop, resulting in an estimated 18% phosphorus load reduction. Therefore, detention depths that range from 0.25" to 0.5" of runoff could be implemented to achieve a basin level of 18% phosphorus load reduction.	Complete
Development of a Graphical User Interface for Analyzing Phosphorus Load and Import/Export in the Lake Okeechobee Protection Plan Area (JGH Engineering)	Developed an ArcGIS 9.0 based graphical user interface to assess the import and export of phosphorus in the LOPP area. It can be used to view current conditions and to assess scenarios based on changes in land use practices. The scenarios are referred to as Phosphorus Control Plans (PCPs) and reflect changes to the quantities of phosphorus import/export associated with specific land uses. Hydrological and water quality modeling were performed for the LOPP area. A drainage area summary tool has been added that produces a table representing the contributing area of a selected hydrologic reach. This table includes phosphorus budget import and export values along with runoff model output data and monitoring data. The project was completed in May 2005.	Complete
S-154 Algal Turf Scrubber ™-Water Hyacinth Scrubber™ (ATS™-WHS™) Aquatic Plant Treatment System (Hydromentia, Inc.)	Evaluated the performance of the ATS™-WHS™ Managed Aquatic Plant System for non-point source pollution control in the Lake Okeechobee watershed under two operational goals; (i) concentration reduction and (ii) nutrient load removal. During the first phase of the study, the system provided an 84% reduction in TP concentration and an areal removal rate of 12.8 g P/m^2-yr. During the second phase of the study where operational changes were made to quantify the impacts of higher hydraulic loading rate, the system provided an average TP removal of 47% Average areal removal rate during this period was 17 g P/m^2-yr, a 33% increase over the concentration reduction optimization period. The project was completed in May 2005.	Complete
Crop Phytoremediation of Phosphorus-Enriched Soils in the Lake Okeechobee Region (UF/IFAS)	The project looked at the effectiveness of three forage species (stargrass, limpograss, and bahiagrass), under differing nitrogen fertilization, amounts in reducing initial soil phosphorus levels of moderately impacted sites. The research has been completed, and guidelines for improved use of pasture production for remediation of phosphorus–impacted sites are being developed and will be presented to growers this year.	Complete

Table 10-7. Continued.

Project Name (Investigator)	Major Objectives/Conclusions	Status
Seepage Testing (Soil and Water Engineering Technology, Inc.)	Determined the lateral and vertical movement and extent of lagoon leakage. Preliminary investigations indicated varying degrees of leakage. Therefore, a more extensive study is being planned at one site.	Complete
Cow/Calf Water Quality BMP Demonstration (UF/IFAS)	To evaluate the effectiveness of cow/calf production BMPs with regard to reducing phosphorus loadings. Specific objectives include: (i) identify selected cow/calf BMPs and design hydrologic monitoring network for evaluating BMPs' effectiveness at watershed-scale for reducing phosphorus discharges; (ii) collect baseline (pre-BMP: 2003) and post-BMP (2004–2005) water quantity and quality data (surface and ground waters) and analyze the results to evaluate the effectiveness of the BMPs with regard to water quality and economics; (iii) use the monitoring data to test and modify selected hydrologic simulation models for their effectiveness in simulating the effectiveness of BMPs; and (iv) disseminate the results of the study to ranchers and state and federal agencies in the Lake Okeechobee Basin. The project started in September 2003 and will be completed in December 2006.	Ongoing
Wetland BMP Research (UF/IFAS)	The study objectives are (i) to demonstrate and determine the efficacy of isolated wetlands located in land areas currently used for dairy and cow/calf operations, on phosphorus assimilation and storage; (ii) to design and optimize on farm or edge-of–the-field treatment wetlands to maximize phosphorus removal performance (both mass removal per unit area basis, and effluent concentration basis) land areas used for cow/calf operation; (iii) review current hydrologic and phosphorus models for adaptation to the Okeechobee Basin wetland systems and to predict phosphorus assimilation capacity of the basin; (iv) to develop phosphorus assimilation coefficients/algorithms for use in water quality models to demonstrate the effectiveness of isolated and constructed wetlands to store P; and (v) to communicate the utility and effectiveness of isolated wetlands in phosphorus assimilation storage to dairy farmers and beef cattle ranchers through extension publications or other appropriate mechanisms.	Ongoing
Taylor Creek Pilot STA Baseline Characterization (UF/IFAS)	The overall objective of the study is to document the existing soil and vegetative conditions in the Taylor Creek Pilot STA following construction but prior to operation. This work effort will allow evaluation of changes in the physical, chemical, and biological functions of the STA over time. The project started in April 2005 and will be completed in May 2006.	Ongoing
Water Quality Best Management Practice (BMP) for Beef Cattle Ranch Demonstration (Archbold Expeditions)	The study objectives are (i) to develop an understanding of the relationship between beef cattle operational practices and water quality and (ii) to provide recommendations for the development of environmentally and economically sustainable cow/calf practices in the Lake Okeechobee watershed. Cattle stocking rates have no measurable effect on nutrient loads from the pastures, which may be related to high concentrations of phosphorus in the soil from past fertilization practices in improved pastures. The current project evaluates the feasibility of on-farm retention/detention of water in controlling phosphorus losses from beef cattle ranches. Water control structures were installed in the ditches to allow management of water in the pastures during high and low flow periods. The project started in May 2004 and will be completed in December 2006.	Ongoing

Table 10-7. Continued.

Project Name (Investigator)	Major Objectives/Conclusions	Status
Dairy Lagoon Seepage Characterization and Remediation Processes (ENSAT Corporation)	An extensive monitoring well system has been established to determine the movement of nutrients in groundwater resulting from lagoon leakage. Preliminary results indicate very little movement of phosphorous. Study to continue through a full dry/wet cycle to determine the effect on phosphorus movement. The monitoring will be completed in May 2006.	Ongoing
Data Review and Evaluation for Upgrading the Phosphorus Assimilation Algorithm (Soil and Water Engineering Technology, Inc.)	To identify the most suitable algorithm and data needs for the development of the phosphorus assimilation algorithms and the associated coefficients. Specific objectives are: (i) to conduct a detailed literature and data review and to recommend an assimilation algorithm that best suits the watershed and data used for validation; (ii) review the watershed-based and program-based monitoring networks and make specific data collection recommendations for upgrading/advancing the phosphorus assimilation algorithm and validating the assimilation coefficients; (iii) design the monitoring network and estimate the annual cost for data collection if needed; and (iv) write final report. The project started in April 2005 and will be completed in April 2006.	Ongoing
SFWMD and City of Okeechobee Cooperative Agreement – Sediment Trap Installation project (City of Okeechobee)	To develop a cooperative agreement with the city of Okeechobee for the installation of two sediment removal technologies. These technologies include a Continuous Deflective Separation (CDS) unit and a Tributary Sediment Trap (TST). These two units were previously studied under a demonstration project by Environmental Research and Design, Inc.; it was determined these technologies were more suited to urban environments where particulate sizes would likely be larger. Installation of these two technologies will not only support the SFWMD's efforts to support the LOPP, but will also enhance the city of Okeechobee's Storm Water Master Plan.	Ongoing
Taylor Creek Tributary Dredging	To remove accumulated sediment material in finger canals that are tributary to the lower section of Taylor Creek in the S-133 basin. Sediments in these canals are detrimental to the quality of water in Taylor Creek, which ultimately flows into Lake Okeechobee. The removal of this sediment will not only remove phosphorus from the system but improve flood protection and navigation in specific reaches. The soil analysis for dredging material has turned up no constituents of concern so it will not be necessary to truck the material to the landfill. The material will be land applied on near by agricultural operations as a soil amendment.	Ongoing
Lake Istokpoga Canal Maintenance Dredging and Sediment Removal (Highlands County)	This project is an evaluation of 15 to 20 residential access canals around the periphery of Lake Istokpoga for dredging and other canal maintenance options. These waterways provide considerable navigational and other benefits to Highlands County. This project will include (i) canal bottom evaluations to determine canal depth and extent of sediment accumulation; and (ii) collection and analysis of sediments in the canals. Information will be used to design an implementation plan, subsequent permitting, and prioritization of canals for maintenance dredging within the project area. Canals deemed eligible for maintenance dredging under the Florida Department of Environmental Protection's rules will then be prioritized and placed in the second phase of this project. Canals where maintenance dredging is not an option will be placed in the third phase of this project if necessary. The sediment characterization will establish the levels of the contaminants in the sediment, which will be used to identify the proper disposal method for the dredged material. All work will be conducted by contractors supervised by the county.	Planning

Assessment of BMP Effectiveness

According to the LOPA, a two-phased approach is used to determine the BMP effectiveness. The first phase requires that the FDEP use best professional judgment in making the initial determination of BMP effectiveness. An interagency team worked with outside experts in the field on developing the initial BMP performance estimates for all land uses. This level of verification provided the necessary confidence to the coordinating agencies to immediately move forward in implementing BMPs even if extensive data on their effectiveness were not available. Implementation of BMPs from adopted and approved BMP manuals based on an FDACS farm assessment or a site-specific plan developed through the NRCS would qualify for this phase.

The second phase involves the District or FDEP to monitor water quality at representative sites to verify the effectiveness of BMPs. This monitoring is conducted at a basin scale through the District's ambient water quality monitoring network and the sub-basin scale by the District through the Works of the District program and the USGS load monitoring program. Additional monitoring at the parcel level is being conducted by UF/IFAS research demonstration projects designed to verify the effectiveness of a typical suite of BMPs (**Table 10-7)**. The data generated from these studies and associated conclusions will provide model input (i.e., the WAM) to support information already being used by the coordinating agencies to assess overall BMP performance for the watershed.

Monitoring of Watershed Water Quality

The water quality monitoring was conducted through the LOWP of CERP, the Lake Okeechobee Watershed Assessment (LOWA) micro-basin monitoring, and through the District's ambient water quality monitoring program. Through the LOWP, the USGS monitors 17 sub-basin sites within the LOWP boundary north of Lake Okeechobee for stream flow, phosphorus, nitrogen, and total suspended solids. Continuous flow and weekly water quality samplings are collected at these stations. Additional information can be found on the CERP web site. Basin water quality data for WY2005 are presented in the *Watershed Status* section of this chapter.

In WY2004 the District restructured the LOWOD farm level concentration monitoring network to the LOWA micro-basin level monitoring network, enabling sites to be moved throughout the watershed to develop baseline data. These data are used by the coordinating agencies, specifically FDACS, to direct technical service providers to areas exhibiting poor water quality. In addition to the sites collected under the program, data collected from the District's ambient monitoring network, the LOWP monitoring network, and the Lake Okeechobee inflow sites are used by LOWA staff to evaluate changes in phosphorus concentrations throughout the watershed. If changes are observed, the District has the ability to do more intensive monitoring within the basin and micro-basins to identify phosphorus sources. If high phosphorus source areas are detected and phosphorus discharges within a basin do not improve, the coordinating agencies can require the implementation of additional BMPs.

For the past two years, data have been collected at newly established micro-basin monitoring sites (**Figure 10-15**; **Table 10-8**). During WY2005, the average TP concentrations in eight of the nine basins sampled were greater than those at the basin discharge structure to the lake. Seven basins had TP concentrations at the structure outlet that were above the target concentration (SWIM plan target) established in Technical Publication 81-2 (SFWMD, 1981). A more detailed data analysis of each basin will be provided to the coordinating agencies to direct BMP resources.

Table 10-8. TP concentration data collected at micro-basin sampling sites in the Lake Okeechobee watershed (May 2004–April 2005).

	Watershed Sampling Sites					Structure Outlet				
Basin	Mean (ppb)	Median (ppb)	Std Dev	Number of Samples	Number of Monitoring Sites	Mean (ppb)	Median (ppb)	Std Dev	Number of Samples	Basin SWIM Plan Concentration Target
Taylor Creek/Nubbin Slough (S-191)	784	451	1025	438	31	430	399	201	74	180
S-133	225	153	220	133	10	207	165	159	15	180
S-154	896	453	1429	106	13	359	203	314	70	180
S-65E	442	266	451	191	21	88	66	58	80	180
S-65D	295	129	378	221	14	75	59	43	76	180
Slough Ditch S-84 (C-41A)	118	96	44	49	7	106	84	73	22	100
Harney Pond Canal S-71 (C-41)	226	124	110	308	20	186	151	122	57	180
Indian Prairie S-72 (C-40)	165	127	35	106	7	244	222	124	45	180
Fisheating Creek	419	300	370	319	23	215	145	162	14	180

CHALLENGES AND UNRESOLVED ISSUES

- Land values have increased in the watershed making it more attractive for agricultural operators to divide their landholdings into smaller parcels for development. As a result, land use in the watershed is moving toward single-family ranchettes and subdivisions. The challenge will be to assure these land use changes will not result in an increase in phosphorus loads to the lake.
- Long-term phosphorus loading on the watershed has created residual phosphorus in the soils, which in turn resulted in increased phosphorus runoff to surrounding tributaries that discharge to the lake. The increase in residual phosphorus has reduced the phosphorus assimilative capacity of soils and wetlands in the watershed, thus sending more phosphorus in discharge to the lake. We need to find ways to manage and capture phosphorus stored in the watershed before it gets to the lake.
- Our ability to quantify phosphorus loads at the sub-basin level, as well as identify high phosphorus source areas within a target sub-basin, is critical in our efforts to determine the effectiveness of suites of BMPs implemented within a sub-basin, as well as to direct resources to problem areas. Reliance on the USGS monitoring network for sub-basin loads, and our in-house biweekly monitoring to determine high phosphorus source areas, is necessary to document management activities on the watershed.

LAKE MANAGEMENT AND RESEARCH

STATUS OF LAKE PERFORMANCE MEASURES IN 2005

The previous sections provided detailed status updates on various components of the lake ecosystem and then summarized as quantitative performance measures restoration goals and existing conditions (**Table 10-1)**. The scientific basis for the performance measures and targets were previously described.

LAKE MANAGEMENT

This section describes in detail two initiatives within the lake: (1) lake regulation schedule modification, and (2) a large-scale habitat restoration project. A third initiative within the lake is exotic plant control, which is covered in Chapter 9 of this volume. The general goal of in-lake restoration is to produce improved habitat and/or water quality in a time frame that is much shorter than the anticipated time that it will take the lake to respond to the LOPA phosphorus load reductions or CERP-influenced changes in water level.

A fourth initiative, the Lake Sediment Management Feasibility Study (BBL, 2003), investigated both dredging and chemical treatment as alternatives. The results indicated that the whole lake dredging option would be cost prohibitive ($3 billion in 2002 dollars), would take 20 years to complete, and would leave a thin veneer of mud sediments that will continue as a source of phosphorus. The chemical treatment alternative (Alum) would be less expensive ($500 million), would take less time (three years once the infrastructure was developed), and would meet the in-lake TP goal. However, unless the external loads are reduced, the treatment will have to be reapplied every 15 years. Thus, BBL (2003) recommended that all efforts should be focused on reducing external loads. If the load reduction does not result in reductions to the in-lake TP concentrations, then the chemical treatment option may be revisited. In addition, District staff are re-evaluating targeted sediment removal in key areas of the lake. Further information can be found on the District's web site at: ftp://ftp.sfwmd.gov/pub/slostal/EvaluationofAlternatives.pdf.

Lake Regulation Schedule Modification

Water levels in Lake Okeechobee are controlled in part by a USACE regulation schedule (USACE, 1999) that was adopted in 2000. The schedule, known as the Water Supply and Environment (WSE), is designed to provide necessary flood protection in the regional system, but in a manner that balances the needs of water supply, navigation, and protection of natural habitat in the lake (e.g., the littoral zone) and downstream ecosystems (east and west coast estuaries and the Everglades Protection Area). There are distinct zones where different discharge rates are specified (a typical component of USACE schedules for lakes and reservoirs) (Figure 10-31). These zones vary with season, so that just prior to the hurricane season (June through November), the lowest water levels are maintained in the lake, whereas later in the year higher water levels are allowed under the schedule's operating rules. However, the unique feature of the WSE is that it has a large zone of "conditional releases" called Zone D. In this zone, release decisions are made based not only on the water level in the lake, but also on tributary hydrologic conditions, short-term climate outlook, and factors known to influence long-term climate and rainfall in South Florida (Enfield et al., 2001), including El Niño and Atlantic Multi-Decadal Oscillation (AMO), which is a long-term cyclic pattern of water temperatures in the North Atlantic Ocean. These decisions are made by following a set of 'decision trees' that are an integral part of the WSE schedule; they specify whether or not to release water in Zone D, and separately consider

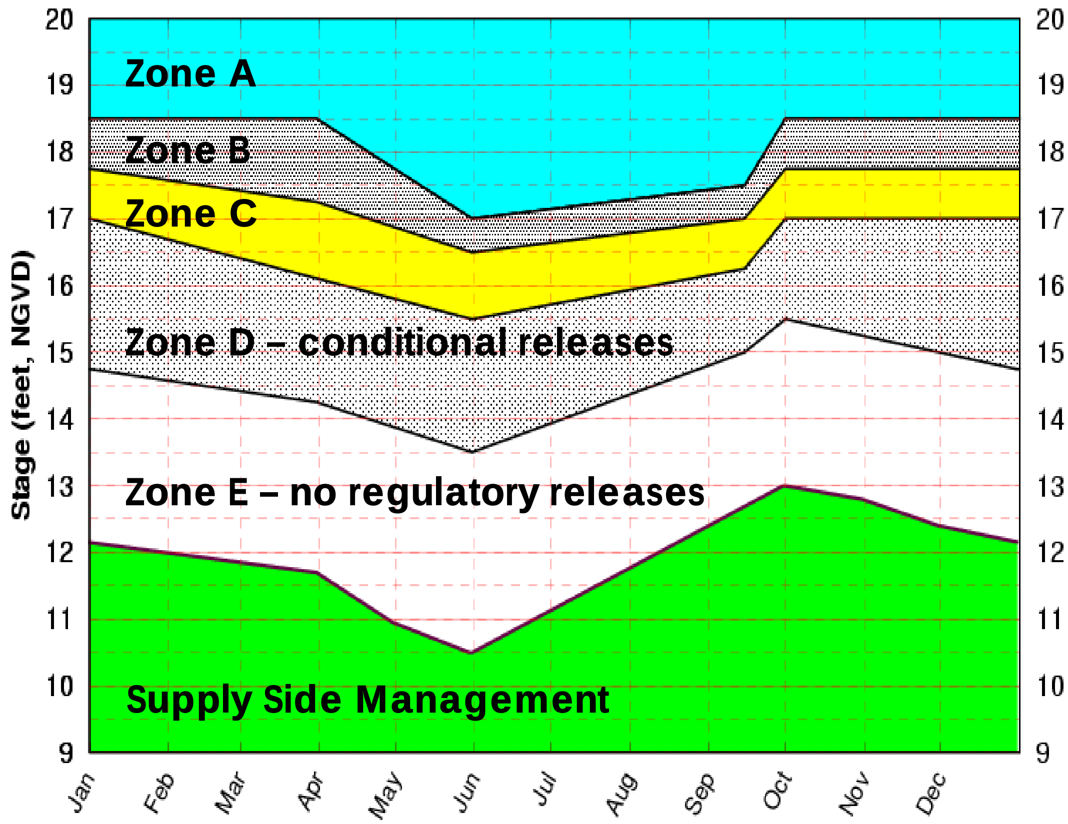


Figure 10-31. The Lake Okeechobee operating schedule, Water Supply and Environment (WSE), showing zones of flood control release (Zones A–C), flood release depending on hydrologic, meteorological, and ecological conditions (Zone D), a zone where flood control releases are not called for under any circumstances (Zone E), and a zone of water-use restrictions (not part of the WSE schedule, but related to the State of Florida Water Supply Authority).

releases to the south (where the water can be stored in the Water Conservation Areas, or WCAs), or to the east and west (where the water is lost to tide). Thus, the WSE is a proactive schedule that aims to hold water in the lake when drought conditions are anticipated and release water when conditions are expected to be wet. Decisions regarding volumes of water to release from the lake at various outlets are also adjusted based on input from experts in lake, estuarine, and Everglades ecology. This is done by considering a suite of science-based performance measures documented in the Adaptive Protocols for Lake Operations (SFWMD, 2003a), which has been developed to complement the WSE schedule.

As an example of how the WSE works, consider two situations where the water level in the lake is exactly the same. In one situation, tributary conditions are very wet and the long-term climate outlook is wet because El Niño conditions exist and the AMO is in the "warm phase" (warmer than normal water temperatures in the North Atlantic). Under these conditions, the decision trees of the WSE schedule may call for "up to maximal releases to tide and the WCAs." The amount of water to release is then determined after consultation with scientists regarding the level of risk to the lake of high water, and the potential for impacting key biota in downstream systems at different flow rates. In a second example, water level of the lake is the same, but tributary conditions are normal and the long-range climate outlook indicates a greater than average probability of low rainfall. Under these conditions, the decision tree may indicate that no regulatory (flood protection) discharges are required. The SFWMD would still release water from the lake for water supply as long as the lake levels are not so low that water use restrictions are called for. Under certain circumstances (as specified in SFWMD, 2003a) the SFWMD may also release water for downstream environmental benefits, for example, to prevent saltwater impacts on freshwater plants in the Caloosahatchee River.

During operation of Lake Okeechobee under the WSE schedule, the SFWMD and USACE have identified areas where performance can be improved. For example, during 2004 the use of El Niño/AMO was formally adopted by the USACE as part of the process for determining long-range climate outlook based on research performed by the SFWMD in cooperation with the NOAA Climate Prediction Center. This increased the accuracy in making such long-range predictions. Notably, there is also tendency for the schedule to be more conservative than anticipated when the lake is in Zone D; releases are called for when stage is rising, but then stopped when stage reaches a plateau. In 2002–2003, this allowed a stepwise rise in water levels in the lake, prolonged deep-water conditions in the lake's nearshore zone, and resulted in a loss of nearly 40 percent of the submerged plant community that had recovered in 2000–2002. In addition to impacting the lake, such a progressive rise in stage can threaten the estuaries. As the stage approaches Zone C, continuous discharges for flood protection purposes are allowed.

In response to these observations, and considerable input from environmental and water supply stakeholders, the SFWMD and USACE implemented a planned temporary deviation from WSE during the 2003–2004 dry season (December–May) to allow low-volume water releases to occur in Zone D, even when the schedule and its decision trees did not specify those releases. The releases were done as pulses that mimicked natural runoff events, and their maximal flow rates were reduced during March to May, which is known to be the spawning season for oysters in the St. Lucie Estuary and for larval fish in the Caloosahatchee Estuary (for further information on the St. Lucie and Caloosahatchee estuaries, refer to Chapter 12 of the 2005 SFER – Volume I (SFWMD, 2005). This temporary deviation allowed for nearly 0.8 ft (0.24 m) of water release from Lake Okeechobee, and maintained good ecological conditions in the estuaries. In fact, the rate of oyster larval settling in the St. Lucie was the highest recorded in recent years. More importantly, the deviation operation was designed to preserve water supply; the process included performance indicators to reduce or stop flows from the lake when water supply impacts were projected to occur. Recognizing the benefits of this operation, the SFWMD requested that the temporary deviation, which concluded on May 31, 2005, be extended to the 2004–2005 dry season. Currently, the SFWMD and USACE are working with stakeholders to identify further adjustments to the WSE schedule to improve lake and estuary conditions, recognizing that the degree of improvement is limited by the lack of alternative water storage locations which are not yet available in the regional system. The schedule will continue to be refined as those projects are completed under CERP, at which time it will be possible to truly optimize performance of the lake.

Lake Okeechobee Habitat Restoration

Restoration of valuable habitat within Lake Okeechobee for fish and wildlife, and for the establishment of native plant and animal communities, continues following the recent removal of the 4.84 miles (7.8 km) of perimeter agricultural berms surrounding Ritta Island, which is along the southern shore of Lake Okeechobee (**Figures 10-32** and **10-33**). This project was accomplished by the FWC through a contract to backfill adjacent ditches with berm material, and remove exotic vegetation. Specific details on these efforts were provided in Chapter 10 of the 2005 SFER – Volume I (SFWMD, 2005).

The removal of these berms was conducted with the specific goals of reestablishing the natural hydrologic connections between the island's wetland habitat and the lake, preserving Okeechobee gourd (*Cucurbita okeechobeensis*) habitat, and increasing the spatial extent of willow and/or pond apple (*Annona glabra*) to benefit wading bird populations. Removal of the man-made levees will increase the usage of the interior marsh by wading birds and other wildlife and will reestablish adult fish spawning grounds and larval and juvenile fish nursery grounds.

Replanting efforts for pond apple and cypress (*Taxodium* spp.) are under way on the restored shoreline by the FWC and the District (**Figure 10-33**). The removal of former agricultural remnant berms on Kreamer and Torry islands, the other two islands along the lake's southern shore, will not be conducted. A 100-acre section of degraded wetland on Torry Island has been replanted in native pond apple as part of this restoration effort. The city of Belle Glade is removing exotic plants adjacent to and along the walkways to provide both access and a clear view of the wetlands of Torry Island.

ASSOCIATED PROJECTS

This project will interface with an environmental education center that is being planned by the city of Belle Glade, Florida in conjunction with the District. Current restoration efforts focus on an existing man-made lake, the surrounding wetlands on Torry Island, and a series of existing dikes that will serve as walkways around the interior and exterior of the wetlands.

LAKE RESEARCH AND MODEL DEVELOPMENT

The lake research/modeling program presently is focused on three main areas related to key uncertainties identified above: (1) developing a predictive understanding of how SAV responds to variations in underwater irradiance; (2) quantifying the role of SAV in the nearshore phosphorus cycle; and (3) enhancing an existing hydrodynamic and water quality model of the lake so that it provides spatially explicit predictions regarding lake-wide water quality and nearshore SAV dynamics. As previously noted, there is also an ongoing research program aimed at optimizing methods for control of torpedograss and other exotic and nuisance plants. Further information on exotic species can be found in Chapter 9 of the 2005 SFER – Volume I (SFWMD, 2005).

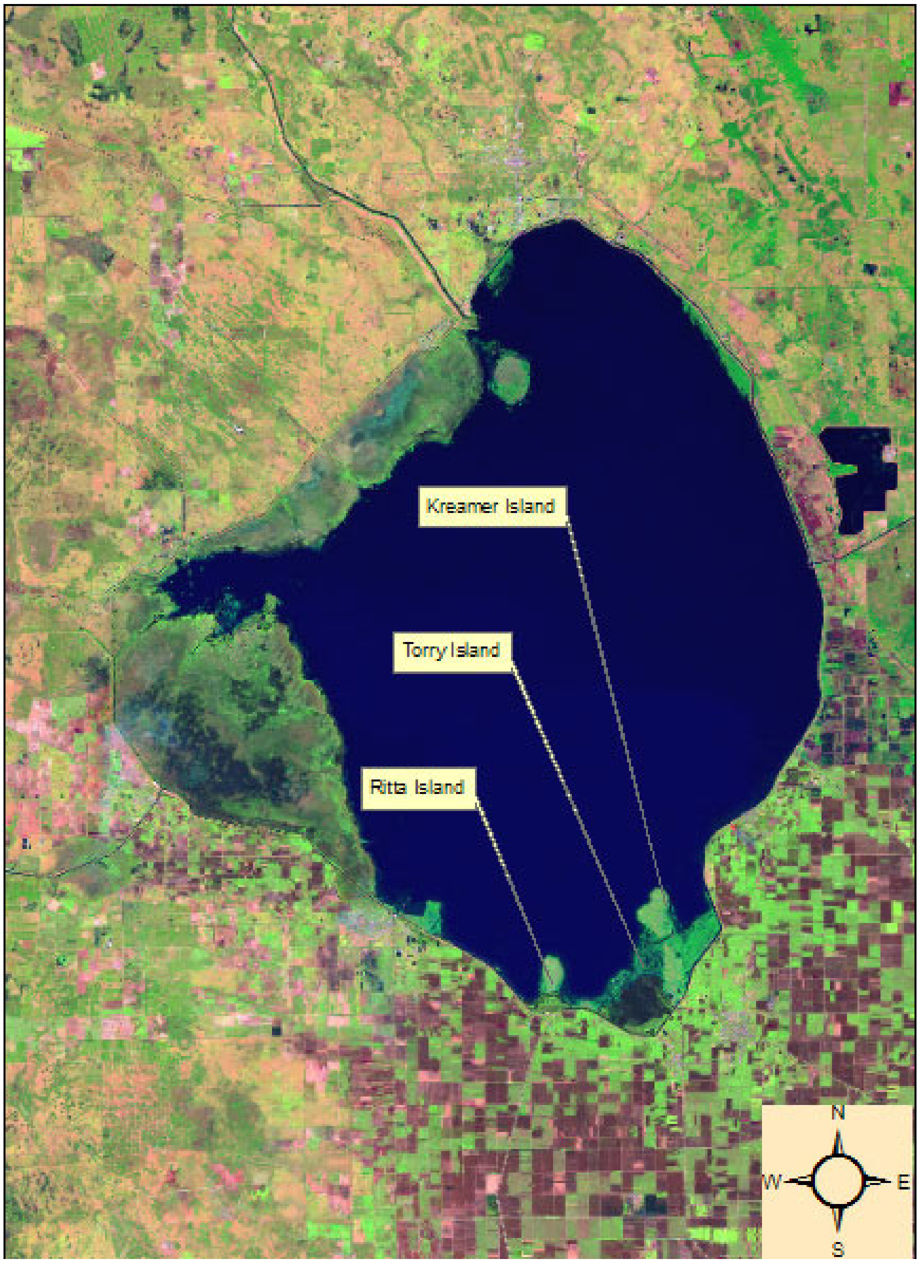


Figure 10-32. Location of three islands where habitat restoration work is occurring in cooperation with the Florida Fish and Wildlife Conservation Commission.

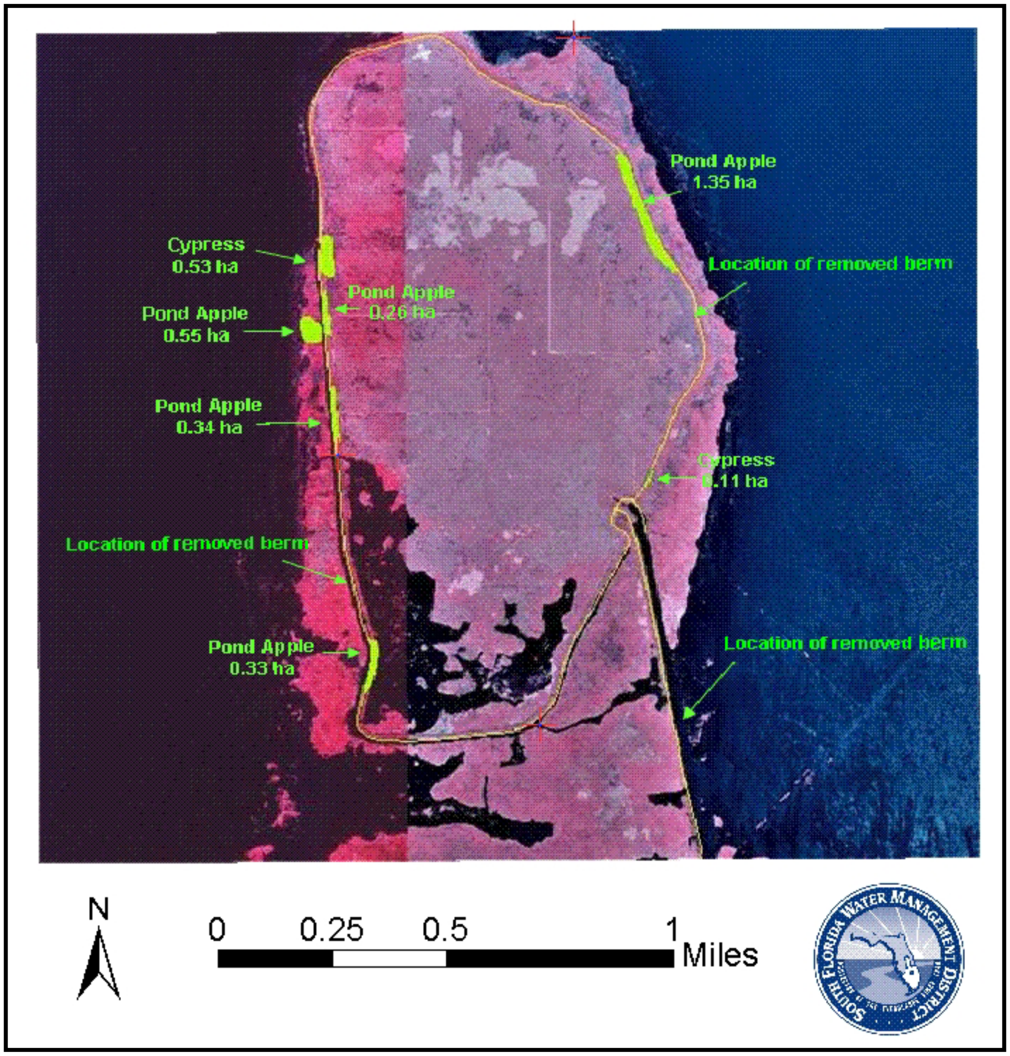


Figure 10-33. Habitat restoration projects on Ritta Island.

Predicting SAV Responses to Water Level Changes

Long-term ecological assessment of the lake has identified a number of hypotheses regarding how SAV responds to prolonged periods of high water, intense wave action, and drought. Succession of SAV in the nearshore region also has been observed following a large-scale drought in 2001 that essentially reset the landscape to soil and a buried seed bank (**Figure 10-23**). While this information is useful, it falls short of the details needed to calibrate and verify models that can be used to predict future SAV community structure and function under conditions with the LOPA and CERP in place. CERP, in particular, is expected to alter substantially the lake's water level regime; the District is providing anticipated benefits in terms of spatial extent of SAV and littoral zone habitat expected to be improved under different planning alternatives. The District has developed a generic SAV model (**Figure 10-34**) in Stella® modeling software (High Performance Systems, Inc. Hanover, NH) and is conducting controlled experiments to provide parameter values for this model. Attached epiphytes were included in the model because they are intimately associated with SAV and play a major role in the way in which the SAV community transforms, recycles, and sequesters nutrients. Benthic mats are primarily important in the interior marsh rather than in the nearshore littoral zone where most SAV growth occurs.

LIGHT EFFECTS ON SAV GROWTH

Controlled experiments initiated in 2000 and continuing to date use large 2,034 gallon (7.7 m^3) aboveground outdoor tanks located adjacent to the SFWMD ecological research laboratory (**Figure 10-35**, Panel A). These tanks are filled with water trucked from Lake Okeechobee and collected from an SAV-dominated nearshore location. Plants used in each experiment are collected from healthy beds in the lake, potted in natural lake sediment, and then subjected in replicate (six per treatment) to a range of light intensities from below 10 to more than 150 μmol photons $m^{-2}\ s^{-1}$. Treatments are produced by varying the number of layers of window screen attached to support structures above the tanks. To date, these experiments have been completed with *Vallisneria americana* (Grimshaw et al., 2002) *Chara zeylanica* (Grimshaw et al., 2005), and *Hydrilla verticillata*. A future experiment to be conducted during the summer months of 2005 will examine the response of *Potamogeton illinoensis* to shading. Collectively, these species constitute the dominant SAV taxa in the lake.

These results provide information regarding effects of solar radiation on morphometric and meristic plant characteristics as well as photosynthetic photon flux density effects on its absolute growth rate (**Figure 10-35**, Panel B). Combined with knowledge regarding the relationship between water depth and underwater light levels, this information can be used to estimate the growth of plants in particular regions of the lake, as well as to parameterize the Stella® SAV model mentioned above. These experiments continue to provide information on critical light levels at which there is no net growth of selected dominant species of SAV from Lake Okeechobee.

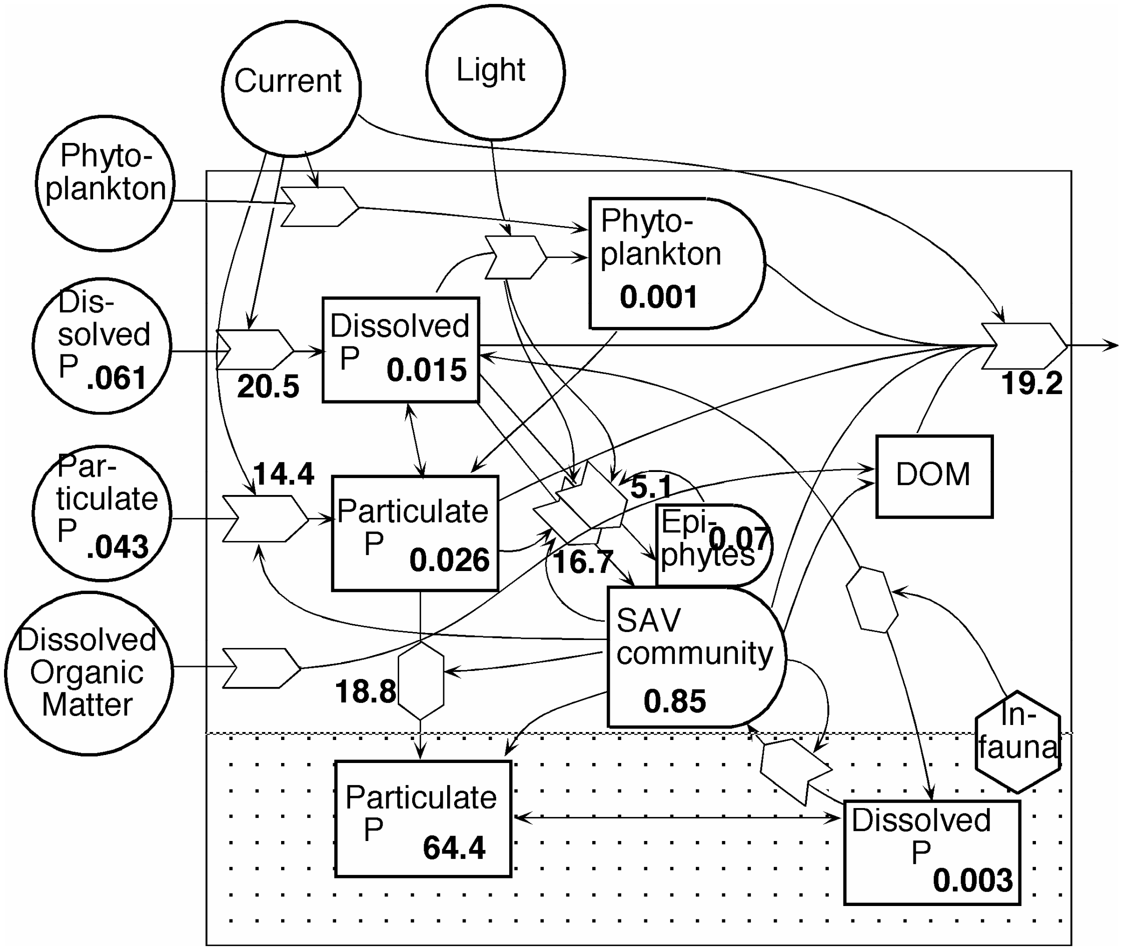


Figure 10-34. Flow diagram for the phosphorus component of an SAV model developed by the SFWMD. Parameter values were obtained from experimental research. This model is being calibrated with field and experimental research data and will be linked with the Lake Okeechobee Environment Model so that submerged vegetation responses to changes in water level can be predicted in lake and regional planning alternatives.

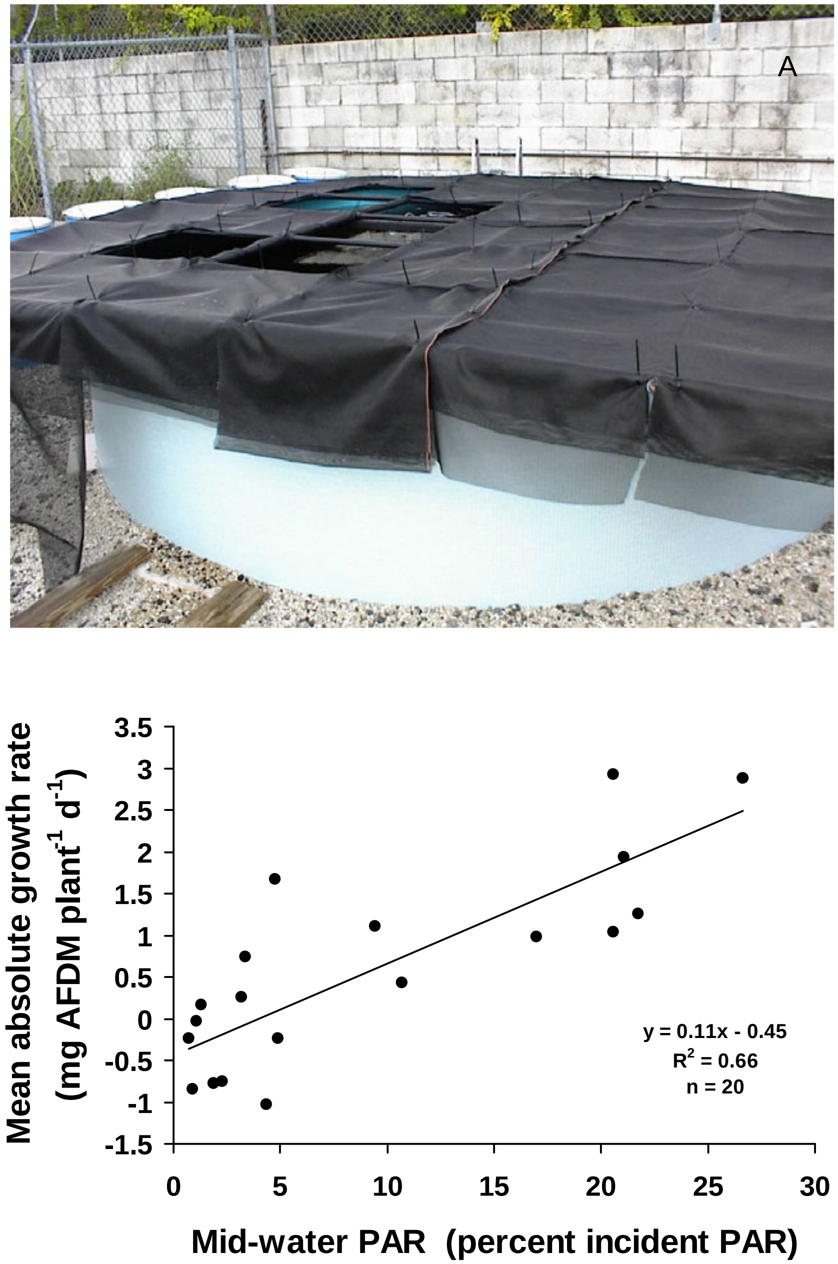


Figure 10-35. (A) Large tank used to conduct experiments to examine effects of light on growth of submerged plants (photo by Jim Grimshaw, SFWMD). (B) Results of an experiment dealing with *Vallisneria americana* (known locally as eelgrass or tapegrass). These data allow the identification of the minimum light requirement for net growth of mature plants and also provide information to calibrate the SAV model. PAR = photosynthetically active solar radiation (the portion of the light spectrum used by plants); data from Grimshaw et al., 2002.

LIGHT EFFECTS ON SAV GERMINATION AND SEEDLING GROWTH

In the SAV model, it is assumed that when light does not reach the lake bottom, there will be no ecologically significant germination of light-sensitive seeds, although there can be expansion of existing plant beds through plant growth. It is currently unknown, however, what light levels, if any, are necessary to elicit seed germination in the dominant species of SAV found in Lake Okeechobee. In fact, this may be the most sensitive portion of a plant's life cycle, because at high lake levels seeds are more likely to be in a dark environment than mature plants with leaves that extend higher in the water column.

In 2000, the District performed the first study to examine germination responses to irradiance (**Figure 10-36**), focusing on *Vallisneria* and *Chara* (Harwell and Havens, 2003). Intact sediment cores were used because preliminary studies indicated that seeds would not germinate from homogenized sediments. Only two treatments (100 and 500 μmol photons m^{-2} s^{-1}) were established, because at the time of the study, the lake was experiencing a rapid decline in water levels and these irradiances encompassed the range of what was observed in the shoreline region. From these results it was concluded that *Chara* germination was much more pronounced than that of vascular plants, especially when cores were desiccated before reflooding. This helps to explain why *Chara* was the first species to colonize the nearshore landscape in 2000, after the lake's recession. The oospores of *Chara* may be (1) considerably more abundant than seeds of vascular plants, (2) have greater long-term survival, and/or (3) be more tolerant of desiccation.

Several experiments to examine the light requirements for seed germination in *Vallisneria americana* were conducted in 2004. Results to date confirm that this species does in fact require light at the sediment-water interface to germinate, and that these seeds become dormant if they are kept in the dark too long. It is anticipated experiments will be conducted for all dominant species of SAV in Lake Okeechobee to determine if light is needed for germination (i.e. light-dark experiments). These results will be used to calibrate the SAV model. If these experiments determine that light is needed for germination of a given species, further experimentation will be conducted to determine the specific light threshold for germination.

Figure 10-36. Experimental setup for seed germination experiments. Results to date indicate that seeds of eelgrass (*Vallisneria americana)* do not germinate unless exposed to light (photo by Jim Grimshaw, SFWMD).

QUANTIFYING THE ROLE OF SAV IN NEARSHORE PHOSPHORUS CYCLING

Submerged plants can influence the phosphorus cycle in shallow regions of lakes by a variety of processes including: (1) stabilization of sediments (Vermaat et al., 2000); (2) uptake of phosphorus by periphyton attached to the plants (Burkholder et al., 1990; Hansson, 1990); and (3) creation of physical and chemical conditions that favor removal of particulate and soluble phosphorus from the water column to the sediments (Jeppesen et al., 1998). Given the documented inverse relationship between SAV and phytoplankton in the lake's nearshore zone (Phlips et al., 1995), it is critical to incorporate SAV influences on phosphorus into nearshore water quality models. The Lake Okeechobee Environment Model (LOEM), as described below, is being developed to include an interface with the Stella® SAV model.

To quantify various processes of phosphorus transformation and uptake associated with actively growing plants, the SFWMD has been conducting experiments in small 132 gallon (0.6 m^3) flow-through tanks (**Figure 10-37**) located on the southern shore of the lake, immediately adjacent to South Bay, one of the largest SAV-dominated regions. Water is pumped into a head tank and then transferred by gravity to the experimental tanks at known rates of flow. This design allows the measurement of inputs and outputs of water and phosphorus from the tanks and the growth of SAV under near-natural conditions. Experiments have been conducted with *Vallisneria americana*, *Hydrilla verticillata,* and benthic algae — primarily a filamentous blue-green algae that colonized unplanted substrate within the tanks — quantifying phosphorus transfer into epiphyton, plant tissues, and sediments during periods of active growth and senescence (triggered by covering the tanks with shade screens). Soluble phosphorus in the water column was consistently lower in the vegetated tanks. Shading caused plant senescence and increased levels of soluble P. Sediment phosphorus accumulations were significantly higher in the *Vallisneria* treatment. This work has provided preliminary lake-specific parameter values for the phosphorus cycling component of the Stella® SAV model (**Figure 10-34**). Greater detail regarding this work in progress will be provided in next year's annual report, after completing studies on phosphorus uptake and recycling using $^{32}P\text{-}PO_4$ (in the laboratory) and flow/ phosphorus depletion studies in large SAV beds on the lake. One of the greatest challenges is taking results from small-scale studies and generalizing them to the scale of beds of plants that cover hundreds of acres in the lake and are influenced by varying flow regimes.

Figure 10-37. Flow through lakeside tanks used to conduct studies to determine role of SAV in the lake's phosphorus cycle (photo by Rick Bartleson, SFWMD).

QUANTIFYING HABITAT VALUE OF PLANT COMMUNITIES

A key issue regarding restoration of hydroperiod, reduction of external nutrient loads, and removal of exotic plants is the potential benefit these management activities provide for the lakes, fish, and wildlife populations. The expectation is that all will benefit; however, certain actions such as reducing nutrients could actually lead to reduced fish productivity. It is assumed that this will be compensated for by the large-scale improvements in habitat quality. Prior to March 2004, there has not been any comprehensive evaluation of how the lake's fauna responds to major changes in plant habitat structure. Since then, the SFWMD's Lake Okeechobee Division has been evaluating two emergent plant communities, spikerush (a native) and torpedograss (an exotic and invasive plant) to assess the type of fish, macroinvertebrate, and periphyton communities found in each plant habitat. This research will continue with bimonthly habitat comparisons through July 2006. Future research is needed to describe floral and faunal communities in all of the lake's major plant assemblages, and this has been identified as a priority research area both in the LOPP and by RECOVER. Development of food web models for the major plant communities in Lake Okeechobee also could provide important information for future refinements to the lake's Minimum Flows and Levels criteria.

DEVELOPMENT OF THE LAKE OKEECHOBEE ENVIRONMENT MODEL

For several years, the SFWMD has used the Lake Okeechobee Water Quality Model (LOWQM) to forecast responses of the lake to long-term management scenarios, such as sediment management and large-scale phosphorus load reduction (James et al., 1997; James et al., 2005; James and Pollman, in review). As indicated, this model treats the lake as a mixed reactor, and does not consider the unique zones that occur in the lake. The model does not have features that explicitly respond to changes in water level, and it does not include submerged or emergent plants. It is expected that the LOWQM will continue to be used for planning studies that require long-term (e.g., 25 or more years) model runs. However, there is a need for a more complex spatially explicit model to address questions regarding how changes in water level will influence nutrient transport into the littoral zone, how changes in loads will affect phosphorus concentrations in the nearshore versus pelagic zone, and how water transparency and biomass of submerged plants in the nearshore zone will be influenced both by changes in water level and reduced phosphorus loads.

The objective of this program is to develop an integrated model (Lake Okeechobee Environment Model, or LOEM) that includes hydrodynamic, sediment transport, and water quality sub-models (**Figure 10-38**). The LOEM can simulate hydrodynamic, sediment transport, and water quality processes in the lake (Jin et al., 2000; Jin et al. 2002; Jin and Ji, 2004). The current model has been calibrated and verified for 3-D hydrodynamic, sediment, and water quality modeling. The wind wave sub-model used within LOEM will be enhanced in 2006 to improve reliability and increase the speed of the model simulations. The submerged aquatic vegetation (SAV) sub-model has been developed and can estimate SAV distribution and biomass. The enhanced SAV model (including a mechanism to erode SAV beds) is under development, and it is anticipated that the LOEM will be ready for application in April 2006.

Future work in support of the LOEM will include research dealing with nutrient uptake and storage in submerged plant beds and studies to determine which factors cause switches from relatively simple early successional plant communities to more complex communities that become established two to three years after recovery from major disturbance (Havens et al., 2004b, **Figure 10-23**). Priority research will need to be integrated with the studies of how plant community structure affects the lake's fishery, wading birds, migratory water fowl, and other key biota.

The LOEM also is being used in a larger effort to evaluate how hurricanes Charley, Frances, and Jeanne (August–September 2004) affected sediment resuspension, transport, water quality, and submerged plant distribution in the lake (**Figure 10-5**).

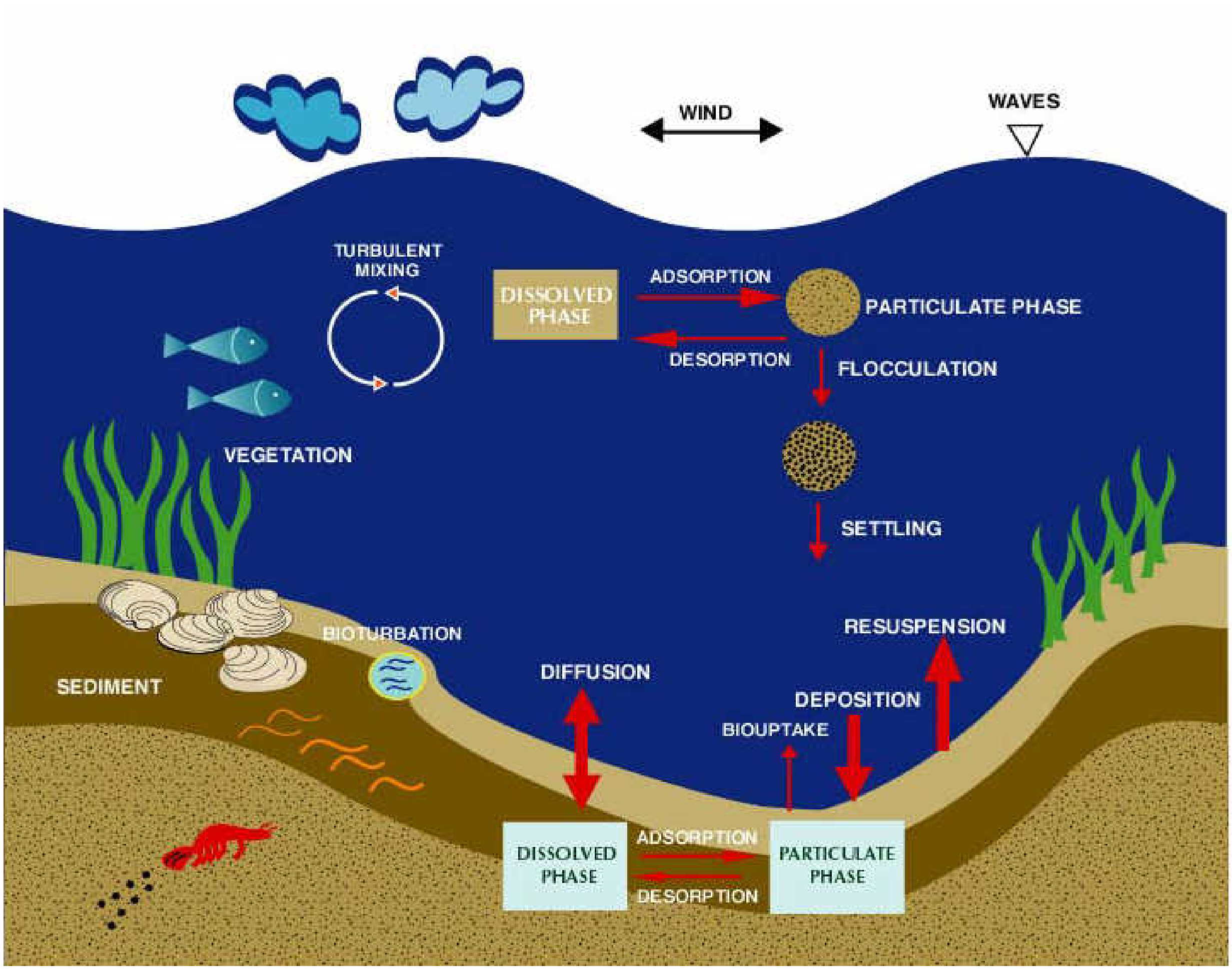


Figure 10-38. Lake Okeechobee Environment Model (LOEM) conceptual diagram of interacting systems.

ENCUMBRANCES/EXPENDITURES

State funding appropriations, encumbrances, and expenditures for the Lake Okeechobee Protection Program for Fiscal Year 2001 through 2005 (FY2001–FY2005) as of May 19, 2005 have been summarized in **Table 10-9**. As presented in this table, the summaries indicate that there were no appropriations from the state in FY2004.

Table 10-9. State funding appropriations, encumbrances, and expenditures for the Lake Okeechobee Protection Program for FY2001–FY2005.

FDACS – FY2001 One-time appropriation, 1591-G, 2000-2001 GAA $15,000,000	Appropriation	Contract Agreement Executed / Encumbered	Expended	Balance	Comments
Operations					
Salaries, Benefits, Operating Capital Outlay, Expenses, Vehicles	$2,200,500	$1,045,658	$1,154,842	$ -	$450,000 needed annually to support administration of Lake O. Protection Program
Contracts					
Cow/calf planning and Cost-Share	$2,899,500	$1,377,817	$1,521,683	$ -	Nutrient management planning and cost-share for cow/calf operations
Dairy Nutrient Management Plans and Cost-Share	$5,377,500	$2,555,341	$2,822,159	$ -	Engineering design and cost-share to implement dairy nutrient management plans
UF/IFAS education, BMP research, and demonstrations	$2,361,000	$1,121,926	$1,239,074	$ -	Research and demonstration for BMP development
Interagency Phosphorus Removal Projects	$2,161,500	$1,027,126	$1,134,374	$ -	Hydromentia / P-sensor project
GRAND TOTAL FOR FDACS - FY2001 APPROPRIATION	**$15,000,000**	**$7,127,868**	**$7,872,132**	**$ -**	

Table 10-9. Continued.

SFWMD – FY2001 Appropriation $23,500,000	Appropriation	Contract Agreement Executed/ Encumbered	Expended	Balance	Comments
Phosphorus Source Control Grant (PSCG) Program					
3-Year Leased Position - Project Manager	$172,075		$172,075	**$ -**	No PSCG leased employee remaining
Training	$947	$ -	$947	**$ -**	Training for new leased employees
Berryman & Henigar - Engineering Oversight Contract	$247,226	$ -	$247,226	**$ -**	
LO Torpedograss Management	$528,142	$28,623	$499,519	$ -	
Davie Dairy, Inc.	$95,270	$700	$94,570	$ -	
Smith Okeechobee Farms, Inc.	$409,560	$17,812	$391,748	$ -	
Evans Properties, Inc.	$157,000	$ -	$157,000	$ -	
Okeechobee Utility Authority, Ousley	$506,000	$ -	$506,000	$ -	
Tampa Farm Service	$1,300,810	$62,433	$1,238,377	$ -	
Irene Lofton	$92,000	$10,650	$81,350	$ -	
Aquaflorida, Inc.	$516,000	$ -	$516,000	**$ -**	
SWA of PBC	$1,125,000	$473,234	$651,766	$ -	
Daniel & Marcia Candler	$120,000	$30,000	$90,000	$ -	
Hydromentia, Inc.	$1,815,215	$74,297	$1,740,918	$ -	
QED Environmental	$351,655	$60,000	$291,655	$ -	Additional $60K from various PSCG project balances
Milking R. Dairy	$63,100	$21,786	$41,314	**$ -**	-
PSCG TOTAL	**$7,500,000**	**$779,534**	**$6,720,466**	**$ -**	
Grassy Island					
Taylor Creek STA Land & Land Improvement	$8,000,000	$ -	$8,000,000	$ -	
Taylor Creek STA Land Acquisition Cost	$500,000	$ -	$500,000	$ -	
GRASSY ISLAND TOTAL	**$8,500,000**	**$ -**	**$8,500,000**	**$ -**	
Restoration of Isolated Wetlands					
Easement Distributions to landowners	$609,357	$ -	$609,357	$ -	Funds transferred to Nubbin Slough Exp & Asmt
3 Yr Leased Employees - Staff Environmental Scientist, Senior Geographer Associate	$286,276	$ -	$245,368	$40,908	No IWR leased employee remaining (balance available for new projects)
Appraisal Services	$17,875	$ -	$17,875	$ -	

Table 10-9. Continued.

SFWMD – FY2001 Appropriation $23,500,000	Appropriation	Contract Agreement Executed/ Encumbered	Expended	Balance	Comments
Restoration Implementation Contract/ Birkett Environmental	$875,000	$232,593	$642,407	$ -	
Restoration Implementation Contract / C&N Environmental	$750,000	$615,555	$134,445	$ -	
Construction Contract	$370,000	$75,202	$ -	$294,798	
Water Quality Monitoring Contract	$150,000	$87,671	$62,329	$ -	
Nubbin Slough STA Expansion Assessment	$12,000	$11,450	$ -	$550	Funds transferred from Land Easements
Nubbin Slough STA Expansion	$1,429,492	$699,808	$ -	$729,684	Balance rebudget to FY2006
ISOLATED WETLANDS TOTAL	**$4,500,000**	**$1,722,279**	**$1,711,781**	**$1,065,940**	
Structure Retrofit and Dredging					
L-62 Dredging / S-192 Gate & Pump Replacement	$1,033,007	$42,500	$990,507	$ -	
PC-01-L59 Culvert Replacement	$112,000	$ -	$112,000	$ -	
L-63N Dredging	$481,775	$ -	$435,906	$45,869	
Taylor Creek Dredging Project	$600,000	$ -	$ -	$600,000	
Urban Stormwater Retrofit - Lemkin Creek	$618,105	$72,781	$33,600	$511,724	
G-106 Structure Retrofit	$105,113	$94,000	$3,351	$7,762	
PL-566 Structure Replacements	$50,000	$24,990	$24,995	$15	
STR. RETROFIT/DREDGE TOTAL	**$3,000,000**	**$234,271**	**$1,600,359**	**$1,165,370**	
TOTAL FOR SFWMD – FY2001	**$23,500,000**	**$2,736,084**	**$18,532,606**	**$2,231,310**	
GRAND TOTAL FOR LAKE OKEECHOBEE - FY2001 APPROPRIATION	**$38,500,000**	**$9,863,952**	**$26,404,738**	**$2,231,310**	

Table 10-9. Continued.

SFWMD – FY2002 Appropriation $10,000,000	Appropriation	Contract Agreement Executed/ Encumbered	Expended	Balance	Comments
In-lake restoration projects (berm removal, Torry Island, native plant revegetation, etc)	$1,800,000	$15,600	$1,124,816	$659,584	$616K in FY06 budget, remainder to be expended in FY2005
Torry Island Pond Apple Replanting	$150,000	$47,570	$102,430	$ -	
Public/Private Partnerships	$2,750,000	$ -	$ -	$2,750,000	
DEP Non-Ag Collaboration	$575,000	$ -	$575,000	$ -	
Cow/Calf BMPs	$450,000	$ -	$450,000	$ -	
Isolated Wetland Research	$700,000	$ -	$610,000	$90,000	$90K refunded from FDEP
Industrial Canal Sediment Removal	$500,000	$ -	$500,000	$ -	
Pahokee Harbor Sediment Removal	$250,000	$ -	$250,000	$ -	
Belle Glade Marina Sediment Removal	$250,000	$5,233	$244,767	$ -	
Glades County/Moore Haven – Stormwater/Wastewater Plan Update	$250,000	$ -	$250,000	$ -	
Okeechobee County – Stormwater/Wastewater Plan Update	$175,000	$ -	$175,000	$ -	
Watershed Assessments	$232,431	$ -	$232,431	$ -	
Vegetation Replanting	$15,400	$ -		$15,400	
Torpedograss Control Studies	$110,000	$ -	$110,000	$ -	
Model Uncertainty Refinement	$391,910	$ -	$391,910	$ -	
LO Pilot Dredging Confined Disposal Facilities	$48,340	$ -	$48,340	$ -	
LO Planning Contract/LO Blue Book Reporting	$99,943	$ -	$99,943	$ -	
Expert Assistance	$50,684	$ -	$50,684	$ -	
Regulatory Assessments	$330,000	$ -	$330,000	$ -	
Equipment/Supplies	$34,327	$ -	$25,844	$8,483	Funds transferred to LO Sediment Be/Pb testing & Ritta Island Revegetation

Table 10-9. Continued.

SFWMD – FY2002 Appropriation $10,000,000	Appropriation	Contract Agreement Executed/ Encumbered	Expended	Balance	Comments
3 Yr Leased Employees - Staff Engineer, Project Manager, Sr. Env. Scientist	$540,000	$ -	$420,464	$119,536	
Assessment of Water Control Practices in the Four Priority Basins of LO Watershed	$115,455	$ -	$115,455	$ -	
Torry Island Nature Center - Design	$20,000	$ -	$20,000	$ -	
Property Appraisal	$20,250	$ -	$20,250	$ -	
Torpedograss Biocontrol	$8,788	$ -	$8,788	$ -	
Lake Okeechobee Structure Survey	$39,590	$ -	$39,590	$ -	
Landuse Change Analysis	$6,360	$ -	$6,360	$ -	
Optimization of BMPs for Beef Cattle Ranching	$55,397	$28,000	$ -	$27,397	
Lake Okeechobee Sediment Beryllium/ Lead Testing	$20,000	$20,000	$ -	$ -	
Ritta Island Revegetation	$11,125	$ -	$ -	$11,125	
GRAND TOTAL FOR LAKE OKEECHOBEE - FY2002 APPROPRIATION	**$10,000,000**	**$116,402**	**$6,202,074**	**$3,681,524**	

Table 10-9. Continued.

SFWMD – FY2003 Appropriation $7,500,000	Appropriation	Contract Agreement Executed/ Encumbered	Expended	Balance	Comments
Alternative Phosphorus Reduction Technologies Feasibility Study	$63,971	$ -	$63,971	$ -	
Pilot STA Performance Optimization	$200,000	$40,250	$9,540	$150,210	
LOADSS Model Upgrade	$50,000	$ -	$50,000	$ -	Transferred to FDACS
Lake Okeechobee Protection Plan development	$103,380	$ -	$103,380	$ -	
S-310 Seawall stablization/Industrial Canal	$315,000	$ -	$315,000	$ -	
NRCS Spectral Nutrient Evaluation	$100,000	$ -	$100,000	$ -	
Optimization of Torpedograss Herbicide Treatment	$69,719	$60,719	$9,000	$ -	
Public/Private Partnerships	$2,000,000	$535,957	$14,043	$1,450,000	
Best Available Technologies for Dairies	$427,750	$65,952	$361,798	$ -	
Buck Island Ranch Study	$126,237		$126,237	$ -	
Mosquito Creek Gates	$131,934	$72,090	$ -	$59,843	Transferred $68,067 to Lake Resoration Activities
Former Dairy Restoration (5 former dairies)	$2,000,000	$1,852,068	$147,932	$ -	
Water Quality/ Alternative Water Supply	$50,000	$ -	$ -	$50,000	$250K transferred to Seminole Project; To be expended in FY2005
Tailwater Recovery System	$150,000	$ -	$ -	$150,000	
On-Ranch Environmental Services Strategies	$50,000	$ -	$50,000	$ -	Transferred to FDACS
Nubbin Slough STA Flow Diversion					
Assessment	$66,009	$ -	$66,009	$ -	
Construction	$370,889	$ -	$ -	$370,889	

Table 10-9. Continued.

SFWMD – FY2003 Appropriation $7,500,000	Appropriation	Contract Agreement Executed/ Encumbered	Expended	Balance	Comments
Lamb Island Tributary Stormwater Treatment Project	$500,000	$458,365	$41,635	$ -	
LOPP BMP Performance Analysis	$12,900	$ -	$12,900	$ -	
Lake Restoration Activities	$153,350	$79,791	$73,558	$ -	
Submerged Plant Study	$5,965	$ -	$5,965	$ -	
S-65E Study/Water Quality	$122,203	$3,500	$118,703	$ -	
Equipment/Supplies	$10,892	$ -	$ -	$10,892	
STA Assessment	$19,440	$19,440	$ -	$ -	
PL-566 Structure Replacements	$105,758	$ -	$ -	$105,758	
Optimization of BMPs for Beef Cattle Ranching	$44,603	$ -	$ -	$44,603	
Seminole Project	$250,000	$ -	$ -	$250,000	Funds transferred from Alternative Water Supply
GRAND TOTAL FOR LAKE OKEECHOBEE - FY2003 APPROPRIATION	**$7,500,000**	**$3,188,132**	**$1,669,671**	**$2,642,196**	

Table 10-9. Continued.

FDACS – FY2005 Appropriation $5,000,000	Appropriation	Contract Agreement Executed/ Encumbered	Expended	Balance	Comments
Operations					
Salaries, Benefits, Operating Capital Outlay, Expenses, Vehicles	$733,500	$733,500	$ -	$ -	$450,000 needed annually to support administration of Lake O. Protection Program
Contracts					
Cow/calf planning and Cost-Share	$966,500	$966,500	$ -	$ -	Nutrient management planning and cost-share for cow / calf operations
Dairy Nutrient Management Plans & Cost-Share	$1,792,500	$1,792,500	$ -	$ -	Engineering design and cost-share to implement dairy nutrient management plans
UF/IFAS education, BMP research, and demonstrations	$787,000	$787,000	$ -	$ -	Research and demonstration for BMP development
Interagency Phosphorus Removal Projects	$720,500	$720,500	$ -	$ -	Hydromentia/ P-sensor project
GRAND TOTAL FOR FDACS - FY2005 APPROPRIATION	**$5,000,000**	**$5,000,000**	**$ -**	**$ -**	

Table 10-9. Continued.

FDEP – FY2005 Appropriation $700,000	Appropriation	Contract Agreement Executed/ Encumbered	Expended	Balance	Comments
Pahokee WWTP Improvements	$700,000	$ -	$700,000	$ -	
GRAND TOTAL FOR FDEP – FY2005 APPROPRIATION	**$700,000**	**$ -**	**$700,000**	**$ -**	

SFWMD – FY2005 Appropriation $7,600,000	Appropriation	Contract Agreement Executed/ Encumbered	Expended	Balance	Comments
Nubbin Slough STA Expansion Project	$4,300,000	$89,666	$ -	$4,210,334	
Nubbin Slough STA Expansion (from FDEP)	$3,300,000	$ -	$ -	$3,300,000	
TOTAL FOR SFWMD - FY2005	**$7,600,000**	**$89,666**	**$ -**	**$4,210,334**	
GRAND TOTAL FOR LAKE OKEECHOBEE - FY2005 APPROPRIATION	**$13,300,000**	**$5,089,666**	**$ -**	**$4,210,334**	

CONCLUSIONS

There is a comprehensive array of state and federal projects occurring in the watershed of Lake Okeechobee, and within the lake, to address the key issues of excessive phosphorus loading, harmful high water levels, and exotic plants. Projects are being implemented in a cooperative manner by the SFWMD, FDEP, and FDACS. Considerable progress has been made to control the spread of exotic plants in the lake, watershed projects have been implemented to reduce phosphorus transport from agricultural lands and capture runoff water during high rainfall periods, and modifications to the lake regulation schedule are under consideration. Because of the complex nature and long history of problems, full implementation of the LOPA will require more than a decade, and improvements in lake water quality are expected to be slowed by internal nutrient recycling. Ongoing research in the watershed is helping to optimize the design of phosphorus reduction/flow attenuation measures, and research in the lake is providing guidance for adaptive management of water levels and exotic plants. Restoration of water quality and ecosystem functions in Lake Okeechobee is critical to South Florida because the lake is the central part of both the natural and man-made regional aquatic system.

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